Who crops coca and why?

The case of Colombian farmers[#]

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WORK IN PROGRESS

Abstract

Approximately 1.2% of Colombia's GNP is spent yearly on the war on drugs, but very little is known about coca farming decision at the household level. To explain the decision to cultivate coca and the proportion of land that is cultivated with coca, we develop a behavioral version of the portfolio model of crime that considers the effect of norms of behavior and lack of options in the legal economy. The model is tested using data from a survey with coca and non coca farmers living in Putumayo, Colombia. We find that the impossibility to make a living out of legal production as well as moral considerations explain coca cultivation decision. We also find that eradication and substitution programs reduce coca cultivation.

Keywords: Coca; Colombia; Portfolio Model of Crime, Norms of Behavior.

JEL classification:

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1. Introduction

Since 1997 when the war on drugs intensified in Colombia the production of cocaine has increased from 230 tons to 340 tons in 2004 at the time that the prices have been almost constant (DNE, 2005). About 1 billion dollars (1.2% of Colombia GDP) are spent on control of supply in Colombia (ONDCP, 2006; Alvarado, et. al. 2005), but very little is known about the factors that determine the decision to cultivate coca at the household level and the effectiveness of the two main strategies used to reduce coca cultivation: eradication and alternative development. What is known about coca production in Colombia corresponds to information at the municipality level,[1] but no previous studies have, as far as we know, used household level data. A better understanding of the individual socioeconomic characteristics that influence the decision to cultivate coca can guide authorities in the design of policy strategies against drugs.

The objective of this paper is to investigate why farmers cultivate coca and what determines the fraction of land that they allocate to coca production. For many the answer may seem rather obvious: coca is cultivated because it is a good business. It must be so otherwise no one would cultivate it. But facing the same economic incentives, why do some farmers cultivate coca while others do not? In lines with traditional models of crime (e.g. Becker, 1968; Ehrlich, 1973, Heineken, 1978) we could expect that lower economic incentives of cultivating coca, higher expected cost of being discovered cultivating coca, and higher risk aversion would discourage farmers from cultivating. However, morality, social norms and institutions could also be influencing the decisions to crop coca (e.g. Hausman and McPherson, 1993; Elster, 1989; Tyler, 1990). For instance, the appearance

[1] See for example, Carvajal, (2002); Moreno et. al (2003); Diaz and Sanchez, (2004); Torres (2001), Forero et al. (2001) Tabares and Rosales (2005); Moya (2005)

and expansion of protestant groups, like Pentecostalism, Adventist, and Evangelicalism, could have indoctrinated farmers changing their attitude towards others and hence towards coca production. Churches could have stigmatized coca production, or on the contrary, could have created a space for farmers to meet and interchange experiences on coca production and spray avoidance techniques. Thoumi (2000) on the other hand argues that low levels of social capital and weak community and governmental institutions are responsible of the extension of coca cultivation in Colombia. For instance, the recent colonization of the areas where coca is cultivated may imply weak social networks that together with the low population density invalidated the mechanisms of social control. Others have explained the expansion of coca cultivation as a result of the agricultural crisis (Garcia, 2000; Ortiz, 2000). Due to the low prices and high transport cost of legal products, farmers are forced to cultivate coca to survive.

In this paper we explore the factors that affect coca cultivation from a theoretical and empirical perspective. An extended version of the economic model of crime is used to explain the effect of normative factors and lack of options in coca cultivation decision. The predictions of the model are tested using a unique data set on agricultural production for coca and non coca farmers living in Putumayo, one of the regions in Colombia with a sizable proportion of coca production. To our knowledge this is the first paper that studies coca cultivation decision using data at the individual household. Our analysis contributes to a better understanding of coca cultivation as key dimensions on coca cultivation decision as morality and social norms cannot be revealed by aggregated data.

The paper is organized as follows: in section two we introduce and extended version of the economic model of crime, section three discusses the empirical measures used to test the model and the results and conclusions are presented in sections four and fifth respectively.

2. Model

Following the traditional portfolio model of crime (e.g. Becker, 1968; Brown and Reynolds 1973; Ehrlich, 1973; Block and Heineken, 1975; Heineken, 1978) farmers who hold L units of agricultural and have access to land and capital (seeds, fertilizers, etc.) decide on the proportion of the land to cultivate with coca, α. Without loss of generality, we assume that the remaining land, L-α, is cultivated with a legal product.[2] Since coca farming is an illegal activity penalized by authorities with eradication, two possible states can occur: either the farmer has bad luck (b) and gets the coca plants discovered and destroyed, which happens with probability p, or he has good luck (g) and escapes without having the coca plants discovered.[3] If the farmer has good luck, his income will be the return of initial wealth (W) plus the profit from coca ($\Pi_i(\alpha)$) and legal products ($\Pi_l(L-\alpha)$). We assume non-increasing returns to scale to land:

$$\frac{d\Pi_i}{d\alpha} = \pi_i > 0; \frac{d^2\Pi_i}{d\alpha^2} = \pi_i^{'} \le 0; \frac{d\Pi_l}{d(L-\alpha)} = \pi_l > 0; \frac{d^2\Pi_l}{d(L-\alpha)^2} = \pi_l^{'} \le 0 .$$

If authorities discover and destroy the coca plants, a loss of income occurs, $F(\alpha)$. As the agricultural land planted with coca plus a fraction of adjacent land gets incapacitated to produce in the next periods in case of aerial eradication, the marginal cost of eradication increases with land planted with coca $\left(\frac{dF}{d\alpha} = f > 0; \frac{d^2F}{d\alpha^2} = f^{'} > 0\right)$.

[2] Labor allocation is considered to result from a production technology.
[3] The law also dictates imprisonment and fines for production and transportation of drugs but in practice this is very seldom used.

