REAL OPTIONS ANALYSIS OF COFFEE PLANTING IN BRAZIL: WHEN TO GET IN OR GET OUT

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Abstract: The main objective of this study is to apply real options theory in the analysis of entry and exit prices regarding investments in coffee crop fields. We confront entry and exit strategies based on real options with neoclassical economics approach and with naïve strategies. Using market data for Arabic coffee, the results based on the real option approach lead to better results when comparing different strategies for implementing and abandoning investments in the culture of coffee.
Key-words: culture of coffee, entry and exit strategies

1. Introduction

The main objective of this study is to apply real options theory in the analysis of entry and exit prices regarding investments in coffee crop fields. We apply a model suggested by Luong and Tauer (2006) that uses the framework developed by Dixit and Pindyck (1994). In particular, we investigate entry and exit prices in investments in the culture of coffee, applied to the Brazilian context.

It is important to highlight that agricultural production is an activity which is done essentially under risky conditions. Therefore, due to information asymmetry and cognitive bias, strategic mistakes are common in the decision making process. These managerial errors may destroy value over time and jeopardize the continuity of the business of a farmer or of an agricultural firm.

It is not uncommon to farmers immediately halt production when prices of agricultural commodities have depreciated and immediately start investments when prices go up.

Thus, using heuristics or some rule of thumbs, farmers and firms are inclined to invest when the price of the coffee is high and stop producing when the price is low.

However, as prices of agricultural commodities may revert to the mean, investing and abandoning strategies must be implementing taking into account some inertia. In this context, this study aims to bring insights to Brazilian coffee producers regarding strategies entry and exit strategies.

2. Theoretical background

2.1. Conventional neoclassic economics and real options approaches

The decision to enter a competitive market, for the neoclassical theory, is made by identifying that the price of a product is higher than the average cost of the project, since fixed costs should necessarily be remunerated by the sale of the product (Varian, 2000). As, in a competitive market, the price of a product is determined by the market, the decision to produce involves the analysis of a cost function, which is a component the producer can manage.

Economic neoclassical theory presupposes the reversibility of an investment, fact that is rarely accomplished in the business practice. In order to contemplate more realistic assumptions, Mossin (1968), for example, developed an algorithm based on activation and deactivation costs to decide on the dry-docking of a ship due to income retraction or on the reactivation of operations due to a higher forecasted income. The model assumes a symmetric Brownian motion and uses matrix of states.

In other study, Brennan and Schwartz (1985) analyze how assets with high sensitivity to market conditions can be valued. The authors show that an optimal strategy regarding the deactivation and reactivation can be implemented using portfolios that replicate future contracts of the involved commodities. Carr (1988) analyzes multi-period investment opportunities by structuring synthetic portfolios following an approach proposed by McDonald and Siegel (1985), who evaluate the postponement of a project as a call option.

Triantis and Hodder (1990) investigate managerial flexibility in investment decisions as a complex option using contingencies pricing techniques. Unlike the usual option pricing models, the authors assume that demand for assets may have a negative drift since many markets are monopolistic or oligopolistic.

Other studies also explore real options framework. Die and Freund (1990) develop a model in two stages. The first stage emphasizes the initial investment decision associated to the productive capacity and the second stage tackles the production decision conditioned to the first stage. Pindyck (1991) defends new perspectives to investment analysis questioning traditional neoclassical economy models arguing that (i) investments are often irreversible or have low reversibility and (ii) the time to invest can be postponed due to investor's disposition and interest to obtaining better information on variables that are important in the decision making process.

Due to these characteristics, investments can be analyzed as the exercise of a call option, since the exercise of the right may be irreversible. Although assets can be sold to other investor, the exercised option and the investment in it cannot be reverted.

Unrecoverable or sunk costs also affect the entry and exit decisions regarding investments. Besides the existence of unrecoverable costs due to an initial investment, there are also, sunk costs that occur in the deactivation of a productive unit and in its reactivation. Irreversibility models of investments explain the hysteresis effect, which consists of the permanence of the effects for a certain time after the cause is interrupted.

