A Model of Entry-Exit Decisions and Capacity Choice under Demand Uncertainty

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Abstract

Many investment decisions of agribusiness firms such as when to invest in an emerging market or whether to expand the capacity of the firm involve irreversible investment and uncertainty about demand, cost or competition. This paper uses an option-value model to examine the factors affecting an agribusiness firm's decision whether and how much to invest in an emerging market under demand uncertainty. Demand uncertainty and irreversibility of investment make investment less desirable than the net present value (NPV) rule indicates. The inactive firm is more reluctant to enter the market when it takes into account demand uncertainty because it preserves the opportunity of making a better investment later. The active firm is more reluctant to abandon the investment because there is an option value of keeping the operation alive. There is a greater distance between the entry and exit thresholds under the option-value approach than under the NPV rule due to demand uncertainty. The results have implications for agribusiness decision-making to understand and respond to uncertainty.

Key Words: agribusiness decision-making, demand uncertainty, entry-exit decisions, net present value, real options, remote sensing.

1. Introduction

Many investment decisions of agribusiness firms such as when to invest in an emerging market or whether to expand the capacity of their operations involve large sunk costs of investment and uncertainty about prices, demand, cost or competition. Most firms have the opportunity to delay the entry decisions to learn more about prices, costs, and other market conditions before making investment expenditures that are at least partially irreversible. In some cases, if flow of their profits became negative, active firms could suspend their operations and later restart the operations, but only at a substantial cost. In an uncertain economic environment, most firms are also faced with a decision whether and how much to expand the capacity of their operations. Firms may need to understand and respond to uncertainty when making these investment decisions.

An excellent example of such an investment decision is the entry and exit decisions and capacity choice of agribusiness firms in remote sensing technologies (RST). Recent technological developments in RST are making it possible for farmers to obtain spatially referenced data about field characteristics such as soil nutrients or growing conditions of crops within a farm field. These data can be used to vary inputs within the field with variable rate technologies that are attached to global positioning systems and computers (Dupont et al., 2000; Willers et al., 1999)[1]. Several studies have shown that this technology has the potential to increase agricultural productivity by enhancing output and/or increasing the efficiency of applied inputs (Babcock and Pautsch, 1998; Thrikawala et al., 1999; Isik et al., 2001; Isik and Khanna, 2002). Despite the potential for providing economic and environmental benefits, recent surveys

[1] Remote sensing refers to a method of collecting data or information about an object without physically touching the object under observation. Photographs of plots of land can be taken using variety of cameras mounted to airplanes or satellites, which then can be used to assess such issues as the health of the plants growing in the fields to predict problems with fertilizers, water, and pests.

show that adoption rates of RST and variable rate technologies are low (Khanna et al., 1999). Farmers are not readily adopting these technologies due to a high degree of uncertainty in returns, high costs of adoption and lack of demonstrated benefits (Khanna et al., 1999; Isik et al., 2001; Isik and Khanna, 2002).

There has been intensive effort by the National Aeronautics and Space Administration (NASA) to commercialize the use of RST in agriculture and forestry. NASA has established several remote sensing research centers to provide incentives in the form of research and development to agribusiness firms that can provide spatially referenced data to farmers. Investment in the collection and dissemination of RST data is crucial for the widespread adoption of RST by farmers. This investment would provide affordable custom services for acquisition of spatial data to farmers. However, investment decisions of firms for RST are complicated. This is because investment in the development and commercialization of RST involves large sunk costs, a high degree of uncertainty in returns, and some leeway in the timing of investment. RST is undergoing rapid technological innovation and improvement. Thus, the resulting technological obsolescence of existing equipment makes it unlikely for firms to recover their sunk costs if the investment were to be liquidated due to a downward turn in revenues. Firms considering investing in RST must also make their investment decisions under limited demand for RST among farmers and under uncertainty about the prospects for future demand for RST. Therefore, firms face not only low current adoption rates of RST but also uncertain future adoption patterns when determining the timing of investment and capacity of their operations.

The purpose of this paper is to develop a model of decision-making for an agribusiness firm with market power considering whether and how much to invest in an emerging market such as RST under demand uncertainty. It uses an option-value model to examine the factors

affecting the firm's investment decision in RST and to understand the role of demand uncertainty and irreversibility on entry-exit decisions and capacity choice. We derive two alternative sets of solutions to the firm's decision problem. First, we examine the entry and exit strategies by obtaining the threshold levels at which it is optimal to invest in RST and to abandon the investment. Second, we derive optimal capital investment of an active firm that has already invested in RST. The model provides a framework for investment under uncertainty in various emerging markets such as biotechnology, internet, telecommunication and computer industry.

