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A Real Options Analysis of Coffee Planting in Vietnam

Quoc Luong and Loren W. Tauer

A REAL OPTIONS ANALYSIS OF COFFEE PLANTING IN VIETNAM

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Abstract

Vietnam grew from an insignificant to the world's second largest coffee producer during the 1990s. To understand this growth, this paper examines Vietnamese coffee growers' investment decisions using real options theory. The study finds that producers, with variable costs of 19 cents/lb and total cost of 29.3 cents/lb, would enter coffee production at a coffee price of 47 cents/lb and exit at a coffee price of 14 cents/lb. Most Vietnamese growers appear to be sufficiently efficient to continue producing coffee even at relatively depressed price levels.

Key words: Vietnam, coffee, real options, price uncertainty, irreversibility, investment, abandonment.

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In 1989 Vietnam held a market share of only 1.2% of the world coffee market. Ten years later Vietnam surpassed Colombia to become the world's second largest coffee exporter with a market share of 12.4%, earning approximately US $600 million and accounting for roughly 17% of all Vietnam's commodity exports. Vietnam's growth is unique in the history of coffee production and has had significant impacts on both Vietnam's economy and the global coffee industry. Coffee production now provides the livelihood for an estimated four million people in Vietnam.

The massive increase in Vietnam's coffee supply is widely believed to be the main factor leading to the price crisis of 2001. This price collapse substantially devastated the livelihoods of 25 million poor coffee producing households in more than 50 developing countries including Vietnam. Despite Vietnam's significant role, little research has been completed to help understand Vietnam's coffee supply response. Partly because of such a lack of understanding, policies implemented to assist Vietnamese farmers have failed. For instance, the government attempted an export retention scheme in 2001, which did not boost farmers' income, yet incurred heavy losses to the state budget. More recently, the Vietnam Coffee and Cocoa Association has discussed a plan to cut 100,000-150,000 hectares of coffee as a remedy to the global oversupply problem. But it remains unclear how much such a plan could raise the world coffee price, if implemented, or where in Vietnam those 100,000-150,000 hectares would be eliminated.

The coffee tree was introduced into Vietnam by the French as early as the 1850s, although production remained limited until 1989. The adoption of market-oriented policies by the government at the end of the 1980s and the collapse of the International Coffee Agreement (ICA) in 1989 provided Vietnamese coffee producers with the necessary conditions to compete freely and globally. Coffee production grew 26% annually from 1990-2001.

Nearly all coffee grown in Vietnam is of the Robusta variety. Only 4% of coffee grown is consumed domestically, with the rest exported. Between 85-90% of planted area is cultivated by small farmers, each holding from 1 to 2 hectares. The remainder (10%-15%) is grown by state-owned farms (SOFs). The four provinces of Kon Tum, Dak Lak, Gia Lai, and Lam Dong in the Central Highland account for over 80% of coffee production. Arabica is produced mainly at a subsistence level in mountainous regions in the North.

Only 13 years (1990-2002) of data are available to analyze Vietnamese coffee supply. Before 1990, the world coffee market was tightly regulated through quotas by the ICA, of which Vietnam was not a member. Only after the collapse of the ICA in 1989, did the global coffee market become fully competitive and open to Vietnamese coffee growers. As such, prices before 1990 might not be appropriate for modeling the explosive expansion of supply from Vietnam, which occurred under recent competitive market conditions. Moreover, the 13 years of data do not cover even one complete cycle of upward and downward movements in supply, but rather mostly an increasing trend, which casts doubt on the ability of regression models to accurately capture supply response. Given the limited data, Vietnam's coffee supply is modeled as the outcome of the entry-exit decisions of coffee growers using real options theory. This approach permits modeling investment decisions under uncertainty and irreversibility and captures supply response through investment decisions.

Previous Studies

Most previous studies of coffee supply response use regression-based models. Coffee production is typically decomposed into two parts: potential production (investment) as a long-term component, and the proportion of potential production harvested as a short-term component [Wickens and Greenfield (1973)]. The investment component is usually seen as comprising the planting decision, modeled as a function of coffee prices lagged the length of the gestation period, and the removal decision, determined by one-year lagged and current prices [Arak (1969)]. The yield decision is explained, in most studies, through three variables: current price, price lagged one year, and output lagged one year. The current and one-year lagged prices represent the expected immediate returns. The inclusion of one-year lagged output accounts for the biennial production cycle of Arabica, especially in Brazil. Some models omitted years of weather shocks, while others used a dummy variable to account for weather impacts. These Nerlove-type models have generally found long-term elasticities to be higher than short-term elasticities [Renne, 1987].

The role of fixed assets in agricultural production, investment and disinvestments was first discussed intensively by Glenn Johnson nearly 50 years ago. Johnson (1958) defined fixed assets as those whose expected value in their present use does not exceed their marginal acquisition cost and does not fall below what could be realized for them if they were diverted to an alternative use. With this definition, a fixed asset has two important features: an acquisition price and a salvage price. For investment, a firm matches the value of an additional fixed asset, which is determined by the services of the asset over its lifetime, with its acquisition price. For disinvestment, the firm equates the present value of the fixed asset in use with its salvage price.

Investment and disinvestment decisions, hence, depend on the differential between the acquisition and salvage prices. If the two are equal, the fixed assets become fully variable. In contrast, if the acquisition price and salvage value differ substantially, durable assets become fixed, and changes in output, if any, would not be influenced by investment despite possibly wide variations in output price. Because of asset fixity, supply response was found to be more elastic at the acquisition and salvage price levels and inelastic within this price range. Supply was found to be more inelastic in the short run than in the long run and was more elastic to price rising than price falling. However, quantifying the impacts of asset fixity on investment/disinvestment in agriculture remained unanswered until McDonald and Siegel (1985), Dixit (1991), and others introduced the concept of real options theory to model asset fixity. Applications of real options concepts to agricultural investment decisions include Richards and Patterson (1998), Carey and Zilberman (2002), Purvis, Boggess, Moss, and Holt (1995), among others.

