Innovator or Owner? Information Sharing, Incomplete Contracts and Governance in Financial Risk Management Systems

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ABSTRACT

Financial risk management has become increasingly important in the financial industry during the last decade, especially due to the financial disasters in the mid-1990s. Value-at-risk (**VAR**), developed by J. P. Morgan in the late 1980s, has been the most widely accepted risk measurement methodology because it provides a single number summary of an institution's portfolio risk. To promote VAR, Morgan provided RiskMetrics, a VAR-based risk management service, for its clients (borrowers). Later, RiskMetrics was spun off as an independent company providing fee-based services. Building upon the theory of incomplete contracts and other related theories, we develop a game theoretic model to explain why adoption of the free RiskMetrics service stalled and how the change in ownership structure of the service led to wider adoption. In particular, we examine a situation where the borrowers have heterogeneous portfolio riskiness and this differential riskiness affects the value they can gain from the service and the impact of the service provider exploiting their private risk information. Our results suggest that the most important roadblock to borrowers' adoption of the free service might have been the potential damage from the service provider's information exploitation. When the service was spun off, borrowers' concern was reduced due to the multi-party independent ownership structure, which led to wider adoption. The spin-off was Morgan's strategic move to maximize long-term profits from RiskMetrics.

KEYWORDS: Economic theory, financial risk management, incomplete contracts, information sharing, information systems, interorganizational IS, ownership, value-at-risk.

INTRODUCTION

Over the past decade, financial risk management has become increasingly important in the financial industry, especially due to the financial disasters in the mid-1990s, such as the bankruptcy of Barings Bank and Orange County (Jorion, 2000). Poor financial controls and risk management have been blamed for these disasters. Among a number of different risk management methodologies that were introduced during 1990s, value-at-risk (**VAR**), developed by New York-based J. P. Morgan Bank in the late 1980s for its own internal reporting purposes, has been the most widely accepted by various kinds of financial and non-financial institutions. VAR provides a summary measure of portfolio risk expressed in a probabilistic statement.

Morgan provided a free risk management service called RiskMetrics to promote VAR among its clients. RiskMetrics is an interorganizational information system (**IOS**) which receives data on a financial services firm's portfolio holdings and generates a measure of portfolio risk in terms of possible loss of value. In 1998, Morgan spun off RiskMetrics by founding an independent software and consulting firm called RiskMetrics Group, with participation from several other financial services firms and the digital quote vendor and international news organization, Reuters.

Despite the initial impact, RiskMetrics was not adopted by a majority of Morgan's clients even when the service was free. The ownership structure of the service played a critical role in this stalling. Because Morgan was the owner, its clients and potential clients expressed concerns about the possibility of their private information (e.g., portfolio position) being exploited by Morgan, which could be detrimental to them. Also, after the spin-off, though the service was no longer free, more firms adopted the service because now they had less risk, and possibly even no risk of exploitation by the service provider. Thus, the spin-off was a move by Morgan to increase adoption by reducing risk for the clients and increasing their willingness-to-pay.

Drawing upon several theories from Economics and Information Systems (**IS**), we develop a game theoretic model to explain how change in the ownership structure of the RiskMetrics service affected clients' adoption behaviors. In particular, we build on the incomplete contracts theory, principal-agent theory, and information sharing, and address the following questions:

- What was the rationale behind Morgan's decision to spin off RiskMetrics? Was it profit maximizing?
- What is the mechanism by which the spin-off positively affected clients' adoption?
- How can existing theories help explain what has happened in the financial risk management arena?

THEORETICAL BACKGROUND

We next look at the theory of incomplete contracts to examine the role of ownership structure, principal-agent theory for Morgan's potential opportunistic behavior, and the literature on information sharing.

Theory of Incomplete Contracts and Bargaining

Based on the observation that contracts are incomplete and should be revised and renegotiated (Williamson, 1985), Grossman and Hart (1986) and Hart and Moore (1990) proposed the theory of incomplete contracts, which underscores the importance of asset ownership. One important concept is that of "observable but non-verifiable" variables. Hart and Moore (1990) argue that some variables (e.g., quality, investments, and benefits) are not verifiable by a third party (e.g., court) even though they may be observable by the parties involved in the contract. Therefore, these variables are "non-contractible," which means the parties cannot enter a contract based on the outcome of those variables. As a result, they must divide the surplus based on their relative bargaining power.

A popular solution concept for distributing surplus is the Nash bargaining solution, which is splitting the incremental value 50:50 between the two parties in a bilateral relationship. For example, examining governance structures (i.e., public or private) for a non-contractible service (e.g., prison), Hart et al. (1997) used the Nash bargaining solution for division of the surplus between the service provider and the customer. In a similar vein, Clemons and Kleindorfer (1992) applied the Nash bargaining solution in a model of firms' investments in IOS and value sharing among the participants. In this study, we use the Nash bargaining solution for division of surplus between the service provider of the RiskMetrics service and each borrower firm that agrees to use it.