The basic model of crime can be extended to consider the effect of three types of norms that have been identified to affect economic behavior: i) ethical or moral considerations (e.g. Dawes, 1980; Hausman and Mc Pherson, 1993; Eisenhauer, 2004), ii) social norms (e.g. Elster, 1989, Glaeser et al. 1996; Calvo and 2004; Garoupa, 1997, 2003a,2003b) and iii) legality of authorities and the rule (e.g. Tyler, 1990; Tyran, 2002). Morality is defined as the internal sense of justice and obligation (Frey, 1997). It is an internalized norm that drives individual behavior. Behaving in accordance with it creates a sense of self-esteem, deviating from it creates a sense of guilt and remorse. Following Eisenhauer (2004), we consider that the profit generated by coca cultivation can have lower utility value due to sense of sin or guilt that breaking own precepts brings.[4] So the profit from coca is weighted by $1 - \lambda$, where λ is a measure of sinfulness. For a moral individual, the sin of engaging in the illegal activity is very high ($\lambda=1$) so he derives no utility from the income generated by the illegal activity while an amoral individual will feel no regret of his actions ($\lambda=0$). We assume that $0<\lambda<1$, or that it is costly to deviate from moral precepts at the time that there exist a moral temptation to engage in coca cultivation. For simplicity, we further assume that having one or ten hectares with coca is self perceived as equally sinful as what is contempt is the act of cropping. Then the cost of the sinful act is independent of the amount of coca that is cultivated, $\frac{d\lambda}{d\alpha} = 0$.

A social norm is an informal external pattern of behavior that is shared by other people and that is sustained by their approval or disapproval (Elster, 1989). The perspective of breaking a social norm affects reputation as far as the individual feels identified with the norm and with the group (Akerlof, 1997). Social norms therefore may control anti-social

[4] An alternative approximation to include the effect of norms of behavior with the same implications as our model is presented in Sutinen and Kuperan (1999) and Hatcher et al. (2000).

behavior by stigmatizing violations to the norm. However, in an environment that is full of anti-social behavior they could have the opposite effect (Opp, 1979; Glaeser et al, 1996; Calvo et al., 2004).[5] The stigmatization for behaving differently from the socially accepted norm can be captured by a cost function that depends on the probability that others observe individual behaviour, q, the weight that others have in the utility function, t, and the distance of individual proportion of land with coca (α), to the average proportion of land with coca($\bar{a}$). Assuming that individuals suffer stigmatization for being either above or for being below the social norm the social cost from deviation can be captured by a quadratic function. It is assumed that $0<q<1$ and $t>0$. So the cost of breaking the social norm could be written as $qt(\bar{a}-\alpha)^2$.

The sense of obligation to comply with the law and with the authority is defined as legitimacy (Easton, 1958). Legal norms may or may not be in accordance with the own morality and with the social norms; however, the acceptance of the authority may be high enough to support compliance with the law (Tyler, 1990). The effect of acceptance of the authorities is therefore affecting both guiltiness – morality (λ) – and cost of social sanction – social norm (t).

Taking into consideration the effect of morality, social norms and legality, the income in case of good and bad luck can be written as:

$$\begin{aligned} Y_g &= W + (1-\lambda)\prod_i(\alpha) + \prod_l(L-\alpha) - qt(\bar{a}-\alpha)^2 \\ Y_b &= W + (1-\lambda)\prod_i(\alpha) + \prod_l(L-\alpha) - qt(\bar{a}-\alpha)^2 - F(\alpha) \end{aligned} \qquad (1)$$

[5] Social interaction reproduces anti-social behavior by: learning effects from criminal peers (Opp, 1989; Calvo and Zenou, 2004, Glaeser, et.al, 1996), crowding out of the legal system (Schrag and Scotchmer 1997), crowding out of legal opportunities (Murphy, et. al, 1993, Haung et al, 2004), and social capital depreciation (Sah, 1991, Williams and Sickles, 1999).

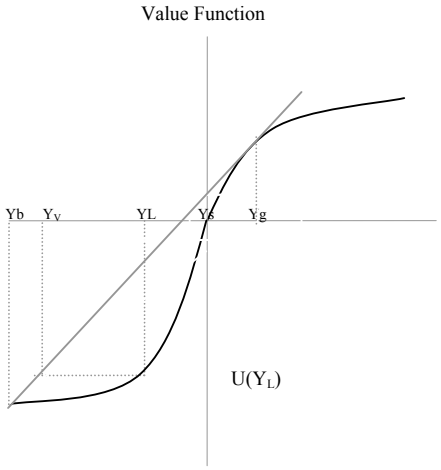
Finally, the low profit of legal agriculture due to the marginality of the areas where coca is cultivated, the lack of infrastructure and high transport cost could be the reason why farmers cultivate coca.

To capture this effect we assume that farmers behave according to cumulative prospect theory (Tversky and Kahneman, 1992). Hence, i) outcomes are taken as gains and losses relative to the reference point (minimum subsistence income). The utility function is kinked at the reference point being concave for gains and convex for losses; ii) losses appear larger than gains, so the utility function is steeper for losses than for similar gains (loss aversion); iii) the evaluation of risky outcomes involve a probability weighting function, p, that over-weights small probabilities and under-weights large probabilities. Following cumulative prospect theory, the utility can be represented by a value function:

$$V = (1-p)U(Y_g) + pU(Y_b) \ , \qquad (2)$$

Graph 1 illustrates a value function that is consistent with cumulative prospect theory. Imagine a situation in which income from coca cultivation in case of bad luck is lower than the maximum income from the legal activity, $Y_b<Y_L= W+\Pi_l(L)$ and where the income from coca cultivation in case of good luck is larger than the income from legal activity, $Y_L<Y_g$. Farmers would be willing to cultivate coca as far as the value function from gambling, $V=(1-p)U(Y_b)+PU(Y_g)$, is greater than the utility from the legal income $U(Y_L)$. In the graphic for an expected income greater than Y_v farmers would prefer to run the risk and engage in the more risky coca cultivation than cultivating the legal crop.

Graph 1. Value Function



The appendix presents the solution for the individual optimization problem. We first elaborate on the conditions that determine the decision to cultivate coca or not and the amount of coca that is cultivated in each case and then present the predictions of the model comparing both cases.

Farmers cultivate coca if the utility from cultivating coca is larger than the expected utility from not cultivating coca, $V(\alpha > 0) > V(\alpha = 0)$. This also implies that at $\alpha = 0$, the marginal expected benefit from coca cultivation has to be larger than the marginal expected benefit from the alternative. Farmers cultivate coca if :

$$\left.\frac{dEU}{d\alpha}\right|_{\alpha=0} = (1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha) - pf > 0 \qquad (3)$$

So coca cultivation has to generate not only economic benefits but has to be enough to pay the disutility from doing what the individual and society judge to be immoral action.