Several studies on investment under uncertainty have examined the impacts of uncertainty and irreversibility of investment on firms' entry and exit decisions (Brennan and Schwartz, 1985; Dixit, 1989; McDonald and Siegel, 1985; Majd and Pindyck, 1987; Myers and Majd, 1999; Dixit and Pindyck, 1994) and capacity choice (Pindyck, 1988; Dixit and Pindyck, 1994; Trigeorgis, 1996)[2]. These studies focused on either (1) whether to invest in a project whose returns are uncertain or (2) how much to invest in the project if the firm has already entered the market. The factors that influence entry and exit decisions also impact the firm's capacity choice. The studies on capacity choice did not address entry and exit strategies of the firm while the studies on entry and exit decisions did not analyze the optimal capacity choice after the firm makes the initial investment required to enter the market. However, these two decisions, entry-exit and capacity choice, are not independent in many situations and should be considered together. This paper sequentially combines the entry and exit decisions of the firm with the capacity choice decisions, and applies the developed framework to an agribusiness firm's decision to invest in an emerging market.

[2] A number of empirical studies in agriculture applied the option value to examine only entry decision, i.e., when to invest in a project (Purvis et al., 1995; Winter-Nelson and Amegbetto, 1998; Khanna et al., 2000; Isik et al., 2001).

The empirical application considers a firm's decision whether and how much to invest in RST. It shows that the net present value (NPV) rule that ignores the role of demand uncertainty and irreversibility on investment decisions tends to overestimate the capital investment in RST. Under demand uncertainty, the firm invests in RST when the demand conditions are sufficiently favorable while it abandons when they become sufficiently adverse. By delaying the investment decision, the firm preserves the opportunity of making a better investment later. A greater uncertainty in industry demand implies less willingness to invest in RST and less willingness to expand the capacity of the firm. The results of the paper are expected to contribute to the understanding of the factors that influence firms' decisions to invest in emerging markets.

2. Theoretical Model

2.1. The Conceptual Framework and Model Assumptions

We examine whether and how an agribusiness firm invests in its capital stock in the RST market. The firm faces demand uncertainty due to unknown future adoption patterns of RST among farmers. It needs to make a fixed capital investment, K_0, to enter the RST market. Thereafter, each unit of capital costs κ and the firm chooses the time path of its capital stock (K_t) to maximize the expected present value of its operating profits. We assume that once the firm makes the initial investment and enters the market, it has the monopoly power to expand its capacity in the industry[3]. Irreversible investment in RST is treated without any costs of adjustments and sunk cost of any addition to the stock of capital is proportional to the size of that addition. It is assumed that the firm's production function shows diminishing returns to scale.

[3] The assumption of the monopoly power is not required to model the firm's entry-exit decision. A model of entry-exit decision with a monopoly and that with a competitive market would yield the similar results. The assumption of the monopoly power for the active firm is reasonable for investment in RST because RST is still undergoing rapid innovation and investment involves high sunk costs. Monetary and technical barriers to entry will likely limit competition in the short term. Extension of the monopoly assumption over the longer term is a limiting assumption.

This allows us to conceptually line up successive units of capital in a decreasing order of their marginal productivity and treat them as distinctive investment projects. It is also assumed that if the operation is suspended, the firm needs to incur some investment costs, *E*, to restart it, but restarting is not as costly as new investment, i.e., $E < K_0$. This involves legally required termination payments to workers and other required expenses. Let ρ be the rate at which the future profits are discounted.

When the firm makes a fixed cost of investment K_0 to enter the RST market, it obtains a project that makes it possible to provide services to *Q* acres of land. It is assumed that the per-acre variable costs of operation (*C*) are known and constant. The industry demand function defines the functional relationship between price and acres demanded by farmers. The demand function is defined as $P = Y - bQ$, where *Y* is the stochastic variable and *b* is the constant slope. It is assumed that *Y* follows a geometric Brownian motion represented by[4]:

$$dY = \alpha Y dt + \sigma Y dz \tag{1}$$

where α is the drift parameter (growth rate of *Y*); σ is the standard deviation in drift; and *dz* is the increment of the Weiner process. Equation (1) says that the current value of *Y* (and thus the current demand function) is known, but future values of *Y* are unknown and are log-normally distributed with a variance that grows with the time horizon. Geometric Brownian motion is a plausible representation of uncertainty in the demand of RST services by farmers in the short term. This is because current adoption rates of RST services and variable rate technologies among farmers are relatively low. Only 12% of the farmers adopted variable technologies in the

[4] Note that geometric Brownian motion is not the only stochastic process to model demand uncertainty. Other stochastic processes such as logistic growth can be employed especially in modeling the demand of RST services in the long term. However, it is not possible to obtain analytical results (i.e., equation (3) below) with these processes and the model must be solved numerically. To preserve analytical clarity as in Dixit (1989) and Dixit and Pindyck (1994) while focusing on the firm's investment decision in the short term, we use a geometric Brownian motion.