The focus of the incomplete contracts theory is how ownership structure affects parties' incentives for non-contractible investments, which in turn determines the total value created. The theory is relevant to the financial risk management service context because there are non-contractible variables such as quality of the service, investments, and benefits. Also, we believe that who owns the service (i.e., Morgan or RiskMetrics Group, in this case) affects the service provider's incentive to engage in information exploitation effort that can be detrimental to the customers of the service.

Principal-Agent Theory

Principal-agent theory focuses on the presence of asymmetric information between the principal and agent. That is, the agent usually has private information that the principal does not know (Pratt and Zeckhauser, 1985). In a standard principal-agent problem, the principal does not know the action of the agent. This is the moral hazard problem where the principal's utility depends on the agent's action and the principal cannot induce the agent to make the first-best (i.e., socially optimal) level of effort because the principal can only observe some result of the agent's action. The theory is relevant to risk management because clients can be regarded as the principals and the service provider as the agent, and there is asymmetric information regarding the actions (or efforts) of the service provider. Customers of RiskMetrics were concerned about the possibility of their private risk information being exploited by the provider of the RiskMetrics service because Morgan's actions were not perfectly observable.

Information Sharing

The value of information sharing has been studied in the Operations Management literature. For example, by sharing buyers' sales and inventory information, a supplier can improve demand forecasting and production planning (Seidmann and Sundararajan, 1997). Information sharing has also been an important topic in the Finance literature. Millon and Thakor (1985) developed a model that explains the formation of financial institutions that acquire and process information about firm values, and underscored the importance of sharing information about common uncertainties (e.g., the return on the market portfolio) among financial institutions. Pagano and Jappelli (1993) examined the factors that affect lenders' incentives to share information about borrowers.

Information sharing is important in the risk management because as more firms share information about their portfolio, the system can provide better benchmark data for risk measurement which, in turn, enhances the quality of the VAR measures the system generates. Therefore, it is important to provide proper incentives for the firms to share their information. However, as mentioned above, their incentives can be significantly reduced if they perceive a risk of their information being exploited by the service provider.

RISK MANAGEMENT AND RISKMETRICS

We next explain why financial risk management has become important, what led to the innovation, how RiskMetrics came into existence, and how the ownership structure changed. We also explain how risk management systems work by describing major elements of a VAR-based risk management system.

Financial Risk Management

Financial risk management is defined as "the process by which various risk exposures are identified, measure, and controlled" (Jorion, 2000). There are various kinds of risks (e.g., business risks and non-business risks), and in this research we focus on financial risks that are related to possible losses in financial markets (e.g., losses due to interest rate changes). Risk management became important due to the increased volatility of financial markets over the past few decades (e.g., Black Monday in 1987 and the Asian turmoil of 1997). In addition, deregulation of financial markets and globalization drastically increased competition among financial institutions, which made them realize the importance of managing financial risks.

The importance of effective financial risk management was highlighted by several financial disasters in 1990s including Barings Bank, Orange County, and Daiwa Securities, which inflicted more than a billion dollars' loss upon investors and shareholders. One of common causes was poor risk management policies and systems. The series of losses led to an industry-wide realization of the need to properly measure and manage financial risks.

Value-at-Risk and RiskMetrics

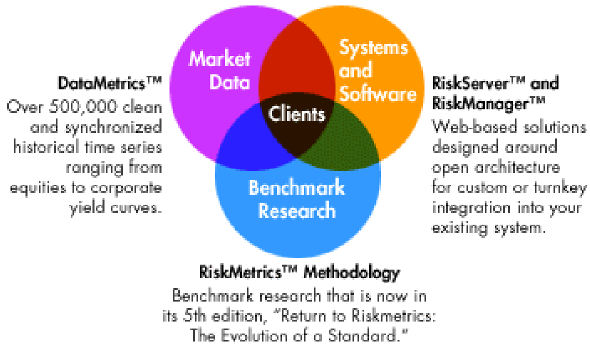
During the early 1990s value-at-risk (**VAR**) became popular as a method to quantify a portfolio's risk. VAR was innovated by Morgan in the late 1980s, for internal risk control at the bank, and was widely adopted by various kinds of financial and non-financial institutions during the 1990s. VAR is defined as "the worst expected loss over a given horizon under normal market conditions at a given level of confidence," and provides a single numeric measure of portfolio risk (Jorion, 2000). For example, if the daily VAR of a trading portfolio of derivative securities is $20 million at the 95% confidence level, it means that there is 5% chance, under normal market conditions, for a loss of $20 million to occur. In contrast to nominal risk measures, VAR provides an aggregate view of a portfolio's risk that accounts for leverage, correlations, and current positions, and is a forward-looking risk measure.

One of the key factors that prompted the widespread adoption of VAR by firms during the mid-1990s was the offering of a product called RiskMetrics, the name of the risk management service offered by Morgan free of charge to its clients from 1994 on to promote VAR as a risk management tool. At the time, VAR was used by some financial firms but mostly unheard of among the less sophisticated players and non-financial firms. The launch of RiskMetrics service was successful especially because of the timing: firms' were gravely concerned about financial risks after witnessing the financial disasters.

