INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty

Supported by the CGIAR

IFPRI Discussion Paper No. 00783

August 2008

Understanding the Investment and Abandonment Behavior of Poor Households

An Empirical Investigation

Ruth Vargas Hill

Markets, Trade and Institutions Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Netherlands, Norway, Philippines, Sweden, Switzerland, United Kingdom, United States, and World Bank.

Published by

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

www.ifpri.org

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have not been subject to formal external reviews managed by IFPRI's Publications Review Committee but have been reviewed by at least one internal and/or external reviewer. They are circulated in order to stimulate discussion and critical comment.

Contents

List of Tables

List of Figures

ACKNOWLEDGMENTS

The author is grateful to Chris Mukiza, Robert Waggwa Nsibirwa, Aliziki Kaudha and the Uganda Bureau of Statistics, without whom this work would not have been possible. Funding for this study was provided by the Economic and Social Research Council (UK) and the Commodity Risk Management program of the World Bank. Many thanks to Marcel Fafchamps, Stefan Dercon, Simon Appleton, Christian Rogg, Sujit Kapadia, Daniel Ali, Miguel Robles and participants at the CSAE seminars in Oxford for comments on an earlier draft.

ABSTRACT

This paper uses models of irreversible investment under uncertainty to examine the investment and abandonment behavior of poor rural households. It considers the decision of Ugandan coffee-farming households to invest in or abandon coffee trees. The observed levels of investment and abandonment are found to be consistent with models of investment that allow for irreversibility, uncertainty, fixed costs and liquidity constraints. The findings highlight the importance of addressing volatility, irreversibility, fixed costs and liquidity constraints in order to increase households' responsiveness to changes in the fundamentals, and to enable households to recover from shocks to their capital stock.

Keywords: investment; uncertainty; fixed costs; shocks; models of friction

1. INTRODUCTION

The decision to invest into or out of a production activity is one that has long-term implications for a household's income and consumption fortunes. Uncertain returns characterize many of the livelihood options faced by households in developing countries, and many of these livelihoods require some degree of sunk investment before they can be undertaken (Dercon and Krishnan 1996; Cadot, Dutoit and Olarreaga 2006). Thus, understanding a household's decision to abandon or acquire productive capital under uncertainty is key to gaining an insight into income dynamics in the context of developing countries. Although a large body of empirical work identifies how risk affects the welfare and short-term production decisions of households, fewer empirical studies have considered household behavior under uncertainty with regard to long-term investment decisions.

A rich theoretical literature exists on investment under uncertainty. In these models, investment is characterized by irreversibility and uncertain returns such that the investor gains information about the profitability of an investment tomorrow from information about the profitability of the investment today (Dixit and Pindyck 1994; Abel and Eberly 1994). These models show that an incentive to delay investment arises as a result of the option value of the investment. Some papers empirically test these models in the context of investment among firms and farmers in OECD countries (Caballero, Engel and Haltiwanger 1995; Asano 2002; Nilsen and Schiantarelli 2003; Pietola and Myers 2000; Boetel, Hoffmann and Liu 2007)[1], and for investment by firms in developing countries [see for example (Pattillo 1997) for an analysis of firm investment behavior in Ghana]. Malchow-Møller adapt these models to simulate investment in coffee trees by households in Nicaragua, highlighting the applicability of these models to the investment problem considered herein (Malchow-Møller 2002).

This paper applies models of irreversible investment under uncertainty to understand the investment and abandonment behavior of poor rural households. It considers a household's decision to invest in or abandon a relatively profitable production activity in which it is already engaged. Specifically, this analysis considers the decision of Ugandan coffee-farming households to invest in or abandon coffee trees. Planting a coffee tree is an investment decision, because coffee trees yield little until their third year of age and stay productive for thirty to forty years. Coffee is a relatively profitable production activity for Ugandan households, but investing in coffee is risky due to price volatility and the trees' susceptibility to disease. [2] Investing in coffee is also, to some extent, irreversible. The tree has no value when it is removed from the ground (there is no secondhand market for coffee trees) and there is no way to recoup the opportunity cost of land being tied up with no output until the trees bear fruit.

Many Ugandan coffee farmers work with extremely old coffee trees; the majority of farmed coffee trees are approximately 40 years old, and some trees are still being farmed at 70 years of age. Anecdotal evidence suggests that households do not cut down trees when the price of coffee falls, but rather keep them in case the price rises again. In these cases, little labor is applied to the trees, and sometimes the trees are not harvested. Over the past few years, changes in coffee tree stocks have been driven more by wilt disease shocks than by investment. A survey of 300 coffee-farming households was conducted in 2003. As shown in Table 1, many of the surveyed households experienced wilt, replaced trees lost to wilt, invested beyond losses to wilt, and abandoned trees during 1999 to 2002. Among the

[1] Caballero, Engel and Haltiwanger analyze plant-level data in the US, and Nilsen and Schiantarelli use panel data on Norwegian firms to examine the pattern of capital adjustment. The Asano paper provides a test between different models of investment as set out by Dixit and Pindyck (1994) and Abel and Eberly (1994) by using panel data on firms in the US. Pietola and Myers consider the investment decisions of pig farmers in Finland, while Boetel, Hoffman and Liu consider hog investments in the US.

[2] In Uganda, returns to coffee are highly uncertain. The coefficient of variation of the farm-gate coffee price has been 0.62 over the last decade, compared to 0.25 and 0.28 for matooke and sweet potatoes (two staple crops grown by many Ugandan households) respectively. Additionally in the past 15 years coffee wilt disease has emerged as a significant risk to coffee yields. This has led to further variation in coffee revenues across farmers and time, and has affected the stock of coffee trees farmers hold as diseased trees eventually die and are either removed or abandoned by the farmers. In some regions of Uganda, households have reported losses equivalent to half their stock of trees.

surveyed households, 15% reported abandoning coffee trees, 29% invested in trees, and 59% lost trees and did not replace all of them (28% replaced no trees at all).

Table 1. Summary of changes in the stock of coffee trees, 1999-2002

Proportion of households that have:	
Had some trees affected by coffee wilt	81%
Replaced no trees lost to wilt	28%
Replaced some but not all trees lost to wilt	31%
Replaced all trees lost to wilt	3%
Replaced or invested (beyond any losses to wilt)	30%
Uprooted (not due to wilt) and did not replace	15%

Source: Household survey data collected by author.

An analysis of the investment and abandonment decisions of these households finds household behavior to be consistent with models of investment that allow for irreversibility, uncertainty, fixed costs and liquidity constraints. In the face of substantial price changes and shocks to the capital stock, the investment responses of households are sluggish. In addition, fixed costs are observed to be present, and there is evidence that the poorer households are constrained by a lack of liquidity. The findings highlight the importance of addressing volatility, irreversibility, fixed costs and liquidity constraints in order to increase households' responsiveness to changes in the fundamentals, and to enable households to recover from shocks to their capital stock.

Although models of investment under irreversibility and uncertainty have not, to the author's knowledge, been tested for developing country households, empirical work has shown that uncertainty impacts the type and number of assets a household holds. Uncertain returns have been shown to affect a household's decision to invest in productive assets (Feder, Just and Zilberman 1985; Rosenzweig and Binswanger 1993), and to necessitate the use of productive assets such as livestock to ensure consumption in the presence of income shortfalls (Rosenzweig and Wolpin 1993; Fafchamps and Pender 1997; Zimmerman and Carter 2003).

Credit constraints have also been used to explain the low levels of investment undertaken by households (Carter and Wiebe 1990; Feder and Lau 1990), particularly for large lumpy investments (McKinnon 1973; Feder 1980). In the presence of credit constraints, investment must be self-financed. Yet low returns on available savings instruments, and the need for households with limited access to insurance markets to use savings for smoothing consumption over time, make it difficult for the poor to save to invest in an indivisible asset (Dercon 1998; Barrett and Carter 2006).

Early studies of the factors determining investment in tree crops used an essentially neoclassical approach to explain investments in coffee trees in Brazil (Wickens and Greenfield 1973), rubber trees in Thailand and Sri-Lanka (Hartley, Nerlove and Peters 1987), and cocoa trees in Brazil (Trivedi and Akiyama 1992). However, although standard investment theory provides a starting point, this investment problem could be better characterized by a model that allows for uncertainty and irreversibility. More recent studies of investment in tree crops have examined the effects of tenure security on irreversible land investments [Besley (1995) in Ghana; Jacoby, Li and Rozelle (2002); Place and Otsuka (2002) in Uganda and Carter and Olinto (2003)]. This literature highlights the importance of uncertainty and credit constraints in making this kind of investment.

Malchow-Møller (2002) has highlighted the importance of using insights from the real options literature to understand investment in coffee trees. The present paper empirically tests some insights from the real options literature, in an effort to increase our understanding of how household investment behavior responds to price changes and shocks to the capital stock. This analysis applies models of investment set out by Dixit and Pindyck (1994) and Abel and Eberly (1994) that explicitly consider investment under uncertainty and irreversibility, and the model of Fafchamps and Pender (1997), which explicitly allows for the presence of credit constraints, to try and explain observed behavior.

The next section provides a theoretical review of investment models as they apply to the decision to abandon or invest in coffee. Section 3 considers how these models can be empirically applied to the available data. Sections 4 and 5 describe the data used and present the empirical results. Section 6 concludes.

2. CONCEPTUAL FRAMEWORK

Model 1: Standard Investment Model

Standard investment theory (Jorgenson 1963; Tobin 1969) predicts that investment will occur if the expected present value of the stream of profits resulting from a marginal unit of investment, V_t, is greater than the unit cost of investment, C.[3] The desired level of capital stock, Q_t^*, is thus determined by the point at which $V_t = C$. If in any period $Q_t \neq Q_t^*$, the level of capital stock will be adjusted through investment and abandonment as necessary to ensure equality. Changes in the return to (and cost of) investing will change the desired capital stock, and investment/abandonment will occur until the desired capital stock is achieved. Similarly, any sudden loss in the capital stock will be immediately and completely replaced (other things equal), ensuring that the household remains at Q_t^*.

For coffee-producing households, V_t can be thought of as $\sum_{t=1}^{\infty} \delta^t (p_t - g_t) q_t$, where p_t is the unit price of coffee, g_t is the unit cost of production, and q_t is the amount of coffee produced by one unit of investment (δ is the household's discount rate). Q_t is a function of the number of trees of vintage *v*, held at time *t*. A household can increase Q_t by planting new coffee trees, or it can increase Q_t without changing the total number of owned coffee trees by replacing an old tree with a new tree. A coffee tree becomes productive three years after it is planted and remains productive for 30 years, after which its productivity declines. Once a new tree becomes productive, its yield may be two or three times higher than that of an old tree.[4] Coffee-producing households can also reduce Q_t by uprooting trees (abandonment).