The Model

In the simple entry-exit model, a firm must invest a sum K to build a project to produce a unit flow of output at a variable cost C. This investment project is assumed to last forever and be non-depreciating. The firm has to pay an exit cost per unit of output X if it decides to exit, and must incur the entry cost K again if it wishes to re-invest. K, X, and C are assumed to be constant and nonstochastic. A unit of the output can be sold at a market price P determined exogenously by the market. Hence, uncertainty comes from the market price P. As will be seen in the empirical application, the Vietnamese coffee industry reasonably satisfies these assumptions.

The model is built through 3 steps:

- Step 1 – Determine the value of an idle project. An idle project means that the investment is waiting to be initiated. At this stage the value of the investment is just the value of the option to invest.
- Step 2 – Determine the value of an active project. An active project means that the investment is in operation. The value of the investment now comprises both the present value of the net revenue generated by the project and the value of the option to abandon the project.
- Step 3 – Simultaneously determine the entry and exit points. At the investment entry/abandonment points, the investor must be indifferent between being "idle" or "active". This results in two equilibrium conditions. First, the value of an idle project must equal the value of an active project. Second, the rate of change of an idle project's value must also be equal to the rate of change of an active project's value. So, equating the values of the idle and active project as well as their derivatives produces a system of four equations. To properly account for the fact that the exit option also includes the ability to re-enter, the four differential equations must be solved *simultaneously*. Although a closed form solution is not available, numerical results can be obtained for the investment entry/exit points.

The mathematics of the model is based on Dixit, A. and R. Pindyck (1994), and Hull, J. C. (1997), using the following notation.

V_0: the value of an idle investment,

V_1: the value of an active investment,

P: Market selling price of a unit of output produced from the investment,

μ: Expected percent growth rate of market price P, if any,

σ^2: Variance rate of the percentage change in market price P,

C: Variable cost of a unit of output produced from the investment,

K: Sunk cost of investment per unit of output,

X: Cost of investment abandonment per unit of output,

ρ: Opportunity cost of capital (the firm's discount rate) with $\rho > \mu$,

H: Market price level at which investment occurs,

L: Market price level at which abandonment occurs.

Since the market price P is determined exogenously, it changes over time in an uncertain way. A standard model for this stochastic process is geometric Brownian motion:

$dP = \mu P dt + \sigma P \varepsilon \sqrt{dt}$, where

ε is a random drawing from a standardized normal distribution.

dt is the small length of time interval during which *dP* takes place.

Since ε is a random drawing from a standardized normal distribution, *dP* has a normal distribution with

mean of $dP = \mu P dt,$ and

variance of $dP = \sigma^2 P^2 dt.$

Define V *(P, t),* the value of the investment, as a function of the price P and the time t. By a second-order Taylor series, *dV* can be approximated as

$$dV = \frac{\partial V}{\partial P}dP + \frac{\partial V}{\partial t}dt + \frac{1}{2}\frac{\partial^2 V}{\partial P^2}(dP)^2 + \frac{\partial^2 V}{\partial P \partial t}dPdt + \frac{1}{2}\frac{\partial^2 V}{\partial t^2}(dt)^2 . \tag{1}$$

In the limit as *dP* and *dt* go to zero, all higher-order terms go to zero except for $(dP)^2$ which becomes $\sigma^2 P^2 dt$. As a result of this, equation (1) becomes

$$dV = \frac{\partial V}{\partial P}dP + \frac{\partial V}{\partial t}dt + \frac{1}{2}\frac{\partial^2 V}{\partial P^2}\sigma^2 P^2 dt .$$

Substituting $dP = \mu P dt + \sigma P \varepsilon \sqrt{dt}$ into the above equation, we obtain Ito's lemma

$$dV = \left(\frac{\partial V}{\partial P}\mu P + \frac{\partial V}{\partial t} + \frac{1}{2}\frac{\partial^2 V}{\partial P^2}\sigma^2 P^2 \right)dt + \frac{\partial V}{\partial P}\sigma P \varepsilon \sqrt{dt} . \tag{2}$$

Since this is an infinite horizon problem, the variable t is not a decision variable and the derivative $\frac{\partial V}{\partial t}$ can be deleted. Now (2) can be re-written as

$$dV = \left(V^{'}(P)\mu P + \frac{1}{2}V^{''}(P\ )\sigma^2 P^2 \right)dt + V^{'}(P)\sigma P \varepsilon \sqrt{dt}$$

with $\frac{\partial V}{\partial P} = V'(P)$, $\frac{\partial^2 V}{\partial P^2} = V''(P).$

Taking expected value of both sides of the equation yields

$$E\ (dV) = \left(V^{'}(P)\mu P + \frac{1}{2}V^{''}(P\ )\sigma^2 P^2 \right)dt , \tag{3}$$

since the expected value of $\varepsilon\sqrt{dt}$ is zero.