Dixit and Pindyck (1994) analyze the problem associated with entry, exit, temporary deactivation and total deactivation of investments. The starting point is the stochastic behavior of prices that define the income of a project and the uncertainty of the profits in future periods. Future results, behaving in a random way, can be negative in medium and long periods, justifying a temporary abandonment of the project. Conversely, a project can be resumed when the perspective of future profits is positive.

Although a simplified model assumes that stop and set-up costs do not exist, more elaborated models take into account the existence of those costs. Thus, on one hand, some models establish that stopping and restarting a project do not imply additional costs. On the other hand, there are models that consider stop and restart costs identical to those initially incurred in the beginning of operations and that are totally lost in case of abandonment of the project.

In real life, none of those situations is true. On one side, when deciding to abandon a project, or to suspend it temporarily, the initial costs of implementation are not totally lost, although equipments may depreciate. In addition, retaking a project may not demand additional investments of the same magnitude of the initial outflow. On the other side, when a project is canceled, there are exit costs that affect the return of the project.

Another variable that have implication on the reactivation decision is the time of stop, because usually the restart costs depend on the stopping time. This characteristic can be modeled through the introduction of a restart option in which the state variable is the stopping time. During the time of stop, the project is not necessarily extinct, because frequently it is convenient to maintain the equipment in conditions of being put back in operation. Thus, maintenance costs may be relevant elements to be analyzed.

Since the coffee culture is particularly important in Brazil, some studies using real options have been conducted. For instance, Sato (2004) discussed the problem of optimal decision of abandonment of a farming of coffee. The optimal abandonment decision is related to the exercise of the option to abandon operations in order to maximize the proprietor’s wealth. In this study, a binomial pricing model was implemented using dynamic programming. The study aimed to identify the value of the abandonment option and the optimal exercise frontier. Nogueira (2005) studied a similar problem, but used a trinomial model with dynamic programming.

In other countries, real options studies have also been conducted, evidencing this approach as relevant to the investigation of strategies for the coffee commodity. Luong and Tauer (2006) developed an analysis of coffee crop fields in Vietnam, determining trigger prices for investment and for abandonment of the farming. Since Vietnam was not part of the World Coffee Organization, the practiced prices in this country did not reflect world demand. In addition, the prices did not cover a complete life cycle of the culture of coffee, which hinders the use of regressive models that appropriately captures the behavior of the prices. Although these limitations, the authors modeled the supply of coffee for Vietnam using the real options theory through which was possible to investigate investment decisions under uncertainty and irreversibility.

The cultivation of coffee is comprised fundamentally by two components: (i) the initial investment and (ii) the annual investments to tract the terrain. The initial investment is associated with the set-up of the farming, will be amortized over the time span and has a long-term fixed component. The annual investments represent a variable component.

The fixed component takes into account the market prices of the coffee, the period of formation of the farming as well as the decision to abandon the farming and to remove the coffee stems. Fixed investments have an acquisition price and a residual value. The investment and abandonment decisions depend on the differential among those prices. Dixit (1991), for instance, used real options theory to model the fixed part of investments.

2.2. Mathematical model

The model developed by Luong and Tauer (2006) was built in three stages: (i) the establishment of the value of an inactive project, i.e., the wait for an initial investment corresponds to the option of investing, (ii) the calculation of the value of an active project, comprised by the present value of the future cash flows and by the option of abandoning the farming, (iii) the simultaneous determination of the entry and exit points.

