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by

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Can we do policy recommendations from a framed field experiment?

- The case of coca cultivation in Colombia. [#]

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Abstract

Laboratory experiments are potentially effective tools for studying behavior in settings where little or no information would otherwise exist such as participation in illicit activities. However, using laboratory experiments to draw policy recommendations is highly debatable. We investigate the external validity of a framed field experiment that mimics coca cultivation and find evidence that behavior in the experiment is consistent with self-reported behavior. We use the experiment to discuss the effectiveness of carrot and stick policies on coca investments. The experiment indicates that subjects are more responsive to changes in the relative profit of cattle farming than to changes in the probability of coca eradication.

Keywords: Coca cultivation; Colombia; Experiment; Public Bad.

JEL classification: C91, C93, D62, K42.

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1. Introduction

Laboratory experiments have been applied to many different areas of economics to study various behavioral issues from purely testing theories to the design of new policies. The strength of laboratory experiments is the way in which they can hold almost all factors other than those being studied constant, allowing for clean tests of the hypothesis under investigation. However, the possibility of generalizing insights that have been gained in a laboratory experiment to the field is highly debatable. For example, Levitt and List (2007) point out that when subjects enter a lab they know that their identity and behavior will be scrutinized by the researcher, so they will appear to be more cooperative than they actually are. Additionally, contextual factors beyond the control of the experimenter, the size of the stakes and the population who self-select to participate in the laboratory experiments, can all explain the different behavior between a laboratory experiment and the field.

In this paper, we investigate external validity of what Harrison and List (2004) coined a framed field experiment to provide reliable inferences about actual decisions for an activity about which little is known - coca cultivation. The experiment was conducted in department of Putumayo in Southern Colombia and it is one of the areas in the world where most coca is cultivated. Our experimental design uses a public bad game that mimics the main features of coca cultivation: 1) higher relative profit compared to other cultivation alternatives, 2) risk of being discovered by the authorities and 3) negative effects on others. The nature of illegal activities, the social norms in relation to these activities and the potential sample selection of people participating in these activities make abstract laboratory experiments with students less suitable for analyzing coca cultivation decision-making. Hence, our sample consists of farmers living in coca cultivation areas who are familiar with the experimental task. Besides "changing the subjects", we use context-relevant information throughout the experiment, while other behavioral factors that cannot be directly controlled in the experiment (e.g. acceptance of the law) are captured using survey information. Hence, our experimental design brings the lab to the field, but it also brings the field to the lab by using complementary survey data to explain the heterogeneity of behavior observed in the lab (Cardenas and Ostrom, 2004). We evaluate the external validity of the framed field experiment by comparing 1) the behavior in the experiment of self-reported coca and non-coca farmers, 2) the motivational factors that affect behavior in the experiment and in the naturally occurring environments and 3) the observed changes in coca cultivation during the period 2003 and 2005 as a result of policy changes with the predictions of the changes in coca cultivation based on the framed field experiment using same policy changes.

Moreover, based on our experimental results we also discuss what could be the effectiveness of anti-drug policies in Colombia. The policy against coca cultivation uses two main strategies: 1) a stick policy whereby coca plants are eradicated by aerial fumigation as well as by pulling up plants manually and 2) a carrot policy that aims to increase the relative profit between non-coca agricultural activities and coca cultivation by implementing alternative development programs (e.g. investment in infrastructure, subsidized loans and technological advice).[1] Although one billion U.S dollars has been spent annually in Colombia on campaigns against coca cultivation, especially on aerial fumigation, little is known about the effectiveness of eradication and alternative development programs. One of the problems encountered in evaluating the effectiveness of different policies against coca cultivation is that revealed data does not provide information on behavior for policy levels that are outside the ranges that have been used historically (e.g. Carvajal, 2002; Moreno-Sanchez *et al.*, 2003; Díaz and Sánchez, 2004; Moya, 2005 and Tabares and Rosales, 2004).[2] A framed field experiment is an alternative way to obtain information on how subjects would behave under different circumstances. The use of laboratory experiments to capture compliance is not new, but this approach has mostly been applied to study the effects of both the probability and the severity of punishment (e.g. Alm *et al.*, 1992a, 1992b, Anderson and Stafford, 2003; Trivedi *et al.*, 2003, 2005, Cardenas *et al.*, 2000, Fortin *et al.*, 2004) and largely disregards the effects of positive incentives. In addition, the experimental literature on exogenous imposed carrot and stick programs (e.g. Sefton *et al.* 2000, Sutter *et al.*, 2006) has not considered how to mix them. In our experiment each participant reports on how they would behave in terms of coca cultivation in nine different policy scenarios that combine different levels of carrot and stick programs.

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[1] In recent years, alternative development has also used voluntary agreements that consist of monetary subsidies in exchange for not cultivating coca (DNE, 2005).

[2] Based on historical data at the municipal level, these studies found that alternative development programs have had a significant impact on reducing coca cultivation, but that aerial fumigation programs have not.