When both coca and legal product are cultivated, the optimal fraction of land that is cultivated is determined by the equity of the marginal rate of transformation of income

from lucky to unlucky state, $\frac{dYg/da}{dYb/da}$ and the marginal rate of substitution of income between those states, $\left.\frac{dYg}{dYb}\right|_{dEU=0}$:

$$\frac{(1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha)}{(1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha) - f} = -\frac{p}{(1-p)}\frac{U'(Y_b)}{U'(Y_g)} \qquad (4)$$

Note that if the marginal cost of being caught cultivating coca, f is greater than the marginal economic incentives to enter into the illegal activity (denominator of the left hand side of expression 4 is negative) there is no complete specialization in coca cultivation occurs.

According to the optimization conditions, there are four distinctive cases:

Table 1 summarizes the prediction of the model in two distinctive cases: i) subsistence is income is covered $Y_s<Y_b< Y_L<Y_g$; ii) subsistence may be under threat if farmers have bad luck $Y_b<Y_s <Y_g$; or if neither legal activity nor coca cultivation generates income to survive, $Y_b<Y_L< Y_g<Y_s$. The proofs are presented in the appendix. The model has very different predictions on the fraction of land that is cultivated when subsistence is under threat.

Higher morality and hence feel more sinful from engaging in coca cultivation (λ) reduce the incentive to cultivate coca and the proportion of land that is cultivated when subsistence is covered. But when subsistence is under threat, the reduction in the slope of the transformation curve (reducing areas) is accompanied by decrease in the slope of the substitution curve (increasing areas). The total effect will depend on which of this opposite forces dominates.

When coca cultivation is stigmatized, $(\bar{\alpha} - \alpha) < 0$, farmers whose subsistence is covered are less likely to cultivate coca and cultivate a lower proportion of land when the probability that others observe individual behavior is higher (q) and when others have higher importance on individual utility (t). But when subsistence is under threat though higher social ties reduce the likelihood to cultivate coca but have undetermined effect on the proportion of land that is cultivated. The reduction in the incentive to cultivate (reduction in the slope of the transformation curve) is accompanied by a increase in the preference for cultivation (decrease in the slope of the substitution curve).

Table 1. Predictions of the model

Decision	*Variable*	*Subsistence is under threat*	*Subsistence is Covered*
Coca cultivation	Higher morality concerns (λ)	Decreases	Decreases
	Higher social capital (q,t) when $\bar{\alpha} < \alpha$	Decreases	Decreases
	Increase in eradication (p,F)	Decreases	Decreases
	Higher opportunity cost (π_l).	Ambiguous	Ambiguous
	Higher Wealth (W)	Ambiguous	Ambiguous
	More Land (L)	Ambiguous	Ambiguous
Proportion of land with coca	Higher morality concerns (λ)	Ambiguous	Decreases
	Higher social capital (q,t) when $\bar{\alpha} < \alpha$	Ambiguous	Decreases
	Increase in eradication (p)	Decreases	Decreases
	Increase in eradication (F)	Undetermined	Decreases
	Higher opportunity cost (πl).	Decreases	Ambiguous
	Higher Wealth (W)	Decreases	Increases
	More Land (L)	Ambiguous	Increases

From a policy point of view, the model predicts that increases in eradication efforts though better technology identifying and destroying coca fields (p) decreases the likelihood and the proportion of land that is cultivated. If more costly penalties (f) are used instead– e.g. land expropriation, or incarceration, the proportion of land cultivated with coca decreases when subsistence is covered but is ambiguous in the case subsistence is threaten.

On the other hand, the model predicts that increases in the profitability of legal products (π_l) by alternative development e.g. provision on subsidized credits, supported prices, or creation of commercialization networks have an ambiguous effect on the likelihood to cultivate coca, but decreases the amount of coca that is cultivated when subsistence is under threat. When subsistence is not under threat the effect of alternative development on the proportion of land that is cultivated is ambiguous as the lower incentives to cultivate coca (smaller slope of the transformation curve) conflict the increase in preferences for coca (decrease in the slope of the indifference curve). The effect of being relatively richer, or having more initial wealth and land is ambiguous on the decision to cultivate coca or not. But higher wealth reduces the amount cultivated with coca when subsistence is under threat and increases the proportion of land when subsistence is covered.

3. Data

Putumayo in the South East of Colombia was selected as the locality for data collection due to its well established tradition in coca production. In 1980's coca production was established in the region and by 2000 about one third of the areas with coca in Colombia were located in Putumayo (DNE, 2005). In addition, this was the first region where eradication campaigns (destruction of coca plants through aerial spraying or manual pulling of the plants) were implemented at a large scale. This was also one of the pioneer regions to benefit from alternative development projects aiming at making non-coca activities more profitable (DNE, 2005). In particular, in 2000 the government implemented Voluntary Agreements of Substitution – VAS – in which farmers agreed to destruct coca plants in exchange of funding (in kind) for a food security project.[6]

[6] Other programs of voluntary substitution are the Forest Guarding Families Program – FGB –in which farmers agreed to destroy coca plants in exchange of a three year monthly monetary subsidy and Productive

Four municipalities were included in our study: Orito and Mocoa where the number of hectares of coca per squared kilometer of total municipal area are low (0.08ha coca/Km^2 to 0.17ha coca/Km^2) and Puerto Asis and Valle del Guamuez where that relation is higher (0.54ha coca/Km^2 to 1.82ha coca/Km^2). Two to four enumerators with at least high school education were trained in each of the four municipalities. In addition, three graduate researchers from Universidad de los Andes conducted the interviews in the four municipalities. Respondents were farmers who voluntarily participated in a meeting called by the local leader to talk to university researchers about coca farming and productive alternatives. To reduce the problem of validity of self reported data due to the illegality of coca cultivation, participants in the survey were informed that it was an academic study and that we were interested in their opinions, therefore no names or addresses were asked. During the morning session participants were interviewed and after a lunch break, they participated in what Harrison and List (2004) call a framed field experiment. In total 293 households were interviewed for about one hour using a pre-tested questionnaire, but due to time limitations a shorter version of the interview was conducted in 38 cases. Using the Mann-Whitney test no significance differences were found between the samples with the short and long questionnaires with respect to hectares with coca, education level, age or gender. The questionnaire included questions about i) productive activities in the farm in 2003 and 2005, ii) coca production in the municipality in 2003 and 2005, iii) attitudinal questions on coca production and anti drug policies, and iv) standard questions on socioeconomic characteristics. The questionnaire also included the Moral Judgment Test developed by Lind et. al. (1985) and a risk experiment that followed Biswanger (1980)

Projects (e.g. palm hearts, flowers, vanilla and cattle rising) which consist on a subsidized credit for the establishment of a legal product plus technological advice and support in commercialization. Due to data limitations we analyze the impact of VAS only.

design. We included a hypothetical choice experiment on coca production to test for the effect of different levels and combinations of eradication and alternative development.