Midwest region of the U.S. in 1998 (Khanna et al., 1999). Adoption rates of these technologies are also expected to increase at a relatively constant rate (about 5% a year) over the next decade as shown by Khanna et al. (1999).

Acres covered by the firm depend on the capital stock of the firm: $Q = G(K)$ with $G'(K) > 0$ and $G''(K) < 0$. The profit of the firm is given by:

$$\pi = [Y - bG(K) - C]G(K). \tag{2}$$

The marginal revenue product of capital is $G'(K)[Y - 2bG(K) - C]$. There are diminishing returns to capital in the sense that the marginal revenue product is decreasing in *K*. This is because of a downward-sloping industry demand curve and diminishing returns in production. The profit flow in (2) is regarded as the outcome of an instantaneous optimization problem where variable inputs such as labor or raw materials are chosen holding the level of capital fixed.

2.2. Optimal Investment in RST

We model the firm's decision to invest in RST using an option-value model in a two-sequential step. In the first step, the firm needs to decide whether to make a fixed cost investment, K_0 to enter the RST market. This step also involves conditions under which the firm abandons the investment. If the firm enters the RST market, the second step deals with the decision when the firm finds it profitable to expand the capacity of the firm.

Entry and Exit Strategies

We build on the models of Dixit (1989) and Dixit and Pindyck (1994) to develop a combined entry-exit strategy for the firm using dynamic programming. The differences between these models and the model presented in this study are in the specification of demand function and the numerical example calibrated to the investment decisions in RST.

Following the model developed by Dixit and Pindyck (1994, pp. 216-218) but instead using a linear demand function, we obtain the following four equations to solve four unknowns, Y_L^O, Y_H^O, *B*, and *A* as:

$$-A\left(Y_H^O\right)^{\beta_1} + B\left(Y_H^O\right)^{\beta_2} + G(K_0)\left(Y_H^O/(\rho-\alpha) - \left(bG(K)+C\right)/\rho\right) = K_0 \quad (3.a)$$

$$-\beta_1 A\left(Y_H^O\right)^{\beta_1-1} + \beta_2 B\left(Y_H^O\right)^{\beta_2-1} + G(K_0)/(\rho-\alpha) = 0 \quad (3.b)$$

$$-A\left(Y_L^O\right)^{\beta_1} + B\left(Y_L^O\right)^{\beta_2} + G(K_0)\left(Y_L^O/(\rho-\alpha) - \left(bG(K_0)+C\right)/\rho\right) = -E \quad (3.c)$$

$$-\beta_1 A\left(Y_L^O\right)^{\beta_1-1} + \beta_2 B\left(Y_L^O\right)^{\beta_2-1} + G(K_0)/(\rho-\alpha) = 0 \quad (3.d)$$

where *B* and *A* are constants to be determined; Y_L^O is the entry threshold for the demand variable; Y_H^O is the exit threshold for the demand variable; and β_1 and β_2 are the positive and negative roots of the quadratic equation $0.5\sigma^2\beta(\beta-1)+\alpha\beta-\rho=0$, respectively. Because the above equations are nonlinear in the thresholds (Y_L^O and Y_H^O), an analytical solution in closed form does not exist. The thresholds need to be solved numerically. These thresholds define the level at which the firm finds it optimal to enter, Y_H^O and optimal to abandon, Y_L^O. Abandonment is optimal at a large threshold level of operating loss depending on the magnitude of the costs of restarting the operation. The firm does not abandon the project as soon as its operating profit turns negative because there is an option value of keeping the operation alive. These results are consistent with those of Dixit (1989) who obtains the entry and exit thresholds of output prices assuming that prices follow a geometric Brownian motion.