In the entry and exit points, the investor should be indifferent between activation or deactivation of the project, i.e., the value of project being active should be identical to the value of being inactive. Additionally, the growth or decrease rate in the value of an active project should be identical to the same rate for an inactive project. Equaling the values of the active and inactive projects, one can obtain a system of four equations. In order to incorporate the option to re-enter a project, after an exit, the equations should be simultaneously valid. We describe the model used in this study, based on Luong and Tauer (2006) and Dixit and Pindyck (1994).

a. Price behavior P

The market price is not under the investor's control, moving in time in an uncertain way, as in a stochastic process. We use the standard geometric Brownian motion to describe the behavior of the market price of the coffee.

$$dP = \mu P dt + \sigma P \varepsilon \sqrt{dt} \tag{1}$$

where ε is randomly selected from a standardized normal distribution and dt is an infinitesimal time change in which a change dP in price occurs.

b. Value of investment V

The value of the investment $V(P,t)$ depends on the market price P of the product and on the time t and its differential can be approximated by a second order Taylor expansion:

$$dV = \frac{\partial V}{\partial P}dP + \frac{\partial V}{\partial t}dt + \frac{1}{2}\frac{\partial^2 V}{\partial P^2}(\mu^2 P^2 dt^2 + 2\mu P dt^{\frac{3}{2}}\sigma P \varepsilon + \sigma^2 P^2 \varepsilon^2 dt) + \frac{\partial^2 V}{\partial P \partial t}dPdt + \frac{1}{2}\frac{\partial^2 V}{\partial t^2}(dt)^2 \tag{2}$$

The expected value of ε is 0 and when dP and dt goes to zero, terms of higher order, except $(dP)^2$, become negligible and thus one has:

$$dV = \frac{\partial V}{\partial P}dP + \frac{\partial V}{\partial t}dt + \frac{1}{2}\frac{\partial^2 V}{\partial P^2}\sigma^2 P^2 dt \tag{3}$$

Since $dP = \mu P dt + \sigma P \varepsilon \sqrt{dt}$, then:

$$dV = \left(\frac{\partial V}{\partial P} \mu P + \frac{\partial V}{\partial t} + \frac{1}{2} \frac{\partial^2 V}{\partial P^2} \sigma^2 P^2 \right) dt + \frac{\partial V}{\partial P} \sigma P \varepsilon \sqrt{dt} \tag{4}$$

As the problem involves an infinite time horizon, t in the above equation is not a decision variable and therefore $\frac{\partial V}{\partial t}$ can be neglected. Thus, the equation can be rewritten:

$$dV = \left(V'(P) \mu P + \frac{1}{2} V''(P) \sigma^2 P^2 \right) dt + V'(P) \sigma P \varepsilon \sqrt{dt} \tag{5}$$

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

Taking the expectation on the two sides of the equation and considering that $E\left[\varepsilon\sqrt{dt}\right] = 0$ then:

$$E[dV] = \left(V'(P) \mu P + \frac{1}{2} V''(P) \sigma^2 P^2 \right) dt \tag{6}$$

c. Determining of the functional form of the value of an inactive project V_0

In equilibrium, the expected capital gain from an inactive project $dV_0(P)$ should be identical to the expected value of the normal return on the investment $\rho V_0(P)dt$, where ρ is the cost of opportunity of the capital. Therefore:

$$\left(V_0'(P) \mu P + \frac{1}{2} V_0''(P) \sigma^2 P^2 \right) dt - \rho V_0(P) dt = 0 \Rightarrow V_0'(P) \mu P + \frac{1}{2} V_0''(P) \sigma^2 P^2 - \rho V_0(P) = 0 \tag{7}$$

The general solution for that equation is:

$$V_0(P) = AP^{-\alpha} + BP^{-\beta} \tag{8}$$

where

$$-\alpha = \frac{\sigma^2 - 2\mu - \left((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} < 0 \text{ and } \beta = \frac{\sigma^2 - 2\mu + \left((\sigma^2 - 2\mu)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} > 1$$

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.

For an inactive project, the value of the investment tends to zero if the price goes to zero. Since $-\alpha < 0$ and $\beta > 0$, then $V_0(P) = AP^{-\alpha} + BP^{\beta}$ goes to zero when P goes to zero only if $A = 0$.