RiskMetrics has three basic components: market risk measurement methodologies, volatility and correlation data sets used in the computation of market risk, and software systems that implement the methodologies (J. P. Morgan and Reuters, 1996). Morgan provided clients with a technical document which could serve as a reference for the statistical estimation methodology for market risk, as well as detailed documentation about the analytics that generate the data sets. These were published daily on Morgan's Web site. The quality of the RiskMetrics service was improved by Morgan's R&D investments. For example, the technical document was revised several times to provide better information for the clients.

In October 1998, Morgan spun off its risk products group as an independent software development and consulting firm called RiskMetrics Group. The quality of the service improved substantially under the ownership of the RiskMetrics Group, and the scope has expanded from market risk to credit risk and wealth management. Also, the RiskMetrics Group provides more comprehensive market data (over 50,000 historical time series). Now over 450 financial institutions all over the world are using the service. The current shareholders of the company include American Express, DB Capital Venture Partners, the Intel 64 Fund, J.P. Morgan Chase, Procter & Gamble, Reuters, and Sony. The company's market risk solutions still have the three main components as did its predecessor, the free RiskMetrics service. (See Figure 1.)

Figure 1. RiskMetrics' Market Risk Solutions



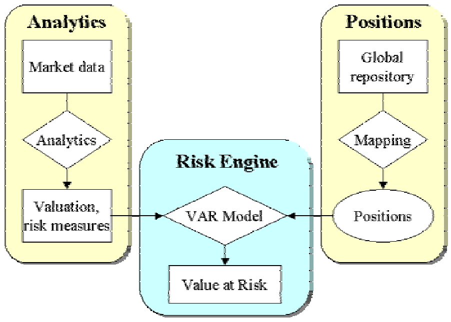
Source: www.riskmetrics.com

When Morgan wholly owned RiskMetrics, borrowers were concerned about potential exploitation of private information. Morgan might use a borrower's portfolio information to adjust its lending rate (e.g., raise interest rates if the borrower's portfolio has become riskier). Also, Morgan might share its clients' private information with other lenders, creating additional impetus for changing the borrower's cost of capital. The borrowers' concern was substantially reduced when RiskMetrics was spun off because now the service provider was no longer the lender. As a result, market-wide perceptions of possible information exploitation are no longer a concern under the third-party ownership by the new RiskMetrics Group.

Financial Risk Management Systems

Recently, enterprise-wide risk management systems have become a key area for strategic IT investments. They enable firms to take a portfolio approach to risk, which can produce diversification benefits and lead to the more efficient allocation of capital. A typical VAR-based risk management system consists of three parts: the analytic platform that collects and filters market data, the positions platform that serves as a global repository for all trades, and a risk measure engine that integrates analytics and positions with a VAR model to create a measure of market or credit risk or both (Jorion, 2000). (See Figure 2.).

Figure 2. Components of a VAR-Based System



Source: Adapted from Jorion (2000)

After deciding to implement a risk management system, institutions must decide whether to develop the system in-house or to purchase an off-the-shelf system from an outside vendor. Although in-house development can offer more flexibility and integration with existing systems, outside systems are preferred by most institutions because of the immediate functionality that the systems offer, lower costs, and the vendors' expertise. However, some institutions that view risk as a strategic aspect of their business or that need a high level of customization resort to in-house development.

AN OWNERSHIP STRUCTURE CHANGE MODEL

We next define our notation and assumptions for a model to explain what drove the ownership structure change in RiskMetrics and how the change affected the behavior of the service provider and the borrowers. Then, we analyze the service provider's optimal investment levels and the borrowers' adoption decision in the free service case and the free-based case.

Basic Setup and Notation

We use the incomplete contracting model for non-contractible services by Hart, et al. (1997) to develop a game theoretic model for the service provider's investment decision and the borrowers' adoption decisions. We will call Morgan or the RiskMetrics Group, "the service provider," and the financial services clients who adopt the service "the borrowers." In our model, there is a single service provider of the risk management system, denoted *s*, and multiple borrowers, indexed by *b*, which is uniformly distributed in the interval [0,1]. *b* represents the relative "riskiness" of a borrower's portfolio where a larger *b* indicates a riskier borrower.

To understand the impact of the ownership structure change of RiskMetrics, we consider two cases: *free service* and *fee-based service*. In the former, the financial institution (i.e., Morgan) is the service provider who offers the service free of charge, and in the latter a third party (i.e., the RiskMetrics Group) is the service provider who charges a fee for the service.

There are two kinds of non-contractible investments that the service provider can make: *e* and *i*. Investment $e \in [0, \bar{e}]$ corresponds to the service provider exploiting borrowers' private information for the service provider's own benefit. This information exploitation occurs because the borrowers have differential riskiness in their portfolios. We call this an "information exploitation investment." This investment gives the service provider a benefit, $u(e) \geq 0$, where $u(e)$ is increasing at a decreasing rate in e and satisfies $u(0) = 0, u'(0) = \infty, u'(\bar{e}) = 0$. For simplicity, we assume that the cost of investment *e* is *e*. This investment has an adverse effect, *a*(*e*), which is increasing at an increasing rate in *e* and there is no effect when there is no investment, *a*(0) = 0. The function *a*(*e*) plays a critical role because it measures how much borrowers get hurt by the service provider exploiting their private portfolio information.