Model 2: Irreversibility and Uncertainty

In reality, many investment decisions are characterized by uncertainty, some degree of irreversibility, and non-linear costs to investment. Dixit and Pindyck (1994) consider an irreversible investment undertaken when the uncertainty surrounding the return to investment is such that waiting one period will allow the investor to gain information about the future return. The investment can be undertaken in this period or in any future period. They show that, for an investment of this nature, it can be optimal to wait before investing even if $V_t = C$. This is because V_t does not cover the additional option value of the investment, $F(V_t)$, that is lost when the investment is made. Taking this into account, investment will only take place when $V_t - F(V_t) > C$, i.e. when

$$V_t \geq \frac{\beta}{\beta - 1} C \tag{1}$$

where β (the solution to the fundamental quadratic) is greater than 1 and decreasing in uncertainty, σ. Uncertainty increases the ratio of $\frac{V_t}{C}$ at which investment will occur. The option value causes an incentive to wait to invest compared to the standard model.

The Dixit and Pindyck model introduces uncertainty by assuming that the value of the investment follows a geometric Brownian motion, such that (in continuous time):

$$dV = \alpha V dt + \sigma V dz \tag{2}$$

[3] For coffee, C includes not only the cost of the coffee tree seedlings, but also the large opportunity cost of land lying with no output for three years until the trees bear fruit.

[4] Based on information in UCTF (2002, p.66), http://en.wikipedia.org/wiki/Coffee, and http://www.hasbean.co.uk/botany.htm.

where dz is the increment of a Wiener process, α is a parameter that indicates the trend of the process, and σ is a parameter reflecting the variance. This law of motion means that although Vt is uncertain, there is some permanence in the return to investment, in that if Vt is high today it is likely to be high tomorrow. An example of such a process would be an AR(1) process with a first-order autocorrelation coefficient equal to 1. The use of such a process provides tractability for the solution, but may be a less useful assumption in practice because many of the price processes that cause uncertainty in Vt are mean-reverting [e.g. an AR(1) process with an autocorrelation coefficient less than 1]. In the context of the present paper, however, the source of uncertainty in V_t is p_t, the price of coffee, and studies by Metcalf and Hassett (1995) and Sarkar (2003) suggest that in this case the use of such a process for ease of tractability is not a bad approximation of a mean-reverting process.[5] This is useful because many studies have shown that the movement of the international coffee price exhibits a considerable degree of autocorrelation (Cuddington and Urzua 1987; Gersovitz and Paxson 1990; Deaton and Laroque 1992; Deaton and Laroque 1996). In a study using annual international coffee price data, Deaton and Laroque (1996) show that the international coffee price can be characterized parsimoniously as an AR(1) distribution, with a first order auto-correlation coefficient (α_1) of 0.8. Expectations about the future coffee price depend on the current price, meaning that the return to coffee today provides information about the return to coffee tomorrow.

The case of coffee investment may be better described as one of costly reversibility (Abel and Eberly 1996) rather than strict irreversibility. Abandonment is possible, but it carries a cost. Rather than there being a unit of capital costing *C* and no way to abandon capital (i.e. the cost of abandonment is infinite), there is a purchase cost, C_I, and a sale value, C_A, of a unit of capital such that $C_I > C_A$. Although the value of a coffee tree cannot be recouped, the opportunity cost of the land committed to coffee production each period can be recovered by uprooting coffee trees and using the land for another purpose. For positive investments in coffee trees, C_I can be thought of as incorporating the costs of seedling purchase, the labor of planting seedlings, and the opportunity cost of the land they are planted on, while C_A is the opportunity cost of the planted land minus the labor used in uprooting the trees.

In the case of costly reversibility, the above result still holds (the option value of waiting is still present whenever there is any degree of irreversibility), but abandonment also carries an option value, $F(V_t^A)$. Abandoning capital stock in a given period means foregoing the option to disinvest in a future period. This additional option value to current capital stock means that the current value of the future flow of profits has to fall below C_A by the value of this option before the capital will be abandoned. In other words:

$$\Delta Q_t > 0 \text{ if } V_t - F^A(V_t) > C_I \tag{3}$$

as before, and

$$\Delta Q_t < 0 \text{ if } V_t + F^I(V_t) < C_A \tag{4}$$

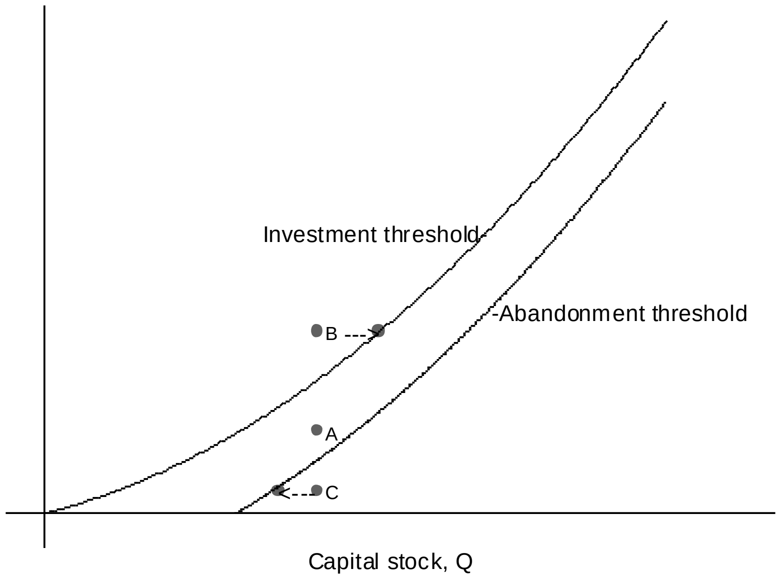
Assuming decreasing returns to successive units of investment, the stock of capital and threshold values of the stochastic variable, p_t, at which investment and abandonment occur can be depicted as shown in Figure 1.[6] If everything else is held constant, the value of V_t varies with movements in the

[5] Metcalf and Hassett (1995) [argue that using a Geometric Brownian Motion process as a tractable approximation of a mean-reverting process is justified because mean-reversion has two opposing effects, and the overall effect on investment should be negligible for the most reasonable parameter values. Sakar (2003) contests this conclusion, arguing that mean reversion has a third effect with an effect on investment, although an exception is made for cases in which the risk of the project in question is uncorrelated with the market portfolio.

[6] Decreasing returns are usually assumed to exist either as a result of the shape of the production function or as a result of the fact that the producer faces a downward sloping supply curve. If there are regions of non-decreasing returns, a threshold value that justifies an increase of one unit of capital may justify investment in other units of capital. As a result, the investment policy will yield sudden jumps in capital stock across regions of constant or increasing returns.

price, p_t, which determines the threshold values of V_t for which equations (3) and (4) hold true. For a given level of capital stock, when p_t lies between the investment threshold (p_I) and the abandonment threshold (p_A), such as point A in Figure 1, no investment or abandonment is observed. However if the price rises above p_I to point B, the capital stock is increased to bring the household to the investment threshold. Conversely, if the price falls below p_A to point C, abandonment of the capital stock takes place until the household reaches the abandonment threshold. Price changes that do not cause the level of capital stock to rise above the investment threshold or drop below the abandonment threshold do not elicit changes in the capital stock.

Figure 1. Investment and abandonment thresholds for investment decisions made under uncertainty

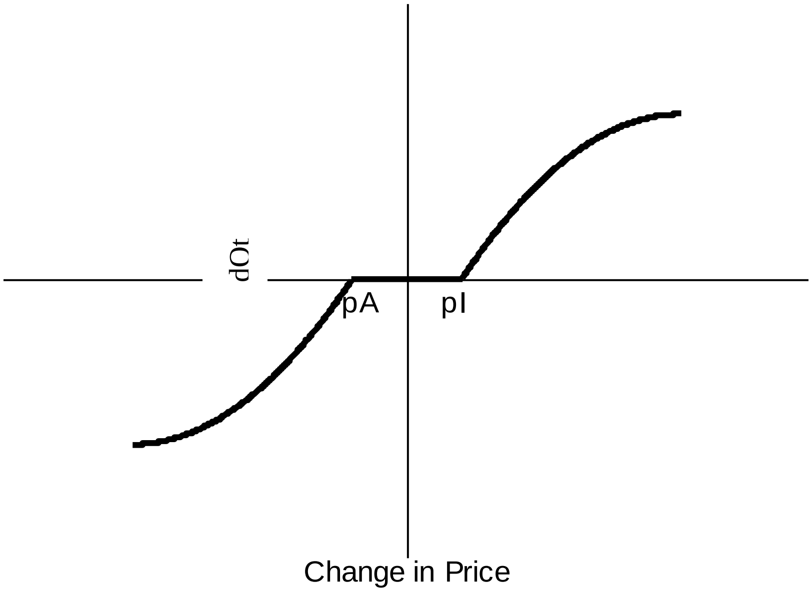


This means that for a given level of capital stock, the investment schedule shown in Figure 2 is observed. The option value of investment and abandonment, and thus the price range over which inactivity is observed, increases with uncertainty about the price and the degree of irreversibility (i.e. the greater the gap between C_I and C_A).[7]

Similarly, a negative shock to the capital stock could, all other things equal, be met with no compensatory investment. Investment only takes place if the fall in the capital stock is large enough to bring the household above the investment threshold. In that case, however, replacement may not be complete, as investment is only undertaken until the household returns to the threshold level. Replacement will only be complete if the price is at p_I for the pre-shock level of Q_t.

[7] In the extreme case of full irreversibility, the salvage value of the capital stock held is zero. As a result, under full irreversibility, there is no abandonment threshold and the capital stock only changes if the price rises above p_I for a given capital stock.