Step 1 - Deriving the functional form of the value of an idle project

In equilibrium, the expected capital gain of an idle project (denoted by $dV_0(P)$) should equal the normal return ($= \rho V_0(P)dt$) from the value of the investment

$$\left(V_0^{'}(P)\mu P + \frac{1}{2}V_0^{"}(P)\sigma^2 P^2\right)dt - \rho V_0(P)dt = 0.$$

Dividing the above equation by dt, yields the differential equation

$$V_0'(P)\ \mu P + \frac{1}{2}\ V_0''(P)\ \sigma^2 P^2\ - \rho V_0(P) = 0.$$

The general solution for this equation is of the form

$$V_0(P) = AP^{-\alpha} + BP^{\beta}, \text{ where}$$

$$-\alpha = \frac{\sigma^2 - 2\mu - ((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2)^{1/2}}{2\sigma^2} < 0, \text{ and} \tag{4}$$

$$\beta = \frac{\sigma^2 - 2\mu + ((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2)^{1/2}}{2\sigma^2} > 1 \tag{5}$$

are the two roots of the quadratic equation $\frac{1}{2}\sigma^2 x(x-1) + \mu x - \rho = 0$ and A and B are constants to be determined [Dixit (1991)].

For an idle project, the value of an investment should go to zero as the price P goes to zero. Since $\alpha > 0$ and $\beta > 1$, $V_0(P) = AP^{-\alpha} + BP^{\beta}$ goes to zero when P goes to zero only if A = 0. So the functional form of the value of an idle project (V_0) becomes

$$V_0(P) = BP^{\beta} \tag{6}$$

Step 2 - Deriving the functional form of the value of an active project

For an active project, in equilibrium the following condition holds normal return = expected capital gain + net revenue flow. This means

$$\rho V_1(P)\ dt = E[dV_1] + (P - C)dt.$$

Substituting E [dV] = $\left(V^{'}(P)\mu P + \frac{1}{2}V^{"}(P\ \ )\sigma^2 P^2\right)dt$ from (3) into the equation above, dividing both sides by dt, and rearranging the equation yield

$$V_1'(P)\ \mu P + \frac{1}{2}\ V_1''(P)\ \sigma^2 P^2 - \rho V_1(P) + P - C = 0.$$

The general solution for this differential equation is $V_1(P) = P/(\rho - \mu) – C/\rho + AP^{-\alpha} + BP^{\beta}$, where $P/(\rho - \mu) – C/\rho$ is the present value of the net revenue and $AP^{-\alpha} + BP^{\beta}$ can be interpreted as the value of the option to abandon the project.

Clearly, as the price P goes to infinity, this option value of abandonment goes to zero. Since $\alpha > 0$ and $\beta > 1$, $AP^{-\alpha} + BP^{\beta}$ goes to zero when P goes to infinity only if B = 0. Therefore, the functional form of the value of an active investment project becomes

$$V_1(P) = P/(\rho - \mu) – C/\rho + AP^{-\alpha}. \tag{7}$$

Step 3 - Deriving the investment trigger point and abandonment point

At the investment trigger point H, the value of the option to invest (the value of the idle project) must equal the net value obtained by exercising it (value of the active project minus sunk cost of investment). So we must have

$$V_1(H) - V_0 (H) = K. \tag{8}$$

This is the value-matching condition. The smooth-pasting condition requires that the two value functions meet tangentially

$$V_1'(H) - V_0'(H) = 0. \tag{9}$$

Similarly, at the abandonment point L we have

$$V_1(L) - V_0 (L) = -X, \text{ and} \tag{10}$$

$$V_1'(L) - V_0'(L) = 0. \tag{11}$$

Substituting the definitions of V_0 and V_1 in (6) and (7) into (8), (9), (10), (11), we obtain the following system of four equations:

$$\frac{H}{(\rho-\mu)} - \frac{C}{\rho} + AH^{-\alpha} - BH^{\beta} = K , \tag{12}$$

$$\frac{1}{(\rho-\mu)} - \alpha AH^{-\alpha-1} - \beta BH^{\beta-1} = 0 , \tag{13}$$

$$\frac{L}{(\rho-\mu)} - \frac{C}{\rho} + AL^{-\alpha} - BL^{\beta} = -X \text{ , and} \tag{14}$$

$$\frac{1}{(\rho-\mu)} - \alpha AL^{-\alpha-1} - \beta BL^{\beta-1} = 0 . \tag{15}$$

The parameters ρ, μ , σ^2 can be estimated from empirical data. Then α, β can be obtained by inserting the estimates into formulas (4) and (5). Finally, substituting the estimates of ρ, μ ,

σ^2, α, β into the four equations (12), (13), (14), (15), the four unknowns A, B, L, H can be obtained numerically.

The two assumptions of irreversibility and uncertainty are approximately met for coffee growing. An investment in coffee planting incurs a heavy irreversible establishment sunk cost, the cost of building infrastructure and planting the trees. To a small coffee grower, coffee prices evolve exogenously with great uncertainty over time.

The third condition, that investment opportunities remain open, does not truly exist in the coffee growing industry, which is a freely competitive market with over 25 million small producers worldwide. At times of lucrative prices, if a farmer waits rather than invests immediately, other farmers will enter and investment opportunities gradually diminish. Leahy (1993) examined this issue and showed, however, that the prices which trigger investment for a firm who anticipates the effects of competitive interactions is the same as those for a firm who ignores competition and considers the industry-wide investment as fixed. The reasoning underlying this result is that at the trigger price points, the value of the option to invest is equal to the value of the physical investment (an investor is indifferent between keeping the option or exercising it to obtain the investment project). Free competition reduces the value of the option to invest, but it does so by reducing the value of the physical investment project. Since competition reduces both the value of the option and the value of the physical investment project at the same time, the trigger price points between the two are unaffected.

The model also requires that the investment has an infinite life and is non-depreciating. Land has an infinite life. Coffee trees and equipment can be replaced so that they can be productive infinitely. One way to ensure this is to add depreciation of equipment and coffee trees to variable costs.

It is reasonable to assume that the variable production cost C does not vary significantly over time. Although diesel and fertilizer prices have increased during the past decade, coffee yield per hectare has also improved significantly. In addition, labor, one of the main inputs in coffee growing, has remained stable at 1.3 US$/manday for many years.

