Social Mechanisms of Low and Stable Coca Production in a Peruvian Farming Community

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The effects of social emulation and cooperation in the levels of coca production of a Peruvian farming community are investigated. The study consists of simulations of one hundred farmers who have to decide between producing either coca or coffee on their available land in each of seventeen time steps (years). The results suggest that social emulation, evaluated under different governmental education policies, is not enough to explain the stable coca production in this community, although it seems to be an important force that influences farmers to keep coca production levels low. On the other hand, the introduction of an artificially strong cooperative behavior in the form of self-restraint not only reduces but also stabilizes coca production. The overall effect of social emulation and cooperation is a reduction and a stabilization of coca production. This final result resembles the conditions observed in the research area. Still, more sophisticated models and further analyses are required to fully identify and understand the social mechanisms that persuade this community to maintain low and stable levels of coca production in comparison with nearby farmer communities of similar size and structure.

Keywords: coca, cooperation, farmers' decision-making, social emulation, Peru

1. Introduction

QQ[1] is a small farming community located in the Peruvian Amazon rainforest. Its inhabitants are mostly indigenous farmers, most of who settled in the area during the 1950s because of widespread poverty in their former home. The community presently numbers around 8,000 inhabitants [1], almost all of whom are involved in the production of coffee as a cash crop. The community also produces a small amount of coca, mostly for traditional indigenous use. Although there is significant disagreement on the precise level and nature of this production, official sources agree that it occurs only in quantities that are small relative to other communities of a similar size and structure [2]. (Precise data on production levels is inevitably hard to find. Indeed, even single official sources produce contradictory data: the UN Office on Drugs and Crime (UNODC) has stated both that coca production has increased in the last ten year [4] and also that it has remained stable [2] in the research area. This confusion is mirrored in journalistic accounts of the situation [5].) Furthermore, production levels are not undergoing major change, and may even be stable over the long term. Why might that be so?

Most previous research regarding the production of coca in the region has focused on economic concerns, such as variations in the price of coca and other agricultural crops. However, if profit were the sole or major factor behind the extent and location of illegal drug production it would be widely produced in other countries with suitable ecosystems and economies. Yet this is not the case: Ecuador, located between Colombia and Peru and equally as suitable for coca production, produces very little coca. The same question may be asked of QQ: if economic profit was the overriding determinant of the level of coca production then many if not all farmers in QQ would produce much more coca than they presently do; it is, after all, more profitable than coffee by several orders of magnitude.

It seems then, that other factors must play a role in the relatively low and stable levels of coca production in QQ. Specifically, the effects of social mechanisms may be crucial, a conclusion held by several international organization and governmental field workers [3]. Such a hypothesis may also explain why the QQ community differs from its neighbors, since it has a particularly high degree

[1]The real name of the community is not mentioned in this paper so as to prevent any potential misunderstanding with the community inhabitants and national governmental authorities.

of community organization in the form of self-organised coffee cooperatives and associations. We seek, then, to investigate the possible impact of relevant social mechanisms on the level of coca production in this community.

We have constructed a mathematical model that included various socio-economic factors thought to play a role in farmers' decision to produce coca or coffee. Those include the ratio between net benefit from coca and total net benefit, the relation between each farmer's total net benefit and the average total net benefit of the community, and the expected farm gate prices of coca and coffee. The initial model's parameters were set using data recently collected data infrom QQ (Garcia-Yi, own survey, 2006).

Having conducted an initial analysis we then added the effects of two social mechanisms: social emulation and cooperation. Social emulation is defined as the movement of an individual from one social group to another. Cooperation is a measure of the tendency of the farmers to keep the overall levels of coca production low to avoid governmental intervention. In addition, different governmental educational policies that could influence social emulation results were evaluated and their effects in the total quantity of coca production in the community registered and discussed.