The NPV rule of investment and abandonment is to compare the rate of return on the investment and that on the disinvestments to the normal return, ρ. Ignoring the uncertainty about demand (*Y*) and assuming that the demand grows at a rate α, the NPV rule obtains the entry threshold as: $Y_H^N = (\rho-\alpha)\left[K/G(K_0) + \left(bG(K_0)+C\right)/\rho\right]$ and the exit threshold as:

$Y_L^N = (\rho - \alpha)[-E/G(K_0) + (bG(K_0) + C)/\rho]$. There is a greater distance between the entry threshold and the exit threshold under the option-value approach ($Y_H^O - Y_L^O$) than under the NPV rule ($Y_H^N - Y_L^N$). When the inactive firm takes into account the uncertainty about future demand conditions, it is more reluctant to invest in RST (i.e., $Y_H^O > Y_H^N$). On the other hand, if the firm is already active, it is more reluctant to abandon the investment (i.e., $Y_L^O < Y_L^N$) due to the option value of keeping the operation alive.

The impacts of ρ and α on the entry and exit thresholds can be determined by obtaining comparative statics results. An increase in ρ and/or decrease in α leads to an increase in both Y_H^N and Y_L^N, thereby discouraging entry to the market under the NPV rule. Under the option-value approach, these results may not hold because ρ and α enter into the quadratic equation whose roots are the powers β_1 and β_2. Thus, changes in these parameters have complicated impacts on Y_H^O and Y_L^O, and the numerical simulations need to be used to examine the impact of ρ and α on the entry and exit thresholds.

When the firm makes the initial investment K_0 to enter the RST market, it also needs to determine capacity of its operation, i.e., the time path of its capital stock (K_t) to maximize the expected present value of its operating profits. This is important because the firm's entry-exit decisions and capacity choice are not independent for investment in the RST market. Both decisions are affected by the demand uncertainty and irreversibility of the investment and the firm still needs to take into account entry-exit strategies when deciding the capacity of its operation.

Capacity Expansion in the RST Market

We now examine the capacity choice of the firm that has already made the initial capital investment, K_0, and entered the RST market. Given the initial capital stock (K_0) and the initial level of the stochastic demand variable, *Y*, the firm chooses the time path of its capital stock, K_t, to maximize the expected present value of its operating profits, net of the costs of investing in RST. We begin with a model of the capacity expansion based on Pindyck (1988) and Dixit and Pindyck (1994).

Following Dixit and Pindyck (1994, pp. 359-365) but instead using a linear demand function, we solve the critical value at which it is optimal to expand the capacity of the firm in terms of *K*, $Y^O(K)$ as:

$$Y^O(K) = \frac{\beta_1(\rho-\alpha)}{(\beta_1-1)}\left[\frac{\kappa}{G'(K)} + \frac{(2bG(K)+C)}{\rho}\right]. \tag{4}$$

Equation (4) indicates that successive units of capital, with successively lower marginal products, require successively higher thresholds of demand. It also indicates that a marginal addition to the firm's capital stock in RST is justified when the expected value exceeds the costs of the capital by the multiple $\beta_1/(\beta_1-1)>1$, which represents the opportunity cost of the option to wait to expand the capacity of the firm in the future.

Under the NPV rule, the firm would obtain its optimal investment from the first-order condition, which leads to a threshold level of the demand variable at which it is optimal to make the additional investment in RST: $Y^N(K) = (\rho-\alpha)[\kappa/G'(K) + (2bG(K)+C)/\rho]$. The threshold at which it is optimal to invest under the option value given in (4), $Y^O(K)$ exceeds that under the NPV rule, $Y^N(K)$ by the option-value multiple $\beta_1/(\beta_1-1)$ (i.e., $Y^O(K) = \beta_1/(\beta_1-1)Y^N(K)$). As the uncertainty about demand (*Y*) increases, the option-value multiple increases and thus the

impact of demand uncertainty on investment decision is to increase the threshold value of demand at which it is optimal to make additional investments. Thus, the capital investment under the NPV rule is higher than that under the option value. This indicates that the demand uncertainty and irreversibility of the investment lead to a reduction in the amount of capital invested in RST[5].

The relationship between entry-exit thresholds and the threshold for capacity expansion under the NPV rule and the option-value approach is presented in Figure 1. It indicates that the firm's capacity choice is linked to its entry-exit decisions. When the firm enters the RST market, it decides the capacity of the firm by taking into account the exit threshold. The firm is more reluctant to abandon the investment due to the option value of keeping the operation alive but still considers whether to exit when deciding how much additional investment would be optimal. The combination of entry-exit decision and capacity choice defines the firm's investment strategies for RST under uncertainty.