Data and Analysis

Empirical application of the entry-exit models requires data on coffee prices, coffee production, area planted, cost of capital, investment (fixed) cost, and variable production cost.

Data on coffee price and coffee production are obtained from the International Coffee Organization (ICO), which was established in London in 1963 under the auspices of the United Nations. The Vietnamese Statistical Yearbook provides data on coffee area and production in Vietnam. The data on the lending rates (cost of capital) in Vietnam from 1994-2002 are found on IMF's website.

There are no official statistics on coffee production costs of Vietnamese coffee growers. The fixed and variable production costs, therefore, are estimated based on current input prices and the farming technology recommended by the Central Highland Institute of Science and Technology for Forestry and Agriculture. This farming technology has been widely adopted by Vietnamese growers. Coffee is a perennial crop with a life cycle of 20-35 years depending on variety. In Vietnam, new Robusta trees require about three years to yield the first commercial harvest. New planting takes place in May, June, or July, the early months of the rainy season. Coffee is a water-intensive crop. Each Robusta tree requires from 3,200 to 4,000 liters of irrigation water during the dry season from December to April. Coffee growing is also labor intensive. Weeding, irrigation, pruning, and harvesting are mostly done by manual labor. The trees bloom in January and it takes about 10 months to produce the ripe cherries. Harvest peaks in November, the end of the rainy season.

Sunk (establishment) costs K include the costs of purchasing land, constructing an irrigation system, other farming infrastructure, and planting young coffee trees with 3 years until the first commercial harvest. All these costs are calculated for a typical farm of an average size of 2 hectares. Total sunk cost is divided by the average yield of such a farm to obtain the sunk cost per pound of coffee output. These costs are itemized in Table 1. The sunk cost per pound is calculated to be 69.5 cents/lb at the exchange rate of 15,500 VND/US$ and average yield of 2,080kg/hectare. This is the average yield achieved by farmers in Dak Lak province in 2000, according to a study by the Information Center of the Department of Agriculture and Rural Development (ICARD) and Oxfam (2002).

Variable cost is also calculated based on the farming technology recommended by the Central Highland Institute of Science and Technology for Forestry and Agriculture. Unit variable cost is then normalized based on an average yield of 2,080 kg/hectare. Estimation is summarized in Table 2. Using the 2001 medium-term lending rate of 9.9% the unit total production cost is estimated to be 8,845 VND/kg (26.48 cents/lb). The cost of 8,845 VND/kg is close to the 8,821

VND/kg production cost of farmers in Cu Mgar, the largest coffee producing district in Dak Lak province, surveyed by Oxfam in 2001 (published in 2002).

Table 1. Establishment Costs for Robusta Coffee for a 2-hectare Farm in Vietnam

Inputs	Year1	Year2	Year3	Total	VND/kg[a]	US$ /lb
	---------------- *1,000VND* --------------					
Land purchase	20,000			20,000	4,807	0.14
Soil preparation	4,000			4,000	962	0.03
Irrigation pump, pipe	28,000			28,000	6,731	0.20
Coffee seedlings	3,000			3,000	721	0.02
Fertilizers	7,000	4,000	5,000	16,000	3,847	0.11
Labor	8,000	7,000	7,000	22,000	5,288	0.155
Irrigation		2,500	3,500	6,000	1,442	0.04
Total	70,000	13,500	15,500	99,000	23,798	0.695

[a] Assumes a yield of 2,080 kg/hectare (4,160 kg total production).

Table 2. Variable Costs for Robusta Production for a 2-hectare Farm in Vietnam

Inputs	1,000VND	VND/kg[a]	US$/lb
Fertilizers	7,200	1,730	0.05
Labor	11,000	2,644	0.077
Irrigation	5,600	1,346	0.039
Depreciation[b]	2,400	577	0.017
Pesticides, miscellaneous	800	192	0.007
Variable cost	27,000	6,489	0.19

[a] Assumes a yield of 2,080 kg/hectare (4,160 kg total production)
[b]Coffee trees and fixed assets.

It is estimated that upon exit about one-fourth of the original value of irrigation pump, engine, well, barn can be recovered since these items can be used for other crops. As a number of crops such as rubber, pepper, cotton, and cocoa can grow well on coffee land, the exit farmer can certainly resell the land at the original purchase price (price of bare land). There exists cost of removing abandoned coffee trees. When the trees are still small, the cost is minimal and can be offset by the value the farmer added to the land when he reclaimed it for the coffee trees (leveling, removing stumps, adding organic fertilizers). When the trees are old, they can be sold as timber. In practice, an abandoned coffee plantation can be sold at the price of bare land, and the coffee tree removing cost is assumed to be cancelled out by either added value to the land or the timber value and as such is not included in the exit costs. Therefore, the cost of abandoning the investment is estimated to be 19 cents/lb.

The opportunity cost of capital ρ to a small farmer is determined by the income he can make from the best alternative use of that capital at the same risk. Due to data limitations, estimation of the profitability of substitute crops is not possible. Alternatively, opportunity cost of capital is approximated by the cost of capital, which is estimated to be the medium-term lending rate charged by local banks. The medium-term lending rate from 1994 to 2002 obtained from IMF statistical records (lending rate for years prior to 1994 is not available) is 14.92% per annum, and thus $\rho = 0.1492$ per annum.