Figure 2. Investment under uncertainty



Model 3: Non-Linear Costs of Investment

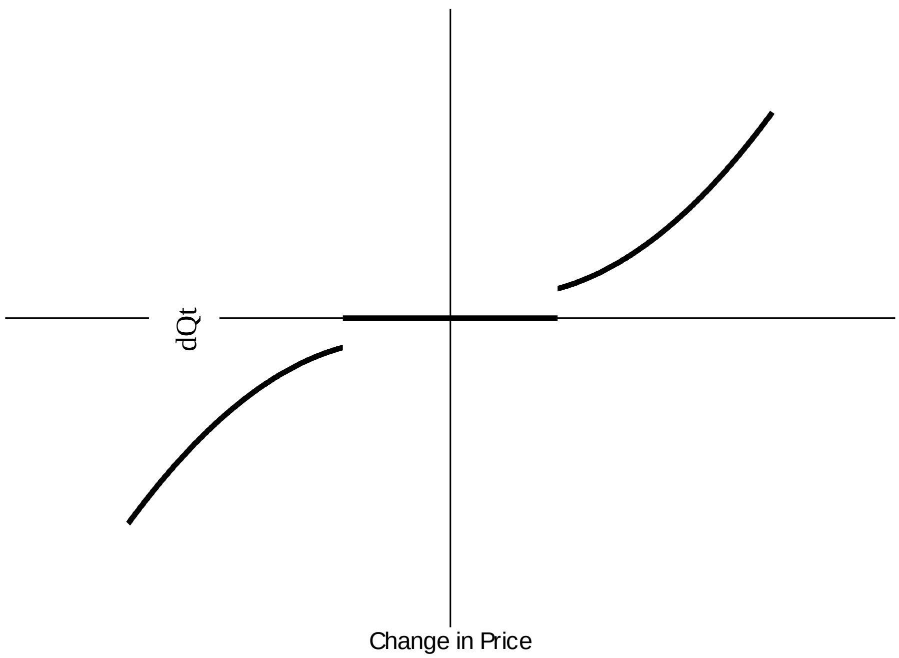
Thus far, we have assumed fixed unit costs of investment and abandonment; however, a more general model of investment, such as that seen in Abel and Eberly (1994), allows for fixed costs and costs of adjustment per unit time in addition to purchase and sale costs (C_I and C_A). Fixed costs of investment are non-negative costs that are independent of the amount of investment, and are incurred whenever investment (positive or negative) is undertaken. Fixed costs of investment (C_I^F) may differ from fixed costs of abandonment (C_A^F). Adjustment costs (C_I^A and C_A^A) are the costs of adjusting to new levels of capital, and increase with the rate at which the capital stock is changed. The cost of investing is thus represented by an augmented adjustment cost:

$$C(Q_t, \Delta Q_t) = \begin{cases} [C_I + C_I^A(Q_t, \Delta Q_t)]\Delta Q_t + C_I^F \text{ if } \Delta Q_t > 0 \\ 0 \text{ if } \Delta Q_t = 0 \\ [\mathrm{I}\, C_A + C_A^A(Q_t, \Delta Q_t)]\Delta Q_t + C_A^F \text{ if } \Delta Q_t < 0 \end{cases} \quad (5)$$

In the context of coffee, convex costs of adjustment might arise as a result of limited availability of seedlings, limited labor available to cut down trees, or the increasing cost to a household of land lying without a return for three years. Fixed costs of investment for coffee could be the cost of traveling to buy seedlings to plant, or may reflect the finding of much econometric evidence which suggests that behavior is inertial Any lumpiness in transaction costs---even implicit costs such as searching for information and prices---can result in the "optimality of usually doing nothing" (Bar-Ilhan and Blinder 1992).

The threshold levels, p_A and p_I, are determined by the augmented adjustment cost function. Abel and Eberly (1994) show that a range of inaction (i.e. a wedge between p_A and p_I) is caused by two aspects of this augmented cost function. The first is that $C_I + C_I^A(Q, \Delta Q)$ and $-C_A + C_A^A(Q, \Delta Q)$ do not approach the same limit as ΔQ→0. This results from the presence of uncertainty and irreversibility (as noted in the above section) and also because it is possible that $C_I^A(Q,0) \neq C_A^A(Q,0)$. Non-linear adjustment costs thus compound the range of inaction observed in Figure 2. Fixed costs are the second cause of inaction. Fixed costs of investment (or abandonment) cause investment (or abandonment) to be observed only when $V_t - F^I(V_t)$ (for abandonment, $V_t + F^A(V_t)$) is large enough to cover both the fixed and variable costs of investing. The presence of fixed costs increases the range of inaction observed and also inhibits small amounts of investment (see Figure 3).

Figure 3. Investment under non-linear costs when fixed costs predominate



The effect of non-linear costs on adjustment outside of the period of inactivity depends on the nature of the adjustment costs. If adjustment costs predominate, a large change in the price will be realized in proportionately smaller changes in the stock. If fixed costs predominate, small changes in the capital stock will not be made but large price changes will be realized in proportionately larger changes in the capital stock (as in Figure 3). Similarly, the effects of adjustment costs on the household's response to a negative shock to the capital stock will depend on the nature of the costs. A concave relationship between the number of trees lost and investment will be observed when convex adjustment costs predominate, whereas the relationship will be convex when fixed costs predominate.

Model 4: Liquidity Constraints

The models of investment considered thus far have assumed that investors are unconstrained in their ability to invest. However, credit constraints are common among the rural poor, meaning that investment by households in developing countries must often be self-financed.[8] In the presence of insurance market failures and the uncertain environment faced by households in developing countries, the need to self-finance an irreversible investment runs counter to the need for households to maintain savings in liquidable form as a means of self-insurance when times are hard. When the investment being made is indivisible, these conditions create an additional incentive to wait to invest. This was modeled by Fafchamps and Pender (1997) to explain the lack of investment in wells in India. The authors show that when a household faces an uncertain income stream, it may decide to delay making an irreversible and indivisible investment, even if it has the savings to finance such an investment. The household will not

[8] Uganda has been shown to have weak credit markets and non-existent insurance markets in rural areas (Deininger and Okidi 2001; Smith, Gordon, Meadows and Zwick 2001; Deininger and Mpuga 2002).

make such an investment until it holds a level of wealth high enough to both finance the investment and smooth consumption.

Unlike investments in wells, investment in coffee trees is very divisible. However fixed costs, if present, would impose some form of indivisibility on investment in coffee. In this case, we would also find an incentive to wait to invest, due to liquidity constraints. Liquidity constraints constrain changes in capital stock, but they are an asymmetric constraint as they only limit investment, not abandonment. Only wealthier households are able to respond to price increases above p_I and replace lost capital.

In the Dixit and Pindyck model, waiting to invest is motivated by the acquisition of new information, whereas the precautionary savings story suggests that waiting to invest is motivated by the acquisition of liquidity. However, both predict a weak investment response for poor households faced with an irreversible investment under uncertainty.

3. EMPIRICAL TESTING STRATEGY

As noted in the previous section, investment in coffee is largely irreversible, uncertain coffee prices cause the return to coffee production to be uncertain, and there is permanence in the price of coffee such that the expected price of coffee in the short term is dependent on current coffee prices. There may be non-linear costs of adjustment involved in investing in coffee trees, and much evidence suggests that coffee-producing households in Uganda are liquidity-constrained. This would suggest that the models of investment discussed above can help explain the decision of households to invest in or abandon coffee trees.

During the period under consideration, households experienced substantial falls in coffee prices, as well as shocks to their capital stock in the form of coffee wilt disease. Table 2 summarizes the various model predictions regarding investment behavior in the face of price changes and shocks to the capital stock (all other things equal). Predictions are presented for: (i) the standard investment model; (ii) investment under irreversibility and uncertainty; (iii) investment with non-linear costs (convex adjustment costs and fixed costs); and (iv) investment in the presence of liquidity constraints. The observed investment response allows determination of which model holds true for Ugandan households. The analysis first determines whether a range of inaction is present in the data, then whether evidence of non-linear adjustment costs can be observed, and finally whether the investment response varies across rich and poor households.

Table 2. Empirical predictions of investment models

Model	Price changes	Shocks to the capital stock
Standard model	Price increases induce investment; price decreases induce abandonment.	All capital lost is replaced.
Irreversibility and uncertainty	An area of inaction is present -small price changes have little effect (Fig. 2); large price changes result in changes in the capital stock.	An area of inaction is present; not all capital lost is replaced; there is a linear relationship between capital lost and replaced.
(3a) Non-linear costs: Convex adjustment costs	An area of inaction is present (Fig. 2); beyond this area a concave relationship between price and capital stock changes exists.	An area of inaction is present; not all capital lost replaced; there is a concave relationship between capital lost and replaced.
(3b) Non-linear costs: Fixed costs (concave)	Small changes in the capital stock are not observed and the area of inaction is increased (Fig. 3). For large enough price changes, a convex relationship between price and capital stock changes exists.	Small changes in the capital stock are not observed and the area of inaction is increased. All other things being equal, not all capital lost is replaced; there is a convex relationship between capital lost and replaced.
Liquidity constraints	Wealthier households invest more in response to positive price changes.	Wealthier households replace a larger share of capital lost.

The Presence of an Area of Inaction

Although standard investment theory (model 1) predicts that changes in the cost and return to investment will result in immediate changes to the capital stock, models 2, 3a and 3b predict that only price changes large enough to move the return to investment outside the area of inaction will induce investment or abandonment. Similarly, in the presence of a negative shock to the capital stock, the standard investment model predicts immediate and full replacement, others things equal, whereas the models of investment under uncertainty or investment under non-linear costs predict that full replacement will only be undertaken if the household was at a point on the investment threshold prior to the shock. This provides a clear test between model 1 and models 2, 3a and 3b. If all price changes and shocks to the capital stock elicit an investment or abandonment response, the predictions of the standard investment model are correct. However, if there is an area of inaction in which small price changes and shocks to the capital stock do not elicit an investment response, models 2, 3a or 3b may be correct.

The analysis begins by estimating the following regression based on the standard investment model:

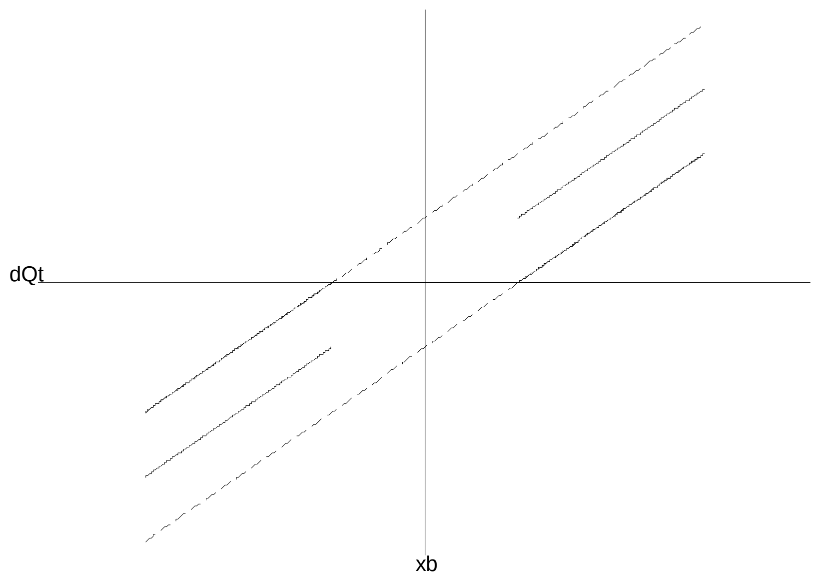
$$\Delta Q_i = \beta_0 + \beta_z z_i + \beta_p \Delta p_i + \beta_g \Delta g_i + \beta_0 Q_i + \sum_{j=1}^{N} \beta_j S_{ji} + \varepsilon_i \quad (6)$$

where ΔQ_i refers to investment in the coffee production potential of the household, z_i represents the number of trees lost to coffee wilt in period t, Δp_i reflects heterogeneity in price changes across households in period t, and Δg_i reflects heterogeneity in the cost of production changes across households. S_i is a vector of household characteristics that might reflect varying perceptions of changes in p_i or g_i across households. Because there is a natural limit to the minimum and maximum number of coffee trees that can be planted in a given area, the initial stock of coffee trees, Q_i, is included.