Thus, the functional form of the value of an inactive project becomes:

$$V_0(P) = BP^{\beta} \tag{9}$$

d. Determining the functional form of the value of an active project V_1

In equilibrium, in an active project, the normal return is equal to the sum of the expected earnings of the investment and the net gain provided by the difference between the price and the costs, as represented in the following equation.

$$\rho V_1(P)dt = E[dV_1] + (P - C)dt \tag{10}$$

Considering equation (6) and rearranging terms, it follows:

$$V_1^{'}(P)\mu P + \frac{1}{2}V_1^{''}(P)\sigma^2 P^2 - \rho V_1(P) + P - C = 0 \quad (12) \tag{11}$$

The general solution of equation (11 is:

$$V_1(P) = P/(\rho - \mu) - (C/\rho) + AP^{-\alpha} + BP^{\beta} \tag{12}$$

where $P/(\rho - \mu) - C/\rho$ is the present value of net income and $AP^{-\alpha} + BP^{\beta}$ represents the value of the option to abandon the project. When P goes to infinite, the value of that option tends to zero. As $-\alpha < 0$ and $\beta > 0$, then $AP^{-\alpha} + BP^{\beta}$ goes to zero when P tends to infinite, only if $B = 0$. Therefore, the functional form of the value of an active investment becomes:

$$V_1(P) = P/(\rho - \mu) - (C/\rho) + AP^{-\alpha} \tag{13}$$

e. Determining the entry and exit points of an investment

The entry and exit points are, respectively, points of time when the investor decides to implement a project or abandon it. In the entry point H, the value of the option of investing corresponds to the value of an inactive project and is identical to the exercise value, which is the value of an active project less the value of the unrecoverable investment. Necessary conditions are (i) the equality condition $V_1(H) - V_0(H) = K$ and (ii) the transition condition $V_1^{'}(H) - V_0^{'}(H) = 0$

In an analogous analysis, in the abandonment point L, the conditions are $V_1(L) - V_0(L) = X$ and $V_1^{'}(L) - V_0^{'}(L) = 0$.

Using V_0 and V_1 as previously calculated, one has the following system of equations:

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

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

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

$$\frac{1}{(\rho-\mu)} - \alpha AL^{-\alpha-1} - \beta BL^{\beta-1} = 0 \tag{14}$$

Parameters ρ, μ σ^2 can be estimated from historical data, α and β can be calibrated by substituting estimates in the general solution of the differential equation. Once α and β are obtained, these five parameters are included in the system of equations. The four unknowns variables are, therefore, A, B, H and L.

3. Methodology

As discussed earlier, the objective of this work is to apply real options framework, in order to identify entry and exit points regarding an investment in the culture of coffee. Basically two phenomena are investigated, using historical data of prices of coffee. First, it will be analyzed whether the market price of the coffee tends to converge to a mean value. Second, it will be compared results from real options model and results from other frameworks in order to identify which entry and exit strategy leads to higher gains. For instance, we confront real options strategies with neoclassical economic models and also simple rule of thumbs models.

Particularly, it is expected that trigger prices for entry and exit in investments, following the approach suggested by Dixit and Pindyck (1994) and Luong and Tauer (2006), will provide higher returns than three alternative approaches: (i) to enter in the highest level of coffee prices and to leave in the lowest level, (ii) to enter when the coffee price becomes larger than the total unit cost and to exit when the price falls bellow the unitary variable cost, as suggested by the neoclassical economic theory and; (iii) to produce in a continuous way independently of the price of coffee.

The variables included in the model are defined as indicated in Figure 1.

Figure 1: Definition of the variables

V_0: Value of an inactive project, corresponding to the value of the option of investing
V_1: Value of an active project, corresponding to the value of net income plus the value of the option of abandonment
P: Market price of a produced unit
μ: expected return of the market price
σ^2: variance of the return of the market price
C: Variable cost of a produced unit
K: Unrecoverable fixed cost for each produced unit
X: Cost of abandonment for each produced unit
ρ: Cost of opportunity of capital or discount rate
H: Market price that triggers investment (entry point)
L: Market price that triggers the abandonment (exit price)

In order to obtain values or estimates for the variables described above, the model requires data on agricultural production of coffee as well as other economic information. The data and source of information are gathered from several sources, as showed in Figure 2.