The price used in the model is the price for Robusta coffee bean paid to growers in Vietnam, recorded in monthly intervals from January 1990 to December 2002 by the International Coffee Organization (ICO). Although investment in coffee production is treated as an annual decision, producers sell coffee in months after harvest. The parameter estimates from monthly prices are annualized. By the ICO definition, this is the average price paid to the growers at the farm-gate. If the price P follows a random walk process without drift, then

$P_t = \lambda P_{t-1} + u_t$, where $\lambda = 1$, P_t is the price at time t, and (16)

u_t is assumed to be a white noise error term, having zero mean and constant variance. Subtracting P_{t-1} from both sides of (16) yields

$$P_t - P_{t-1} = \lambda P_{t-1} - P_{t-1} + u_t \text{ or } \Delta P_t = \delta P_{t-1} + u_t \quad \text{where } \delta = (\lambda - 1).$$

If the null hypothesis that the coefficient $\delta = 0$ (i.e. $\lambda = 1$) cannot be rejected, the result is consistent with a random walk model. The hypothesis is tested for three alternate models.

P_t follows a random walk: $\Delta P_t = \delta P_{t-1} + \alpha \Delta P_{t-1} + u_t$.

P_t follows a random walk with drift: $\Delta P_t = \beta_1 + \delta P_{t-1} + \alpha \Delta P_{t-1} + u_t$.

P_t follows a random walk with drift around a deterministic trend:

$$\Delta P_t = \beta_1 + \beta_2 t + \delta P_{t-1} + \alpha \Delta P_{t-1} + u_t,$$

where u_t is a pure white noise error and $\Delta P_{t-1} = (P_{t-1} - P_{t-2})$, which was added to make the error terms uncorrelated. Additional lagged terms were not necessary to reduce the residual error to white noise as verified by the Durbin-Watson statistics. Using monthly prices from 01/1990-12/2002 (156 observations), the Dickey-Fuller Unit Root Test fails to reject that $\delta = 0$ (i.e. $\lambda = 1$) for all three equations at the confidence level of 0.1. So it is reasonable to treat the price P as following a random walk model without drift and trend.

The annual variance rate σ^2 and mean of the proportional change in price μ are estimated using the monthly coffee prices. Define:

P_i : Nominal coffee price at end of the i^{th} interval (i = 0,1,…, 155)

$t_i - t_{i-1}$: length of time interval in years = $\frac{1}{12}$, and

$\theta_i = \ln\left(\frac{P_i}{P_{i-1}}\right)$ for i = 1,…, 155,

then s is given by the standard formula

s = $\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\theta_i - \bar{\theta})^2}$, where $\bar{\theta}$ is the mean of the θ_i's, and $\sigma = \frac{s}{\sqrt{t_i - t_{i-1}}}$ = s* $\sqrt{12}$.

Using the monthly prices, s = 0.09342 and σ = 0.3236, so the volatility (σ) of the nominal coffee price facing Vietnamese coffee growers is estimated to be 32.36% a year.

One way to estimate μ is to estimate the expected value of ln $\frac{Pi}{P_{i-1}}$. From

$$\ln \frac{Pi}{P_{i-1}} \sim N\left[\left(\mu - \frac{\sigma^2}{2}\right)(t_i - t_{i-1}), \sigma\sqrt{t_i - t_{i-1}}\right]$$ where t is measured in years, and letting

the expected value of $\ln \frac{Pi}{P_{i-1}}$ be $\gamma = \left(\mu - \frac{\sigma^2}{2}\right)(t_i - t_{i-1})$, μ can be derived as

$$\mu = \frac{\gamma}{t_i - t_{i-1}} + \frac{\sigma^2}{2}.$$

Using the monthly prices, γ is estimated to be -0.00461, which is not statistically different from zero, consistent with the conclusion from the Dickey-Fuller test that the drift rate of nominal price is zero. Using $\sigma^2 = 0.105$ (from the estimate of σ above) and the formula

$\mu = \frac{\gamma}{t_i - t_{i-1}} + \frac{\sigma^2}{2}$, μ is estimated to be -0.00461*12 + 0.105/2 = -0.00282.

Results

The entry-exit model finds that a small farmer will enter coffee production when farm-gate price rises above 47.2 cents/lb and will exit the business if price drops below 14.2 cents/lb. When price varies within the inactive zone 14.2-47.2, no entry or exit would occur, producing hysteresis. Price and planted area from 1990-2002 are plotted in Figure 1 to show how these results relate to the investment decisions of Vietnamese coffee growers. In interpreting the graph, it should be noted that there is one-year lag from the time the investment decision is made until young trees are physically planted in a new farm and recorded as new cultivation.

Figure 1 shows three distinct periods. From 1990-1993, coffee prices stayed within the inactive zone, and there was no investment entry. Coffee area in 1994 basically stood at the same level of 1990, even though coffee prices had risen sharply (recall the lag in planting). The variation in growing area during this period probably was due to the replacement of old trees.

From 1994-1999, prices stayed consistently above entry level, and consistent with the model results, planted area increased continuously by 59% a year from 1995 to 2000. In 2000-2002, price fell back to the inactive zone and was near the exit level. According to the baseline scenario, there should be neither entry nor exit during those years. However, coffee area increased by 3,400 hectares in 2001. This increase may have resulted from a 42 million US$ Arabica coffee development program funded by the French government's Development Agency (AFD). No official data exist on the new Arabica area developed in 2001 under this program, but in the crop year 2002-2003, according to Tuoi Tre Newspaper another 10,000 hectares of Arabica was newly planted. If this figure is correct, Robusta area decreased by perhaps 44,000 hectares in 2002.