2. The basic model

In order to construct the basic farmers' decision-making model, we first define the net benefit (NB) due to coca received by farmer h at time t:

$$NB_{cc,h}(t) = Q_{cc,h}(t) \cdot (P_{cc}(t) - C_{cc}) \tag{1}$$

$$NB_{cf,h}(t) = Q_{cf,h}(t) \cdot (P_{cf}(t) - C_{cf}) \tag{2}$$

where $Q_{cc,h}(t)$ is the quantity of coca produced by farmer h at time t, $P_{cc}(t)$ is the price of coca at time t, and C_{cc} is the unitary cost of coca production. $Q_{cf,h}(t)$, the quantity of coffee produced by farmer h at time t, is defined similarly.

We now define an intermediate variable $x_{cc,h}(t)$, which is a relation between net benefits of coca and total net benefit of the farmer:

$$x_{cc,h}(t) = \frac{NB_{cc,h}(t)}{NB_{cc,h}(t) + NB_{cf,h}(t)} \tag{3}$$

We are now able to define $y_{cc,h}(t)$, a measure of the proportion of land the farmer is expect to dedicate to coca production after taking into account specific socio-economic decision factors. Those socio-economic factors are, first, the net benefit of coca related to total net benefit; second, how much the farmer's future behavior will be affected by his success relative to others; and third, how much he will attend to the fluctuating farm gate price of the crops. These two last factors are measured by the parameters α and β, respectively, where $\alpha + \beta = 1$.

$$y_{cc,h}(t) = x_{cc,h}(t) + \alpha \cdot \left(1 - \frac{x_{cc,h}(t)}{\langle x_{cc}(t)\rangle_{h \in QQ}}\right) \cdot U + \beta \cdot \left(\frac{(P_{cc}(t) - \overline{P_{cc}(t)}^{(3)}) \cdot Q_{cc,h}(t)}{(P_{cf}(t) - \overline{P_{cf}(t)}^{(3)}) \cdot Q_{cf,h}(t)}\right) \cdot V_{cc} \cdot W \tag{4}$$

Where $\overline{P_{cc}(t)}^{(3)}$ and $\overline{P_{cf}(t)}^{(3)}$ are the last three year average farm gate price of coca and coffee, respectively. $\langle x_{cc}(t)\rangle_{h \in QQ}$ is the average of $x_{cc,h}(t)$ at year t for all members ($h \in QQ$) of the community. U, V and W are indicator functions defined as follows:

$$U = \begin{cases} 1 & \text{if } \langle x_{cc}(t)\rangle_{h \in QQ} \geq x_{cc,h}(t) \\ 0 & \text{if } \langle x_{cc}(t)\rangle_{h \in QQ} < x_{cc,h}(t) \end{cases} \tag{5}$$

$$V_i = \begin{cases} 1 & \text{if } P_i(t) - \overline{P_i(t)}^{(3)} \geq 0 \\ -1 & \text{if } P_i(t) - \overline{P_i(t)}^{(3)} < 0 \end{cases} \qquad (i = cc, cf) \tag{6}$$

$$W = \begin{cases} 1 & \text{if } V_{cc} + V_{cf} = 0 \\ 0 & \text{if } V_{cc} + V_{cf} \neq 0 \end{cases} \tag{7}$$

We now normalize $y_{cc,h}(t)$ to give the proportion of land that the farmer will dedicate towards coca production at time $t+1$:

$$P^r_{cc,h}(t+1) = \frac{y_{cc,h}(t)}{y_{cc,h}(t) + y_{cf,h}(t)} \tag{8}$$

We assume that at each time step farmers use one additional plot of land for the production of either coca or coffee. It therefore follows that $P^r_{cf,h}(t) = 1 - P^r_{cc,h}(t)$.

3. Social emulation and cooperation

We now define additional equations to include the impact of the social mechanisms that we hypothesized play a role in the low and stable level of coca production in QQ: social emulation and cooperation.

In the case of social emulation, we must first determine the number and nature of the social groups. We therefore conducted a discrete logistic regression on our data set. Individual farmers' production of coca (yes or no) was regressed versus socio-economic and local geographic data. This suggested that members of the community who produce coca are most significantly distinguished along two dimensions: years of education and the distance of their plots from the main road that links QQ with surrounding communities. After that, a cluster analysis on our data set allowed us to separate four groups based on those variables, as per table 1.

