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Economic Analysis of Eradication and Alternative Crop Policies for Controlling Coca Supply in Colombia

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by

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Coca leaf is the primary input in cocaine production. Colombia is among the three largest coca producers and is the world's main supplier of cocaine. This thesis examines the interplay between the policies for controlling coca supply in Colombia: eradication (aerial spraying of coca) and a price support for alternative crops (coffee and cocoa) that compete for land allocation with coca. The study calibrates a multi-market partial equilibrium model to simulate different eradication and price support scenarios in order to assess farmers' response to policy changes.

The results suggest that an alternative crops policy alone holds little promise to significantly reduce coca production. A price support on individual crops has little effect on coca cultivation and coca production. There is a small gain in reducing coca cultivation by providing a simultaneous price support to coffee and cocoa. However, if peasant farmers seek to maximize profits, they would be lured to substitute more land between coffee and cocoa rather than taking away land from coca production.

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CHAPTER 1: INTRODUCTION

1.1 Statement of the Problem

Coca is the primary input in cocaine production. Colombia is among the three largest coca producers and is the world's main supplier of cocaine. The other top producers are Peru, and Bolivia (Dion & Russler, 2008; Lee & Clawson, 1993; Rolles, Murkin, Powell, Kushlick & Slater, 2010). Unlike Colombia where coca cultivation is primarily tied to cocaine processing (UNODC, 2014), Bolivia and Peru make a distinction between use of coca for cocaine production and use of coca in its natural state for culturally tied consumption, such as coca leaf chewing, tea, and medicine (Koops, 2009; UNODC, 2014).

Colombia is pursuing two policies in its campaign to discourage cocaine production. The first policy is to eradicate coca through manual destruction and aerial spray of herbicides over planted fields. The second policy is to provide farmers with economic incentives to abandon coca cultivation (Lee & Clawson, 1993; Veillette & Navarrete-Frías, 2005; Vargas, 2005).

Eradication through spraying has been the dominant anti-drug policy in the last three decades in Colombia (Vargas, 2005; Reyes, 2014). Although there has been considerable decline in the total area under coca cultivation, little of this reduction has been attributed to successful eradication policy alone. Rather a combination of factors including economic risk, violence, and alternative economic activities appear to make significant contributions. According to UNODC coca cultivation survey (2014), the area under coca decreased by almost a half: falling from 98,899 hectares (ha) in 2007 to

48,189 ha in 2013. Recently, however, coca cultivation increased in indigenous and Afro-Colombian communities, National Parks and protected areas. Although the trend at the national level shows a general reduction of coca cultivation, 31,641 ha of woodland were cleared as a direct result of new coca cultivation during the past two years. A large proportion of this area corresponds to primary woodland, largely concentrated in the Southern region of the country along the pacific coast and the borderlands with Ecuador.

Preponderance of evidence suggests that the eradication policy is doing more harm than good. Glyphosate is the active ingredient used in the herbicides sprayed over coca plants. Although some Colombian and American authorities have argued that aerial spray of glyphosate is harmless (Vargas, 2005); others argue that indiscriminate spraying of glyphosate in woodlands and biodiverse areas can produce long term effects on fauna and flora that cannot be predicted in the short run (Sherret, 2005). Moreover, indiscriminate aerial spraying of glyphosate destroys legal agriculture in the proximities to coca plantations (Bishop 2003; Ibanez & Martinsson, 2013). In addition to environmental costs, the policy has negative economic, social, political, and human consequences (Moreno-Sanchez, Kraybill & Thompson, 2003; Veillette & Navarrete-Frías, 2005; Vargas, 2004; Dion & Russler, 2008).

Peasant farmers respond to the risk of eradication in different ways. Some respond by planting coca more extensively (Moreno-Sanchez et al., 2003). Others either reduce or abandon coca production. These shifts in responses in coca cultivation result in higher coca prices, which in turn lure farmers to expand coca cultivation in other locations. Peasants also suffer from displacement as a result of eradication that wipes out indiscriminately their subsistence crops (Dion & Russler, 2008).