Under the standard investment model, β_p and β_z will be positive and significant, and β_g will be negative and significant. In models that allow for uncertainty and non-linear costs of adjustment, there may be a range of values for which shocks to the capital stock, and changes in p_i and g_i do not result in increased or decreased investment. As a result, insignificant values of β_z, β_p and β_g would be consistent with these models. We would also expect β_z to not significantly differ from 1 in the standard investment model. However, if the shock to the capital stock brings with it new information about the return to coffee, households may not fully replace trees lost.

If models 2 or 3 correctly characterize investment then the estimation approach needs to allow for a positive probability mass in the distribution at zero investment. Consider Figure 4. The bold line indicates the type of inaction caused by models 2 and 3, while the thin line indicates the type of inaction that would be observed in a model of reversible investment under certainty and fixed costs (i.e. model 3b modified to consider a reversible investment in a certain world). As we can see from this figure, if any one of models 2, 3a and 3b is correct, there will be a shift in the regression line at $\Delta Q_i = 0$.

Figure 4. A model of friction



A Tobit model allows for the possibility of a positive probability mass at one end of the distribution. However, as the choices available to the household include the options to both invest and abandon, we need a specification that allows for a positive probability mass in the middle. Rosett's model of 'friction' is used (Rosett 1959). This model provides an empirical framework for the analysis of any phenomenon where there is some insensitivity to small changes in the state of the world [see, for example, its use by Udry (1994) and Kazianga (2006) to account for transaction costs in lending and borrowing, and its use by Asano (2002) in this context]. The model is given by:

$$\begin{array}{lll} \Delta Q_i = X_i\beta + \varepsilon_i & \text{if} & X_i\beta + \varepsilon_i < 0 \\ \Delta Q_i = 0 & \text{if} & 0 < X_i\beta + \varepsilon_i < \alpha \\ \Delta Q_i = X_i\beta - \alpha + \varepsilon_i & \text{if} & X_i\beta + \varepsilon_i > \alpha \end{array} \qquad (7)$$

where α is a threshold that must be reached before changes in capital stock are observed, and $X\beta + \varepsilon$ refers to the right hand side of equation (6). This gives rise to a relationship between $X\beta$ and ΔQ_i , as indicated by the bold line in Figure 4. The likelihood function is given as:

$$L(\Delta Q_i;\ \beta,\alpha,\sigma_\varepsilon) = \prod_{\Delta Q_i<0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i=0} \Phi\left(\frac{\Delta Q_i - X_i\beta}{\sigma_\varepsilon}\right) - \Phi\left(\frac{-X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i>0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta + \alpha}{\sigma_\varepsilon}\right) \qquad (8)$$

where ϕ denotes the standard normal density function, and Φ denotes the standard normal cumulative density function (it is assumed that ε is normally distributed). A test of the significance of α provides a test of friction in the model, which is commensurate to testing the relevance of models 2, 3a or 3b for Ugandan households' investment in coffee.

Non-Linear Investment Costs

Testing for non-linear investment costs to distinguish between model 2, 3a and 3b is more difficult. Consider first the presence of fixed costs, as set out in model 3b. The presence of fixed costs increases the range of inaction and causes small changes in the capital stock not to be observed. The presence of fixed costs can thus be tested by determining whether or not small changes in the capital stock are observed.

If fixed costs of investment and abandonment are present but uncertainty or irreversibility are not, then there will be no shift in the regression line on either side of zero, and a line similar to the thin solid line in Figure 4 will be observed. A modified version of the Rosett model can be used to estimate this line. In this case, the observation of ΔQ_i can be summarized as [adjusting the Rosett model presented in equation (7):

$$\begin{aligned} \Delta Q_i &= X_i\beta + \varepsilon_i && \text{if} \quad X_i\beta + \varepsilon_i < -\tau^A \\ \Delta Q_i &= 0 && \text{if} \quad -\tau^A < X_i\beta + \varepsilon_i < \tau^I \\ \Delta Q_i &= X_i\beta + \varepsilon_i && \text{if} \quad X_i\beta + \varepsilon_i > \tau^I \end{aligned} \tag{9}$$

where τ^I and $-\tau^A$ are non-zero unknown thresholds determined by the fixed costs of investment and abandonment, respectively. Carson and Sun (2007) show that for a non-zero unknown threshold in a Tobit model (such as the thresholds τ^I and $-\tau^A$ in equation 7) a superconsistent estimator is given by estimating τ^I as $\hat{\tau}^I = \min\{\Delta Q_i^+\}$, where ΔQ_i^+ refers to all non-zero positive observations of ΔQ_i. Similarly $-\tau^A$ can be estimated as $\hat{\tau}^A = \min\{\Delta Q_i^-\}$, where ΔQ_i^- refers to all non-zero negative observations of ΔQ_i. These can be estimated directly from the data, allowing the following likelihood function to be estimated:

$$L(\Delta Q_i;\ \beta, \sigma_\varepsilon) = \prod_{\Delta Q_i<0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i=0} \Phi\left(\frac{\widehat{\tau^I} - X_i\beta}{\sigma_\varepsilon}\right) - \Phi\left(\frac{\widehat{-\tau^A} - X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i>0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta}{\sigma_\varepsilon}\right) \tag{10}$$

A model that allows for both fixed costs and a shift in the regression line commensurate with uncertainty and irreversibility enables us to estimate investment and abandonment decisions under model 3b. The likelihood function for this model is given as:

$$L(\Delta Q_i;\ \beta, \alpha, \sigma_\varepsilon) = \prod_{\Delta Q_i<0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i=0} \Phi\left(\frac{\alpha + \widehat{\tau^I} - X_i\beta}{\sigma_\varepsilon}\right) - \Phi\left(\frac{\widehat{-\tau^A} - X_i\beta}{\sigma_\varepsilon}\right) \prod_{\Delta Q_i>0} \frac{1}{\sigma_\varepsilon}\phi\left(\frac{\Delta Q_i - X_i\beta + \alpha}{\sigma_\varepsilon}\right) \tag{11}$$

Also, in the presence of fixed costs, the cost of changing the capital stock falls with each successive unit, meaning that we would expect higher price changes to be met with larger proportional changes to the capital stock. When convex adjustment costs are present, the opposite is true, with the cost of changing the capital stock increasing with each successive unit of investment or abandonment. However, a non-linear relationship (convex or concave) can also arise as a result of increasing or decreasing returns to marginal capital. Decreasing returns to capital give rise to exactly the same concave relationship between price changes and capital stock adjustments as the presence of convex adjustment costs. Therefore, we are not able to distinguish between these two models by assessing the non-linearities present in the response of capital stock adjustments to price changes.

However, the relationship between negative shocks to the capital stock and investment is somewhat different, allowing us to distinguish among models 2, 3a and 3b. Beyond the range of inaction in which small losses are not replaced, model 2 predicts a linear relationship between shocks and investment regardless of the assumptions made about the returns to capital. In contrast, a model that allows for non-linear investment costs predicts a non-linear relationship between shocks to the capital stock and investment beyond the range of inaction. When fixed costs are present (resulting in concave adjustment costs, model 3b) a higher proportion of capital lost will be replaced when losses are larger. In this case, the introduction of a squared term of the negative shock would be positive and significant. If convex adjustment costs are present (model 3a), the square of trees lost will be negative and significant (assuming that the increasing marginal costs of investment come from the increased cost of investing rather than that of adjusting to a new level of capital stock).

Liquidity Constraints

If liquidity constraints are present, there may be some heterogeneity in the observed investment behavior across households with different levels of wealth, because richer households are more able to respond to positive price shocks and similarly, to replace capital lost. In Equation (10), the investment response to changes in the price and shocks to the capital stock is allowed to vary across rich and poor households. The coefficient on the wealth interaction terms is a test for the importance of liquidity constraints for Ugandan coffee-producing households. If liquidity constraints are important, we would expect the interaction terms to be positive and significant (or negative and significant, as in the case of $W_i * \Delta g_i$).

$$\Delta Q_i = \beta^0 + \beta_z z_i + \beta_p \Delta p_i + \beta_g \Delta g_i + \beta_{Wp}(W_i * \Delta p_i) + \beta_{Wg}(W_i * \Delta g_i) + \beta_{Wz}(W_i * z_i) + \sum_{j=1}^{N} \beta_j S_{ji} + \beta_Q Q_i + \varepsilon_i \quad (12)$$

This model can be estimated with any of the Rosett models presented above. The empirical strategy used to test the four investment models is summarized in Table 3 (commensurate with Table 2).

Table 3. Summary of empirical testing strategy

Model	β_g	β_p	β_z	β_{z^2}	α	τ^A, τ^I
(1)	negative and significant in OLS	positive and significant in OLS	positive and significant	insignificant	insignificant	insignificant
(2)	negative and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	insignificant	significant	insignificant
(3a)	negative and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	negative and significant	significant	insignificant
(3b)	negative and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	positive and significant in Friction model, less significant in OLS	positive and significant	significant	significant
(4)	negative and significant for richer households	positive and significant for richer households	positive and significant for richer households	no prediction	no prediction	no prediction

4. DATA

Data on a sample of 300 coffee-producing households drawn from four districts of Uganda are used to examine the effects of price changes and capital stock shocks on abandonment and investment in coffee trees. Data were collected by the author through the Uganda Bureau of Statistics at the beginning of 2003. Coffee-producing households were sampled from four districts (Mukono, Luwero, Masaka and Bushenyi) that together are responsible for about 50 percent of all Robusta coffee produced in Uganda. The sample of coffee-producing households was drawn randomly from a sampling frame constructed from a national household survey conducted in 1999/2000, which was used to identify coffee-growing households. As the period between the baseline and the follow-up survey was relatively short, there was little attrition. Most of the surveyed households were still in existence within the villages, and it was relatively easy to trace them. Questions on production and household characteristics that were asked in 1999/2000 were repeated, allowing a small panel to be generated. In addition, data on the number of coffee trees owned by each household and lost to wilt in the prior three years was collected.

The majority of coffee grown in Uganda is produced by smallholders. Consistent with this, more than two-thirds of the studied households own less than or equal to five acres of land. The majority of households are headed by a male, and the average age of the household head is 50 years. The mean level of education of household heads is 5 years.

The coffee trees farmed in Uganda are very old--the majority of trees are aged about 40 years and some trees are still being farmed at 70 years. These trees have experienced many changing fortunes, particularly in the last decade as liberalization has resulted in a higher, but more volatile price. In the three-year period considered here (2000 to 2003), the producer price of coffee in Uganda fell from $0.47 to $0.26 per kilo.[9] Anecdotally, it appears that many of the trees have remained in the ground through these changing fortunes and price drops, and disinvestment is more likely to be shown by neglect than removal.

Summary measures of the variables used in the analysis and described below are presented in Table 4. As can be seen from the table, on average the price of coffee relative to other crops fell by over a third during the study period, and on average 30% of trees were affected by coffee wilt disease. Although 95% of households reported removing some trees, only 31% of households reported removing trees for reasons other than coffee wilt disease. The proportion of trees removed is also much lower when trees are removed for reasons other than disease. Coffee wilt disease is thus a significant random shock to the number of trees held by the surveyed households. The substantial price changes and the high incidence of coffee wilt underlines the importance of understanding a household's response to these changes. Table 4 also shows that the number of coffee trees per hectare fell from 150 to 101 trees per acre during the study period (a fall of 32.7%), although this is largely explained by the high numbers of trees lost to coffee wilt (an average 45 trees per household). Per capita liquid wealth fell slightly from 1999 to 2002 and the ratio of land to labor increased.