3. Empirical Applications

We use a simulation model to illustrate the extent to which demand uncertainty and irreversibility have impacts on entry-exit decisions and capacity choice of agribusiness firms using the case of Global Positioning Solutions (GPS), Inc. located in Mississippi[6]. GPS invests in aircraft and a variety of cameras to take photographs of the farm fields in the Delta region of Louisiana, Mississippi and Arkansas in the U.S. These photographs can provide detailed information about the field characteristics such as growing conditions of crops and potential pest

[5] The impacts of ρ and α on the capacity expansion threshold are also similar to those on the entry-exit thresholds examined above. An increase in ρ and/or decrease in α leads to an increase in the capacity expansion under the NPV rule. Under the option-value approach, these factors could reduce the capacity expansion threshold because ρ and α enter into the multiple $\beta_1/(\beta_1 - 1)$, which decreases with an increase in ρ and a decrease in α.

[6] GPS, Inc is currently operating. However, for the simulation model, it was assumed that GPS was attempting to make the decision to invest. Current data from GPS was used to formulate the simulation.

population (Willers et al., 1999), which then can be used by farmers to address problems with fertilizers, water and pests at a varying rate within the field to meet location specific needs at the sub-field level. RST can make it possible for the farmer to apply fertilizers and pesticide at a spatially varying rate across the field, as opposed to conventional farm management practices that apply fertilizers and pesticide uniformly across the field. This technology has the potential to increase crop yields and/or reduce applied inputs, thereby increasing farm profitability.

Photographs of the farm fields can also be taken by satellite. However, there is no commercial satellite currently capable of providing a resolution less than three meters, which is not particularly useful for agricultural uses because this resolution is not capable of detecting subtle changes in the crop conditions[7]. Photographic equipment mounted on aircrafts, however, is capable of delivering 1-meter and sub-meter resolution. Another drawback to using satellites is the fact that satellites are on a regular earth orbit. If weather conditions are not favorable when the satellite is over a farm, then it may be days or weeks before the satellite is back into position over that farm to take the necessary photographs. By contrast, if weather conditions are bad today, an airplane can still fly whenever the weather conditions clear. This issue of timeliness is an advantage of using aircraft to do flyover photography. Because field and plant conditions can change quite rapidly during the growing season, being able to deliver information to farmers "on-demand" would be a competitive advantage over satellite photography. The management of GPS believes that it will take 8 to 12 years before satellites with sufficient resolution to be commercially viable. Therefore, it is assumed that the investment horizon of GPS is 12 years.

To enter the RST market, GPS needs to make a $500,000 investment to set up the business. This includes leasing two airplanes, remote sensing equipment and necessary office

[7] Resolution refers to the general quality of the photograph, and is generally measured in the number of meters.

and legal expenses. There are exit costs if the firm ever shutdowns the business and later restarts the operation. These costs include legal expenses, capital losses on equipment, and required payments to workers. These costs were estimated to be about $250,000 for GPS. The firm's production function defines the relationship between the acres covered (Q) and the amount of capital invested (K), and assumed to take the Cobb-Douglas form. The production function is calibrated using the relationship between the capital investment and the amount of acres served by GPS. GPS can provide services to 100,000 acres in a year with a $500,000 investment[8]. GPS can cover an additional 70,000 acres with an additional $500,000 in RST. Using this relationship, we obtain the parameters of the Cobb-Douglas production function as:

$$Q = 4.3375K^{0.765}. \tag{5}$$

The parameters of the demand function, Y and b, are obtained using the current price and quantity for GPS; the current price is $4.7 per acre per year for the services it provides. The parameters of the demand function are assumed to depend on the elasticity of demand. We use two alternative parameters for the elasticity of demand to get the value of the slope (b) and the current value of the constant (Y) in the demand function. When the elasticity of demand is 0.4, the current value of Y is equal to 16.45 and b is equal to 0.000117. When the elasticity of demand is 1.4, Y and b are 8.06 and 0.000034, respectively. Variable cost of services (C) is assumed to be $1.2 per acre per year. We use three alternative discount rates (ρ) and unit cost of capital (κ) - 5%, 10% and 15%. The expected growth rate in Y (α) is assumed to take two alternative values: 2% and 10%. In the simulations, we also use two alternative standard deviations of Y (σ), 0.10 to represent the case of low uncertainty and 0.40 to represent the case of high uncertainty.

[8] At this point, the scientific evidence suggested that RST is only viable on cotton production in the Mississippi Delta. There are approximately three million acres of cotton planted each year in that region. Also, note that the 100,000 acres is photographed four times during the growing season so that GPS is actually covering 400,000 acres.

The model first estimates the entry and exit thresholds and compares the entry threshold to the current value of *Y*. If the current value of *Y* is as large as the entry threshold, the firm enters the RST market. If the firm invests in RST, we then obtain the threshold value of *Y* at which the additional investment is optimal and the optimal quantity of additional investment.

