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Melinda Cline
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Ni and Khazanchi Asymmetric Information and New IT investment

AYMMETRIC INFORMATION AND NEW IT INVESTMENT

Jinlan Ni
Department of Economics and Real Estate
College of Business Administration
University of Nebraska at Omaha
Omaha, NE 68182
Email: jni@mail.unomaha.edu,
Phone: (402)554-2549

Deepak Khazanchi
Information Systems & Quantitative Analysis
College of Information Science and Technology
University of Nebraska at Omaha
Omaha, NE 68106
Email: khazanchi@unomaha.edu
Phone: (402)554-2029

ABSTRACT

This paper investigates the impact of asymmetric information on IT managers' investment decisions in a rational expectation model. In our model, we capture the different levels of IT investment across managers by introducing heterogeneity across managers in terms of different levels of initial capital. One result of this assumption is that, in equilibrium conditions, some managers acquire an information advantage over others. We find that it is the manager with larger initial capital who is particularly interested in acquiring information about their IT investments in order to reduce any asymmetry with competitors. We also conclude from our study that the degree of IT investments across managers is linked to their size of initial capital outlay.

1. INTRODUCTION

The IT revolution and its contribution to the economy have been widely discussed in the literature [8] [19] [6]. Dedrick *et al.* systematically discussed and confirmed that greater investment in IT is associated with greater productivity growth [8]. The evidence that supports this view is based on return of IT investment calculated from disaggregated firm level data [12] [9] [1] [2]. Particularly, Anderson *et al.* found a positive relationship between firm value and relatively large IT spending and a negative relationship between firm value and relatively small IT spending [1]. The question that is of interest here is that if greater IT investment is linked to greater firm value, then why don't all firms invest more in IT?

In this paper we propose a model to explain that the different levels of IT investment across firms are due to asymmetric information. In other words, we investigate the role of asymmetric information on IT investment decisions by studying the link between the size of IT investment and the information used to make such decisions. *Information asymmetry* is created when one IT manager has more information than others. We evaluate two types of managers: the *informed* and *uninformed*. The *informed manager* can perceive the return of his future investment by paying a cost for the information-gathering process. Whereas, the *uninformed manager* cannot observe the return but can observe the cost of the investment through the price and then deduce the future return. The existence of information asymmetry may have significant effects on the level of IT investment. For example, the manager who has more information about the IT industry is perhaps more likely to have more profitable IT investments.

Specifically, our paper addresses the following research questions: (1) How do we measure the asymmetric information across IT managers?, and (2) What happens to the size of IT investment if IT managers have asymmetric information regarding the future return of their IT investment? To address these two questions, we set up a rational expectation model to explain that the measurement of asymmetric information depends upon the manager's initial capital. The rational expectation model introduces heterogeneous investors (in terms of initial capital) who decide whether to acquire costly information on the proposed IT investment. The number of informed investors is endogenously determined; in equilibrium, the market price reveals sufficient information such that the marginal investor is indifferent between acquiring and not acquiring information. We show that the informed investors have higher new IT investments, and we link the acquisition of information directly to initial capital by assuming that initial capital and absolute risk averseness are inversely related.

It should be noted that this paper is not the first one to introduce the role of uncertainty in the context of IT investment decision making. Zhu and Weyant showed how asymmetric information about firm's cost function affects firms' decisions to adopt the technology [22]. In contrast our model emphasizes the market uncertainty on the return of IT investment. This leads to the information acquisition decision of each manager. In this setup, the information asymmetry is **endogenous and so the decision maker will become informed if and only if it is beneficial to do so**. Several related studies view asymmetric information across decision makers technology investments as real options, such as [14] [5] [21] and [20]. Their approach assumes that the firm has a monopoly power over an investment opportunity. In contrast, our model views technology investments as asset investment such as [13] and [4], and all IT decision makers are price-takers in the competitive market.

The rest of the paper is organized as follows. Section 2 characterizes the model and the corresponding results. Section 3 uses a simulation to validate our model. The final section provides some concluding remarks.

2. MODEL

Our proposed model is an extension of the noisy rational expectation model with costly information acquisition introduced by [13]. In order to capture the different levels of IT investment across managers, we introduce heterogeneity across managers in terms of different levels of initial capital. There are a large number of investors such that each investor has an infinitesimal effect on the new IT investment market. The investors are uniformly distributed over the range [0, 1] according to the level of their initial capital. Besides this risky IT investment, the investor also has a risk-free asset to invest with a lower average return.