Descriptive statistics

From the descriptive statistics presented in table 2 we see that the self-reported proportion of coca farmers, the number of hectares and the proportion of land cultivated with coca decreased between 2003 and 2005. The detailed exercise conducted with each household to estimate the profitability of coca and the best agricultural activity reveals that in 2003 coca was about five times more profitable than the best alternative while in 2005 that relation was about three times.[7] About one third of the sample declared to have participated in the program of coca substitution – VAS -. The average risk of eradication measured as number of hectares sprayed over total number of hectares with coca in the municipality increased from 1.12 during 2000-2002 to 6.69 during 2002-2004.[8] Moreover, the index of market conditions that captures the effect of price variability, credit availability and market facility between coca and legal products decreased from 2003 to 2005, revealing harder conditions for coca cultivation

>>>>>TABLE 2<<<<<<

The Moral Judgment Test (Lind et. al., 1985) was used to capture stage of moral development or the also called preferences for moral arguments. According to the cognitive theory of social psychology (Kohlberg, 1969) in which this test is based,

[7] The estimated median annual profit from coca and second best alternative are consistent with the estimated values in other studies e.g. DNE (2005); Rocha (2006) and Uribe (2005).

[8] To destroy coca plants it is needed to spray them more than once since they are resistant to the herbicides. More over since coca is often mixed with other agricultural products, more than one hectare needs to be sprayed. In addition, given that spraying is carried out from high altitudes the procedure less efficient.

individuals with the lowest stage of moral development, pre-conventionalists, motivate their actions by individualistic and opportunistic behavior (e.g. avoid personal harm or obtain personal satisfaction). In an intermediate stage, conventionalists motivate their actions by social concerns (e.g. what others would think or preserve social order). At the highest stage of moral development, post-conventionalists justify their moral actions by higher objectives such as human rights and reasons of conscience. As predicted by the cognitive theory of social psychology, we find that the average stage of moral development of coca farmers is in general lower than that of non coca farmers although that difference is not significant at the 10% level using Mann Whitney test.[9] It is also interesting that although most of the farmers declared to be Catholic, the percentage of persons that have a different religion -mainly Protestantism- was higher for non coca farmers compared with coca farmers and a larger proportion of non coca farmers declared not to belong to any church. Some evidence of habituation on coca cultivation decision is found as the average number of years cultivating coca is significantly larger for coca farmers than for non coca farmers. Note that although the average number of years of experience cultivating coca may seem to be too small (6.15 years), the peak in coca production in Putumayo was in 2000.

The perceived proportion of coca farmers in the municipality (79% in 2003 and 47% in 2005) is remarkably close to the sample's self reported percentage of coca farmers (71% and 43%) which give us an indication of the good quality of the self reported information. Since coca farmers may declare a higher proportion of coca farmers in order to justify their behavior this measure may be subject to endogeneity. Therefore, the effect of social norms is captured using the density of coca in the municipality (number of hectares with coca

[9] Aguirre (2002) studies criminal participation and moral development in Bogota, Colombia using Lind's (1985) Moral Judgment Test.

over total municipal area). To measure tightness of social networks and importance of others in well being we use the degree of trust and participation in communitarian organizations. We find that the average degree of trust of non-coca farmers is not significantly different from that of coca farmers, but non coca farmers on average participate significantly more than coca farmers at 1% significance level using Mann-Whitney test. Following the theory of procedural justice (Tyler, 1990) perceived obligation to comply (or legitimacy) was measured as acceptance to a series of statements relative to participation in defining the rule effectiveness of the rule, fairness of the law and agreement with the rule. Not surprisingly non coca farmers have significantly higher perceived level of obligation to comply than coca farmers.

Finally, we say that a farmer lacks options when the maximum income attainable from cultivating all the available land with the best legal product is insufficient to cover a minimum income requirement. If we use a subjective measure of the minimum income requirement, 58% of the farmers in our sample fall in this category compared with 45% of the farmers that fall in that category when the poverty line (93,000 pesos per person per month)[10] is used as reference. It turns out that both measures are highly and negatively correlated with the stated amount of land per household, so we use this measure in the econometric analysis to capture the effect of lack of options.

We used Binswanger (1980) risk experiment design and asked farmers to compare five sets of lotteries in which the payment for lottery A was held constant at 1 million pesos with no risk while lottery B offered with equal chance a payment above or below 1 million. The expected payment of lottery B increased in each choice set but so did the variance. By

[10] That is equivalent to 45 dollars

finding the point in which farmers switch from option B to option A, it is possible to estimate the average coefficient or partial risk aversion. According to this measure more than half of the sample had high or extreme level of risk aversion.

Other individual household head characteristics considered to explain the decision to cultivate coca and the proportion of land that is cultivated are: Age, gender, education level, risk preferences, transport cost to the closest market, and land per capita. It captures the attention the low level of education of the sample as half of the sample had maximum two years of schooling.