Other studies have investigated the link between behavior in the field and in the naturally occurring environment. For example Karlan (2005) showed that behavior in a trust game predicted repayment rates of subjects' loans in a microcredit program in Peru. Similarly, Carpenter and Seki (2004) found a positive correlation between pro-social behavior in an experimental setting and productivity in group work for fishermen in Japan, while Barr and Serneels (2004) found a positive correlation between wages and an experimental measure of reciprocity. In addition, the effect on the economic performance of experimental measures on social capital and cooperation was investigated by Carter and Castillo (2002) who found a positive correlation between these variables. Our research differs from this approach, however, as it compares how individuals behave in a laboratory experiment with how they behave in a similar natural environment. Other papers investigating behaviour in similar settings concluded that subjects are more pro-social in the laboratory than in comparable natural environments (e.g. List, 2006; Gneezy *et al.*, 2004; Lusk *et al.*, 2006), but they used a between-subject design while we apply a within-subject design. Unlike Benz and Meier (2006) who compare donation behavior of students in an artificial laboratory experiment and in a natural environment, we study the behavior of a non-student population. Though we recognize the limitations of lab-generated data, we consider that the most important contribution of our paper is the attempt to learn about an illegal activity about which little is currently known.

The remainder of the paper is organized as follows. Section 2 describes the design of the experiment and the following section explains the experimental procedure. Section 4 presents the results and Section 5 concludes the paper.

2. Experimental design

In the experiment we used a framed public bad experiment. Each group in the experiment consisted of five people. Each person was endowed with 10 tokens that represent the amount of land, labor and capital available to them for investing in agricultural activities and their task was to decide how many tokens to invest in coca cultivation and cattle farming respectively. The three key features of coca cultivation included in the public bad experiment are: 1) coca production is more profitable than the best non-coca cultivating alternative of cattle farming, 2) there is a probability that the coca plants will be eradicated by the authorities, and 3) coca production generates negative externalities (e.g. environmental damage and social problems that affect everyone in the community). In the experiment, each unit invested in coca cultivation yields a return of one, while each unit invested in cattle farming gives a return of less than one, mimicking the fact that investment in coca cultivation yields a higher profit than investment in cattle farming. Based on historical levels and potential future scenarios, we included the following three levels of relative profits between cattle farming and coca cultivation; 0.2, 0.44 and 0.68. In the survey that we conducted parallel to the experiment, the participants stated that the average relative profit of the alternative was 0.18 and 0.32 for 2003 and 2005, respectively, which is in-line with the figures applied in the experiment. The second feature of coca cultivation is that investment in coca cultivation is a risky decision since the plantation can be detected and subsequently eradicated. Since successful eradication involves both detection and eradication, we introduce the probability of successful eradication. We applied the following three levels of successful eradication: 0%, 10% and 30% that corresponded to real life values before 1997, in 2003 and in 2005, respectively.[3] If coca plants are sprayed, farmers can collect and process the leaves immediately in order to sell them, but the coca plantation is lost, and the sprayed land cannot be used for any crops for a considerable time. For each unit invested in coca when eradication is successful, the resulting effect is a loss of income of 1.2 tokens in the experiment. It should be noted that 1 token is harvested so the net loss of income is 0.2 tokens. We keep the loss of income from eradication constant as other consequences such as imprisonment are very unusual. The third specific feature of coca cultivation is that it generates negative externalities such as environmental damages and social problems that affect everyone in the community.[4] These effects were included in the experimental design by making each unit of coca cultivation in the group reduce the income for every person in the group by 0.17, including the one who made the investment. We explained to the

[3] The probability of eradication is estimated as the number of hectares sprayed in Putumayo between 1999 and 2005 (210,244 hectares) divided by the number of hectares that need to be sprayed in order to destroy it completely (3 to 8). This ratio is then divided by the total number of hectares with coca (200,004 hectares). Hence, the estimated probability to destroy one hectare is estimated to be between 13 and 35 percent.

[4] Cattle farming also has some negative environmental impacts related to soil erosion and deforestation, but our main interest is to capture the effect of violence generated by the illegality of coca, thus assume this effect to be small so we can neglect it in our design.

participants that these costs were related to the increase in violence and environmental problems that arise from coca production.[5] As we used three levels of probability for eradication and three levels of relative profit, each person participated in 9 one-shot experiments to test all combinations. The pay-off for subject *i* can then be expressed as

$$\pi_i = c_i + a\,(10 - c_i) - 0.17\sum_{i=1}^{5} c_i - 1.2\,pc_i\,,$$

where c_i is the amount invested in coca cultivation, a is the relative profit and p is the probability of eradication. The parameters included in the experiment ensure a social dilemma situation since there are incentives to invest in coca even though the group would be better off if no one did it. The social cost related to one unit invested in coca is 0.85 (0.17*5=0.85), which is larger than the private benefit (1-a), where a (relative profit) varies between 0.2 and 0.68. Differentiating with respect to c_i yields the first order condition for a risk-neutral individual who maximizes expected utility

$$\frac{d\pi_i}{dc_i} = 1 - a - 0.17 - 1.2\,p = 0.$$

Thus, it is expected that a subject who is a self-interested utility maximizer and who is risk-neutral will make a non-zero investment in coca if $1 - a - 0.17 - 1.2p > 0$. Table 1 summarizes the marginal profit from coca cultivation in all the nine treatments applied in the experiment, with the treatments being labeled *A* to *I*. As can be seen from the table, coca cultivation results in positive marginal benefits in all cases except treatment *I*. Thus a risk-neutral subject who maximizes the expected utility of the profit function given above will invest fully in coca cultivation in all cases except *I*, where nothing would be invested instead.