[9] In constant 2003 US $.

Table 4. Descriptive statistics

	1999		2002
Number of trees per acre (average)	150		101
Number of trees lost to coffee wilt, per acre (average)		45	
Future production potential (average)	164		95
Liquid wealth per capita (constant US$) (median)	248		230
Land to labor ratio (median)	1		1.275
Relative price of coffee (median)	1.875		1.194
UCDA program dummy		0.685	
Share of trees lost to wilt (average)		0.305	

Source: Household survey data collected by author.

The production potential of a coffee tree depends on its age. A newly planted tree has the most potential, whereas a tree at the end of its productive life has little production potential. Although no detailed data are available on the age profiles of coffee trees held by the sampled households, the surveys did include whether the trees are newly planted or at the end of their productive life. This allows the following weighting function to be used to loosely estimate a household's coffee production potential, or capital stock, as: $Q_i = total_i - 0.8 * old_i$, where "total" refers to the total number of trees, and "old" refers to trees classified by the household as being at the end of their productive lives. Using this formula we see that the future coffee production potential fell more than the number of trees between 1999 and 2002. The difference in coffee production potential between 1999 and 2002 provides a measure of net investment or abandonment in coffee production over this three-year period once any change resulting from coffee wilt disease is netted out. This wilt-adjusted measure of production potential is used as the dependent variable in the following analysis. The productive potential is divided by the household's endowment of land, as a household chooses coffee production potential for each unit of land it owns.

The number of trees lost to wilt divided by the household's endowment of land provides a measure of the shock to capital stock experienced by the household during the study period. The number of trees per acre in 2000 is also included in all regressions to control for any possible effect of the initial stock levels on investment and abandonment undertaken, due to there being a natural limit on the minimum and maximum number of trees per acre.

The change in price, p_t , that is of importance to the investment decisions is the relative price of coffee to other crops the household could grow and sell. To capture this change, we use a ratio of the coffee price to an average per-kilo price of other crops grown by the household. The main staple crops grown by the household during the first survey period are considered. Several studies have shown that staple crops are increasingly being sold for cash in the sampled areas of Uganda, suggesting that this may be an appropriate ratio to consider. Crop prices reported by households are used to estimate average village prices for coffee and the main staple crops in 1999 and 2002. An average of these village prices is calculated for the combination of crops relevant to each household.

Although technology is assumed to be constant across households, if coffee production is more or less labor intensive than other crop production, and the markets are not perfect for either labor or land, technological considerations will enter into the household's decision of how many coffee trees to hold. Changes in the household land-to-labor ratio between 1999 and 2002 are included in the analysis (measured as the ratio of total cultivatable land owned to available household labor[10]) to reflect changes in the relative cost of coffee production for the household.

[10] Available household labor is calculated as the number of household members older than 14 and able to work, multiplied by 312 days.

Data on household asset ownership are used to construct measures of per capita asset wealth, which are used to split the sample into groups containing richer and poorer households. To examine the effect of liquidity constraints, the investment response of households is allowed to vary for households in the bottom percentiles of the distribution. Various percentile cut-offs are used to check the robustness of the results.[11] As a further robustness check, a non-asset based measure of welfare (the number of times the family ate fish or meat in the week prior to the 1999 survey) is also used to split the sample into families that ate meat or fish, and those that did not. There is quite a wide variation in this measure, which is found to correlate well with other measures of household welfare.

In recent years, in an effort to alleviate poverty and provide assistance to coffee farmers, the Ugandan government and the Uganda Coffee Development Authority (UCDA) established a program to distribute coffee tree seedlings to households for free. This is based on the rationale that if farmers can replace their old low-productivity trees with new (often clonal) seedlings, the per-acre coffee yields will increase, thereby helping boost incomes even when prices are low (Uganda can be considered a price-taker). The program did not operate in all areas of the country at the time of the surveys, but it was active in some parts of all four regions sampled in the survey. Through this program, some households have ready access to free seedlings. In areas where this program is not active, coffee farmers must either travel to the nearest nursery (if there is one) to buy seedlings, or they must grow their own seedlings. The latter is a time-intensive and risky business, as young coffee seedlings are easily destroyed. For households where the UCDA programs are available, the cost of investment is lower than for households who have no access to such programs. To control for this variation in costs of investment, a dummy is included that takes the value of 1 if a UCDA coffee seedling program was recorded as being present in the village over the period 1999 - 2002.

As mentioned in the introduction to this paper, some studies have found a significant relationship between tenure security and investments in land, such as planting coffee trees. It is thus also important to control for the type of tenure security in the sampled households. In a study examining this very issue in Uganda, Place and Otsuka (2002) noted a "perceived lack of tenure security for individual households under some customary systems." A dummy taking the value 1 if the household has security of tenure on the plots of land on which coffee is planted, and 0 if there is not security of tenure (customary land, public land, squatters and leaseholders) is included in all regressions.

Expectations about the quantity of coffee a household will receive from a given tree will vary across regions, and perhaps also with household characteristics. To control for this, the regressions include regional dummies and characteristics of the household head, including age (in case life-cycle effects impact the discounted return to investment) and years of education.

[11] Regressions were run splitting the sample at the 20th, 25th, 50th, 75th and 80th percentiles.

5. RESULTS

Main Results

First, results of a simple OLS estimation of equation (4) are presented in Table 5 (first column). Standard errors are controlled for clustering at the village level in all results. The results show the change in price to be significant and positive. The coefficient on the change in land-to-labor ratio is negative, as predicted, but it is not significant. It is unclear whether this is because it is a poor measure of the cost changes faced by the household, or due to the presence of an area of inaction which biases the coefficient to zero. The shock to coffee trees is significant and positive as predicted by the standard investment model, but the observed coefficient is significantly different from 1. This is consistent with models 2 to 4; however, as discussed above, there are a number of reasons why a one-to-one replacement of coffee trees may not be observed, even in the standard investment model.

The initial stock of coffee trees is not significant, suggesting that there is no difference in investment across households as a result of a varying stock of coffee trees. Surprisingly, the UCDA dummy is also insignificant, implying that the cost of investing in coffee production does not vary across villages dependent on whether the UCDA program is present. Possibly, households within program-covered villages have differential access to program-provided seedlings. Indeed, it was suggested by some of the respondents that politically well-connected village members had greater access to these seedlings. To explore this possibility, regressions are repeated interacting the UCDA dummy with a dummy that reflects whether or not an individual is a village official (regression results are not shown to conserve space). However, no significant impact on investment is found when this was done. If it is true that access to UCDA seedlings does not impact investment, this finding suggests that seedling investment does not represent a large part of the cost of investing in coffee. It also suggests that if fixed costs are present, they do not come from the cost of traveling to purchase seedlings. The age of household head and a dummy reflecting tenure security are also insignificant, whereas the coefficient on years of education of the household head is positive and significant.

The results from a Rosett estimation are presented in the second column of Table 5. This estimation method allows for a range of inaction, and the significance of the friction parameter provides a test of a sluggish investment response to changes in the fundamentals, as predicted by models of investment with uncertainty and irreversibility. The results show that the friction parameter is significant, indicating that a range of inaction is indeed present. Comparing these results with those in the first column, we see that allowing for bunching of values at zero increases the magnitude of coefficient estimates on price change and shocks to the capital stock, as expected. However, the change in the land-to-labor ratio remains insignificant.

Table 5. Rosett model results allowing for a period of inaction

Dependent variable = ΔQ (net of wilt shocks) per acre	(1) OLS	(2) Friction	(3) Fixed Costs	(4) Friction and Fixed Costs
Tree lost to wilt per acre	0.21	0.23	0.21	0.23
	(0.10**)	(0.10**)	(0.10**)	(0.10**)
Δ relative coffee price	3.78	4.88	3.17	4.86
	(1.66**)	(2.07**)	(1.51**)	(2.07**)
Δ In (land to labor ratio)	-2.45	1.82	-1.37	1.77
	(1.85)	(2.53)	(1.59)	(2.51)
UCDA dummy	4.34	7.00	3.51	6.95
	(4.51)	(6.26)	(4.25)	(6.23)
Stock of trees (per acre)	16.37	18.60	14.65	18.53
	(12.29)	(12.23)	(10.81)	(12.20)
Age of head	0.14	-0.06	0.39	-0.05
	(0.19)	(0.21)	(0.15)	(0.21)
Education of head	1.74	2.27	1.58	2.26
	(0.58***)	(0.73***)	(0.54***)	(0.72***)
Tenure security dummy	-0.10	-2.98	0.15	-2.96
	(2.96)	(4.92)	(2.85)	(4.89)
Constant	-3.07	37.97	-2.17	37.56
	(8.54)	(13.04***)	(8.09)	(12.98***)
Rosett friction parameter, α		50.05		49.45
		(8.91***)		(8.92***)
τ^I			0.50***	0.50***
$-\tau^A$			0.11	0.11
Regional dummies included, but not shown				
Number of observations	277	277	277	277
Wald χ^2	2.04**	27.25***	27.10***	27.01***
R-squared	0.2568			

Source: Regression results using household survey data collected by author
Note: Standard errors are corrected for clustering at the village level (*** denotes significance at 0.01, ** at 0.05, * at 0.1 and ‘at 0.15).

In the third column of Table 5, the results from a Carson and Sun estimation are presented. This estimation method allows for the presence of fixed costs, but not uncertainty and irreversibility. In column 4, the friction parameter, α, is again included in the estimation to allow for both fixed costs and uncertainty and irreversibility. Confidence intervals for the parameters τ^I and τ^A can be estimated using the formula presented in Carson and Sun (2007). Constructing confidence intervals of 90%, 95% and 99%, we see that τ^I is significantly different from zero at the 1% level, whereas the threshold on abandoning, τ^A, is not significant at any level. This suggests there are fixed costs to investing but not to abandoning. However, the estimate of τ^I is only 0.5, suggesting that the fixed costs of abandoning are not large.[12] The coefficients on all of the other variables of interest mirror those in columns 1 and 2. The regression model presented in column 4, by allowing for a range of inaction, increases the magnitude of the coefficients of significant determinants of investment and abandonment.