4. Results

The coca cultivation decision can be analyzed using an extended version of the Generalized Tobit Model. In the first step farmers first decide whether to cultivate coca or not, and then decide what proportion of land to cultivate with coca. A farmer cultivates coca (z=1) if the utility of coca cultivation is larger than the expected utility of not cultivating ($EU^* > 0$),

$$z = \begin{cases} 1 & V^* = \beta_1 X + \alpha D + \varepsilon_1 \geq 0 \\ 0 & otherwise \end{cases} \quad (1)$$

Conditional on cultivating coca, the proportion of land cultivated with coca (α) is:

$$\alpha = \begin{cases} \beta_2 X_2 + \alpha D + \varepsilon_2 & \text{If } z = 1 \\ 0 & otherwise \end{cases} \quad (2)$$

And $(\varepsilon_1, \varepsilon_2) \sim N(0,0,\sigma^2,1,\rho)$. X_1 and X_2 are vectors of economic and non-economic factors previously discussed ($\pi_i, \pi_l, W, p, f, \lambda, q, t, \bar{a}, z$) and D is a binary variable that represents participation in programs of voluntary substitution (D=1).

$$D = \begin{cases} 1 & \text{If } D^* = \beta_3 X_3 + \varepsilon_3 > 0 \\ 0 & \textit{otherwise} \end{cases} \qquad (3)$$

However, since participation in programs of substitution is voluntary, unobserved characteristics that affect the decision to participate into the substitution program (ε_3) can be correlated with the unobserved characteristics that affect the decision to cultivate coca (ε_1) and the amount of coca to be cultivated (ε_2). So the model will be subject to self-selection bias. The estimation of this model is rather complicated when it is assumed that $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ are $iid \sim N(0, \sum)$ where Σ is a correlation matrix (Ham, 1982). As an alternative we divide the problem into two parts: First we control for selection bias on coca cultivation decision estimating a bivariate probit model that considers the effect of participation in substitution program on the decision to cultivate coca (Equations (1) and (2)). And then we control for selection bias on the proportion of land cultivated with coca using a two step procedure. In the first step we estimate the probability to cultivate coca (equation 1) and estimate the inverse Mills ratio. In the second step a Generalized Tobit model that includes the estimated inverse mills ratio is estimated using equations (2) and (3).

Coca farming decisions for 2003 and 2005 were treated as independent to allow variability in the profit of coca and in the risk so a pooled data set was used. To avoid scale effects monetary related variables such as profit from coca and best alternative and number of hectares per household were normalized using natural logarithms.

Table 3 presents the estimation for the biprobit model for coca cultivation decision and participation in agreements of voluntary substitution. The econometric results support the hypothesis of correlation between unobserved characteristics that affect the decision to

cultivate coca and participation in agreements of voluntary substitution at the 5% significance level. It is reasonable to think that all farmers face the same market incentives to enter into coca cultivation and that they are all aware of the high profitability of coca cultivation compared with legal production, so if they take different productive decisions it must be because they face different opportunities, risks and needs. Econometric results confirm that hypothesis. Those farmers who had more opportunities and participated in VAS were less likely to cultivate coca; farmers that faced higher risk of having coca plants destroyed are significantly less likely to cultivate coca at 5% significance level and farmers with less land have fewer options to make a living from legal production which significantly increases the likelihood to cultivate coca.

>>>>> TABLE 3 <<<<<<

Interestingly, other non-economic factors can to some extent explain the decision to cultivate coca or not. Being Protestant compared with being Catholic significantly decreases the likelihood to cultivate coca. This could be interpreted as result of the renewed interest in religion that Protestant churches brought to the region. In addition, the positive and significant effect of living in a municipality with more coca could be interpreted as the result of lower stigmatization or learning effects from other coca farmers (Glaeser et al, 1995). Higher perceived obligation to comply with the law and with the authorities is significantly reduces the likelihood to cultivate coca too. Other individual household head characteristics such as age, gender, education, risk aversion and distance to the market are not significant explaining the decision to cultivate coca. It is interesting to note that the likelihood to cultivate coca decreases with age, level of education and for female respondents, while it increases with distance to the market and level of risk

aversion. This result is not strange taking in consideration that legal production has less credit availability, faces harder market conditions and more price variability than coca.

On the other hand, as can be seen in table 3, farmers with a higher degree of trust of others and those who participate in communitarian organizations are more likely to participate in agreements of voluntary substitution - VAS. Similarly there is a positive effect of age and education on participation in this program. The negative and significant effect of risk aversion on participation in VAS could be revealing lack of trust on the compensation offered by the program. Finally, farmers living in Orito, and Valle are significantly less likely to participate in VAS compared with farmers from Mocoa which reveals that substitution programs were directed to areas with better accessibility.

Table 4 presents the estimation of the generalized Tobit model on proportion of land that is cultivated with coca and participation in voluntary agreements of coca substitution –VAS. The estimation results revel that the proportion of land that is cultivated with coca depends on technological factors and that neither economic nor normative factors are significant explaining it. The proportion of land that is cultivated with coca significantly decreases with the farm size (number of hectares per household) probably as a strategy to reduce risk of eradication since bigger plots are more likely to be discovered by authorities. No significant effects are found with respect to incentive to cultivate coca or risk of eradication. Although Protestant farmers are less likely to cultivate coca than Catholics, once that they decide to cultivate coca they cultivate the same proportion of land with coca. Social norms or acceptance to the authorities does not affecting the proportion of land that is cultivated with coca. Farmers with more experience in coca cultivation, cultivate a lower proportion of their agricultural land with coca probably as a strategy to avoid eradication.

There is also a significant and negative effect for female respondents that we cannot explain. Although participation in VAS has a negative effect on the proportion of land that is cultivated with coca, this effect is not significant.

5. Conclusions

In this paper we explain both from a theoretical and empirical perspective the decision to cultivate coca and the amount of land that is cultivated with coca. We develop a behavioral version of the economic model of crime that explains coca farming decision as result of morality and social norms. In addition, our model considers situations in which subsistence is threaten. Coca is cultivated because it is a good business, but also because it is tempting enough to compensate for the internal and social disapproval that cultivation generates. Therefore higher moral standards or more social pressure reduce the likelihood to cultivate coca suggesting that in addition to eradication authorities can use educational campaigns that increasing awareness of the negative effect of coca cultivation to reduce the likelihood to cultivate coca. The model recommends that the authorities should use differential policies to control coca cultivation depending if subsistence is covered or not. Stronger eradication campaigns (e.g. increases in the cost of eradication), may increase the proportion of land that is cultivated when subsistence is under treat while alternative development is an appealing option in this case.

We test our model using data from a survey with coca and non-coca farmers living in Putumayo, Colombia, one of the regions with longer tradition on coca farming in the country. We used a generalized tobit model to explain the decision to cultivate coca and the proportion of land cultivated. We found that the lack of options in legal economy to make a living explained coca cultivation decision. Religiosity, social norms and

acceptance to the authorities were found significant in explaining coca cultivation. The availability of governmental substitution programs and tougher eradication campaigns succeed in reducing coca cultivation. We find that economic factors do not affect the proportion of land that is cultivated with coca and that the decision depends on the amount of land available.