The policy to incentivize farmers to abandon coca cultivation in Colombia has been implemented in the last two decades (Lee & Clawson, 1993). This policy identifies legal crops to replace coca labor and income. This policy also provides physical and social infrastructure to improve other legal activities such as agricultural industrialization, building roads and bridges, assistance to develop export channels, and new schools (Lee & Clawson, 1993). Although this policy has historically received less support compared to eradication, it holds more promise because it gets to the root the coca problem (Vargas, 2005; Lee & Clawson, 1993). Moreover, empirical evidence suggests that alternative crops to coca production are generally more effective than eradication in reducing coca supply in the short run and the long run (Moreno-Sanchez et al. 2003; Ibanez & Carlsson, 2010; Tabares & Rosales, 2005). Nevertheless, alternative crops are less competitive in terms of land and labor requirements compared to coca. Coca is relatively more lucrative than most alternative crops, requires little care, can grow in poor quality soils, and produces several annual harvests (Lupu, 2004; Ibanez & Martinsson, 2013). Also, coca is a secure cash crop because it has a secure market and it exceeds the profitability of most alternative crops even under moderate price risks and aerial fumigation.

Nevertheless, the literature suggests that the policy of alternative crops can be designed towards successful long-term coca supply reduction. To begin with, coca growers are willing to adopt alternative crops in exchange for abandoning coca (Ibanez & Martinsson, 2013; Ibanez & Carlsson, 2010) but, given the heterogeneity of growers, different growers require different incentives to abandon coca (Ibanez & Martinsson, 2013). Coca cultivators prefer working in a legal environment. Also, an increase in state government presence in coca growing regions reduces significantly coca cultivation

(Dion & Russler, 2008). Although some coca peasant farmers have religious, moral, and political motivations to oppose coca cultivation, in many cases coca constitutes the only secure source of income to sustain a family in the rural area. In addition, violence and insurgent groups' influence promote an illegal environment providing economic incentives for farmers to grow and supply coca leaves to the system (Ibañez et al., 2013; UNODC, 2014; Dube & Varga, 2006; Holmes, Gutiérrez & Curtin, 2006).

Historically, periodic low prices of alternative crops have not produced sufficient profits and absorb enough labor in coca growing regions. Farmers abandoned traditional crop cultivation in periods of low prices. Comparative disadvantage, high transportation costs, low market appraisals for alternative agriculture, little government support, and insurgent groups' influence push farmers out of conventional crops into coca cultivation. Consequently, alternative crops alone cannot provide farmers with enough incentives to abandon coca cultivation. Evidence has shown that the threat of violence, economic risks, and the fall in the prices of legal crops increases economic incentives for farmers to switch to high-return illicit crops (Dube & Varga, 2006; Moreno-Sanchez et al., 2003; Ibañez et al., 2013). Completely eliminating coca cultivation is not possible under the threat of violence and extreme poverty (Ibañez et al., 2013; Moreno-Sanchez et al., 2003; Veillette & Navarrete-Frías, 2005).

In sum, it seems that the eradication policy has produced little real impact and in some cases the opposite impact in the objectives of reducing the area under coca cultivation, and with negative environmental consequences. The alternative crop policy has not been significantly more effective than the eradication policy. Although farmers are willing to switch to alternative crops, many are not able to switch because alternative crops are not profitable in many coca growing regions.

1.2 Objectives and Methodology

The objective of this thesis is to contribute to the understanding of the effectiveness of two policies: eradication and alternative crops to reduce the area under coca cultivation. I plan to do so by examining the interplay between the eradication policy and a price support policy for coffee and cocoa as alternative crops, competing for land allocation with coca under alternative scenarios of eradication. Coffee and cocoa are traditional crops broadly grown in Colombia. These two crops are among the most implemented alternative crops in crop substitution programs because of their large national and international market. Competition of these crops with coca for land allocation depends on different factors. The most important factors are crop prices and coca eradication levels. The higher the returns from alternative crops the more likely the area under coca cultivation and coca supply will decrease. Moreover, eradication also induces farmers to switch from coca to alternative crops. Understanding how alternative crops and coca cultivation interact under price supports and eradication allows assessment of the costs and benefits of the coca supply reduction policy.

The methodology used in this thesis is:

- Develop a multi-market partial equilibrium model that determines optimal land allocation between coca, coffee, and cocoa under price supports for coffee and cocoa.
- Calibrate the model to the current situation in Colombia using national data on national production and land allocation of coca and alternative crops.

- Simulate different eradication and price support scenarios.