Table 6. Testing for the presence of fixed costs

Depended variable = ΔQ (net of wilt shocks) per acre	**OLS**	**Model of friction with fixed costs**
Trees lost to wilt (per acre)	-0.08	-0.04
	(0.04*)	(0.05)
Square of trees lost to wilt	0.0005	0.0004
	(0.0001***)	(0.0001***)
Δ relative coffee price	4.18	5.61
	(1.54***)	(2.04***)
$\Delta \ln$ (land to labor ratio)	-2.46	0.487
	(1.69)	(2.44)
UCDA dummy	5.43	8.26
	(4.12)	(6.16)
Stock of trees (per acre)	15.03	18.58
	(10.54)	(11.89)
Age of head	0.001	-0.0
	(0.143)	(0.20)
Education of head	1.42	2.03
	(0.52***)	(0.67***)
Tenure security dummy	1.50	-1.42
	(3.00)	(4.90)
Constant	4.30	39.67
	(7.94	(13.15)
Rosett friction parameter		44.34
	(6.47***)	
Estimate of τ^I		0.5***
Regional dummies included, but not shown		
Number of observations	277	277
F-test or Wald χ^2 test	2.53***	35.76***
R-squared or $\ln L$	0.4301	-1108.12

Source: Regression results using household survey data collected by author.
Note: Standard errors are corrected for clustering at the village level (*** denotes significance at 0.01, ** at 0.05, * at 0.1 and ‘ at 0.15).

Combined, these results suggest that a range of inaction is present in the investment/abandonment response of households, indicating that the investment decision can be characterized by irreversibility and

[12] This is derived from the case of a farmer who has 4 acres and planted only 2 trees from seedlings of older trees that were lost to coffee wilt disease. While this is the only observation in the sample in which fewer than 4 trees were planted, it highlights that we would ideally like to allow τ^I to be stochastic, such as by modeling it as $\tau^I + e_i$, where e_i is an error term. While it is quite possible to do this for a Tobit model (e.g. Nelson 1977), it is problematic in a model in which the censoring occurs in the middle [see Amemiya's critique of Dagenais (Amemiya 1984)].

uncertainty, and perhaps fixed costs. To further test for the presence of fixed costs, a squared term of the trees lost to wilt is included. The results are shown in Table 6. In both an OLS specification, and a specification that allows for bunching at zero, the squared term is significant and positive, indicating that fixed costs are present.

If it is true that fixed costs cause investment to only take place when large price changes are realized or when a household experiences a large shock to the capital stock, then we might expect that this would be seen in a probit regression in which the dependent variable is a dummy taking the value of 1 if a household invests in coffee production and 0 when a household does not invest (including those households that choose to abandon coffee). We would expect that households would be more likely to undertake investment upon receiving larger shocks. A simple cross tab suggests this may be the case. Households that chose not to invest lost 33 trees per acre on average, whereas households that chose to invest lost 54 trees per acre on average (the hypothesis that these are equal can be rejected, t-stat=1.86). The results of a probit (Table 7) show that households that lost more trees were more likely to invest.

Table 7. Probit estimates on the decision to invest

Dependent variable = 1 if households invest, 0 otherwise		
Tree lost to wilt per acre	0.001	(0.0008*)
Δ relative coffee price	0.085	(0.068)
Δ In (land to labor ratio)	0.271	(0.091***)
UCDA dummy	0.198	(0.206)
Stock of trees (per acre)	-0.153	(0.117)
Age of head	-0.008	(0.005)
Education of head	0.059	(0.022***)
Tenure security dummy	-0.063	(0.263)
Constant	0.414	(0.452)
Number of observations	284	
F-test (11, 71)	3.07***	

Source: Regression results using household survey data collected by author.
Notes: Regional dummies are included but not shown. Standard errors are corrected for clustering at the village level (*** denotes significance at 0.01, ** at 0.05, * at 0.1 and ‘ at 0.15).

Liquidity Constraints

Thus far it has been assumed that the households face no liquidity constraints to investing. However, liquidity constraints among poorer households may limit the purchase of new seedlings and the amount of land that can have zero output for three years while the coffee trees mature. To test for the presence of liquidity constraints, a household's investment response to the number of trees lost and price changes is allowed to vary across households according to their level of wealth.[13] First a measure of asset wealth is used to split households, then a measure of household welfare (the number of times meat or fish was consumed in the week prior to survey) is used.

[13] Given that the square of trees lost is significant in specifications that include both the number of trees lost and its square, the square of trees lost is allowed to vary with the wealth level of the household.

Table 8. Testing for the presence of liquidity constraints

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable =	**25th Percentile**		**75th Percentile**		**Meat or fish**	
Δ*Q* (net of wilt shocks) / acre	**OLS**	**Friction**	**OLS**	**Friction**	**OLS**	**Friction**
Tree lost to wilt per acre	-0.02	-0.02	-0.06	-0.06	0.01	0.06
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
Sq. of trees lost to wilt per acre	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001***)	(0.0001)	(0.0001)
Sq. trees lost * wealth dummy	0.0004	0.0004	0.0003	0.0001	0.0003	0.0004
	(0.0001***)	(0.0001***)	(0.0002**)	(0.0002)	(0.0002**)	(0.0001**)
Δ relative coffee price	4.15	5.29	3.50	4.39	6.37	7.77
	(2.06**)	(2.96*)	(1.75**)	(2.29*)	(1.67***)	(2.77***)
Δ rel. price * wealthy dummy	-0.60	-0.34	3.21	6.80	-.3.43	-3.53
	(2.52)	(3.49)	(3.02)	(4.34)	(2.17)	(3.23)
Δ In (land to labor ratio)	-2.43	0.30	0-2.50	0.41	-1.42	1.53
	(1.73)	(2.37)	(1.71)	(2.46)	(1.48)	2.22)
UCDA dummy	4.64	7.34	5.74	8.86	4.26	6.94
	(4.08)	(6.02)	4.26)	6.26)	(3.91)	(5.89)
Stock of trees (per acre)	12.74	16.13	15.20	18.92	15.39	18.72
	(9.08)	(10.43)	(10.84)	(12.47)	(9.82)	(11.16*)
Age of household head	-0.02	-0.10	0.02	-0.05	-0.03	-0.11
	(0.15)	(0.20)	(0.14)	(0.20)	(0.14)	(0.20)
Education of household head	1.29	1.87	1.54	2.26	1.36	1.95
	(0.51**)	(0.66***)	(0.54***)	(0.69***)	(0.51***)	(0.66***)
Tenure security dummy	1.15	-1.50	1.86	0.73	2.04	-0.66
	(2.81)	(4.64)	(3.18)	(5.08)	(2.69)	(4.53)
Constant	5.39	38.32	1.81	35.37	3.90	37.68
	(7.88)	(12.39)	(8.79)	(13.93**)	(7.43)	(12.69)
Rosett friction parameter, α		41.46		44.49		42.60
		(5.82***)		(6.49***)		(6.54***)
Estimate of $\mathcal{T}^1$		0.5***		0.5***		0.5***
Number of observations	277	277	277	277	277	277
F-test or Wald χ^2 test	4.88***	69.70***	2.29**	38.15***	3.24***	53.83***
R-squared or In L	0.4904	-1099	0.4326	-1107	0.4753	-1100

Source: Regression results using household survey data collected by author.
Notes: Regional dummies are included, but not shown. Standard errors are corrected for clustering at the village level (*** denotes significance at 0.01, ** at 0.05, * at 0.1 and ‘ at 0.15).

Table 8 presents the results for households split between the bottom wealth quartile and top three wealth quartiles (columns 1 and 2), households split between the bottom three wealth quartiles and top wealth quartile (columns 3 and 4), and households split between those that ate meat or fish in the week prior to survey (60% of households) and those that did not (columns 5 and 6).[14]

The results show that only richer households replace trees lost to wilt. This is true in five of the six specifications shown. In the specification used in column 4, there is no significant difference in the investment response of poorer and richer households, and this was true when percentile cut-offs from the 50th percentile up were used. This suggests that households in the bottom half of the wealth distribution are constrained by lack of liquidity. The impact of wealth on changes in prices does not support this conclusion, as there is no significant difference in the investment response of richer households to changes in price. However, this is perhaps not surprising given that three-quarters of the sample experienced decreases in the relative price of coffee during this time, and liquidity constraints do not constrain abandonment.

Robustness Checks: Non-Parametric Analysis

The empirical results suggest that the investment decision can be characterized by uncertainty and irreversibility, and that fixed costs of investment are present. There is also some evidence that liquidity constraints limit a household's positive investment response. The data in Tables 2 and 3 seem broadly consistent with model 3b, and there is some evidence that is consistent with the investment behavior predicted by model 4.

However, much of the above data analysis has imposed quite stringent assumptions on the error term. The models of friction used to identify the presence of an area of inaction are essentially generalized Tobit models, and are therefore subject to the same problems of bias in the face of non-normality or heteroscedasticity of the error term. The results from linear regression models presented in Tables 3, 4 and 5 are consistent with those from the models of friction. Relying on OLS results alone, we might conclude that changes in the capital stock respond to shocks and changes in the price (column 1 of Table 5), that fixed costs are present (column 1 of Table 6), and that liquidity constraints may limit a household's ability to undertake positive investment (columns 1, 3 and 5 of Table 7). However the OLS results are unable to test for the presence of inaction that is predicted by models of irreversible investment under uncertainty.

To determine whether an area of inaction is present in the data when strict assumptions are not imposed on the error term, nonparametric analysis on the two variables of interest—shocks to the coffee stock, and changes in the price—is also undertaken. The non-linear relationships between ΔQ_i and z_i, and between ΔQ_i and Δp_i, are estimated sequentially using a Robinson (1988) partial linear model. The estimated relationship is given in equation (13). (The example used is that of z_i, with $\varphi(z_i)$ representing the non-linear relationship between ΔQ_i and z_i. The same principles hold for estimation of the relationship between and ΔQ_i and Δp_i.)

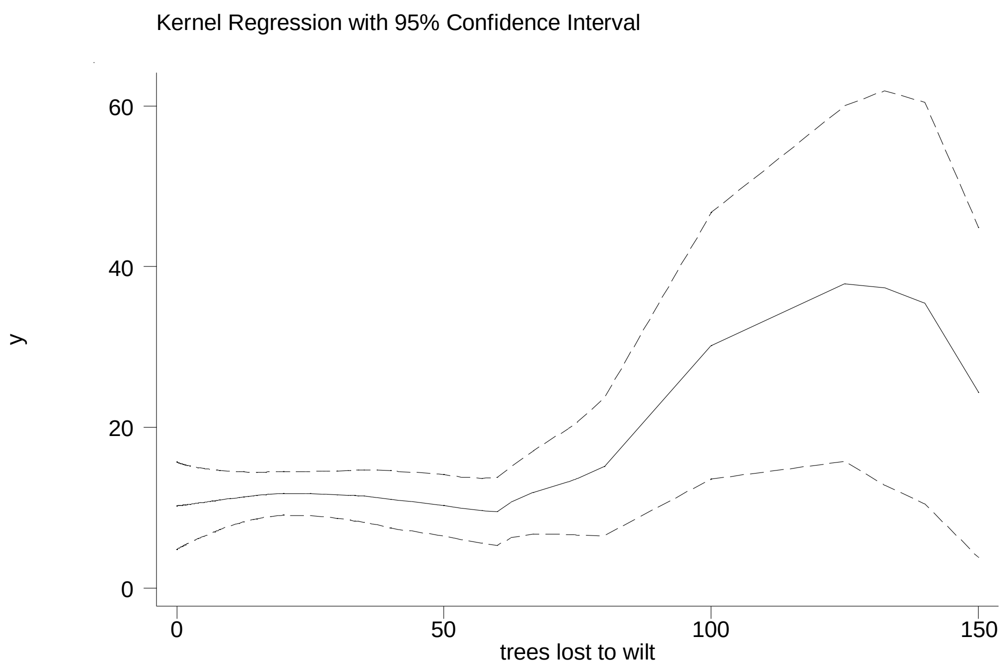
$$\Delta Q_i = X_i\beta + \varphi(z_i) + \varepsilon_i \qquad (13)$$

In this case, $\varphi(z_i)$ is estimated as follows: conditioning on z_i and subtracting gives $\Delta Q_i - E(\Delta Q_i|z_i) = (X_i - E(X_i|z_i))\beta + \varepsilon_i$; $E(\Delta Q_i|z_i)$ and $E(X_i|z_i)$ are estimated using nonparametric regressions (as X_i is a vector of variables, a separate nonparametric regression is run for each variable in X, each time with x_i as the independent variable); performing the regression $\Delta Q_i - E(\widehat{\Delta Q_i}|z_i) = \left(X_i - E(\widehat{X_i|z_i})\right)\beta + \varepsilon_i$ provides an estimate of $\hat{\beta}$; and, finally, using this estimate of β in the original regression allows the regression problem to be written as $\Delta Q_i - X_i\hat{\beta} = \varphi(z_i) + \varepsilon_i$, allowing the nonparametric estimation of φ.