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Appendix

The individual maximization problem can be written as:

$$\underset{\alpha}{\text{Max}}\ V = (1 - p)\, U(Yg) + p\, U(Yb) \tag{1}$$

Where if $\prod_l(L) < Y_{min}$

$$Y_g = W + (1-\lambda)\prod_i(\alpha) + \prod_l(L-\alpha) - qt(\bar{a}-\alpha)^2 \tag{2}$$

$$Y_b = W + (1-\lambda)\prod_i(\alpha) + \prod_l(L-\alpha) - qt(\bar{a}-\alpha)^2 - F(\alpha)$$

The first order conditions for maximization imply

$$\frac{\partial V}{\partial \alpha_i} = (1-p)U'(Y_g)((1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha)) + pU'(Y_b)((1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha) - f) = A + B = 0 \tag{3}$$

Where:

$$\frac{\partial \prod_k}{\partial \alpha} = \pi_k \quad \text{for k = i,l}$$

$$\frac{\partial F}{\partial \alpha} = f$$

$$\frac{\partial U(Y_z)}{\partial \alpha} = U'(Y_z) \text{ for z = g, b}$$

The second order condition for maximization imply

$$\frac{\partial^2 V}{\partial \alpha^2} = (1-p)U''(Y_g)a^2 + pU''(Y_b)b^2 + (1-p)U'(Y_g)a' + pU'(Y_b)b' = \Delta < 0 \tag{4}$$

Where

$$a = ((1-\lambda)\pi_i - \pi_l + 2qt(\bar{a}-\alpha))$$

$$b = ((1-\lambda)\pi_i - \pi_l - f + 2qt(\bar{a}-\alpha))$$

$$a' = \frac{da}{d\alpha}; b' = \frac{db}{d\alpha};$$

Coca is cultivated if: $Y = (1-p)U(Y_g) + pU(Y_b) - U(W + \prod_l(L)) > 0$. Which implies the following effects on the decision whether to cultivate coca or not.

$$\frac{\partial Y}{\partial \lambda} = ((1-p)U'(Y_g) + pU'(Y_b))(-\pi_i) < 0 \tag{5.1}$$

Higher morality, or sinfulness about coca cultivation reduces the likelihood to cultivate coca. As it is presented in equation 5.2 higher social tights (q, t) also reduce the likelihood to cultivate coca.

$$\begin{aligned} \frac{\partial Y}{\partial q} &= ((1-p)U'(Y_g) + pU'(Y_b))(-t(\bar{a}-\alpha)^2) < 0 \\ \frac{\partial Y}{\partial t} &= ((1-p)U'(Y_g) + pU'(Y_b))(-q(\bar{a}-\alpha)^2) < 0 \end{aligned} \tag{5.2}$$

Higher eradication efforts decrease the likelihood to cultivate coca

$$\begin{aligned} \frac{\partial Y}{\partial p} &= -U(Y_g) + U(Y_b) < 0 \\ \frac{\partial Y}{\partial F} &= -pU'(Y_b) < 0 \end{aligned} \tag{5.3}$$

And increases in the profitability of the legal alternative for example through alternative development have an undetermined effect on the likelihood to cultivate coca.

$$\frac{\partial Y}{\partial \pi_l} = (1-p)U'(Y_g) + pU'(Y_b) - U'(Y_L) = ? \tag{5.4}$$

The effect of being relatively poorer or having less wealth or less land, on the decision to cultivate coca is undetermined.

$$\begin{aligned} \frac{\partial Y}{\partial W} &= (1-p)U'(Y_g) + pU'(Y_b) - U'(Y_L) = ? \\ \frac{\partial Y}{\partial L} &= ((1-p)U'(Y_g) + pU'(Y_b) - U'(Y_l))(\pi_{lL}) = ? \end{aligned} \tag{5.5}$$

On the optimum when coca and legal crops are cultivated the effect of changes in the parameters (x) can be found taking the total derivative from the first order condition and solving for da/dx, The effect of changes in morality on the proportion of land that is cultivated with coca is:

$$\frac{\partial \alpha}{\partial \lambda} = \frac{1}{\Delta}\left[\prod_i ((1-p)U''(Y_g)a + pU''(Y_b)b) + \pi_i\ ((1-p)U'(Y_g) + pU'(Y_b))\right] \tag{6.1}$$

Defining R(Y) as the coefficient of absolute risk aversion, $R(Y_z) = -\frac{\mathrm{U''(Y_z)}}{U'(Y_z)}$, the expression can be rewritten as:

$$\frac{d\alpha}{d\lambda} = \frac{1}{\Delta}\left[-(R(Y_g)A + R(Y_b)B)\prod_i + \pi_i\,((1-p)U'(Y_g) + pU'(Y_b))\right]$$

Using first order condition,

$$\frac{d\alpha}{d\lambda} = \frac{1}{\Delta}\left[-(R(Y_g)(-B) + R(Y_b)B)\prod_i + \pi_i\,((1-p)U'(Y_g) + pU'(Y_b))\right]$$

Assuming decreasing absolute risk aversion and decreasing risk loving risk coefficient,

For $Y_g > Y_L > Y_b > \mathrm{Y_s}$

$$R(Y_b) = -\frac{\mathrm{U''(Y_b)}}{U'(Y_b)} > -\frac{\mathrm{U''(Y_g)}}{U'(Y_g)} = R(Y_g) > 0 \qquad (7.1)$$

For $Y_b < Y_L < Y_g < \mathrm{Y_s}$

$$R(Y_b) = -\frac{\mathrm{U''(Y_b)}}{U'(Y_b)} < -\frac{\mathrm{U''(Y_g)}}{U'(Y_g)} = R(Y_g) < 0 \qquad (7.2)$$

for $Y_b < Y_s < Y_L < \mathrm{Y_g}$ or $Y_b < Y_L < Y_s < \mathrm{Y_g}$

$$R(Y_b) = -\frac{\mathrm{U''(Y_b)}}{U'(Y_b)} < 0 < -\frac{\mathrm{U''(Y_g)}}{U'(Y_g)} = R(Y_g) \qquad (7.3)$$

It is possible to show that when subsistence is not under threat, $Y_g > Y_L > Y_b > \mathrm{Y_s}$, increases in moral concerns decrease the amount of coca that is cultivated, $\frac{d\alpha}{d\lambda}$<0. However, when subsistence is under threat, $Y_b < Y_L < Y_g < \mathrm{Y_s}$ or $Y_b < Y_s < \mathrm{Y_g}$, the effect of increases in moral concerns is ambiguous.