Figure 2 - Source of data for variables of the study

Prices of the coffee: IPEA, CEPEA, ICO
Productivity: Agrianual
Cultivated area: CEPEA
Cost of capital: Brazilian Central Bank
Fixed investment: Agrianual
Variable prduction cost: Agrianual
Life cycle of the culture: IAC, Agrianual
Cost of land: Agrianual
Life cycle of equipments: Agrianual
Equipment costs: Agrianual

Obs: IPEA: Brazilian Institute of Research in Applied Economics, CEPEA: Center for Advanced Studies in Applied Economics of the University of Sao Paulo, ICO: International Coffee Organization, Agrianual: report of the Informa Group

The model used by Luong and Tauer (2006), applied to the Brazilian conditions, establishes that a firm invests an amount of K in a project that aims to produce an output at a variable cost C. We assume that the project is perpetual and is not subjected to depreciation. In the case the firm decides to abandon the project, there is an exit cost X for each produced unit. In the case the firm decides to restart the project, it re-invests K. Each output unit is sold by the price P, which is exogenously determined by the market and subject to uncertainty.

The methodology is thus quantitative aiming to show how entry and exit prices are affected by the behavior of market prices, fixed and variable costs and time of implementation of the farming. As the study involves the use of time series, it is convenient to obtain a sample with a high number of observations. The series that presents the largest number of observations is published by the International Organization of Coffee (OIC), which is denominated in cents of dollar by pound. In the Brazilian market, the farmer receives in Brazilian reais currency for a 60-kilo sack. Since coffee is a commodity, the price in the internal market should follow fluctuation in the international market and the exchange rate.

4. Estimate of parameters values and analysis of data

As discussed earlier, initially we investigate the behavior of coffee prices. In special, we analyze the hypothesis regarding the price of coffee do not follow a mean reversion behavior. In the model suggested by Dixit and Pindyck (1994), the basic hypothesis about the behavior of prices is:

$$P_t = \lambda P_{t-1} + u_t \text{ or } P_t - P_{t-1} = (\lambda - 1)P_{t-1} + u_t = \delta P_{t-1} + u_t \qquad (15)$$

where $\lambda = 1$, $\delta = \lambda - 1$, P_t is the price at instant t and u is white noise with zero average and constant variance.

If the null hypothesis, $\delta = 0$, or alternatively $\lambda = 1$, cannot be rejected, then there is evidence to support random walk. In order to detect stationarity of the time series of coffee prices, tests of unitary root and Durbin-Watson were conducted. The results for the variable price paid to the producer, denominated “OIC sack”, are shown in the table below.

Table 1. Dick-Fuller test for nominal dollar prices of coffee

ADF test of unitary root: Price for producer (OIC in nominal dollars)

Equation	$P_t - P_{t-1} = b_1 + (l - 1)P_{t-1} + u_t$
First order autocorrelation of u	-0.00200
l -1	-0.06002
tau	-3.84335
p-value	0.00251
Equation	$P_t - P_{t-1} = b_1 + b_2 t + (l - 1)P_{t-1} + u_t$
First order autocorrelation of u	-0.00200
l -1	-0.06024
tau	-3.84124
p-value	0.01450
Equation	$P_t - P_{t-1} = b_1 + b_2 t + b_3 t^2 + (l - 1)P_{t-1} + u_t$
First order autocorrelation of u	-0.00200
l -1	0.06023
tau	-3.83554
p-value	0.04953

In all cases, p-value is inferior to the significance level of 5% and thus the null hypothesis can be rejected. Therefore, it can be assumed that prices to the producer, as indicated by OIC data, do not follow a random walk. Continuing the analysis of price, a mean reversion process is configured when $\lambda < 1$ (Watsham and Parramore, 2002). The analysis conducted with coffee prices leads to a coefficient of -0.0602, with p-value of 0.0495, implying a mean reversion process.