Each investor makes two sequential decisions: strategic information acquisition about IT investment and demand decision of this risky IT investment. If the investor decides to acquire information, she pays a cost c. Otherwise she remains uninformed about the future return of the IT investment. In order to focus on the information acquisition decision, we *assume that there are no barriers to investment other than the cost of information*. The decision to acquire information on a new IT investment is based on a comparison of the expected utility when informed to the expected utility when uninformed. To emphasize the role of asymmetric information, we view the IT manager as a single investor who maximizes his utility. There is no principle-agent problem between the firm and IT manager. The IT manager represents the firm to make a decision that brings the highest future return for the firm.

The information acquisition process leads to two types of investors in the market: the Informed (I) investors with information on IT market, and the Uninformed (U) investors. Below we identify a cutoff default initial capital $\bar{K}$, such that only investors with initial capital above this cutoff become informed. Given the distribution of initial capital $f(K_0)$, a higher cutoff $\bar{K}$ implies a lower proportion of informed investors. Both informed and uninformed investors make demand decisions about the new IT investment. The quantity of investment of informed investors depends on the revealed information on the future return of the new IT investment. The demand of uninformed investors depends on the asset prices only. Equilibrium prices clear the market by equating IT investment supply to its demand.

Since our rational expectation model is based on a two-stage game, we use the back-ward method. That is, starting with the second stage, we first solve the demand decisions given the information type. This is achieved by maximizing the IT investor's expected utility of future total return. The future total return is calculated from the return of current new IT investment and the return of risk-free investment. The First Order Condition (FOC) from this maximization procedure yields the demand of new IT investment for both types of investors. Second, we solve the equilibrium price by equating total IT investment supply (which is given) to total IT investment demand (sum up the demand of new IT investment of informed and uninformed investors). We can then use the investment demand and supply information to make the first stage decision – that is the information acquisition decision. This decision is made by comparing the expected utility of being informed and being uninformed. The investor will choose to be informed if the expected utility of being informed is higher than that of being uninformed. The detail derivation and corresponding results for this analysis are elaborated in the following sections.

2.1 The New IT Investment Decision

Assume that each investor has an initial capital K_0 that will be invested in two types of assets: a risk-free investment giving normal return and a risky IT investment with higher return. Denote by I^l the demand of risky asset by individual of type l ($l = I, U$). In a manner similar to [3], we further assume that investors have access to a risk-free asset available in limitless supply. Then the investor of type l will borrow/lend an amount of the risk-free asset equal to $K_0 - (\rho c + I^l P)$, where ρ is a function that equals zero if the investor is uninformed ($l = U$) and one if the investor is informed ($l = I$), P is the price of risky asset, and c is the information cost paid by an informed investor. Denote the gross real return of risky asset and the risk-free asset by R and r respectively. The variable R is defined as:

$$R = \theta + \varepsilon \,, \tag{1}$$

where the random variable θ has a normal distribution with mean $\overline{\theta}$ and variance ϕ. The error term ε is normally distributed with zero mean and variance σ^2. The random variables θ and ε have a multivariate normal distribution with $E(\theta\varepsilon) = 0$ and $Var(R \mid \theta) = \sigma^2$. θ is observable to the informed investors at cost *c*. Thus, given the risk-free return *r*, the investor of type *k* with initial capital K_0 has future total investment return (in period one) K_1^l of the form $K_1^l = (K_0 - \rho c)r + I^l (R - rP)$.

Next, we characterize the maximization of expected utility for different types of investors. Assuming an exponential utility function, the investor of type l ($l = I, U$) has utility $V(K_1^l)$ of the form:

$$V(K_1^l) = -\exp(-aK_1^l)\,, \tag{2}$$

where a is the coefficient of absolute risk aversion for an individual. It is reasonable to assume that one will be less risk averse if he owns larger initial capital. We thus adopt the following simple form of the inverse relationship between initial capital and risk aversion: $a = a(K_0) = 1/K_0$. Both informed investors and uninformed investors maximize the above expected utility in terms of the future capital income. For the informed investors, the maximization of the above expected utility with respect to I^I yields:

$$I^I = \frac{\theta - rP}{a\sigma^2} \quad \text{where } a = \frac{1}{K_0} \tag{3}$$

For the uninformed investors $(l = U)$, she infers partial information about this realized asset return component from the price function $P^*(\theta, s)$, where s, the random per capita supply of the risky asset, is independent of the random variables θ and ε. The first order condition yields the demand for the uninformed investors are:

$$I^U = \frac{E(R \mid P^* = P) - rP}{aVar(R \mid P^* = P)}, \qquad a = \frac{1}{K_0} \tag{4}$$

where $E(R \mid P^*)$ denotes the expected return on asset for an uninformed investor based on the observed price.