[14] Other percentile cut-offs were used for liquid wealth; the two shown here are representative of the other regression results.

The results from partial kernel regressions for z_i and Δp_i are presented in Figures 5 and 6, respectively.[15] Figure 5 clearly indicates a range of inaction with investment non-responsive to tree losses up to about 40 trees. Beyond this range of inaction, a non-linear relationship is observed in which the rate of investment increases with the magnitude of the shock up to about a 100 trees, and decreases thereafter. The graph supports a model of irreversible investment under uncertainty, in which fixed costs dominate up to a point. Figure 6 is less clear, with strong non-linearities present for large negative and positive price changes. Disregarding the endpoints (which are less reliable in a kernel regression), the rest of the graph is not inconsistent with the predicted pattern. The graph increases until about -1.2, flattens until -0.6 (consistent with a range of inaction), and increases again after -0.6. These graphs seem to support the conclusions of the Rosett model estimates.

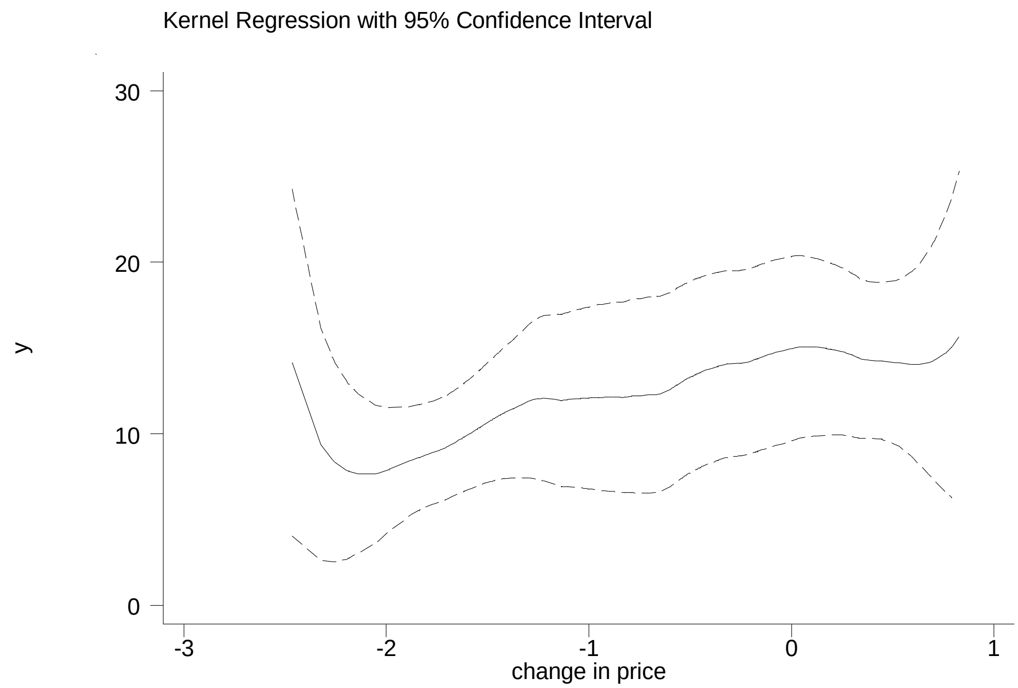
Figure 5. Partial kernel regression of trees lost to wilt on y, where $y = \Delta Q_i - X_i\hat{\beta}$



Source: Regression results using household survey data collected by author.

[15] The program used for estimating these partial kernel regressions was written by Marcel Fafchamps, University of Oxford.

Figure 6. Partial kernel regression of change in the relative price of coffee on y, where $y = \Delta Q_i - X_i\hat{\beta}$



Source: Regression results using household survey data collected by author.

Robustness Checks: A Different Dependent Variable

With the exception of the probit estimates presented in Table 7, the results presented have as their dependent variable an imperfect measure of ΔQ_i. The production potential of a coffee tree depends on its age, but since there is no detailed data on the age profile of the coffee trees held by a given household, a weighting function is used to approximate a household's coffee production potential (see Section 4). The robustness of the results to varying this weighting function is tested by using the unweighted number of trees to calculate the unweighted change in the number of trees, which is then used as the dependent variable.

The results for this dependent variable are presented in Table 9. The OLS results are presented in column 1, the results for a model of friction with fixed costs in column 2, and the results for a model of friction with fixed costs and liquidity constraints in column 3. The significance of the Rosett friction parameter in columns 2 and 3 suggests that a period of inaction is present in the data, consistent with a model of irreversible investment under uncertainty. The results in columns 1, 2 and 3 show that investment increases with the number of trees lost to wilt, in a manner consistent with the presence of fixed costs to investment. In particular, the square of the number of trees is significantly positive in columns 2 and 3, and τ^I is positive and significant in columns 2 and 3. Although positive, the relationship between investment and price changes is not significant. Column 3 suggests that changes in price have a significant impact on investment for wealthier households, but the investment response to coffee wilt shocks does not increase for wealthier households, as a model with liquidity constraints would predict. Overall, the results are robust to changing the dependent variable in this way.

Table 9. Using changes in the number of trees as the dependent variable

Dependent variable =change in the number of trees	(1) OLS and fixed costs	(2) Friction and fixed costs	(3) Friction, fixed costs and liquidity constraints
Tree lost to wilt per acre	0.224	0.016	0.042
	(0.105**)	(0.072)	(0.086)
Square of trees lost		0.0004	0.0004
		(0.0002**)	(0.0002*)
Square of trees lost * top 25th percentile of wealth			-0.0002
			(0.0003)
Δ relative coffee price	2.534	4.455	1.117
	(1.810)	(2.724’)	(2.954)
Δ relative price * top 25th percentile of wealth			15.87
			(6.462**)
Δ In (land to labor ratio)	2.138	5.180	4.975
	(2.165)	(3.529’)	(3.557)
UCDA dummy	5.992	10.17	11.90
	(8.520)	(11.43)	(11.79)
Stock of trees (per acre)	3.420	6.852	7.845
	(8.613)	(9.895)	(9.925)
Age of household head	-0.260	-0.397	-0.307
	(0.316)	(0.406)	(0.387)
Education of household head	1.219	1.781	2.394
	(0.559**)	(0.743**)	(0.786***)
Tenure security dummy	2.556	-0.276	1.647
	(12.653)	(6.368)	(6.870)
Constant	-1.352	46.28	35.03
	(10.76)	(18.00***)	(18.28*)
Rosett friction parameter, α		54.91	55.77
		(11.57***)	(11.76***)
$-\tau^{l}$		0.50***	0.50***
Number of observations	277	277	277
F-test or Wald χ^2	1.26	26.97***	32.72***
R-squared	0.2239		

Source: Regression results using household survey data collected by author.

Notes: Regional dummies are included, but not shown. Standard errors are corrected for clustering at the village level (*** denotes significance at 0.01, ** at 0.05, * at 0.1 and ‘at 0.15).

6. CONCLUSION

This paper examines the investment and abandonment behavior of poor rural households, endeavoring to determine the underlying models of investment consistent with observed investment responses to price changes and shocks to the capital stock. The results suggest that the observed behavior is consistent with models of investment characterized by uncertainty, irreversibility and fixed costs.

The findings indicate that some friction is present in changes made to the capital stock, consistent with predictions of a model of irreversible investment under uncertainty. However, this analysis does not determine the extent to which reluctance in household stock adjustment stems from the presence of uncertainty, as opposed to the irreversible nature of investment in coffee. The observed relationship indicates that policies allowing a household to be more certain of future returns from coffee production may encourage a more responsive investment strategy.

The analysis also shows that investment in coffee is characterized by fixed costs, causing households that have experienced larger price changes or capital shocks to invest more in coffee production. The analysis suggests that if fixed costs were reduced, households' investment in (but not abandonment of) coffee would respond more quickly to changes in the fundamentals. However, further work is needed to identify these fixed costs and determine what policy response would help alleviate them. Although it was thought that part of the fixed cost of investing in coffee trees would be the cost of traveling to purchase seeds, the present results show no significant difference in investment for households that receive free seedlings, indicating that this is not a large part of the cost of investment borne by households. It may be that there is an implicit fixed cost to investment such as the need to watch and monitor new seedlings that drives the observed empirical relationship (as suggested by Bar-Ilhan and Blinder 1992).

Additionally, the present results show that poorer households are less able to respond to shocks to the capital stock. Poorer households are less likely to replace diseased trees. This is seen even when the availability of free seedlings is controlled for, indicating that a significant cost of investment in coffee trees is the cost of land lying with no output for three years. Policies that provide initial three-year credit or finance to households that undertake investment in trees for these first three years may be crucial in enabling investment for many poorer households. Given that coffee is a relatively profitable production activity, further research into this issue is warranted.

REFERENCES

Abel, A. B., and J.C. Eberly. 1994. A unified model of investment under uncertainty. *American Economic Review* 84 (5), 1369-1384.

Abel, A. B., and J.C. Eberly. 1996. Optimal investment with costly reversibility. *Review of Economic Studies* 63, 581-593.

Amemiya, T. 1984. Tobit models: A survey. *Journal of Econometrics* 24, 3-63.

Asano, H. 2002. Costly reversible investment with fixed costs: An empirical study. *Journal of Business and Economic Statistics* 20 (2), 227-240.

Bar-Ilan, A. and A. Blinder. 1992. Consumer durables: Evidence on the optimality of usually doing nothing. *Journal of Money, Credit and Banking* 24 (2), 258-272.