Investment $i \in [0, \bar{i}]$, which we call a "quality enhancement investment," increases the quality of RiskMetrics service by $q(i) \geq 0$ at the cost of $c(i) \geq 0$. *q*(*i*) is increasing at a decreasing rate in *i* and satisfies $q(0) = 0, q'(0) = \infty, q'(\bar{i}) = 0$. *c*(*i*) is increasing at an increasing rate in *i*, and includes the monetary cost and intangible costs associated with *i*. For example, the service provider may change its internal processes or train employees to provide better service in addition to investing in the software. Investment *i* can be viewed as an R&D investment.

V·b denotes the value a borrower *b* gets from the "basic" service without quality improvement, and this means that as a borrower's portfolio becomes riskier, the borrower can gain more from the service. This value is assumed to be the same whether the service is free or fee-based. For example, *V·b* might be the borrower' benefit from allocating its capital more efficiently and effectively based on VAR measures that RiskMetrics provide.[1] *C* is the one-time costs of adoption, which is assumed to be identical for all the borrowers and can be viewed as the net

[1] As is usual in IOS adoption, externalities play a role in each borrower's adoption decision. There are two kinds of positive externalities associated with RiskMetrics adoption: the service provider's benefits increase with the number of adopting borrowers because it can enjoy economies of scale and can accumulate more accurate market data, and an adopter's own benefits also increase as more borrowers adopt due to "information pooling;" with portfolio data from others, borrowers can get more accurate risk management benchmark data. However, to make our model more tractable, we do not take externalities into account.

present value of the costs that borrowers incur over time. P denotes the price of the basic service in the fee-based service case, which is the same for all borrowers. We assume, without loss of generality, the service provider's cost of providing the basic service to each adopter is zero. Π_b and Π_s represent borrower b's net benefit and the service provider's profit from a single adopting borrower respectively. We use superscripts f and p to represent the free service case and the fee-based service case respectively. (See Appendix A for summary of notation.)

Timing and Assumptions

Our model consists of three periods. (See Figure 3.) At Date 0, each borrower decides whether to adopt the service or not based on the expected benefit, and if a borrower chooses to adopt, it writes an incomplete contract with the service provider (Morgan or RiskMetrics). At Date 1, the service provider chooses the levels of the two types of investments. Finally, at Date 2, the value is shared through bilateral bargaining between the service provider and each borrower. Therefore, there are n bargaining pairs, and these bargaining pairs are totally independent, that is, the service provider's investment decision and the borrower's adoption decision in each pair do not affect the decisions in other pairs. We adopt the Nash bargaining solution (i.e., 50:50 split) for surplus distribution in each pair. In the fee-based service case, we assume that the price has already been determined by the service provider before Date 0, and so we do not analyze its pricing decision.

We make the following assumptions.

Assumption 1: *Only the consequences of the quality enhancement investments (i.e., q(i) and c(i)) are subject to bargaining at Date 2.* This means that everything except for the costs and benefits of Date 1 investments are sunk, and $u(e)$ and $a(e)$ affects only a single party, that is, the service provider and a borrower respectively.

Assumption 2: *The effects of information exploitation investment are proportional to borrowers' riskiness b.* This assumption implies that the riskier a borrower is, the greater the adverse effect of the service provider exploiting the portfolio information (e.g., adjusting the lending rate or sharing information with other lenders), and the greater the service provider's gain from the exploitation. For the sake of simplicity, we multiply $a(e)$, and $u(e)$ by b.

Assumption 3: *There is no information exploitation problem in the fee-based service case*. This is because in the fee-based service case, the owner of the service is no longer the lender, but a third party (RiskMetrics Group) with multiple shareholders.

We further assume that both the service provider and the borrowers are risk neutral. We also make a technical assumption: $u'(e) - a'(e) \geq 0$.

We analyze the model backward from Date 1 in both cases. We first analyze the service provider's investment decision, and then the borrowers' adoption decision. We look at the first-best (e.g., socially optimal) situation where everything is contractible as a benchmark. This might be a situation where the service provider and each borrower can write a complete contract on each other's actions and consequences, and share the gains based on the contractual terms. In this case, for each relationship pair, the service provider and the borrower together would choose e and i to maximize the total net surplus from their relationship:

$$\max_{e,i} \Pi(e,i) = V \cdot b - C - a(e) \cdot b + u(e) \cdot b + q(i) - c(i) - e \quad (1)$$

With standard assumptions of convexity, concavity and monotonicity of the benefit and cost functions for each relationship pair, there exists a unique solution (e^*, i^*) that satisfies the following two first-order conditions:

$$b[-a'(e^*) + u'(e^*)] = 1 \quad and \quad q'(i^*) - c'(i^*) = 0 \quad \forall b \quad (2)$$

Analysis of Free Service Case (Before Spin-Off)

Service provider's Investment Decision. Assuming that the benefit from quality improvement is split 50:50 between the service provider and the borrower in each relationship pair, their profits are:

$$\Pi_b^f = V \cdot b - a(e) \cdot b - C + \frac{q(i)}{2} \quad \forall b \quad (3a)$$