<<< TABLE 1 <<<

There is extensive experimental evidence that a large proportion of subjects are conditional cooperators, i.e. they contribute if others contribute and vice versa (e.g. Sugden, 1984; Fehr *et al*. 1997; Fichbacher *et al.*, 2001; Falk and Fischbaher, 2002; Falk *et al.*, 2004; Fischbacher and Gächter, 2006). Similarly, a tendency towards negative cooperation is found in e.g. Ostrom *et al.* (1992) and Fehr and Gächter (2000),

[5] Instructions are available from the corresponding author upon request.

where non-cooperators are punished despite the fact that there is a cost involved in the punishment. In order to analyze how much the cultivation decisions of others affect the subject's own cultivation, we elicited the subject's beliefs about how much others invested in coca cultivation. To motivate careful thinking, we gave monetary rewards for correct guesses (e.g. Gächter and Renner, 2006; Sonnemans *et al.*, 2001). Those who correctly guessed the average amount invested by others received 1.6 tokens and those whose guesses were only one or two tokens wrong obtained 1.2 or 0.8 tokens respectively.

To reduce the cognitive burden on the participants, we provided them with pay-off tables based on the layout in Cardenas *et al.* (2000). In the pay-off table, the columns indicate the total investment in coca cultivation made by the subject, while the rows show different levels of total investment in coca cultivation made by others in the group. Thus, by making an assumption about other people's investments in coca as well as about their own investment, the monetary outcome in Colombian Pesos can be read directly from the pay-off table. Each experimental token was converted to 1,250 Colombian Pesos; in addition, participants received a show-up fee of 15,000 Colombian Pesos to cover any losses that might arise from the experiment as well as to compensate them for their time.[6] A separate pay-off table was provided for each of the relative profits. In the situations where there is a probability of eradication, it was explained that a lottery would be used to determine whether eradication would take place. If eradication occurred, their pay-off would be reduced by 1,500 Colombian Pesos for each token invested in coca compared with the figures shown in the pay-off table.

The experimental session consisted of five stages. First, the instructions of the modified public bad experiment were read aloud to the subjects, followed by several examples and individual exercises. To check that the subjects understood what was required of them, an enumerator accompanied them and verified that they understood their task. Then, the experiment began and subjects decided how much they wanted to invest in coca cultivation and how much they expected others to invest in coca cultivation in each of the nine treatments, where the probability of eradication and relative profits varied as described above. In the third stage, we used a random lottery to determine which of the nine treatments would be paid in cash, where each treatment had

[6] At the time of the experiment 1 USD was equal to 2,200 Colombian Pesos.

the same chance of being selected. If a treatment with a positive probability of eradication was selected, then a second lottery was used to determine whether successful eradication took place. The outcomes of these lotteries were common to everyone in a session mimicking the actual situation since both relative profits and successful eradication are normally the same for people living close to each other. Finally, all subjects were paid privately using checks made payable to them in their local store. It would have been better to use cash, but for security reasons we preferred to avoid carrying large amounts of money. Afterwards, following similar procedures as applied by Cardenas and colleagues (e.g. Cardenas *et al.*, 2000), there was a group discussion on the experiment and its relation with real life conditions.

3. Experimental procedure

We conducted the experiment in the department of Putumayo, one of the poorest regions in Columbia with a long tradition of coca cultivation, in June 2006. Four different municipalities were included in the study: Orito, Mocoa, Valle del Guamuez and Puerto Asis. The participants in the experiment were farmers who faced cultivation decisions in real life, allowing motivational factors behind coca investments to be included in the analysis. The recruitment procedure was similar in all four municipalities, where the local leaders invited people from their community to a meeting with university researchers to discuss coca and alternative production. The meetings consisted of a morning and an afternoon session on the same day. During the morning session, the subjects were interviewed individually, while in the afternoon session we conducted the experiments. On average, each interview lasted for one hour, while each experimental session lasted for approximately two hours.

In the individual interviews, we did not ask names, addresses or any other identifying information in order to encourage honest answers. To match survey and experimental information we asked them for a number that they could remember later. The survey consisted of a battery of standard questions on socioeconomic characteristics and some specialized questions relating to how much coca they had cultivated in 2003 and 2005, risk preferences and legitimacy (acceptance of the authorities and the law). Risk preferences were elicited using a hypothetical risk experiment based on the design in Binswanger (1980). In this design, subjects were asked to choose between a safe alternative and an alternative with two outcomes one of which had a lower pay-off than the safe alternative and the other a higher pay-off. The probability of selecting each of the outcomes was 50%. Each farmer was asked to make five such choices, where in each subsequent choice that was presented to them, both the expected pay-off and its variance increased in the risky alternative. The point at which the subject chose to switch from the risky to the safe alternative allowed us to calculate their degree of risk aversion, where we assumed a constant partial relative risk aversion utility function.