Barrett, C., and M. Carter. 2006. The economics of poverty traps and persistent poverty: An asset-based approach. *Journal of Development Studies* 42, 178-199.

Besley, T. 1995. Property rights and investment incentives. *Journal of Political Economy* 103, 913-937.

Boetel, B. L., R. Hoffmann, and D.J. Liu. 2007. Estimating investment rigidity within a threshold regression framework: The case of the U.S. hog production sector. *American Journal of Agricultural Economics* 89 (1), 36-51.

Caballero, R. J., E. Engel, and J.C. Haltiwanger. 1995. Plant-level adjustment and aggregate investment dynamics. *Brookings Papers on Economic Activity* 1995 (2), 1-39.

Cadot, O., L. Dutoit, and M. Olarreaga. 2006. How costly is it for poor farmers to lift themselves out of subsistence. World Bank Policy Research Working Paper 3881.

Carson, R. T., and Y. Sun. 2007. The Tobit model with a non-zero threshold. *Econometrics Journal* 10, 488-502.

Carter, M., and P. Olinto. 2003. Getting institutions "right" for whom? Credit constraints and the impact of property rights on the quantity and composition of investment. *American Journal of Agricultural Economics* 85, 173-186.

Carter, M., and K. Wiebe. 1990. Access to capital and its impact on agrarian structure and productivity in Kenya. *American Journal of Agricultural Economics* 72, 1146-1150.

Cuddington, J. T., and M. Urzua. 1987. Trends and cycles in primary commodity prices. Economics Department, Georgetown University, Processed Paper.

Deaton, A., and G. Laroque. 1992. On the behaviour of commodity prices. *Review of Economic Studies* 59 (1), 154-192.

________. 1996. Competitive storage and commodity price dynamics. *Journal of Political Economy* 104 (5), 896-915.

Deininger, K., and P. Mpuga. 2002. Land markets in Uganda: Incidence, impact and evolution over time. World Bank Policy Research Working Paper, Washington D.C.

Deininger, K., and J. Okidi. 2001. Rural households: Incomes, productivity and non-farm enterprise. In: Collier, P., Reinikka, R. (Eds.), *Uganda's Recovery: The Role of Farms, Firms and Government*. World Bank.

Dercon, S. 1998. Wealth, risk and activity choice: Cattle in western Tanzania. Journal of Development Economics 55 (1), 1-42.

Dercon, S., and P. Krishnan. 1996. Income portfolios in rural Ethiopia and Tanzania: Choices and constraints. *Journal of Development Studies* 32 (6), 850-875.

Dixit, A. K., and R.S. Pindyck. 1994. Investment Under Uncertainty. Princeton University Press, Princeton, NJ.

Fafchamps, M., and J. Pender. 1997. Precautionary saving, credit constraints, and irreversible investment: Theory and evidence from semiarid India. *Journal of Business and Economic Statistics* 15 (2), 180-194.

Feder, G., R.E. Just, and D. Zilberman. 1985. Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33 (2), 255-298.

Feder, G. 1980. Farm size, risk aversion, and the adoption of new technology under uncertainty. *Oxford Economic Papers* 32, 263-283.

Feder, G., and L. Lau. 1990. The relationship between credit and productivity in Chinese agriculture: A microeconomic model of disequilibrium. *American Journal of Agricultural Economics* 72 (5), 1151-7.

Gersovitz, M., and C. Paxson. 1990. The economies of Africa and the prices of their exports. Princeton University, Studies in International Finance, No. 68.

Hartley, M. J., M. Nerlove, K.R. Peters. 1987. An analysis of rubber supply in Sri Lanka. *American Journal of Agricultural Economics* 69 (4), 755-762.

Jacoby, H. G., G. Li, and S. Rozelle. 2002. Hazards of expropriation: Tenure insecurity and investment in rural China. *American Economic Review* 92 (5), 1420-1447.

Jorgenson, D. W. 1963. Capital theory and investment behavior. *American Economic Review*, Papers and Proceedings 53 (2), 247-259.

Kazianga, H. 2006. Motives for household private transfers in Burkina Faso. *Journal of Development Economics* 79, 73-117.

Malchow-Møller, N. 2002. Dynamic behaviour and agricultural households in Nicaragua. Ph.D. thesis, University of Aarhus, Denmark.

McKinnon, R. I.. 1973. Money and Capital in Economic Development. The Brookings Institution, Washington D.C.

Metcalf, G., and K. Hassett. 1995. Investment under alternative return assumptions: Comparing random walks and mean reversion. *Journal of Economic Dynamics and Control* 19 (8), 1471-1488.

Nelson, F. 1977. Censored regression models with unobserved, stochastic censoring thresholds. *Journal of Econometrics* 6, 309-28.

Nilsen, O. A., and F. Schiantarelli. 2003. Zeros and lumps in investment: Empirical evidence on irreversibilities and non-convexities. *Review of Economics and Statistics* 85 (4), 1021-1037.

Pattillo, C. 1997. Investment, uncertainty and irreversibility in Ghana. IMF Working Paper 97/169.

Pietola, K. S., and R. Myers. 2000. Investment under uncertainty and dynamic adjustment in the Finnish pork industry. *American Journal of Agricultural Economics* 82, 956-67.

Place, F., Otsuka, K., 2002. Land tenure systems and their impacts on agricultural investments and productivity in Uganda. The Journal of Development Studies 38 (6), 105-128.

Robinson, P. M. (1988). Root N-consistent semi-parametric regression. Econometrica 56, 931-954.

Rosenzweig, M., and H. Binswanger. 1993. Wealth, weather risk and the composition and profitability of agricultural investments. *Economic Journal* 103, 56-78.

Rosenzweig, M., and K. Wolpin. 1993. Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investment in bullocks in India. *Journal of Political Economy* 101 (2), 223-244.

Rosett, R. N. 1959. A statistical model of friction in economics. *Econometrica* 27 (2), 263-267.

Sarkar, S. 2003. The effect of mean reversion on investment under uncertainty. *Journal of Economic Dynamics and Control* 28 (2), 377-396.

Smith, D. R., A. Gordon, K. Meadows, and K. Zwick. 2001. Livelihood diversification in Uganda: Patterns and determinants of change across two household districts. *Food Policy* 26 (4), 421-35.

Tobin, J. 1969. A general equilibrium approach to monetary theory. *Journal of Money, Credit, and Banking* 1, 15-29.

Trivedi, P. K., and T. Akiyama. 1992. A framework for evaluating the impact of pricing policies for cocoa and coffee in Cote d'Ivoire. *The World Bank Economic Review 6* (2), 307-330.

Udry, C. 1994. Risk and insurance in a rural credit market: An empirical investigation in Northern Nigeria. *Review of Economic Studies* 61, 495-526.

Uganda Coffee Trade Federation. 2002. The Coffee Yearbook 2001-2002. Kampala, Uganda.

Wickens, M. R., and J.N. Greenfield. 1973. The econometrics of agricultural supply: An application to the World coffee market. *The Review of Economics and Statistics* 55 (4), 433-40.

Zimmerman, F. J., and M.R. Carter. 2003. Asset smoothing, consumption smoothing and the reproduction of inequality under risk and subsistence constraints. *Journal of Development Economics* 71, 233-260.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

782. *Access to irrigation and the escape from poverty: Evidence from Northern Mali*. Andrew Dillon, 2008.

781. *Structural changes in the Philippine pig industry and their environmental implications*. Maria Angeles O. Catelo, Clare A. Narrod, and Marites M. Tiongco, 2008.

780. *Evaluating alternative policy responses to higher world food prices: The case of increasing rice prices in Madagascar*. David Coady, Paul Dorosh, and Bart Minten,, 2008.

779. *Contract farming of swine in Southeast Asia as a response to changing market demand for quality and safety in pork.* Marites Tiongco, Maria Angeles Catelo, and Ma. Lucila Lapar, 2008.

778. *On-site and off-site long-term economic impacts of soil fertility management practices: The case of maize-based cropping systems in Kenya.* Ephraim Nkonya, Patrick Gicheru, Johannes Woelcke, Barrack Okoba, Daniel Kilambya, and Louis N. Gachimbi, 2008

777. *Development under conditions of inequality and distrust: Social cohesion in Latin America*. Marco Ferroni, Mercedes Mateo, Mark Payne, 2008.

776. *Exploring strategic priorities for regional agricultural R&D investments in East and Central Africa.* Liang You and Michael Johnson, 2008.

775. *Reforming the agricultural extension system in India: What Do We know about what works where and why?* Katharina Raabe, 2008.

774. *An experimental inquiry into the effect of yardstick competition on corruption*. Angelino Viceisza, 2008.

773. *Alianzas para la innovación agroalimentaria en Bolivia: Lecciones para la formulación de políticas*. Frank Hartwich, Luis Ampuero, Tito Arispe, Vicente EguezJaime Mendoza, y Nancy Alexaki, 2008.

772. *Tracing power and influence in networks: Net-Map as a tool for research and strategic network planning*. Eva Schiffer and Douglas Waale, 2008.

771. *Estimating household income to monitor and evaluate public investment programs in Sub-Saharan Africa.* Samuel Benin and Josee Randriamamonjy, 2008.

770. *Does Africa trade less than it should, and if so, why? The role of market access and domestic factors*. Antoine Bouet, Santosh Mishra, and Devesh Roy, 2008.

769. *Impacts of the Hutan Kamasyarakatan social forestry program in the Sumberjaya Watershed, West Lampung District of Sumatra, Indonesia.* John Pender, Suyanto, John Kerr, and Edward Kato, 2008.

768. *Finance and cluster-based industrial development in China*. Jianqing Ruan and Xiaobo Zhang, 2008.

767. *Introducing a genetically modified banana in Uganda: Social benefits, costs, and consumer perceptions*. José Falck-Zepeda, Enoch Kikulwe, and Justus Wesseler, 2008.

766. *Global macroeconomic developments and poverty*. Eugenio Diaz-Bonilla, 2008.

765. *Economic partnership agreements between the European union and African, Caribbean, and Pacific countries: What is at stake for Senegal.* Valdete Berisha-Krasniqi, Antoine Bouet and Simon Mevel, 2008.

764. M*arriage behavior response to prime-age adult mortality: Evidence from Malawi*. Mika Ueyama and Futoshi Yamauchi, 2008.

763. I*mpacts of inventory credit, input supply shops, and fertilizer microdosing in the drylands of Niger*. John Pender, Tahirou Abdoulaye, Jupiter Ndjeunga, Bruno Gerard, and Edward Kato, 2008.

762. *Plant genetic resources for agriculture, plant breeding, and biotechnology : Experiences from Cameroon, Kenya, the Philippines, and Venezuela*. José Falck-Zepeda, Patricia Zambrano, Joel I. Cohen, Orangel Borges, Elcio P. Guimarães, Desiree Hautea, Joseph Kengue, and Josephine Songa, 2008.

761. *How change agents and social capital influence the adoption of innovations among small farmers: Evidence from social networks in rural Bolivia.* Mario Monge, Frank Hartwich, and Daniel Halgin, 2008.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org