1.3 Organization of the Study

The next chapter provides a general overview of coca cultivation and its causes and consequences in Colombia. Chapter 3 reviews the scholarly literature on Colombia's coca leaf supply reduction policies. Chapter 4 presents the multi-market equilibrium model. Chapter 5 calibrates and simulates the model under alternative combinations of eradication price support levels and consequent welfare impacts on farmers. Chapter 6 summarizes the results and draws policy implications.

CHAPTER 2: OVERVIEW OF COCA INDUSTRY AND RELATED POLICIES

2.1. The Coca Industry

Coca (*Erythroxylum sp.*) has been cultivated in the Peruvian, Bolivian, and Colombian Andes for more than one thousand years (Pacini & Franquemont, 1985; Dillehay, Rossen & Netherly, 1997; Martin, 1970), and it maintains cultural significance and use today. Unlike conventional crops, coca is a powerful symbol of cultural identity widely acknowledged in Peru and Bolivia (Pacini & Franquemont, 1985; Koops, 2009; Grisaffi, 2010). In Bolivia, ancestral use of coca leaf is protected by constitutional law as a natural and social symbol and cultural patrimony (Ledebur & Youngers, 2013). In Peru, cultural practices like coca chewing date pre-Inca time (Murphy & Boza, 2012). In Colombia, extensive coca cultivation is a recent phenomenon. Coca cultivation rose as an export crop during the crisis in the mid and late 1970s (Pacini & Franquemont, 1985, p. 89).

Besides cultural symbolism, coca cultivation also represents an economic alternative for many households in rural communities in the Andean countries. It has several advantages compared to other crops. First, it can grow and adapt in most places in tropical South America where other crops have little possibilities to grow. Second, it has little handling problems, which in turn can decrease costs of labor and transportation since the weight-to-price ratio is relatively high compared to other crops. Third, it is more lucrative than most other crops because its income cycle is permanent and has a secure market (Lee & Clawson, 1993; Lupu, 2004). In addition, illicit coca buyers are willing to buy coca at the farm gate (Lee & Clawson, 1993; Ibañez et al., 2013; UNODC, 2008).

Acknowledging the harmful side of coca, peasant farmers are willing to grow alternative crops. However, there is no real substitute for the coca crop. Thus, coca cultivation would represent a permanent alternative of income diversification for many households in the Andean Countries. Finding an attractive substitute for coca most likely requires government intervention, protection and marketing support for alternative crops.

In the Andean Countries, coca leaf is sold in both licit and illicit markets. Peasants harvest, dry, and sell coca leaf primarily to coca middlemen and in many cases retain small volumes for domestic traditional consumption (UNODC, 2008). Coca has been employed in licit industries like flavoring beverages (e.g. Coca-Cola) and for global pharmaceutical markets (Lee & Clawson, 1993). Pro-coca leaders have attempted to legitimate export of coca leaf as a conventional crop for tea and chewing (Koops, 2009). In the past, defenders of the coca legal market have seen coca leaf as an industrial crop, and they have proposed the exploitation of coca's legal market as an alternative to both eradication and substitution in controlling the supply for illicit markets. However, their assessment of the legal market's potential to absorb coca expansion appeared to be overoptimistic, even if some industrialized countries had permitted coca imports, (Lee & Clawson, 1993, p 19).

According to the agreements established in the United Nations Single Convention on Drugs and Narcotics signed in 1961 by Colombia Peru, and Bolivia, coca cultivation for illicit markets such as cocaine manufacturing is banned in all Andean countries. The use of coca is restricted to demonstrated and significant legal practices admissible by the Convention. The document established that "The Parties shall so far as possible enforce the uprooting of all coca bushes which grow wild. They shall destroy the coca bushes if illegally cultivated", and that "The Parties may permit the use of coca leaves for the preparation of a flavoring agent, which shall not contain any alkaloids, and, to the extent necessary for such use, may permit the production, import, export, trade in and possession of such leaves". However the Convention intended to progressively eliminate traditional uses in the implicated countries. The document states the following: "Coca leaf chewing must be abolished within twenty-five years from the coming into force of this Convention". Nevertheless, local governments continued in their struggle to legitimize and preserve licit coca cultivation. According to Ledebur and Youngers (2006), traditional coca growing zones in Bolivia have agreed with the government on the new anti-drug law to allow regulated cultivation of coca in certain areas to supply traditional local markets.