According to Tyler's (1990) theory of procedural justice, the legitimacy of the authorities plays a crucial role in legal compliance. The fairness of the law, the efficacy with which that law is enforced and the possibility of participating in decisions regarding its regulation have all been identified as factors that affect law compliance behavior. Participation in fixing regulations by voting or by communication between subjects has been identified as a factor that positively affects legal compliance (e.g. Cardenas *et al.*, 2000; Cardenas 2004, 2005; Murphy and Cardenas, 2004; Ostrom *et al.*, 1992; Tyran and Feld, 2006; Feld and Tyran, 2002). In addition, Fortin *et al.* (2003) and Trivedi *et al.* (2003) find that the fairness of the rule affects compliance, while Nadler (2005) concludes that the perceived injustice of authorities can also affect general compliance. Galbiati *et al.* (2005) find that imposing the obligation to comply increases the average level of contributions. To capture the effect of obligation to comply with authorities, we constructed an index that captures the level of agreement with statements regarding respect towards the law, the fairness of authorities executing the law and local say of the community in defining substitution alternatives.

4. Results

In total, 293 farmers participated in the interviews, while 164 of them also took part in one of the 13 experimental sessions. The average earnings in the experiment were 19,227 Colombian pesos and the minimum and maximum earnings were 7,000 and 25,100 Colombian pesos respectively. This compares with a daily wage in agricultural activities of 15,000 Colombian Pesos. We test for attrition between the survey and the experiment, and we cannot reject the null hypotheses of an equal proportion of coca farmers and an equal number of hectares cultivated with coca between those who only took part in the interview and those who took part in both the interview and the experiment at 5% significance level using a Proportion test and Wilcoxon rank-sum test respectively. Whether our sample is representative for the populations of farmers living in these areas is difficult to evaluate, but the proportion of coca plots larger than 3 hectares in our sample is not significantly different at 5% significance level from the official reports from DNE (2006).

A natural question for all experiments is how well the behavior in the experiment captures behavior in the natural occurring environment. If our experiment succeeds in capturing the main features of coca cultivation, self-reported coca farmers are expected to invest more in coca cultivation than non-coca farmers. In addition, it is expected that people should bring the same moral attitudes and values that affect their behavior in the naturally occurring environment to our framed field experiment. The experimental data would then be able to serve as a platform to discuss policy recommendations if it succeeds in predicting the observed reduction that followed the increase in eradication and increase in relative prices between 2003 and 2005. To measure the correspondence between behavior in the lab and in the field, we use three different measures as presented below.

4.1. Behavior of coca and non coca farmers.

We compare behavior in the experiment of self-reported coca and non-coca farmers and report the results in Table 2. The coca farmers on average invest more in coca cultivation than non-coca farmers. In the nine treatments, we reject the null hypothesis of equality of the distributions of investments in coca cultivation between coca and non-coca farmers at 10% significance level using a Wilcoxon rank-sum test. A more detailed analysis reveals that is possible to reject the null hypothesis of equal proportion of non-zero investments in coca cultivation for coca and non-coca farmers at 5% significance level using the proportion test in all nine treatments. However, if we compare investments in coca cultivation from coca and non-coca farmers given that investment took place, i.e. the conditional investment in coca cultivation, as is presented in the last columns of Table 2, we find that it is not possible to reject the null hypothesis of equality in the distributions. Hence, non-coca farmers are less likely to invest in coca cultivation in the experiment but if they decide to invest then they behave in the same way as the coca farmers. One possible explanation for this behavior is that most of those who are not cropping coca today did so a few years ago and some of them would potentially cultivate coca again if the relative profits or risk of eradication were different.

Table 3 presents the expected average number of tokens invested in coca cultivation, the expected proportion of non-zero investments in coca cultivation and the expected conditional number of tokens invested in coca cultivation by others separately for self-reported non-coca and coca farmers. Interestingly, expectations follow the same pattern as actual investments for coca and non-coca farmers. Coca farmers believe that more tokens would be invested in coca cultivation and a larger proportion of farmers would invest in coca cultivation than non-coca farmers, but conditional on a non-zero investment, coca and non-coca farmers expect others to invest similar amounts in coca cultivation. In the nine treatments, we reject the null hypothesis of equality of the distributions of expected investments between coca and non-coca farmers at 5% significance level using a Wilcoxon rank-sum test. A more detailed analysis reveals that it is possible to reject the null hypothesis of equal proportion of expected non-zero investments for coca and non-coca farmers at 5% significance level using the proportion test in all nine treatments, but not the null hypothesis of equality of the distributions of expected conditional investments between coca and non-coca farmers at 5% significance level using a Wilcoxon rank-sum test.

<<<TABLE 2<<<

<<<TABLE 3<<<

4.2. Behavioral motivation in the lab and in the field.

Another way to test for correspondence between behavior in real-life and in experiment is to compare the motivational factors that affect coca cultivation in both situations. Table 4 presents the descriptive statistics on the socioeconomic characteristics of the 141 participants in the experiment who answered all socioeconomic questions. We find no significant differences in the investment decisions between participants with complete and incomplete responses to the questionnaire. The second column presents the descriptive statistics for the whole sample and the third and fourth columns present the same information but separated between coca and non-coca farmers, respectively.

We test the null hypothesis of equal distribution of the variables between coca and non-coca farmers separately for each of the variables, where the significance levels are shown in the last column of the table. As presented in the last column, coca farmers are significantly different from non-coca farmers with respect to education levels, experience in cultivating coca, religious beliefs, participation in community organizations and in statements about obligation to comply. The differences in observable characteristics of the participants might explain investment decisions in the experiment as well.