4. Results

Entry-Exit Decisions

Table 1 presents the critical value of the demand variable *Y* at which it is optimal to invest in RST and at which it is optimal to abandon the investment under both the NPV rule (Y_H^N and Y_L^N), and the option-value approach (Y_H^O and Y_L^O) assuming 10% discount rate and 2% growth rate of *Y*. Under the NPV rule, the entry and exit thresholds vary with the assumed elasticity of demand. The current values of the demand variable *Y* with the inelastic demand (16.45) and with the elastic demand (8.06) are higher than the threshold value of *Y* at which it is optimal to invest in RST. This indicates that it is optimal for the firm to make the required capital investment to enter the RST market regardless of the value of the elasticity of demand considered here under the NPV rule.

Under the option value, the entry and exit thresholds depend on the demand volatility and the elasticity of demand. As expected, as the uncertainty represented by volatility in *Y* increases, the entry threshold increases while the exit threshold decreases. It is not optimal to invest in RST in most cases examined here because the current value of *Y* is lower than the critical value of *Y* at which it is optimal to invest in RST (Y_H^O). The firm would not enter the RST market if the degree of uncertainty were relatively high. The critical value of demand level (*Y*) at which it is optimal to invest under the option-value approach is much higher than that under the NPV rule. This indicates the importance of demand uncertainty and irreversibility of the investment on the entry

and exit decisions. If the inactive firm considers the uncertainty over future demand conditions and irreversibility of the investment in investment decisions, it is more reluctant to invest in the RST market. On the other hand, the firm is more reluctant to abandon the investment if it is already active in the market[9].

Capacity Choice of the Firm

Table 1 also presents the critical values of the demand variable at which it is optimal for the firm that has already entered the RST market in order to expand the capacity of the firm ($Y^O(K)$ and $Y^N(K)$). The NPV rule indicates that if the demand is elastic, the firm makes the additional investment while it does not make the additional investment if the demand is inelastic. This result illustrates the basic monopoly problem. The firm would not make the additional investment in RST unless the additional investment increases its profit. Because an increase in the capital investment leads to an increase in the profit if the demand is elastic, it is optimal to invest additional capital in the RST market. If the demand is inelastic, an increase in the capital investment in the RST market does not lead to an increase in the profit. The critical value at which it is optimal to make the additional investment in RST under the option value, $Y^O(K)$ is almost three times as high as that under the NPV rule, $Y^N(K)$ due to the uncertainty about demand and irreversibility of RST investment. The firm would not make any additional investment in RST regardless of the elasticity of demand when considering demand uncertainty and irreversibility of the investment.

[9] The results indicate that the entry is not optimal for GPS under uncertainty and irreversibility. There might be other factors affecting the firm's actual entry decision, which are not incorporated here. Such factors include loans with low interest rates, learning, and expectations of future demand. GPS has received assistance in the form of low interest loans and grants from the government for start-up. Also, if the firm can learn more about the industry by entering early, or has different expectations about future adoption patterns, its entry-exit strategies will be different. However, the firm's current attitude toward capacity expansion is consistent with the results presented below.

Impacts of Discount Rate and Other Variables on Investment Decisions

We also examine the impacts of the discount rate on the entry-exit decisions and capacity choice of the firm. For example, a decrease in the discount rate from 10% to 5% marginally increases the present value of the expected returns from the investment in RST but also increases the value of the option to invest in the future under the option-value approach (Table 2). The magnitude of an increase in the value of option to invest in RST in the future is much higher than the increase in the present value of the expected returns from the investment. Thus, under the option-value approach, the net impact of a decrease in the discount rate from 10% to 5% is to significantly increase the entry and exit thresholds as well as the threshold for the additional investment to increase the capacity of the firm under the option value. This indicates that a decrease in the discount rate under the option-value approach would decrease incentives to invest in RST. On the other hand, under the NPV rule, a decrease in the discount rate from 10% to 5% marginally reduces the estimated thresholds due to an increase in the present value of the expected returns from investment in RST, thereby leading to an increase in the incentives to make investment in RST. These results are consistent with the comparative statics results presented in the theoretical model[10].