2.2 Equilibrium Price Distribution and Information Acquisition Decision

Equilibrium price of new IT investment equate investment supply to investment demand. That is, $\int_0^{\bar{K}} I^U f(K_0) dK_0 + \int_{\bar{K}}^1 I^I f(K_0) dK_0 = \int_0^1 sf(K_0) dK_0$, where s is per capita supply of the risky asset with mean $\bar{s}$ and variance χ. The right side of the equation is the supply of the asset. The left side is the sum of the demand by informed investors and the demand by uninformed investors. For the moment, we take as given that there is a common cutoff initial capital ($\bar{K}$) across investors, with only investors with initial capital above $\bar{K}$ becoming informed. We further define a prior price function w in order to characterize the equilibrium price. In our context, the prior price function is defined as:

$$w(\theta, s) = \theta - \frac{\sigma^2 (s - \bar{s})}{\frac{1}{2}(1 - \bar{K}^2)}, \tag{5}$$

Assuming that θ, ε and s are mutually independent with a joint normal distribution, there exist an equilibrium price such that total supply equals to total demand. The particular form of the prices is (Proof is available upon request):

$$P = \frac{\frac{\frac{1}{2}(1-\bar{K}^2) \cdot w(\theta, s)}{\sigma^2} + \frac{\frac{1}{2}\bar{K}^2 \cdot E(R \mid w(\theta, s))}{Var(R \mid w(\theta, s))} - \bar{s}}{\frac{1}{2} r \left(\frac{1-\bar{K}^2}{\sigma^2} + \frac{\bar{K}^2}{Var(R \mid w(\theta, s))}\right)}, \tag{6}$$

We now define the equilibrium cutoff initial capital $\bar{K}$, such that for the marginal investor with capital $\bar{K}$, the expected utility of becoming informed is equal to that of remaining uninformed, i.e., $E(V(K_1^I)) = E(V(K_1^U))$, which can be solved for the cutoff of initial capital for the marginal investor, $\bar{K}$. In particular, we have the following equilibrium condition that determines the capital of the marginal investor:

$$\exp(a(\bar{K}) rc) \cdot \sqrt{\frac{Var(R \mid \theta)}{Var(R \mid w)}} = 1, \quad \bar{K} \in (0, 1] \tag{7}$$

Given r, c and the variance parameters, we can solve (7) for the equilibrium $\bar{K}$.

We now characterize the individual decision of information acquisition**.** The expected gain of acquiring information is the difference between the expected utility of being informed and the utility of being uninformed, i.e., $G = E(K_1^I \mid \bar{K}) - E(K_1^U \mid \bar{K})$. An investor becomes informed if $G > 0$. At equilibrium, the expected gain G equals zero for the marginal individual as characterized by our overall equilibrium. We can show that the expected gain to becoming informed is an increasing function of the initial capital and a decreasing function of the cost of information. In other words, the investors who have the lowest information cost per unit of initial capital (hereafter referred to as the *information cost ratio,* c/K_0) will purchase the information first, and so on until the gain of acquiring information goes to zero and the equilibrium $\bar{K}$ is determined. We thus have the following propositions (detailed proofs will be available upon request):

Proposition 1: Given our assumption of a uniform distribution of investors' capital, information cost ratios are monotonically decreasing over the range $[0,1]$. There exists a cutoff information ratio, $c/\bar{K}$, such that an investor purchases information if and only if $c/K_0 \leq c/\bar{K}$.

Proposition 2: Given the parameters defining the home and foreign markets, the equilibrium cutoff capital, $\bar{K}$, is an increasing function of the information cost. That is, $\partial\bar{K} / \partial c \geq 0$.

Proposition 3: The expected demand of one's new IT investment is lower for the uninformed investors than for the informed investors.

Proposition 4: The investment level between the informed and uninformed will be more pronounced if the information cost increases.

Proposition 5: Given the information cost for acquiring information, investors with larger initial capital tend to invest more in the new IT investment.

In summary, the information cost ratio allows us to interpret the effect of asymmetric information on investment levels in two ways. First, we expect to see that the different levels of investment will be more pronounced if the cost for information gathering increases. Second, we have an implication to further empirical studies that the extent of investment tends to be larger for those investors who have larger initial capital.

3. AN EXAMPLE SIMULATION

The simulation is conducted using Maple software. To do this simulation, we first initiate the parameters in our model using Macro data (the mean of the gross return is set 1.12 for risky asset and 1.01 for the risk-free asset) or calibrated parameters from other literature (the variances of the return is 0.5, observation error is 0.4531 and asset supply are referred from Coval, 1999 [3] as mean 1 and variance 0,5735). Second, we generate 1000 observations for the random supply of new IT investment and the return of this IT investment according to its normal distribution using the given mean and variance. Third, for a fixed cost, we calculate the cutoff initial capital and thus the proportion of informed investors. Note that the initial capital is assumed to be uniform distribution in the model across the investors, and we choose an array of the number ([0, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1]) so that we can describe the individual decisions. We further calculate the price and the demand of new IT investment for each observation. We also calculate the gain of information acquisition for each investor. Finally, we take an average of the new IT investment over 1000 observations for each investor. In order to show how information cost affect the level of new IT investment, we repeat the third step and after by increasing the information cost according to the recurrence function $c_t = c_{t-1} + 0.04$, and then collect new demand of IT investment. We report these results in Table 1.