Similarly, when coca is socially stigmatized $(\bar{a} - \alpha)$<0, stronger social tightness decreases the proportion of land that is cultivated with coca when individuals do not lack alternatives. But, if coca is not stigmatized, the effect of increases in q and t is undetermined. On the

other hand, when individuals lack alternatives, social norms and social pressure have an undetermined effect on the amount of coca that is cultivated when coca is stigmatized, $(\overline{a}-\alpha)<0$, but they increase the amount of coca that is cultivated when coca is accepted, $(\overline{a}-\alpha)>0$.

$$\begin{aligned}\frac{\partial\alpha}{\partial q}&=\frac{-1}{\Delta}\Big[(R(Y_g)A+R(Y_b)B)(t(\overline{\alpha}-\alpha)^2)+\\&\qquad((1-p)U'(Y_g)+pU'(Y_b))2t(\overline{\alpha}-\alpha)\Big]\\\frac{\partial\alpha}{\partial t}&=\frac{-1}{\Delta}\Big[(R(Y_g)A+R(Y_b)B)(q(\overline{\alpha}-\alpha)^2)+\\&\qquad((1-p)U'(Y_g)+pU'(Y_b))2q(\overline{\alpha}-\alpha)\Big]\end{aligned}\tag{6.2}$$

Increases in eradication efforts through better detection techniques decrease the fraction of land that is cultivated with coca independently on whether subsistence is under threat or not.

$$\frac{\partial\alpha}{\partial p}=\frac{-1}{\Delta}\Big[-U'(Y_g)a+U'(Y_b)b\Big]<0\tag{6.3}$$

If the authorities increase the cost of being discovered (eg. land expropriation, incarceration, etc.) the proportion of land with coca will decrease for those whose subsistence is not under threat. But the effect will be undetermined for those whose subsistence is under threat.

$$\frac{\partial\alpha}{\partial F}=\frac{-1}{\Delta}\Big[R(\mathrm{Y_b})\mathrm{B}+pU'(Y_b)(-f_F)\Big]\tag{6.4}$$

Increases in the opportunity cost of coca cultivation, or in the profitability of legal alternatives decrease the amount of land cultivated with coca when subsistence is under threat but have an ambiguous effect on the other case.

$$\begin{aligned}\frac{\partial\alpha}{\partial\prod_l}&=\frac{-1}{\Delta}\Big[-(R(Y_g)A+R(Y_b)B)\prod_l-((1-p)U'(Y_g)+pU'(Y_b))\pi_{l\neq l}\Big]\\\frac{\partial\alpha}{\partial\prod_l}&=\frac{-1}{\Delta}\Big[-(R(Y_g)-B+R(Y_b)B)\prod_l-((1-p)U'(Y_g)+pU'(Y_b))\pi_{l\neq l}\Big]\end{aligned}\tag{6.5}$$

Higher initial wealth increases the fraction of land that is cultivated with coca for farmers whose subsistence is not under threat but reduces the amount of land that is cultivated with coca for farmers when subsistence is under threat.

$$\frac{\partial \alpha}{\partial W} = \frac{-1}{\Delta}\left[-(R(Y_g)A + R(Y_b)B)\right] \tag{6.6}$$

$$\frac{\partial \alpha}{\partial L} = \frac{-1}{\Delta}\left[-(R(Y_g)A + R(Y_b)B)\prod_{lL} - ((1-p)U'(Y_g) + pU'(Y_b))(\pi_{l,L})\right]$$

When it is assumed decreasing marginal return of land, ($\pi_{l,L}$ <0), increases in land endowments increase the proportion of land that is cultivated with coca when subsistence is not under threat. But when subsistence is under threat, the effect is undetermined.

Table 3. Seemingly unrelated bivariate probit

	Coca cultivation decision n = 329				Participation in Agreements of Substitution n = 329				Mean Values
	Coef.	Std. Err.	ey/ex	Std. Err.	Coef.	Std. Err.	ey/ex	Std. Err.	
Log net income coca	-0.1616	0.1066	-0.3551	0.2409					8.1162
Log net income Alternative	-0.0259	0.0842	-0.0441	0.1437					6.2920
Index of Market conditions	0.0776	0.0749	-0.0045	-0.0045					-0.2143
Sprayed ha/Total ha with coca in municipality	-0.0367	0.0172 **	-0.0446	0.0238					4.4879
Dummy Atheists	-0.1771	0.3740	-0.0031	0.0064	-0.0143	0.3301	-0.0011	0.1440	0.0638
Dummy Non Catholic	-0.9438	0.3257 ***	-0.0280	0.0101	-0.2128	0.3074	-0.0274	3.6233	0.1094
Years cultivating coca	0.0254	0.0168	0.0449	0.0317	-0.0026	0.0171	-0.0200	2.6410	6.5167
Moral development (Missing=0; Pre-Conv=1; Conv=2; Post-Conv=3	-0.1694	0.1589	-0.0576	0.0547	0.1031	0.1573	0.1525	20.1290	1.2553
Degree of trust (not at all=1, a lot=5)	0.0189	0.0803	0.0153	0.0645	0.1751	0.0743 **	0.6148	81.1730	2.9787
Dummy participation communitarian organizations	-0.2404	0.2037	-0.0352	0.0297	0.3417	0.1919 *	0.2179	28.7670	0.5410
Ha with coca/Municipal Area	0.3470	0.0629 ***	0.2841	0.0390			0.0000	0.0000	3.0238
Obligation to comply (Compl disagree=1, Compl. Agree=5)	-0.4877	0.1550 ***	-0.4664	0.1567	0.0270	0.1494	0.1125	14.8650	3.5324
Age	-0.0238	0.0425	-0.2660	0.4788	0.0824	0.0408 **	4.0061	528.9400	41.2705
Squared Age	0.0002	0.0005	0.1183	0.2378	-0.0005	0.0004	-1.1023	145.5400	1897.3
Female	-0.1558	0.2075	-0.0145	0.0196	0.2690	0.1854	0.1089	14.3740	0.3435
Education (None=0,Basic=1, Primary=2, More=3	-0.1411	0.4141	-0.0641	0.1888	1.1222	0.3951 ***	2.2189	292.9700	1.6778
Squared Education Grade	0.0854	0.1168	0.0838	0.1158	-0.2121	0.1100 *	-0.9055	119.5500	3.6231
Coefficient of risk aversion (miss=0,lover=0. ….extreme=	0.0162	0.0276	0.0165	0.0282	-0.0821	0.0251 ***	-0.3646	48.1350	3.7662
Cost of transport (Thousand COL)	0.0011	0.0342	0.0009	0.0260	0.0204	0.0334	0.0675	8.9163	2.8055
Log Land per capita	-0.3184	0.0955 ***	-0.0912	0.0312	-0.0051	0.0959	-0.0063	0.8423	1.0578
Dummy miss stage moral development	1.3916	0.6138 **	0.0298	0.0132	0.6579	0.4037	0.0613	8.0903	0.0790
Dummy miss risk aversion	-0.7765	1.2240	-0.0026	0.0041	-6.9384	17302.6500	-0.0994	261.0400	0.0122
Constant	4.3092	1.4365 ***			-4.0478	1.1878 ***			
Dummy Orito					-1.1715	0.2544 ***	-0.5036	66.4870	0.3647
Dummy Puerto Asis					-0.2797	0.3051	-0.0661	8.7313	0.2006
Dummy Valle del Guamuez					-1.3294	0.3517 ***	-0.3429	45.2710	0.2188
/athrho	-0.3467	0.1382							
rho	-0.3334	0.1229							
Likelihood-ratio test of rho=0 chi2(1)		6.5489							
Prob > chi2		0.0105							