This conclusion contradicts the price behavior found in the Luong and Tauer's (2006) study, in which prices were found to follow a random walk. The different results can have origin in three factors that are distinct in this research as compared to Luong and Tauer's (2006): (i) price series used in the original study of Luong and Tauer (2006) was for the robust coffee while, in the present research, price series are associated with Arabic coffee, (ii) prices series used by Luong and Tauer (2006) covered a time span of only ten years, which is inferior to a productive cycle and do not allow the observation of important market cycles; in contrast, in the present study, 30 years of data were incorporated in the analysis, and (iii) the intense government intervention in the Vietnamese market can distort prices received by the producers of coffee in that country.

We now investigate whether results of entry and exit strategies based on a real options approach lead to superior performance compared to the gains with other strategies, as for instance, the neoclassical model and other simple heuristics. To run the mathematical algorithm and calculate entry and exit points to invest in or abandon the culture of coffee, we must obtain estimates values for the parameters μ, σ^2, ρ, α, β, K, C and X.

4.1. Estimation of expected return and variance of returns for the producer (μ and σ^2)

Decisions made by coffee producers accompany the annual periodicity of the culture. In order to estimate the average and the variance of annual returns for coffee producer, we conducted the following steps: (i) 362 monthly prices of coffee were gathered from OIC database, (ii) the series of market prices were deflated by Consumer Price Index, (iii) the neperian log of the quotient of two consecutive periods were taken, (iv) the average and variance for monthly returns were estimated and (v) these parameters were annualized using Luenberger (1998) methodology. Thus, if μ_m and σ_m^2 are, respectively, the monthly average return and variance of returns, the annual equivalents μ and σ^2 are calculated as:

$$\mu = 12\mu_m + \frac{\sigma^2}{2} \text{ and } \sigma^2 = 12\sigma_m^2 \quad (16)$$

Table 2: Descriptive statistics of monthly returns

Data from January/1976 to December/2005	
Mean	0.00048427
Median	-0.0077385
Minimum	-0.64187
Maximum	0.54291
Standard deviation	0.11873
Variation coefficient.	245.17
Skewness	0.25329
Ex. kurtosis	4.6102

Using the statistics depicted on Table 2, $\mu = 0.090392$ and $\sigma^2 = 0.169162$

4.2. Estimation of opportunity costs or discount rate

As discussed, in equilibrium, the producer is indifferent between investing or not. In this case, the expected value of an inactive project should be equal to the expected value of the investment. The immediate alternative investment for the producer would be to invest in a risk-free rate, as for instance, by purchasing treasury bonds.

According to the monthly bulletin of the Brazilian Central Bank, as of December/2005 interest rates were 16.48% a year. It is important to emphasize that the Brazilian interest rates are among the highest in the world. This characteristic of the Brazilian economy can distort results, since investment in production demand extremely high expected returns. In contrast, studying real options in high risky environments can lead to new insights about the importance of flexibility in strategies as the more riskier the environment, probably the more valuable the real option.

4.3. Calculation of α and β

The quadratic differential equation that defines the value of the inactive project is:

$$V_0^{'}(P)\mu P + \frac{1}{2}V_0^{''}(P)\sigma^2 P^2 - \rho V_0(P) = 0 \tag{17}$$

As previously discussed the general solution is given in equation (8) and the parameters are:

$$-\alpha = \frac{\sigma^2 - 2\mu - \left(\left(\sigma^2 - 2\mu\right)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} = -1.413624 < 0 \tag{18}$$

$$\beta = \frac{\sigma^2 - 2\mu + \left(\left(\sigma^2 - 2\mu\right)^2 + 8\rho\sigma^2\right)^{1/2}}{2\sigma^2} = 1.344910 > 1 \tag{19}$$

4.4. Implementation costs (K)

The implementation costs were obtained from the Agrianual (2007) report for the area of Franca, in the State of São Paulo. The cost of implementation of the coffee farming is, in Brazilian currency, \$16,257 per hectare, considering the income of the third year as a deduction in the implementation costs.