Table 1: Farmers categorization results based on a discrete logistic regression and a cluster analysis

Variables	**Group 1 (N=45)**		**Group 2 (N=25)**		**Group 3 (N=14)**		**Group 4 (N=23)**	
	Mean	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Coca	0.33	0.48	0.12	0.33	0.00	0.00	0.61	0.50
Education	8.31	2.79	10.48	1.39	10.50	1.56	6.30	2.84
Distance	73.27	70.39	106.60	94.75	35.43	25.32	53.30	66.23

We then describe a transition matrix, $M(t)$, which defines how individuals may transition from one social group to another and hence emulate their behavior. Each entry $m_i j$ refers to the likelihood that an individual in group i will move to group j at time t.

$$M(t) = \begin{pmatrix} 1-\omega(t) & \omega(t) & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & \varepsilon & 1-\varepsilon & 0 \\ \delta & \delta\omega(t) & \omega(t) & 1-\omega(t)-\delta-\delta\omega(t) \end{pmatrix} \tag{9}$$

Here δ represents the likelihood that an individual with a high level of education will move from a location near the road to one far from the road and ε represents the corresponding value for an individual with low education. Both are small but non-zero; although rare, such change does occasionally occur for reasons external to our model. They are, however, more likely for farmers of low education, and hence $\delta > \varepsilon$. $\omega(t)$ is a function of time that represents the Government's education policy. We manipulate this function to explore the possible effects of different Governmental education policy on levels of coca production.

We model cooperation as an artificially strong form of self-restraint. So, we set a randomly chosen proportion k of the farmers to behave as previously defined unless the community's net coca production $y(t) = \sum_{h \in QQ} y_{cc,h}(t)$ exceeds some threshold γ, at which point they will produce only coffee.

$$P^r_{cc,h}(t+1) = \begin{cases} \frac{y_{cc,h}(t)}{y_{cc,h}(t)+y_{cf,h}(t)} & \text{if } y(t) \leq \gamma \\ 0 & \text{if } y(t) > \gamma \end{cases} \tag{10}$$

Then, in order to run the simulations we made four simplifying assumptions. First, at $t = 0$ farmers have an equal amount of coffee and coca land area. Second, each farmer receives one additional plot of land at each time step. The decision the farmer must make is what proportion of that new land he will dedicate towards the production of coca. The remaining proportion is supposed to be planted with coffee. Third, once a farmer has made this decision it is fixed for the long term. That is, farmers do not revisit patches in future time steps; they simply make a decision about the crop balance of their new plot. Fourth, we assume that the costs of crop production are fixed over time.

The initial conditions of the simulation were based on real data (Garcia-Yi, own survey). Accordingly, one hundred farmers were modelled over seventeen time steps. The parameters α and β were set such that the ratio α/β reflects the behavior of the different social groups, as defined in table 2.

Table 2: Values of the ratio α/β for different social groups

GROUP	1	2	3	4
α/β	$<<1$	<1	$>>1$	>1

4. Results and discussions

In figure 1, we observe the results for the basic and social emulation models. The basic model shows an increasing proportion of coca production on time. A similar coca production trend has been experienced in other neighboring communities, but not in the community under research. On the other hand, the social emulation model slows the rise of coca production, but its overall effect is not sufficient to achieve stable coca production. Note that the two low peaks in years 7 and 13 are consequence of short-term compensations as the net benefit of the farmers approaches the average. The amplitude of those peaks depends on the value of α in equation (4).