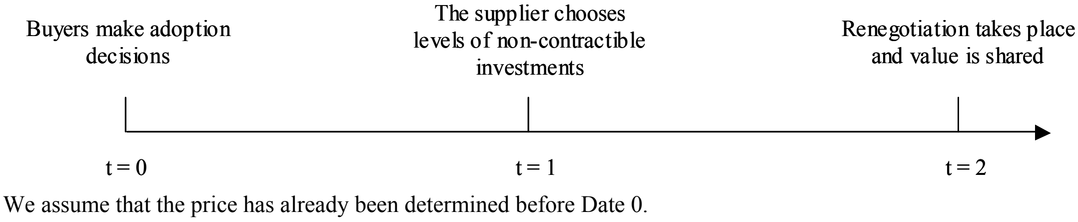
$$\Pi_s^f = u(e) \cdot b - e + \frac{q(i)}{2} - c(i) \quad \forall b \quad (3b)$$

Because the service is free, the intangible costs of effort i, $c(i)$, is borne solely by the service provider while the benefit from the effort is shared with the borrowers. The service provider chooses e and i to maximize its profit Π_s^f. With the unique solution (e^f, i^f), the corresponding two first-order conditions are:

$$u'(e^f) \cdot b = 1 \quad and \quad \frac{q'(i^f)}{2} - c'(i^f) = 0 \quad \forall b \quad (4)$$

Because borrowers' riskiness affects the service provider's equilibrium investment in information exploitation, we write $e^f(b)$. Due to the concavity of $u(e)$, the riskier a borrower is, the higher the service provider's information

FIGURE 3. TIMING OF ACTIONS IN THE MODEL



Note: We assume that the price has already been determined before Date 0.

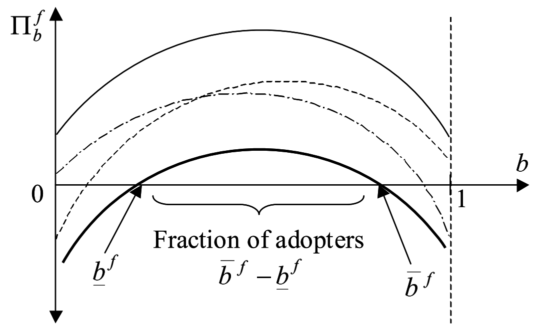
exploitation investment, and therefore $\frac{de^f(b)}{db} > 0$.

Borrowers' Adoption Decision. Because borrowers' relative riskiness affects the equilibrium level of e, a borrower's net benefit function becomes:

$$\Pi_b^f = V \cdot b - a(e^f(b)) \cdot b - C + \frac{q(i^f)}{2}. \quad (5)$$

Because $a(e)$ is convex and e^f is an increasing function of b as discussed above, under a mild assumption the benefit function is concave. (See Appendix for proof.) Given the concavity of the benefit function, there are four possible cases in terms of where the function assumes zero values. (See Figure 4.)

Figure 4. Possible Adoption Patterns for Free Service



Note: There are four possible cases in terms of where the function assumes zero values due to concavity.

We will focus on the case where non-adoption occurs at both extremes of riskiness, that is, $\Pi_b^f(b=0) < 0$ and $\Pi_b^f(b=1) < 0$ will be true. Using Eq. (5) and rearranging the terms, we get

$$C > \frac{q(i^f)}{2} \quad and \quad a(e^f)|_{b=1} > V - C + \frac{q(i^f)}{2}. \quad (6)$$

Let us represent the two marginal borrowers who are indifferent between adopting and not adopting RiskMetrics as $\bar{b}^f$ and $\underline{b}^f$, where $\underline{b}^f < \bar{b}^f$. Eq. (6) means that those borrowers who are less risky than $\underline{b}^f$ do not adopt RiskMetrics even though it is free because the value they get from the service is too small to offset the adoption costs. Those riskier than $\bar{b}^f$ also do not adopt because the risk of their information being exploited (i.e., $a(e)$) is so large that the net benefit becomes negative. So the fraction of borrowers who adopt RiskMetrics is $\bar{b}^f - \underline{b}^f$.

Analysis of Fee-Based Service Case (After Spin-Off)

Service provider's Investment Decision. There are three important distinctions from the free service case: there is a price, P, charged for the basic service; because now a third party with multiple shareholders owns it, the service provider does not make information exploitation investment e; and because the service is not free, not only the benefit from the quality enhancement but also the cost of the effort, $c(i)$, will be shared by the service provider and the borrower in each relationship pair during the bargaining at Date 2. So, assuming Nash bargaining over the gains, the parties' profits are:

$$\Pi_b^p = V \cdot b - P - C + \frac{q(i) - c(i)}{2} \quad \forall b \quad (7a)$$

$$\Pi_s^p = P + \frac{q(i) - c(i)}{2} \quad (7b)$$

The service provider will choose i to maximize its profit, Π_s^p. Denote the unique solution i^p, and the corresponding first-order condition is:

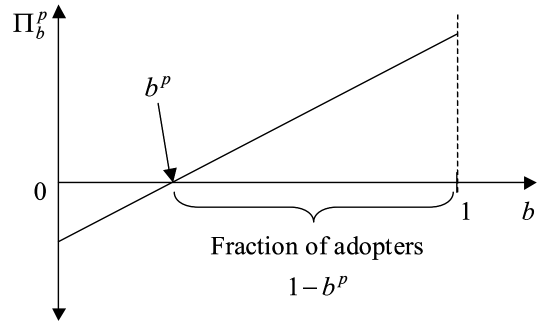
$$\frac{q'(i^p) - c'(i^p)}{2} = 0 \quad (8)$$

Borrowers' Adoption Decisions. We look at the marginal borrower, b^p, who is indifferent between adopting and not adopting the RiskMetrics service in the fee-based service case. Borrower b^p may be risky enough to gain value that just offsets the price and the costs of adoption. Setting the marginal borrower's benefit to zero, we get $0 = V \cdot b^p - P - C + \frac{q(i^p) - c(i^p)}{2}$. Solving for b^p yields

$$b^p = \frac{P + C - \frac{q(i^p) - c(i^p)}{2}}{V}. \quad (9)$$

Then, as shown in Figure 5, ($1-b^p$) is the fraction of borrowers adopting RiskMetrics because any borrower who is riskier than b^p will adopt the service (due to the linearity of Π_b^p in b).

Figure 5. Adoption Pattern for Fee-Based Service



MAIN RESULTS AND INTERPRETATION

We now provide four propositions based on our model to explain why Morgan had to change the ownership structure of RiskMetrics and how it affected borrowers' behavior and the owner's investment incentives.

When Morgan was the service provider, the borrowers were concerned about Morgan adjusting their lending rates based on their portfolio risk information submitted to the RiskMetrics system or sharing this information with others. This concern was substantially reduced when RiskMetrics was spun off. Additionally, the quality of the service has significantly improved after spin-off. This leads to our Proposition 1:

PROPOSITION 1 (SERVICE PROVIDER'S EQUILIBRIUM INVESTMENTS): *In the free service case, the service provider overinvests in information exploitation effort e, and underinvests in quality enhancement effort i relative to the first-best levels:* $e^f > e^*$, $i^f < i^*$. *In the fee-based service case, the service provider makes first-best level investments in the quality enhancement effort i:* $i^f < i^p = i^*$. *In addition, the riskier the borrower, the greater the service provider's information exploitation investment.*

Proof: Comparing Eqs. (2), (4), and (8) yields the result. (Q.E.D.)

Morgan's overinvestment in e is due to the fact that it reaps the full benefit from the investment (i.e., $u(e)$) while it does not bear the adverse effect of the investment (i.e., $a(e)$). However, Morgan underinvests in the quality enhancement (i.e., R&D for RiskMetrics) because it has to spit the benefit from the investment with the adopters while bearing the entire cost of quality enhancement. After the spin-off, the risk of information exploitation was substantially reduced or disappeared due to the multi-party ownership; now Morgan cannot utilize the clients' risk information for its own benefit because it is not the sole owner. Further, the quality enhancement investment increased after the spin-off because now the RiskMetrics group can split both the benefit and cost of the quality enhancement.

The positive relationship between the borrowers' riskiness and the service provider's incentive for information exploitation is intuitive. The riskier a borrower is, the greater the benefit from utilizing the borrower's risk information. For example, if Morgan found out that a borrower has become riskier, it might want to raise the lending rate or stop lending to the borrower to avoid potential loss.

As we mentioned above, despite the potential benefit of the free RiskMetrics service, the adoption by Morgan's clients stalled. We believe this was caused by two factors: the adoption costs and the potential damage by Morgan exploiting borrowers' risk information. This leads to our Proposition 2:

PROPOSITION 2 (ADOPTION STALLING BEFORE SPIN-OFF): *When the adoption costs are relatively high,* $C > \frac{q(i^f)}{2}$, *or the potential adverse effect of the information exploitation by the service provider is large,* $a(e^f)|_{b=1} > V - C + \frac{q(i^f)}{2}$, *full adoption does not take place in the free service case. Those borrowers who have too much or very little portfolio risk do not adopt the free RiskMetrics service.*

Proof: Examining Eq. (6) yields the result. (Q.E.D.)

This result is interesting in that non-adoption can occur around both extremes of riskiness. Borrowers who have very safe portfolio benefit little from the service, and so if the adoption costs are too high (e.g., it requires a lot of integration with their internal systems), their net benefit becomes negative. And others whose portfolio is very risky can benefit a lot from keeping track of their market risk through RiskMetrics. However, the service provider's incentive for exploiting their information also increases, and if the potential damage becomes too large, they cannot adopt the service despite the large potential benefit. This explains why adoption of RiskMetrics was limited when Morgan owned the service; only those borrowers who are moderately risky and could afford the adoption costs and the adverse effect adopted the service.