To these costs, we added the cost to acquire the land for the culture of coffee, which was estimated in \$10,650. Thus, the total cost to invest in the culture of coffee was defined as \$26,907. The average life of the farming in the area of Franca/Brazil is 18 years. During the first two years, no income is expected. In the third year, the productivity is 20 sacks per hectare/year. From the fourth to the eighteenth years, the productivity is approximately 40 sacks by hectare/year. Under those conditions, the cost of implantation of the farming for is \$46.39 (US\$19.82) per sack of coffee and the cost of land is \$18.36 (\$7.85) per sack

4.5. Annual maintenance costs (C)

The costs of annual maintenance were obtained of the report Agrianual (2007). The maintenance cost calculated from tot expected production is \$203.54 or US\$86.98 per sack.

4.6. Cost of abandonment (X)

At the end of the productive period, or when there is abandonment of the production, the residual value of the project can be considered equivalent to the value of the land. Thus, in the implemented the model, X is \$18.36 or US\$ 8.46 per sack.

4.7. Calculation of the entry and exit prices (H and L)

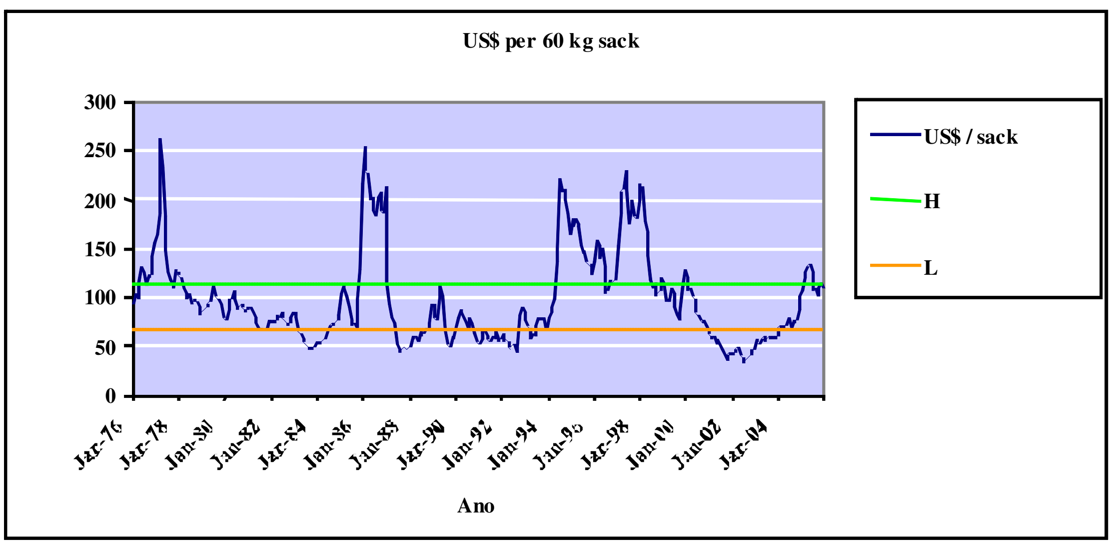
The entry and exit prices, according to the model proposed by Dixit and Pindyck (1994), can be calculated by solving the system of equation in (14). The solution for the system of equations was obtained with the software MAPLE 10 and is described in Table 3.

Table 3: Final results for nominal prices o coffee

A	57.042,95
B	1,93
H	114,43
L	67,74

The results, using a real options approach, suggest that the farmer should invest only when the price of coffee reaches US$114.43 per sack and should leave the cultivation when the price reaches US$67.74 per sack. Figure 3 shows entry and exit points and the behavior of the price of coffee.

Figure 3: Dynamics of entry and exit strategies in the culture of coffee in Brazil



The comparative result shown in the Table 4 clearly demonstrates the superiority of the method proposed by Dixit and Pindyck (1994) using real options theory. Ex-post analysis imply that entry and exit strategy based on real options outperform (i) the strategy based on price-cost analysis as suggested by the neoclassic economics and also outperform naïve strategies as (ii) entry in higher levels and exit in lower levels and (iii) continuous production.