<<< TABLE 4 <<<

In the experiment each participant took 9 decisions, hence a random effects probit model is applied to analyze the determinants of the binary decision on whether or not to invest in coca cultivation; while random effects generalized least squares (GLS) is used to analyze the amount invested in coca cultivation given a positive amount invested. In Table 5, we present the estimated elasticities evaluated at the average relative profit and probability of eradication in 2005 (0.32 and 0.3, respectively) and at the mean values for the other variables. The values for the constant and the correlation coefficient of unobserved heterogeneity (rho) correspond to the estimated coefficients.

The estimated correlation coefficient of unobserved heterogeneity between decisions is large and significant which supports the use of random effects probit and a random effect generalized least squares. Both treatment variables in the experiment; relative profit (profit from cattle/profit from coca) and expected cost of eradication (probability of eradication times lost of income -1.2), have a significant and negative impact on the probability of cultivating and the conditional amount invested in coca.

<<< TABLE 5 <<<

Consistent with other experimental findings, individual behavior, both whether to invest in coca cultivation and conditional investment, is significantly affected at 1% level by the beliefs about others' behavior, i.e. conditional cooperation. In addition to economic incentives, we also find that normative factors affect investments in coca cultivation.

Protestants are significantly less likely to invest in coca cultivation than Catholics, which could be associated with an indoctrination effect that increases awareness of the negative effect of coca cultivation. Farmers who report having more experience cultivating coca are significantly more likely to invest, which could indicate habituation effects of coca cultivation. Social capital, measured as trust and membership in organizations, has neither a significant effect on the decision to cultivate coca, nor on the amount cultivated. The probability of investment in coca cultivation and the amount invested decreases significantly with age, which could be associated with more impatience, i.e. higher discount rate. We also find that participants with a higher level of education were significantly more likely to invest in coca cultivation, though we have no clear interpretation on this counter-intuitive result. Subjects who have smaller areas of land are more likely to invest in coca, which could be associated with the difficulty of making a living from legal production given the low profitability per hectare.

We also asked participants to self-report the amount of coca that they had cultivated in 2003 and 2005 so that we could study the motivational factors that affect the self-reported investments in coca. The decisions on whether to cultivate coca or not and on the number of hectares to cultivate can be correlated, so we estimated a Heckman selection model that pooled the data from both years. Table 6 presents the estimated elasticities evaluated at the mean values, while the rho corresponds to the estimated coefficient. The rho coefficient is large and significant, which supports the use of the Heckman selection model. We find that increases in the relative profit of the best alternative to coca significantly decrease the likelihood of investing in coca cultivation and the number of hectares that are cultivated with coca, while increases in the risk of eradication measured as the number of hectares sprayed over the number of hectares cultivated does not have a significant effect on the likelihood to cultivate coca but does increase the number of hectares that are cultivated. Ibanez (2007) developed a theoretical model that considered this positive effect on the number of hectares with coca. She explained that when subsistence is under threat, farmers become risk-loving and are willing to take extra risks in order to try to survive. Similar to the experimental data, we find a positive and significant effect on the number of hectares that were cultivated in the municipality in previous periods. This effect could be related to a positive social rule that favors coca cultivation but it could also be indicative of specific characteristics of those municipalities that favor coca cultivation. In addition we find that other non-monetary factors are significant in explaining the decision to cultivate coca: being protestant, having a higher degree of obligation to comply with the authorities and having more land all decrease the likelihood of cultivating coca. The number of hectares that are cultivated with coca decreases with the level of education, which could be related to a higher opportunity cost of labor. The positive and significant effect of trust is not surprising as farmers who are better connected can learn more about illicit activities from their neighbors. In addition, farmers who live farther from the market and who have more land cultivate significantly more coca. The first effect can be interpreted as being caused by a lack of opportunities to engage in legal cultivation due to high transport costs while the second effect can be related to the high cost of establishing coca plants.

<<< TABLE 6 <<<

In summary, we find that there is a positive correspondence between the factors that affect the decision on whether or not to invest in coca cultivation between the experiment and the self-reported data. In particular, we find that the density of coca cultivation in the municipality (an indicator of social norms), Protestantism and the size of farm are significant factors when explaining the decision to invest in coca or not in both the experimental and the field settings. We do not find a comparably good correspondence for the models that explain the amount invested.