Providing a detailed technical document for its clients can be viewed as Morgan's effort to help those at the "lower tail" to adopt its service by reducing their adoption costs. Likewise, we believe that changing ownership structure by spinning off RiskMetrics Group was an effort to incentivize those at the "upper tail" to adopt by eliminating their concern about potential information exploitation. As a result, we believe more borrowers adopted the RiskMetrics service after spin-off. This leads to Proposition 3:

PROPOSITION 3 (FULL ADOPTION AFTER SPIN-OFF): *When the price charged by RiskMetrics Group is lower than a certain level,* $P \le \frac{q(i^P) - c(i^P)}{2} - C$, *full adoption occurs in the fee-based service case. Therefore, more borrowers will adopt the service in the fee-based case than in the free service case.*

Proof: Full adoption is possible if the least risky borrower's (b=0) net benefit is non-negative, that is, $\Pi_b^p(b=0) = V \cdot 0 - P - C + \frac{q(i) - c(i)}{2} \ge 0$. Rearranging terms, we get the above inequality. (Q.E.D.)

It may sound counterintuitive that more borrowers adopt the service when the service becomes fee-based, but this can happen due to two factors: the quality increase is greater in the fee-based case because the service provider's incentive for quality enhancement effort is greater, and the adverse effect from the service provider's information exploitation, $a(e)$, disappears in the fee-based case. As a result, borrowers' willingness-to-pay increases, and if the price is less than a certain level, then more borrowers will adopt with fees.

We showed that under certain conditions more borrowers will adopt RiskMetrics service after the spin-off. Now what about the profit of the service provider? Was it profit-maximizing for Morgan to spin off RiskMetrics? This leads to our final proposition:

PROPOSITION 4 (SERVICE PROVIDER'S PROFIT BEFORE AND AFTER SPIN-OFF): *Given the conditions in Proposition 2 and 3, if the price is greater than the decrease in the service provider's net benefit from its non-contractible investments, then the service provider's total profit is higher in the fee-based service case than in the free service case.*

Proof: Assume the conditions in Proposition 2 and 3 hold true (i.e., partial adoption before spin-off and full adoption after spin-off) and let F be the cumulative distribution function (uniform) for b. Then, based on Eqs. (3b) and (7b), the service provider's total profit in each case is given in Eqs. (10a) and (10b) below:

$$\int_{\underline{b}^f}^{\bar{b}^f} \Pi_s^f(b)dF = \int_{\underline{b}^f}^{\bar{b}^f} [u(e^f)\cdot b - e^f + \frac{q(i^f)-c(i^f)}{2}]dF$$

$$= \int_{\underline{b}^f}^{\bar{b}^f} [u(e^f)\cdot b - e^f]dF + (\bar{b}^f - \underline{b}^f)[\frac{q(i^f)}{2} - c(i^f)]$$

$$\int_0^1 \Pi_s^p(b)dF = \int_0^1 [P + \frac{q(i^p)-c(i^p)}{2}]dF$$

$$= P + \frac{q(i^p)-c(i^p)}{2}$$

Setting Eq. (10b) ≥ Eq. (10a) yields:

$$P \geq \int_{\underline{b}^f}^{\bar{b}^f} [u(e^f)\cdot b - e^f]dF + (\bar{b}^f - \underline{b}^f)[\frac{q(i^f)}{2} - c(i^f)] - [\frac{q(i^p)-c(i^p)}{2}] \qquad (11)$$

(Q.E.D.)

The right hand side represents the decrease in net benefit from the service provider's non-contractible investments (information exploitation and quality enhancement) when the service becomes fee-based. The inequality means that RiskMetrics Group could earn more profit than Morgan did as long as the price charged for the RiskMetrics service at least covers the loss in the benefit from its non-contractible investments.

Our last proposition partially explains why Morgan decided to spin off RiskMetrics; even though Morgan reduced its ownership share in RiskMetrics after spin-off, it still might have earned a greater profit because the borrower adoption level increased. Another key factor that does not show up in our model but can justify Morgan's decision is the one-time gain that Morgan must have enjoyed by selling ownership shares to such companies as American Express and Reuters.

CONCLUSIONS

We used the theory of incomplete contracts and other related theories to understand and explain why the RiskMetrics service, one of the most important innovations in the financial risk management arena during the last decade, was spun off and how the change in ownership structure affected borrowers' adoption behaviors and the service provider's profit. We analyzed two cases: free service and fee-based service. The former case corresponds to Morgan's ownership of RiskMetrics, and the latter case corresponds to RiskMetrics Group providing the service after spin-off from Morgan. One of the most important aspects of our model is borrowers' differential riskiness. We assumed that how risky a borrower is affects the value from the service through the impact of the service provider's information exploitation. Assuming Nash bargaining over the surplus from the non-contractible investments, we analyzed the service provider's investment decision and the borrowers' service adoption decision and found the following.

In the free service case where the service provider make two types of non-contractible investments, quality enhancement and information exploitation, we have shown that the service provider overinvests in information exploitation and underinvests in quality enhancement relative to the first-best levels. We have also shown that in the fee-based service case where it is assumed that there is no information exploitation, the service provider's equilibrium investment in quality enhancement is higher than in the free service case. We have also shown that the service provider's information exploitation is more severe for riskier borrowers.