Table 4: Comparative analysis of approaches to entry and exit strategies

Approach	Real options	Entry and exit in peaks andvalleys	Neo classic econom.	Continuous production
H – Entry price	113.62	Higher evel	106.80	
L – Exit price	67.16	Lower levl	86.98	
Entrance	Jan-76	Mar-77	Jan-76	Jan-76
Exit	May-92	Nov-83	Jul-87	Dec-05
Entrance	Nov-92	Jan-86	Jun-88	
Exit	Feb-01	Oct-87	Aug-89	
Entrance	Feb-05	May-89	Feb-90	
Exit	Dec-05	Sep-92	Nov-90	
Entrance		Jul-94	Oct-92	
Exit		Sep-02	Apr-93	
Entrance		Jun-05	Aug-93	
Exit		Dec-05	Aug-00	
Entrance			Jan-05	
Exit			Dec-05	
Result in dollars	30,836	(7,046)	22,895	(25,038)

Observing the above data, the strategy of considering the entry and exit limits based on real options leads to a present value of US$30,836, significant higher than the neoclassical economics approach which results in a present value of US$22,895. It is worth noticing that naïve approaches, which are commonly used as heuristics or rules of thumbs, destroy value.

5. Final comments

Unlike the results found by Luong and Tauer (2004) for the Vietnamese, in which coffee prices follow a random walk, the results for the Brazilian market suggest coffee prices behave as a mean reverting process. The reversion to a long-term average is a usual characteristic in commodities and several elements of the Vietnamese market can reflect the non-expected results, as for instance: (i) short length of historical data and (ii) government influence on the market by securing minimum prices to the producer.

In the present study, we followed the methodology proposed by Dixit and Pindyck (1994) using a version described in Luong and Tauer (2006), which represents a powerful tool to value strategic options. Comparative results show the superiority of this method in relation to the methods of the conventional neoclassical economy and of common practices or heuristics implemented by farmers. The method can be easily applied to other commodities and to specific areas where one has a relatively long series of historical data of market prices.

Ex-post results from the model of this study, which aims to identify entry and exit prices in the Brazilian environment, showed that a real option approach to decide on investments in the culture of coffee leads to higher gains in comparison to the following alternative strategies: (i) to produce in a continuous way, (ii) to begin the culture when coffee price reaches the a high price level and to abandon it when the market reaches a low level, (iii) to adopt the conventional neoclassical entry and exit strategy, which depends on the relationship between price of output and cost of production.

The parameters used in the model are based on the historical behavior of market prices for coffee in Brazil. Although based on the study of Luong and Tauer (2006), this research presents some differences. For instance, although Loung and Tauer (2006) considered series of nominal prices, we analyzed not only nominal price but also deflated prices. This fact was thought to be extremely important in the Brazilian context due to several periods of high instability which implied hyper-inflation levels. However, results show little difference between entry and exit prices using nominal and deflated values. For nominal prices, triggers to entry and exit the culture of coffee were calculated, respectively, as US$114.43 and US$ 67.74 per sack. For deflated prices, entry and exit levels were US$113.62 and US$67.16, respectively.

It is important to point out that decision under uncertainty conditions, which involves irreversibility or high cost reversibility, is always subject to some inertia. Investments should only be made when the state variable assumes clearly favorable conditions and should be halted only when conditions become clearly unfavorable. There in an interval of values for the state variable in which inertia is the most appropriate strategy (Dixit, 1991).

In particular, for the producer of coffee, the fundamental question, in a context of hysteresis, is to identify entry and exit points for its investments in cultivation. Due to the lack of appropriate analysis tools, many coffee producers do not revert or halt investments al all, working on a continuously basis. Other group of producers, when prices seem to achieve a peak, immediately starts investing and when prices drop to a local minimum, immediately abandons production. Therefore, many producers do not engage in a strategy that takes advantage of optimal points to invest and abandon, considering that prices may follow a men reverting process.

The model studied in this paper can help coffee producers to determine the ideal time for inertia taking into account the price behavior of the commodity. Using market data for Arabic coffee, the results based on the real option approach lead to better results when comparing different strategies for implementing and abandoning investments in the culture of coffee.

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