The impact of the growth rate of Y on the entry and exit thresholds and capacity expansion threshold is also analyzed. The thresholds with the 10% growth rate and 10% discount rate are summarized in Table 3. Comparing Table 3 and Table 1 where α is 2% indicates that an increase in the growth rate of Y decreases the entry and exit thresholds as well as the capacity threshold under the NPV rule due to an increase in the expected present value of returns form

[10] We also examined the impacts of an increase in the discount rate from 10% to 15% on the entry-exit decisions and capacity choice. The results are not presented here because the findings are similar to those of an increase in the discount rate from 5% to 10%. An increase in the discount rate reduces the entry-exit thresholds and the capacity expansion threshold under the option-value approach, while it increases the thresholds under the NPV rule.

investment. Thus, an increase in the growth rate of demand leads to an increase in the incentives to invest in RST. On the other hand, under the option value it increases the entry and exit thresholds as well as the capacity expansion threshold, thereby reducing the incentives to invest in RST. This occurs because an increase in the growth rate increases the impact of uncertainty on the thresholds more than the increase in the expected present value of the future returns, which leads to a significant increase in the entry-exit and capacity expansion thresholds. Thus, an augmented growth rate of Y increases the expected present value of the future returns but also increases the value of the option to invest in the future.

5. Conclusions

Many agribusiness firms make their entry-exit decisions and capacity choice in emerging markets under uncertainty about prices, demand, cost or competition. This paper uses an option-value model to examine an agribusiness firm's decision whether and how much to invest in an emerging market under demand uncertainty and irreversibility of investment by sequentially combining the firm's entry and exit decisions with capacity choice. It also provides a framework for sequential investment with demand uncertainty and irreversibility of the investment for agribusiness-decision making. The paper contributes to the understanding of the factors that influence firms' decisions to invest in emerging markets, and provides information about barriers to the development and commercialization of new technologies such as RST in agriculture.

The application of the model to the RST investment indicates that demand uncertainty and irreversibility make investment in RST less desirable than the NPV rule may indicate. The inactive firm is more reluctant to enter the market when it takes into account uncertainty over future demand conditions because it preserves the opportunity of making a better investment later. On the other hand, the firm that has already made the initial investment to enter the RST

market is more reluctant to abandon the investment because there is an option value of keeping the operation alive. There is a greater distance between the entry and exit thresholds under the option-value approach than under the NPV rule due to demand uncertainty and irreversibility of the investment. When the firm enters the RST market, it is less willing to make any additional investment to expand its capacity due to the high opportunity cost of investment in the future.

The results show that the impact of interest rates (discount rates) and the growth rate of demand on entry-exit decisions and capacity choice differs under the NPV rule and the option-value approach. Under the option value, a reduction in interest rates and/or an increase in demand can discourage entry to the market and capacity expansion, while under the NPV rule these factors can encourage entry and capacity expansion. These results have policy implications on how to stimulate economic activities in an uncertain economic environment. Reducing interest rates has been a policy tool for the central bank to stimulate the economic activity. Under uncertainty and irreversibility of investment, this policy tool could discourage new investments and expansions of existing economic activities. Policies toward reducing uncertainties, on the other hand, could have significant impacts on stimulating economic activities.

The results from this study have general implications for agribusiness decision-making. Most of the investment opportunities of agribusiness firms involve various sources of uncertainty such as demand, cost or competition. Managers of agribusiness firms may need to understand and respond to uncertainty when making decisions such as when to enter an emerging market or when to abandon the investment. The framework developed in this study gives managers a decision-making tool that creates value through implementation of investment decisions under uncertainty. The approach developed here can also be applied to investment decisions in other areas such as biotechnology, telecommunication industry, internet, and computer industry.

Table 1. Optimal Entry-Exit and Capacity Expansion Thresholds under the NPV Rule and the Option Value (Discount Rate= 10%, Growth Rate=2%)

		Elasticity of Demand			
		0.4		**1.4**	
		Standard Error		**Standard Error**	
		0.10	**0.40**	**0.10**	**0.40**
Entry-Exit Decision					
NPV Rule	**Entry Threshold**	12.46*	12.46*	4.78*	4.78*
	Exit Threshold	11.54	11.54	3.86	3.86
Option Value	**Entry Threshold**	17.66	24.11	6.89**	10.67
	Exit Threshold	11.47	9.53	3.71	2.78
Capacity Choice[a]					
NPV Rule	**Threshold**	22.52	22.52	7.27	7.27
	Additional Investment ($)	0	0	85,560	85,560
Option Value	**Threshold**	32.68	63.58	10.55	20.39
	Additional Investment ($)	0	0	0	0

*indicates that entry is optimal under the NPV rule.
**indicates that entry is optimal under the option value.
[a] Additional investment is made only if the firm enters the RST market.