Table 1 reports the sign of the gain to information acquisition and the level of investment for the above simulations. We report the level of the investment for each investor with different initial capital. As we expected, the level of investment is lower for the uninformed investor with the lowest initial capital, and the level of investment rises with the investor with the greater initial capital. The rest of the Table indicates how an increase in the information cost decreases the percentage of informed investors (notice the switch of the sign of the information value for each investor). Instead, we see that the percentage of new IT investment by the informed rises with the information costs.

Table 1: Information Acquisition Decision and Individual Investment As Cost Changes

t	Cost	Cutoff wealth	Investors with initial wealth at following values									
			0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
			-	-	-	-	-	-	+	+	+	+
1	0.004	0.67	54	109	163	218	272	326	**379**	**434**	**488**	**542**
			0.02	0.04	0.06	0.07	0.09	0.11	0.13	0.15	0.16	*0.18*
			-	-	-	-	-	-	+	+	+	+
2	0.03	0.70	50	100	149	199	249	299	**389**	**445**	**501**	**556**
			0.02	0.03	0.05	0.07	0.09	0.10	0.13	0.15	0.17	*0.19*
			-	-	-	-	-	-	-	+	+	+
3	0.06	0.73	46	92	138	184	230	276	322	**457**	**514**	**571**
			0.02	0.03	0.05	0.07	0.08	0.10	0.11	0.16	0.18	*0.20*
			-	-	-	-	-	-	-	+	+	+
4	0.09	0.76	43	86	128	171	214	257	299	**469**	**527**	**586**
			0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.17	0.19	*0.21*
			-	-	-	-	-	-	-	+	+	+
5	0.12	0.79	40	80	121	161	201	241	281	**481**	**542**	**602**
			0.02	0.03	0.04	0.06	0.07	0.09	0.10	0.18	0.20	*0.22*
			-	-	-	-	-	-	-	-	+	+
6	0.15	0.82	38	76	114	152	190	228	266	304	**556**	**618**
			0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.12	0.22	*0.24*
			-	-	-	-	-	-	-	-	+	+
7	0.18	0.85	36	72	109	145	181	217	253	290	**572**	**635**
			0.01	0.03	0.04	0.06	0.07	0.09	0.10	0.12	0.23	*0.25*
			-	-	-	-	-	-	-	-	+	+
8	0.21	0.89	35	69	104	139	174	208	243	278	**587**	**653**
			0.01	0.03	0.04	0.06	0.07	0.08	0.10	0.11	0.24	*0.26*
			-	-	-	-	-	-	-	-	-	+
9	0.24	0.93	33	67	100	134	167	201	234	268	301	**666**
			0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.12	0.14	*0.31*
			-	-	-	-	-	-	-	-	-	+
10	0.27	0.99	21	42	63	84	105	126	147	168	189	**431**
			0.02	0.031.	0.05	0.06	0.08	0.09	0.11	0.12	0.14	*0.31*

Note: "+" ("-") means gain (loss) to acquire information. The number below the (+) or (-) sign reports the level of the individual investment. We also report the percentage of indidual investment to the total investment below each level of investment.

4. CONCLUSIONS

This paper explores the role of asymmetric information in explaining the different levels of IT investment at the firm level. Our model considers the information acquisition process with heterogeneous investors as the context in which such investment decisions are made. Using a simulation, we demonstrate a direct link between initial capital available, the acquisition of information cost and the different levels of new IT investments.

Recent empirical research reiterates the importance of IT investment and its impact on firm value or productivity. In contrast, our study of the different levels of IT investment in firms indicates that not all the firms have taken advantage of IT investments. The reason, as our model shows, is related to the lack of awareness of IT managers and their understanding of the true nature of IT investment returns due to the cost of acquiring information. Specifically, we found that firms with larger initial capital outlay have a competitive advantage in their ability to acquire information about the context of their IT investment portfolio because the information cost per unit of investment is relatively low.

Our research has important implications for IT managers who make critical investment decisions in their firms. The results also provide some indication as to how IT projects should be evaluated and the managerial ability needed to effectively invest and optimize an organization's IT portfolio. For example, IT managers who can obtain more information about the IT industry and different applications, cost and risks associated with cutting-edge IT are perhaps more likely to have more profitable IT investments.

Appendix and References are available upon request from the first author at jni@mail.unomaha.edu.