4.3. Self-reported vs. Predicted change in investment.

A third way to validate the experimental data is to test the predictive power of the estimated models. Although our experimental design does not include the same conditions that prevailed in 2003 and 2005, we can use the estimated parameters in the model to predict the proportional change in the proportion of non-zero investments and in the conditional investments in coca cultivation between these two years. The Table 7 presents the self-reported and the predicted proportional changes in the proportion of non-zero investments and conditional investment in coca cultivation. The last column presents the test comparing self-reported and predicted values. In the predictions, we take into account the fact that the average relative profit of the alternative investment was 0.18 in 2003 and 0.32 in 2005 and that the probability of eradication was around 10 and 30 percent, respectively. All other parameters are evaluated at their mean values. The model predicts that due to the higher relative profit of the alternative investment and the higher risk of eradication, the mean proportion of non-zero investments decrease from 0.66 to 0.55 while the self-reported proportion of coca farmers decreased from 0.75 to 0.45 between 2003 and 2005. The predicted change in the proportion of coca cultivation of 16% is significantly lower than the observed 38% reduction in self-reported coca farmers at 5% significance level using a Student test. On the other hand, farmers self-reported to have decreased the average number of hectares by 37% (from 1.54 to 1.17 between 2003 and 2005), which is not significantly different at 5% level from the predicted change in the tokens invested (22%). We conclude that the experiment does a fairly good job of predicting the proportional changes in the conditional investment in coca cultivation, although it is not particularly accurate at predicting the proportional changes in the self-reported proportion of non-zero investments in coca cultivation. The inability of the experiment to explain the change in the proportion of non-zero investments could possibly be explained by changes in circumstances that we cannot provide a control for in the experiment, such as the emergence of voluntary agreements of substitution.

<<< TABLE 7 <<<

4.4. Policy Implications

The three measures that we use to compare behavior in real-life and in the experiment externally validate the use of a framed field experiment to discuss policy issues. Hence, we can use our experimental measures to obtain an indication of the relative effectiveness of different alternative development and eradication programs - carrots and sticks - in reducing coca cultivation considering a partial equilibrium analysis. The total elasticity of the investment to changes in carrots and sticks can be estimated as

$$\frac{\partial E(Ha_i)}{\partial x_i}\frac{E(x_i)}{E(Ha_i)} = \frac{\partial P(Crop_i = 1)}{\partial x_i}\frac{E(x_i)}{P(Crop_i = 1)} P(Crop_i = 1) + \frac{\partial E(Ha_i \mid Ha_i > 0)}{\partial x_i}\frac{x_i}{E(Ha_i)} P(Crop_i = 1)$$

where Ha_i is the investment in coca cultivation for farmer *i*, and x_i is a covariate and *P* is the probability of a non-zero investment in coca. Table 8 presents the estimated total elasticity. The estimated total elasticity is significantly higher for increases in relative profit than for increases in expected cost from eradication suggesting that individuals respond more to carrots than to sticks.

<<< TABLE 8<<<

The optimal balance of carrots and sticks depends on the effectiveness of eradication and alternative development programs, but of course it also depends on its cost to implement. Logan (2006) estimated that spraying one hectare cost USD 626, but as we discussed before, in order to destroy one hectare completely, between three and eight hectares must actually be sprayed. Thus, the total cost of destroying one hectare is between 1,878 USD and 5,008 USD. In 2003, the government established a monetary subsidy by which households who agreed to keep their land free of coca received 1,524 USD per year for three years. This compares with an average profit of 1,402 USD per hectare of coca per year (Ibanez, 2007). On average, households that participated in the program in Putumayo agreed to keep 10 hectares free of coca, so the average cost of the subsidy per hectare year is 152 USD. In other words destroying one hectare by spraying is between 12 to 33 times more expensive than offering a monetary subsidy. However, the total cost of the anti-drug policy depends on the total number of hectares of coca that need to be sprayed and the total number of potential beneficiaries from the subsidy. If the number of hectares declared by potential beneficiaries of the subsidy is much higher than the number of hectares that need to be sprayed, then spraying would be preferable to the alternative development. In addition, if conducting a complete cost benefit analysis, it should also include the economic cost generated by drugs (Perez *et al.*, 2002).

5. Discussion and conclusions

Despite the enormous cost of the war on drugs, little is known about the effectiveness of the different preventative regimes of carrot and stick policies in Colombia. To investigate how farmers could react to a wide range of different combinations of stick and carrot policies, we used a framed field experiment that mimics the decision that

Colombian farmers in the department of Putumayo are faced with. However, since the external validity of experimental data to draw any form of policy implication is debatable, we also evaluated the external validity of our experimental design. Our results suggest that experimental behavior is consistent with self-reported coca cultivation. We find that farmers who self-report to be cultivating coca invest more in coca cultivation in the experiment than those who self-report not to be cultivating, suggesting that behavior in real life does affect behavior in the experimental setting. Further evidence on how consistent behavior in the experiment is with self-reported behavior is provided by the fact that the same motivational factors that explain behavior in the naturally occurring environment also explain behavior in the experiment. In addition to monetary incentives, non-monetary factors affect investment decisions in coca cultivation in the experiment. Interestingly, the same non-monetary factors also affect the actual self-reported decision to cultivate coca. Lastly, we find that the model succeeds in giving an accurate prediction of changes in conditional investment with coca cultivation, though the predictions on changes in the probability to cultivate are less accurate.