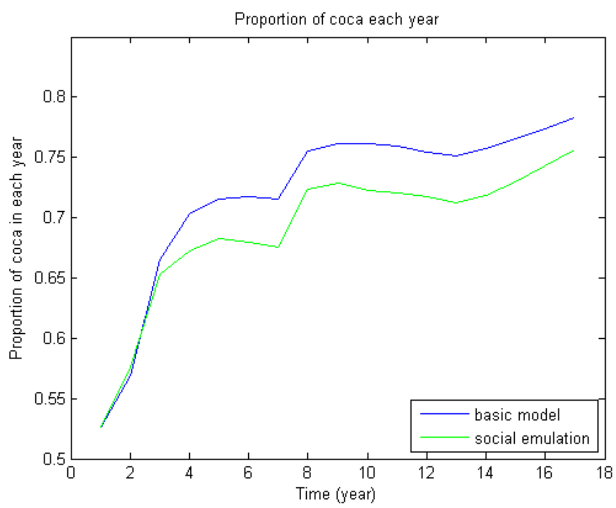

Figure 1: Evolution on time of the proportion of coca production of the basic farmers' decision making and social emulation models

Figure 2 indicates the effects of social emulation including different education policies on crop ratios. The education policies are uniformly high; uniformly low; two peaks (high at $t = 4$ and $t = 5$

and also at $t = 8$ and $t = 9$, but otherwise low); beginning low but increasing with time; and finally a policy of high education for those near to the road and low for those further away.

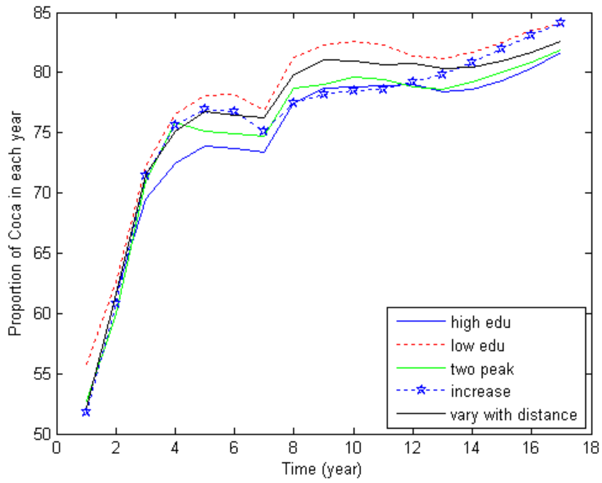

Figure 2: Effects of different education policies in the proportion of coca production

These results corroborate that social emulation under different educational policies also has little effect on the stability of coca production: education policies are able to slow the rise in the level of coca production, but cannot enforce overall stability.

The results of the cooperative self-restraint model are illustrated in figure 3. Here, the sharp decrease in coca production is evident after reaching some threshold at $t = 9$. It is important to note that this notion of a cooperative threshold has some real-world basis, since if coca production becomes too great then the authorities are likely to impose a clamp down. However we do not expect that cooperation involves only such a crude mechanism as self-restraint. It is implemented here as an exploratory tool, and is likely to be far more complex in the real world.

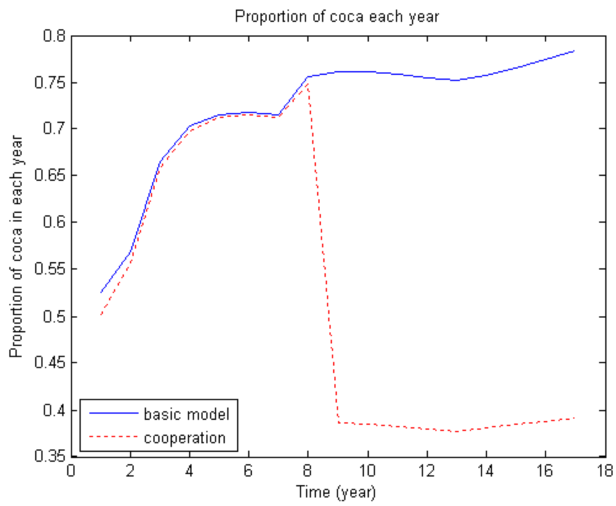

Figure 3: Evolution on time of the proportion of coca production of the basic farmers' decision making and cooperative self-restraint models

The aggregate effect of the basic farmers' decision making, social emulation and cooperation models are shown in figure 4. This aggregate effect not only lowers coca production levels but also seems to stabilize them, at least in short-term. This is similar to the overall effect observed in the research area. Figure 5 illustrates the proportion of coca grown by each individual farmer in his new plot at each time step, when both social emulation and cooperation are taken into account. Again the most notable transition to stability comes at $t = 9$, and is largely due to cooperative self-restraint.