Table 4. Treatment Effects model controlling for Pariticipation decision

	Proportion of land cultivated with coca n=214				Participation in Agreements of Substitution P=1 n=214				Mean Values
	Coef.	Std. Err.	ey/ex if P=1	ey/ex if P=0	Coef.	Std. Err.	ey/ex	Std. Err.	
Log net income coca	0.0085	0.0083	0.2146	0.2359					8.1231
Log net income Alternative	-0.0040	0.0113	-0.0772	-0.0849					6.2254
Index of Market conditions	-0.0099	0.0271	0.0022	0.0024					-0.0724
Sprayed ha/Total ha with coca in municipality	0.0008	0.0140	0.0085	0.0094					3.3171
Dummy Atheists	0.0570	0.0377	0.0095	0.0120	0.3254	0.4740	0.0327	0.0475	0.0701
Dummy Non Catholic	0.0817	0.2236	0.0316	0.0274	-1.5416	0.5937 ***	-0.1549	0.0617	0.0701
Years cultivating coca	-0.0035	0.0063	-0.1037	-0.0996	0.0296	0.0238	0.3018	0.2456	7.1210
Moral development (Missing=0; Pre-Conv=1; Conv=2; Post-Conv=3)	0.0196	0.0181	-0.0068	0.0346	0.5236	0.2501 **	0.8838	0.4208	1.1775
Degree of trust (not at all=1, a lot=5)	0.0100	0.0086	0.0546	0.0795	0.0980	0.0968	0.4101	0.4079	2.9205
Dummy participation communitarian organizations	-0.0057	0.0274	-0.0220	-0.0172	0.1987	0.2744	0.1451	0.2006	0.5093
Ha with coca/Municipal Area	0.0011	0.0029	0.0144	0.0158					4.3012
Obligation to comply (Compl disagree=1, Compl. Agree=5)	0.0236	0.0439	0.1096	0.1942	0.3200	0.1883 *	1.5487	0.9112	3.3761
Age	-0.0079	0.0069	-1.5920	-1.4256	0.1182	0.0538 **	6.8036	3.1759	40.15
Squared Age	0.0001	0.0001	0.6571	0.6312	-0.0007	0.0006	-1.9093	1.5212	1810.20
Female	-0.1110	0.0263 ***	-0.1252	-0.1345	0.1295	0.2509	0.0642	0.1254	0.3458
Education (None=0,Basic=1, Primary=2, More=3	-0.0078	0.0834	-0.2880	-0.1854	1.0931	0.5140 **	2.7532	1.3287	1.7570
Squared Education Grade	0.0090	0.0139	0.2121	0.1788	-0.2024	0.1459	-1.1387	0.8286	3.9252
Coefficient of risk aversion	0.0032	0.0034	0.0842	0.0673	-0.0986	0.0333 ***	-0.5284	0.1873	3.7376
Cost of transport (Thousand COL)	0.0043	0.0047	0.0213	0.0320	0.0451	0.0445	0.1801	0.1781	2.7850
Log Land per capita	-0.1523	0.0668 **	-0.3814	-0.4289	-0.1690	0.1241	-0.2041	0.1521	0.8427
Dummy miss stage moral development	0.0641	0.1337	0.0005	0.0127	1.5299	0.5269 ***	0.2562	0.0887	0.1168
Dummy miss risk aversion	0.2866	0.5405	0.0155	0.0132	-6.0381	0.5231 ***	-0.0809	0.0091	0.0093
Inversed Mills Ratio	-0.0626		-0.0632	-0.0695					0.3243
Dummy Participation Substitution Program	-0.0632	0.1665							0.2804
Constant	0.4345				-6.3889	1.6241 ***			
Dummy Orito			0.0742	0.0419	-1.7027	0.4365 ***	-0.8326	0.2263	0.3411
Dummy Puerto Asis			0.0051	0.0029	-0.1659	0.4165	-0.0567	0.1422	0.2383
Dummy Valle del Guamuez			0.0520	0.0294	-1.2620	0.5420 **	-0.5833	0.2622	0.3224
/athrho	0.2641	0.4209							
/lnsigma	-1.5991	0.0638							
rho	0.2581	0.3928							
sigma	0.2021	0.0129							
lambda	0.0522	0.0811							
Wald test of independent equations	0.3900								
Prob > chi2	0.5304								