In terms of policy recommendations, our main results support earlier findings, based on municipal data, that changes in relative profit have more impact on reducing coca cultivation than changes in the probability of eradication. Although the cost of destroying one hectare is higher than the cost of the subsidy offered by the authorities, it may still be cost-effective to use eradication when the number of hectares to be subsidized is substantially higher than the number of hectares of coca to be eradicated. The current form of voluntary agreement to substitute coca with alternative development is a direct monetary pay-off. However, the longer-term strategy must be to increase the relative profit more permanently by, for example, improving the infrastructure or undertaking policies to tackle the agricultural crisis in Colombia. Related to this is the issue of the effect of eradication on the income of farmers. If the two policies are expected to result in the same amount of coca cultivation, then the policy that has a higher level of eradication will cause a greater number of farmers to be below the poverty line because farmers lose their income if their coca fields are eradicated. Since many farmers are already living close to or under the poverty line, it may explain why they respond to changes in relative profit more than they do to changes in eradication levels. Thus, a mix of policies resulting in the same amount of coca cultivated may have very different impacts on welfare, especially on those farmers who are already below the poverty line. Our results suggest that a more systematic social welfare analysis, especially focusing on poverty, of stick and carrot policies is needed in general, but also that the use of alternative development programs to increase the relative profits of non-coca activities seems to be a promising way of reducing coca cultivation.

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Table 1. Marginal incentives to cultivate coca.

	Probability of eradication (p)		
Profit cattle/coca (a)	0%	10%	30%
0.2	A = 0.63	B = 0.51	C = 0.27
0.44	D = 0.39	E = 0.27	F = 0.03
0.68	G = 0.15	H = 0.03	I = -0.21

Note. We calculate the marginal incentive for coca cultivation as $1-a-0.17-1.2\,p$

Table 2. Investment in coca cultivation separated by coca and non-coca farmers (coca farmers n=74; non-coca farmers n=90).

Profit cattle /coca	Group	Total investment in coca			Proportion of non-zero investments in coca			Conditional investment in coca		
		Probability of Eradication			Probability of Eradication			Probability of Eradication		
		0%	10%	30%	0%	10%	30%	0%	10%	30%
0.2	**Non-Coca Farmers**	3.50 *	3.08	2.66	0.61 ***	0.58 **	0.54 **	5.72	5.32	4.87
	Coca Farmers	4.92	4.04	3.55	0.80	0.76	0.70	6.17	5.34	5.08
	All	4.17	3.54	3.11	0.7	0.66	0.62	5.97	5.35	5.02
0.44	**Non-Coca Farmers**	2.16 ***	1.67 **	1.36 **	0.56 **	0.52 **	0.43 ***	3.88	3.19	3.13
	Coca Farmers	3.09	2.64	2.23	0.73	0.72	0.67	4.21	3.68	3.30
	All	2.62	2.13	1.77	0.64	0.61	0.54	4.01	3.47	3.26
0.68	**Non-Coca Farmers**	1.16 ***	0.72 ***	0.44 ***	0.37 ***	0.32 ***	0.23 ***	3.15	2.24	1.91 *
	Coca Farmers	1.82	1.50	1.54	0.59	0.58	0.53	3.07	2.58	2.92
	All	1.48	1.09	0.95	0.47	0.44	0.37	3.15	2.48	2.59

The test for equal distribution of total investments and conditional investments between coca and non-coca farmers is based on the Wilcoxon ranks-sum test, while the test for equal proportions is based on a two-sample test of proportions. *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively.

Table 3. Expected investments in coca cultivation separated by coca and non-coca farmers (coca farmers n=74; non-coca farmers n=90).

Profit cattle /coca	Group	Expected total investment in coca			Expected proportion of non-zero investments in coca			Expected conditional investment in coca		
		Probability of Eradication			Probability of Eradication			Probability of Eradication		
		0%	10%	30%	0%	10%	30%	0%	10%	30%
0.2	**Non-Coca Farmers**	2.98 ***	2.55 **	2.59 **	0.81 **	0.82 ***	0.81 ***	3.68 **	3.10	3.20
	Coca Farmers	4.26	3.32	3.19	0.95	0.96	0.97	4.50	3.46	3.27
	All	3.59	2.93	2.88	0.87	0.88	0.88	4.11	3.31	3.25
0.44	**Non-Coca Farmers**	2.21 ***	1.64 ***	1.64 ***	0.73 ***	0.76 ***	0.72 ***	3.02	2.17 *	2.27
	Coca Farmers	3.10	2.51	2.26	0.97	0.93	0.91	3.19	2.70	2.50
	All	2.64	2.05	1.94	0.84	0.84	0.80	3.14	2.44	2.40
0.68	**Non-Coca Farmers**	1.15 ***	0.90 ***	0.64 ***	0.62 ***	0.60 ***	0.49 ***	1.84	1.50	1.30
	Coca Farmers	1.75	1.47	1.33	0.89	0.81	0.74	1.97	1.82	1.80
	All	1.42	1.18	0.97	0.74	0.70	0.60			

The test for equal distribution of total investments and conditional investments between coca and non-coca farmers is based on the Wilcoxon rank-sum test, while the test for equal proportions is based on a two-sample test of proportions. *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively.

Table 4. Descriptive statistics.