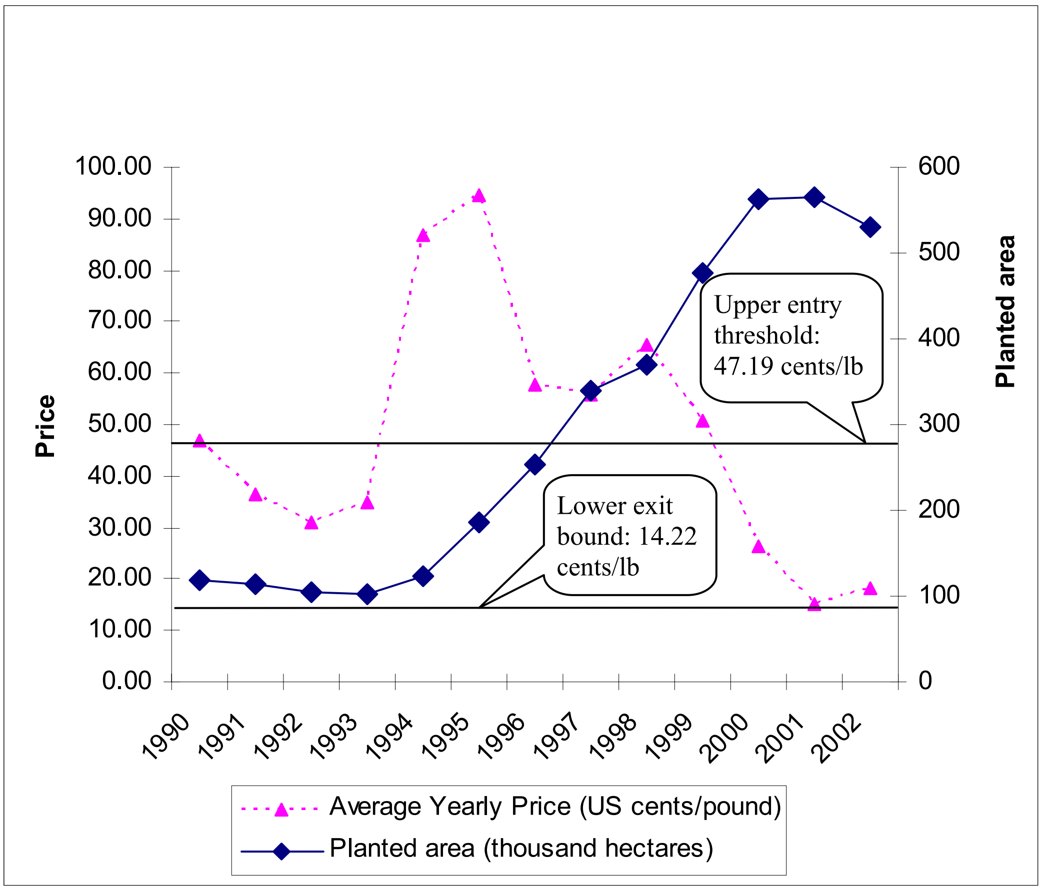

Figure 1 - Vietnam's Investment Entry and Exit with Homogeneity in Cost

The assumption of identical farmers can be relaxed by defining three groups of Vietnamese coffee growers with different yields, hence different average variable costs. All other parameters are assumed the same for the three groups.

Low cost producers: It is estimated that with the same amount of inputs worth 13,500,000 VND/hectare, the most efficient farmers achieve a yield of 3 tons per hectare (Information Center for Agricultural and Rural Development of Vietnam). At this yield, variable production cost would be calculated as 13.2 cents/lb, and the entry-exit trigger points for this group are H = 38.8 cents/lb, and L = 10.2 cents/lb.

Average cost producers: This group achieves a yield of 2.08 tons/hectare and average variable cost of 19 cents/lb, as presented in the baseline scenario. For this group the entry and exit price levels are H = 47.2cents/lb, and L = 14.2 cents/lb.

High cost producers: This group comprises producers in marginal areas where soil is less fertile, transportation is more costly and irrigation water is scarce. It is estimated that with the same inputs, these inefficient farmers achieved only 70% of the average yield of 2.08 tons per hectare. At this productivity, their variable production cost would be around 27 cents/lb. The price levels for entry and exit for this group are H = 58.4 cents/lb, and L = 20 cents/lb.

The effects of heterogeneity are depicted in Figure 2, where the entry and exit price levels are not two clear-cut ceiling and floor lines, but rather two corridors above and below. When price goes up to 38.8 cents/lb, efficient farmers start expanding planted area. If price continues to rise to 47.2 cents/lb, average cost farmers would enter. Less efficient farmers enter if price hits 58.4 cents/lb. Conversely, when price drops to below 20 cents/lb, less efficient growers would start to exit, but efficient farmers would continue to stay until price drops to around 10 cents/lb. Again three distinct periods can be seen. From 1990-1993, when coffee price stayed within the inactive zone, there was no investment entry. Coffee areas in 1994 and in 1990 are almost the same. From 1994-1999, price stayed consistently above the entry level even for the inefficient producers. As a result, planted area increased, expanding to marginal areas, where land is less fertile, far from irrigation water source and more remote from transportation roads. From 2001-2002, price fell below 20 cents/lb, the exit level for less efficient growers. As a result, the area planted to Robusta contracted in 2001 and 2002.

The entry and exit prices also vary as the parameters change, most notably the cost of capital, the production cost which has been illustrated, and the volatility of coffee prices. Two alternative scenarios are simulated for average cost farmers. First, the cost of capital ρ is allowed to deviate by five percentage points around the baseline level of 14.92% per year. Second, the volatility of coffee prices is permitted to rise to 40% and drop to 20% per year from the baseline level of 32.36% per year.

When ρ increases, both the entry and exit prices increase. When ρ decreases from 14.92% to 10% a year, the exit threshold falls from 14.2 to 13.2 cents/lb. This suggests that if the government wants to keep existing planted area through difficult years, given the availability of public resources, reducing the cost of capital through a credit subsidy might be a good policy. Changes in σ show that the higher the volatility of prices, the wider the gap between entry and exit prices and vice versa. This suggests that in the presence of some price stabilization mechanism, entry and exit would take place more frequently, reducing hysteresis.