Our result suggests that if the risk management service is free, adoption may stall because borrowers who have extreme values of riskiness do not adopt. Too risky borrowers may not adopt because of the high potential risk of their private information getting exploited by the service provider (Morgan). On the other hand, the safe ones may not adopt the service because the value they get from the service does not offset the adoption costs. The risk of information exploitation existed because Morgan was a lender as well as the service provider; it had an incentive to utilize its clients' private risk information for its lending operation. When a third party (RiskMetrics Group) owned the service, however, this risk disappeared because the service provider was no longer the lender, and therefore more—and possibly all if the price is not so high—borrowers adopted the service despite the fee charged for the service. Also, our model shows that the third-party has a greater incentive for enhancing the quality of the service, and we believe that this also contributed to increased adoption of the RiskMetrics service after the spin-off.

Finally, we have shown that within a certain price range (i.e., high enough to compensate for the decrease in the net benefit from its non-contractible investments when the service becomes fee-based, but low enough for more borrowers to adopt) the service provider's profit is greater in the fee-based service case compared with the fee-based service case. We believe this result justifies Morgan's decision to spin off RiskMetrics in 1998. Although Morgan reduced its ownership share in RiskMetrics, it might have earned greater profit after spin-off not only because the size of the "pie" got larger but also because it earned a large one-time profit by selling its ownership share to the other current shareholders of RiskMetrics Group. We believe the spin-off was a strategic move by Morgan to maximize it long-term profit from RiskMetrics.

To facilitate our analysis, we made some simplifying assumptions. Future research should investigate more realistic models to get additional insights by relaxing those assumptions. For example, we imposed an assumption that in the fee-based service case there is no information exploitation (i.e., *e*), but the model can be extended by making the choice of *e* endogenous in the fee-based service case. Also, the service provider's profit-maximizing pricing decision can be analyzed in addition to its investment decision. Another important extension is to incorporate externalities into the model, which may be useful to characterize the borrowers' and service provider's behavior during different stages of diffusion of RiskMetrics. Finally, it will be interesting to analyze a situation where not only the service provider but also the borrowers make non-contractible investments (e.g., integration with their internal systems), as suggested in Clemons and Kleindorfer (1992).

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APPENDIX A. MODEL ELEMENTS

ELEMENT	DESCRIPTION
b	index of borrowers riskiness. $b \in [0,1]$
e	service provider's non-contractible investment to exploit borrowers' private information ("information exploitation investment"). $e \in [0, \bar{e}]$
i	service provider's non-contractible investment to improve the quality of the service ("quality enhancement investment"). $i \in [0, \bar{i}]$
$V*b$	value of the basic service to borrower b
$u(e)$	service provider's benefit from e $u(0)=0, u'(0)=\infty, u'>0, u''<0, u'(\bar{e})=0$
$a(e)$	adverse effect of e. $a(0)=0, a'\ge 0, a''\ge 0$
$q(i)$	benefit from the quality enhancement effort i $q(0)=0, q'(0)=\infty, q'>0, q''<0, q'(\bar{i})=0$
$c(i)$	intangible costs of quality enhancement $c(0)=0, c'\ge 0, c''\ge 0$
C	borrower's one-time cost of adoption
P	price of the basic service
Π_b	borrower's net benefit
Π_s	service provider's profit from one adopter

APPENDIX B. PROOF OF CONCAVITY OF Π_b^f

For Π_b^f to be concave in *b*, its second derivative must be negative. The first order condition and the second order condition are:

$$\frac{d\Pi_b^f}{db} = V - a(e^f(b)) - b\frac{da(e^f(b))}{de^f(b)}\frac{de^f(b)}{db}$$

$$\begin{aligned}\frac{d^2\Pi_b^f}{db^2} &= -\frac{da(e^f(b))}{de^f(b)}\frac{de^f(b)}{db} - \frac{da(e^f(b))}{de^f(b)}\frac{de^f(b)}{db} \\ &\quad - b\frac{d^2a(e^f(b))}{d[e^f(b)]^2}\left[\frac{de^f(b)}{db}\right]^2 - b\frac{da(e^f(b))}{de^f(b)}\frac{d^2e^f(b)}{db^2} \\ &= -2\frac{da(e^f(b))}{de^f(b)}\frac{de^f(b)}{db} - b\frac{d^2a(e^f(b))}{d[e^f(b)]^2}\left[\frac{de^f(b)}{db}\right]^2 \\ &\quad - b\frac{da(e^f(b))}{de^f(b)}\frac{d^2e^f(b)}{db^2}\end{aligned}$$

As long as $e^f(b)$ is not strongly concave in b, the second derivative is negative because $a(e^f(b))$ is convex in $e^f(b)$, and $e^f(b)$ is increasing in b, that is,

$$\frac{da(e^f(b))}{de^f(b)} > 0,\quad \frac{d^2a(e^f(b))}{d[e^f(b)]^2} > 0,\quad \frac{de^f(b)}{db} > 0\ .\ \text{(Q.E.D.)}$$