Table 2. Optimal Entry-Exit and Capacity Expansion Thresholds under the NPV Rule and the Option Value (Discount Rate= 5%, Growth Rate=2%)

		Elasticity of Demand			
		0.4		**1.4**	
		Standard Error		**Standard Error**	
		0.10	**0.40**	**0.10**	**0.40**
Entry-Exit Decision					
NPV Rule	**Entry Threshold**	12.21*	12.21*	4.61*	4.61*
	Exit Threshold	11.48	11.48	3.88	3.88
Option Value	**Entry Threshold**	23.59	34.35	9.12	15.62
	Exit Threshold	11.36	11.13	3.75	3.35
Capacity Choice[a]					
NPV Rule	**Threshold**	22.27	22.27	7.18	7.18
	Additional Investment ($)	0	0	96,823	96,823
Option Value	**Threshold**	44.53	111.33	14.36	35.89
	Additional Investment ($)	0	0	0	0

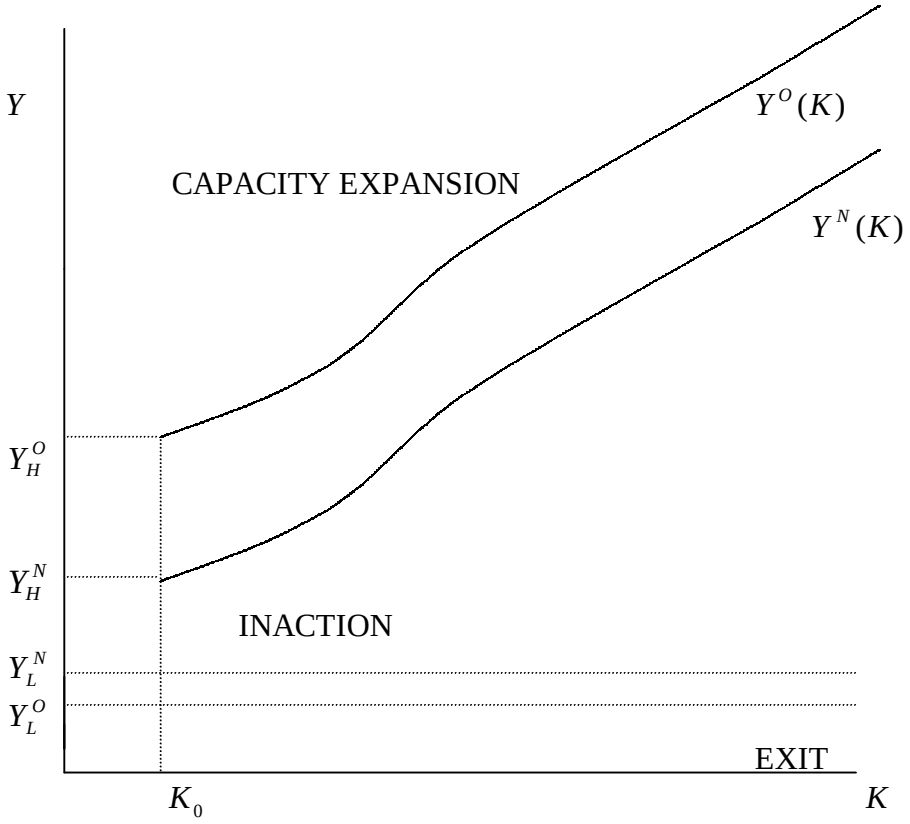
*indicates that entry is optimal under the NPV rule.
**indicates that entry is optimal under the option value.
[a] Additional investment is made only if the firm enters the RST market.

Table 3. Optimal Entry-Exit and Capacity Expansion Thresholds under the NPV Rule and the Option Value (Discount Rate= 10%, Growth Rate=10%)

		Elasticity of Demand			
		0.4		**1.4**	
		Standard Error		**Standard Error**	
		0.10	**0.40**	**0.10**	**0.40**
Entry-Exit Decision					
NPV Rule	**Entry Threshold**	9.52*	9.52*	3.77*	3.77*
	Exit Threshold	8.55	8.55	2.80	2.80
Option Value	**Entry Threshold**	18.69	26.48	8.02**	11.29
	Exit Threshold	8.22	7.29	2.74	2.55
Capacity Choice[a]					
NPV Rule	**Threshold**	16.89	16.89	5.47	5.47
	Additional Investment ($)	0	0	396,750	396,750
Option Value	**Threshold**	35.39	53.51	11.68	17.33
	Additional Investment ($)	0	0	0	0

*indicates that entry is optimal under the NPV rule.
**indicates that entry is optimal under the option value.
[a] Additional investment is made only if the firm enters the RST market.

Figure 1. Relationship Between Entry-Exit Thresholds and Capacity Expansion Threshold



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