Variable	Overall mean n = 141		Non-Coca Farmers n = 81		Coca Farmers n = 60		Ho: no difference between coca and non-coca farmers
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	
Atheist	0.070	0.256	0.062	0.241	0.083	0.277	
Protestant	0.134	0.341	0.160	0.367	0.100	0.300	***
Years of experience cultivating coca	5.687	5.222	4.654	4.796	7.083	5.462	***
Degree of trust (not at all=1, a lot=5)	2.951	1.286	3.049	1.324	2.817	1.233	
Participation in community organizations	0.570	0.495	0.679	0.467	0.433	0.496	***
Obligation to comply (Compl disagree=1, Compl. Agree=5)	3.432	0.811	3.678	0.718	3.101	0.820	***
Age	42.085	13.598	44.494	13.019	38.867	13.814	***
Female	0.355	0.478	0.358	0.480	0.350	0.477	
Education grade (none=0,basic=1,primary=2, higher=3)	1.553	0.836	1.383	0.795	1.783	0.839	***
Level of risk aversion (neutral=1,Moderate=2,Severe=3)	1.910	1.146	1.988	1.135	1.800	1.161	
Transport cost to market (Thousand COL)	2.641	2.213	2.494	2.045	2.850	2.423	
Log farm hectares per capita	0.870	1.184	1.012	1.201	0.691	1.142	

The test of equal distribution is based on the Wilcoxon rank-sum test for continuous variables and on the proportion test for binary variables.
*, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively

Table 5. Elasticities on Random effects probit model (n=141) and GLS model (n=103).

Variables	Dummy equal to one if points invested in coca are greater than zero		Conditional investment in coca	
	Elasticity	Std. Err.	Elasticity	Std. Err.
Profit cattle/ coca	-0.212 ***	0.037	-0.442 ***	0.037
Probability of eradication * Lost in Income	-0.141 ***	0.043	-0.187 ***	0.048
Expected investment of others	0.228 ***	0.034	0.289 ***	0.035
Atheist	-0.023	0.016	-0.006	0.012
Protestant	-0.041 *	0.023	-0.012	0.014
Years of experience cultivating coca	0.106 *	0.060	0.025	0.051
Degree of trust (not at all=1, a lot=5)	0.044	0.143	0.041	0.100
Participation community organizations	-0.089	0.068	0.005	0.045
Obligation to comply (Compl disagree =1, Compl Agree=5)	-0.289	0.259	-0.137	0.166
Age	-0.373 *	0.198	-0.255 *	0.143
Female	0.049	0.044	0.016	0.035
Education grade (none=0,basic=1,primary=2,higher=3)	0.212 *	0.117	-0.082	0.093
Level of risk aversion (neutral=1,Moderate=2,Severe=3)	0.002	0.007	0.041	0.071
Transport cost to market (Thousand COL)	0.009	0.072	-0.093	0.057
Log of hectares per capita	-0.093 **	0.043	-0.016	0.026
Constant	2.266	1.408	7.092	
Rho	0.808		0.401	

Note. *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively.
The values for the constant and rho correspond to the estimated coefficients

Table 6. Elasticities on Heckman Selection Model. Pooled data 2003 and 2005.

Variables	Probability of investing in coca n= 346		Conditional hectares with coca n= 121	
	Elasticity	Std. Err.	Elasticity	Std. Err.
Profit cattle/ coca	-0.022 *	0.013	-0.042 **	0.021
Sprayed Hectates/Hectares cultivated lagged	-0.015	0.018	0.120 **	0.050
Number of hectares in the municipality	0.342 ***	0.042	0.300 ***	0.097
Atheist	-0.008	0.006	0.009	0.013
Protestant	-0.028 ***	0.009	0.016	0.023
Years of experience cultivating coca	0.038	0.028	0.071	0.053
Degree of trust (not at all=1, a lot=5)	0.041	0.060	0.203 *	0.112
Participation community organizations	-0.027	0.023	0.016	0.043
Obligation to comply (Abs Disagree =1, Abs Agree=5)	-0.499 ***	0.145	-0.132	0.191
Age	-0.247	0.389	-0.439	0.954
Squared Age	0.103	0.189	-0.015	0.457
Female	-0.023	0.016	-0.100 ***	0.026
Education grade (none=0,basic=1,primary=2, higher=3)	-0.209	0.168	-0.797 **	0.399
Square education grade	0.138	0.108	0.535 **	0.239
Level of risk aversion (miss=0,neutral=1,Moderate=2,Severe=3)	0.000	0.037	0.146 **	0.071
Transport cost to market (Thousand COL)	-0.008	0.027	0.070 *	0.043
Log farm hectares per capita	-0.061 **	0.025	0.251 ***	0.050
Missing coefficient of risk aversion	0.006	0.004	0.038	0.029
Rho	-0.751			

Note. *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively.
The values for the constant and rho correspond to the estimated coefficients

Table 7. Self-reported vs. predricted behavior.

Proportional Change between 2003 and 2005	Self-reported (Std. Err.)	Predicted (Std. Err.)	t-test (P-value)
	A	B	Ho: A=B
Proportion of non-zero investments in coca	0.378 (0.051)	0.164 (0.039)	2.868 (0.004)
Conditional investment in coca	0.374 (0.182)	0.224 (0.149)	0.855 (0.393)

Table 8. Total Elasticity of carrots and sticks.

Variable	Elasticity of probability of non-zero investment (Std. Err.)	Elasticity of conditional investment (Std. Err.)	Total Elasticity (Std. Err)
	A	B	Ho: A=B
Profit cattle/ coca	-0.212 (0.037)	-0.442 (0.037)	-0.359 (0.034)
Prob. eradication times Fine	-0.141 (0.043)	-0.187 (0.048)	-0.180 (0.036)