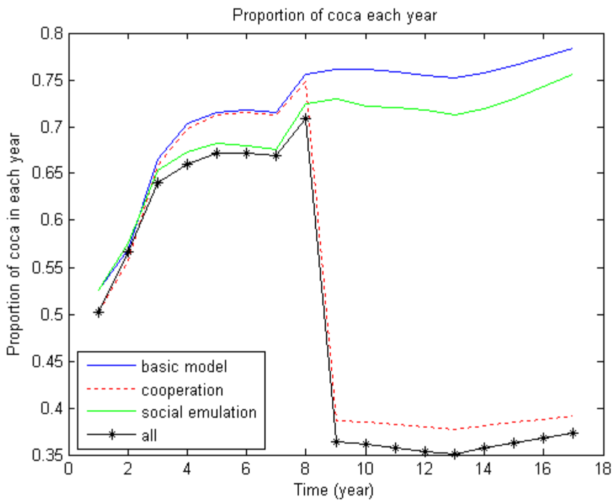

Figure 4: The aggregate effect of the basic farmers' decision-making, social emulation and cooperative self-restraint models

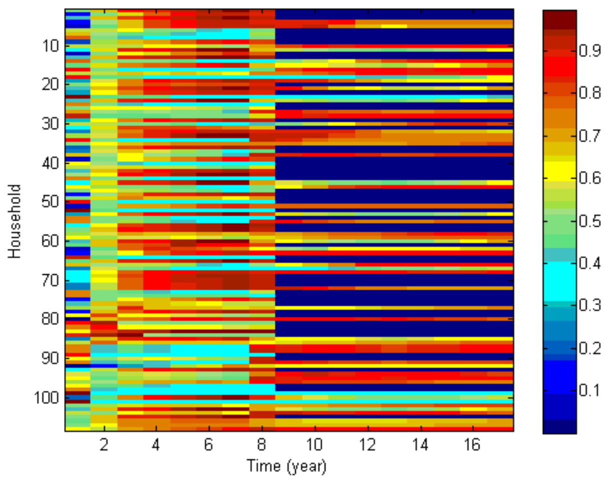

Figure 5: Individual farmers' effect of social emulation and cooperation together

5. Conclusions and future work

Our results suggest that whatever social mechanisms do get coca production low and stable in QQ they are not straight-forward to explain: social emulation and education policies slow coca production levels but are not enough to curb its otherwise inexorable rise. On the other hand, the artificially strong form of cooperation that we implemented in our model put an immediate break and stabilized coca production in short-term. Although unrealistic itself, this does suggest that some form of constraint may play a significant role. The overall effect of social emulation, cooperation and education policies is that they not only low down but also stabilize at least in short-term coca production levels. In general, this final result resembles the situation observed in the research area.

In addition, it is important to indicate that the model and results presented here are only exploratory and clearly more sophisticated models and deeper analyses are required. One significant factor unrepresented in our model, is the effect of Fairtrade certification, which places regulatory constraints on the farmers' organizations. Future refinements of the model should include a focus on such effects. They should also take account of data regarding the fluctuating local prices of the crops and perhaps a host of other biophysical dynamics, such as soil erosion, altitude, and the like.

Our results also suggest that greater knowledge of the community's structure and social networks are also of particular importance if we are to explain how QQ has thus far avoided a rising trend of coca production and the subsequent tragedy of the commons.

6. Acknowledgements

The paper was developed during the Complex Systems Summer School (Beijing, 2007), organized by the Santa Fe Institute of U.S. and the Institute of Theoretical Physics of China. We would like to acknowledge Dr. John Pepper, Dr. Lee Altenberg, Dr. Henry Wright, Dr. Han Zhangang, Dr. Marcus Feldman and Liu Wen Hui for useful comments and help in different parts of the paper. The data used in this paper is from Garcia-Yi's doctoral thesis (in progress), who has a DAAD scholarship. The elaboration of this paper was partially supported by the US National Science Foundation, via award OISE 0623953.

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