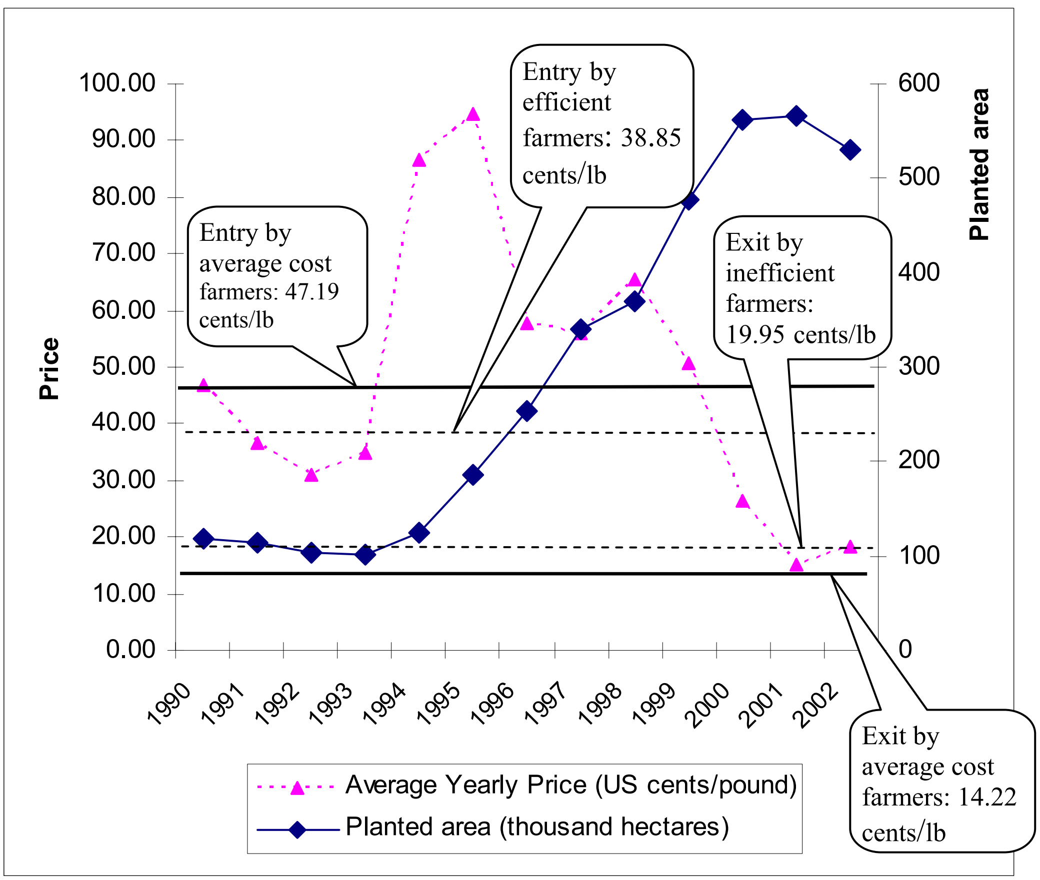

Figure 2. Vietnam's Investment Entry and Exit with Heterogeneity in Cost

Who Should Grow Coffee?

Due to large establishment sunk costs and a high degree of price uncertainty, the existence of price-below-cost periods following intervals of super-normal profits is inevitable. During price-below-cost periods such as the one in 2001-2002, only the most efficient coffee growers can make a positive profit while the majority of producers would experience losses.

Among those producers with negative profits, however, are two distinct groups. The first contains inefficient producers who would have a negative profit in the long run. The second group comprises those producers who, on average, would generate a positive profit in the long run. A clear realization of the difference between the two groups is important for policy makers, since they often interpret all producers whose variable costs are greater than selling price as economically non-viable. For the Vietnamese coffee industry, at the 2001 price level of 15.12 cents/lb, virtually all coffee producers operated at a loss. Only the most efficient producers (group A) could generate a positive cash inflow with variable costs around 13.2 cents/lb. Both producers with average efficiency (group B) and low inefficiency (group C) with variable costs of 19 cents/lb and 27cents/lb, respectively, lost 3.9 cents and 11.9 cents, respectively, for every pound of coffee produced.

Although groups B and C both had variable costs greater than the selling price of 15.12 cents/lb, they differed in one crucial aspect. The exit price for group B was about 14.2 cents/lb, which was still below the selling price of 15.12 cents/lb, while the exit threshold for group C was almost 20 cents/lb, well above 15.12 cents/lb. When coffee price hit 15.12 cents/lb, group B endured losses, but should continue to stay in the coffee business because it was economically optimal for them to do so, while for group C it was optimal to leave.

Using the 2001 price and the sample parameter estimates as baseline, those who should grow coffee are producers with variable production costs below 19 cents/lb (6,500 VND/kg). Since the parameters employed in the model are estimates, the boundary of 19 cents/lb cannot be treated as exact, but it gives policy makers an indicator for defining efficient versus inefficient producers (as well as suitable versus unsuitable coffee areas).

Many farmers started growing coffee during years of lucrative prices (such as 1994-1999) not realizing that, for high cost producers, it might not be profitable in the long run. Farmers in marginal areas (group C), despite high variable production costs, were able to make a profit at 1994-1999 price levels, but do not appear to be economically viable in the long run. Credit extended to this group should be for the purpose of switching to other crops such as rubber, cocoa, pepper, or cashew, which biologically suit their land better than coffee.

Conversely, although efficient growers (with variable cost below 19 cents/lb) sustain losses during times of depressed prices, they are profitable in the long run. As shown by the model, it is economically sensible to continue financing them so that they get through cash flow problems during price-below-cost periods. The model helps define efficient versus inefficient producers in terms of production cost. Producers should be made aware of their long-term (real options) viability before making an investment decision.

Sensitivity analysis shows that decreasing production costs would lower both the entry and exit bounds. Reduction of coffee production costs depends largely on the availability of irrigation water and a more efficient use of fertilizers, which require additional investment in irrigation reservoirs and extension services. Irrigation reservoirs would provide farmers with a stable and cheaper source of water compared to private wells, which often drain at the end of the dry season during drought years. With readily available surface water, growers can afford a better irrigation regime and thus improve coffee yield. A better extension network would allow poor farmers, who have practiced coffee farming more by experience, spread by word of mouth, to gain a more efficient use of inputs.

Following the 2001 price crisis, about 44,000 hectares of Robusta coffee was abandoned in Vietnam. This number is equivalent to 8.3% of total planted areas. Put another way, around 91.7% of Vietnamese coffee growers survived the 2001 crisis. This is evidence that most Vietnamese farmers are efficient; they can compete successfully in the global coffee market. Therefore, there appears to be little ground for the recommendation by Vietnam's Cocoa and Coffee Association that Vietnam should eliminate from 100,000 to 150,000 hectares of Robusta coffee.

Summary and Conclusion

This study analyzes how Vietnamese coffee growers invest or disinvest under uncertainty and irreversibility. The entry and exit decisions of coffee growers are modeled as real options, which refer to the rights to activate (to acquire) or to abandon (to sell) a physical investment project (an asset) at a predetermined price. These rights have value and, analogous to options on financial assets, can be quantified using financial option pricing methods.

Empirically, the investment model is built for a small Robusta grower in the Central Highlands in Vietnam. The selection of a small Robusta grower to represent Vietnamese coffee producers is based on three factors. First, nearly all coffee grown in Vietnam is of the Robusta variety. Second, about 80% of coffee is produced in the Central Highlands. Third, 85%-90% of coffee is grown by small farmers, each holding, on average, a 1-2 hectare farm.

The model is applied to three groups of farmers. The high-cost group has a variable production cost of 27cents/lb. The average cost group has a variable production cost of 19 cents/lb, and the figure for the low cost group is 13.2 cents/lb.

The empirical results indicate that when coffee price increases to 38.9 cents/lb, efficient farmers enter production. If price continues to rise to 47.2 cents/lb, average cost farmers would enter. Less efficient farmers would enter if price hits 58.37 cents/lb. Conversely, when price drops to below 20 cents/lb, less efficient growers would start to exit. But efficient farmers would stay until price drops to about 10 cents/lb.

The existence of price-below-cost periods following intervals of super-normal profits is inevitable in coffee growing due to large establishment costs and large variability of coffee prices. This implies that the common perception that producers who have variable costs higher than output price are inefficient is not always valid. As shown by the empirical model, during price-below-cost periods such as the one in 2001-2002, only the most efficient coffee growers can make a profit while the vast majority of producers would experience losses.

Among those loss-making producers, however, there are two distinct groups. The first group contains those who would have a negative profit even in the long run. The second group comprises those producers who on average would generate a positive profit in the long run. At times of price-below-cost, although both groups appear to be in the same situation - suffering losses - they differ in that the second group is optimally running their farms by enduring losses and waiting for price to rebound, while for the first group at some price levels it is optimal to exit. A clear realization of the difference between the two groups is particularly important for policy makers and credit providers, since it allows them to channel credit and land in such a way that "truly" efficient farmers are encouraged to stay in the coffee business and inefficient farmers are encouraged to shift to other crops.

References

(1998). Manual for Cultivation of Robusta Coffee, the Central Highland Institute of Science and Technology for Forestry and Agriculture.

(2002). The impact of the global coffee trade on Dak Lak province, Vietnam-analysis and policy recommendations, ICARD, Oxfam Great Britain, Oxfam Hong Kong**:** 67.

(2002). Vietnam's Statistical Yearbook, General Statistics Office.

Arak, M. (1969). "Estimation of Asymmetric Long-run Supply Functions: The Case of Coffee." Canadian Journal of Agricultural Economics **17**: 15-22.

Carey, J. M. and D. Zilberman (2002). "A model of investment under uncertainty: Modern irrigation technology and emerging markets in water." American Journal of Agricultural Economics **84**: 171-183.

Dixit, A. (1991). "Analytical Approximations in Models of Hysteresis." The Review of Economic Studies **58**(1): 141-151.

Dixit, A. and R. Pindyck (1994). Investment under Uncertainty, Princeton University Press.

Hull, J. C. (1997). Options, Futures, and Other Derivatives, Prentice Hall.

Johnson, G. L. (1958). Supply Function - Some Facts and Notions. Agricultural Adjustment Problems in a Growing Economy. E. O. Heady, H. G. Diesslin, H. R. Jensen and G. L. Johnson, The Iowa State College Press.

Leahy, J. V. (1993). "Investment in competitive equilibrium: the optimality of myopic behavior." Quarterly Journal of Economics **108**(4): 1105-1133.

McDonald, R. and D. Siegel (1985). "Investment and the valuation of firms when there is an option to shut down." International Economic Review **26**: 331-349.

Purvis, A., W. G. Boggess, et al. (1995). "Technology adoption under irreversibility and uncertainty." American Journal of Agricultural Economics **77**: 541-551.

Renne, M. A. (1987). An econometric model of the world coffee economy, published PhD dissertation, State University of New York at Buffalo**:** 333.

Richards, T. J. and P. M. Patterson (1998). "Hysteresis and the shortage of agricultural labor." American Journal of Agricultural Economics **80**: 683-695.

Wickens, M. R. and J. N. Greenfield (1973). "The econometrics of agricultural supply: an application to the world coffee market." Review of Economics and Statistics **55**: 433-440.

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