Despite the numerous efforts to condemn illicit coca trade, the coca industry has been dominated by the illicit market (Lee & Clawson, 1993). Unlike Peru and Bolivia, there is no significant legal market for coca leaf in Colombia, where coca cultivation has primarily served as a fuel for Colombia`s internal conflict. According to Angrist and Kugler (2008), coca cultivation has fueled Colombian internal conflict while generating few economic benefits for local residents (Angrist & Kugler, 2008, p. 192). Contrary to the general view, the coca industry does not seem to improve the standard of living in the coca growing regions (Morales, 1986; Kennedy, Reuter & Riley, 1993; Angrist & Kugler, 2008). According to Holmes and Gutierrez (2006), coca cultivation has no significant effects on the Colombian economy in comparison with its effect on political violence.

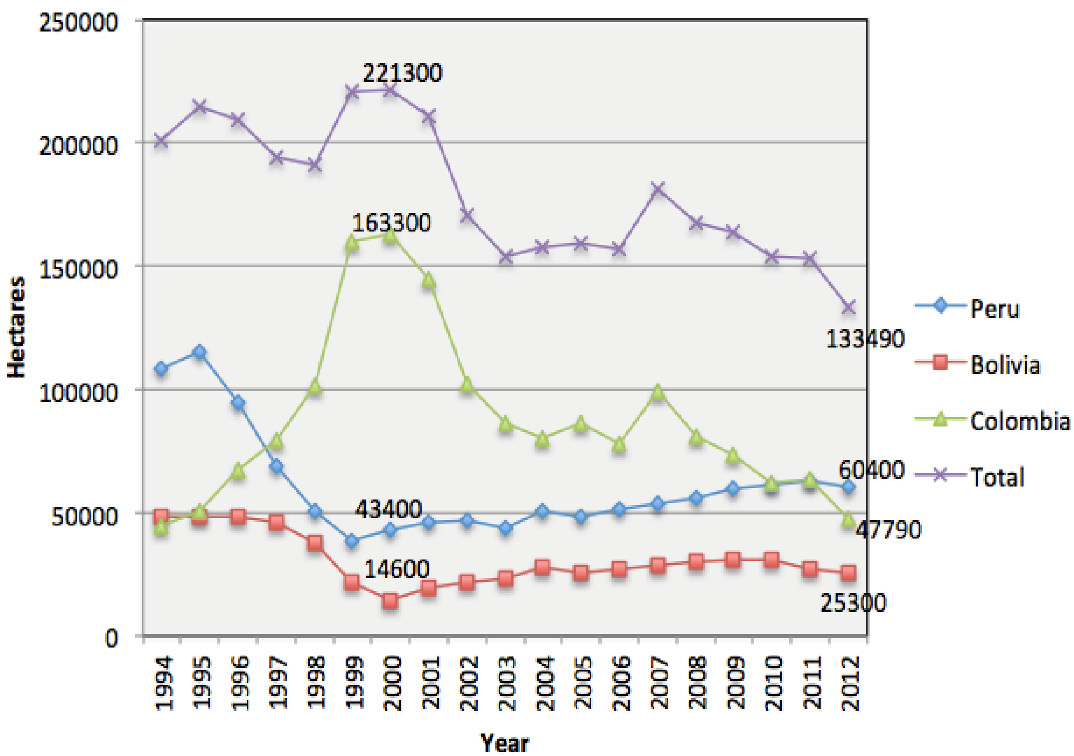
There appears to be an ambiguous relation between anti-drug policies and coca prices in determining coca supply. As UNODC (2008, p. 18) states, "prices for coca and derivatives in the illicit market do not necessarily react like market prices in the licit economy." Dube and Vargas (2006) also support this view claiming that coca prices alone are not a clear determinant of coca cultivation. Although total coca cultivation has decreased significantly in Colombia during the last five years, coca prices have been fairly constant in the same period moving from US$ 1.3/kg in 2009 to US$1.1/kg in 2013 (UNODC, 2014). Accordingly, other determinants of demand and supply may have a significant influence in the coca industry in Colombia. For instance, the high heterogeneity of producers can have a significant effect on decisions to cultivate coca (Ibanez & Martinsson, 2013). Unlike other countries, coca growers in Colombia participate in the illicit coca industry and carry out the transformation of the coca leaf to different degrees. According to UNODC estimations, in Colombia 63% of current coca producers sell dry coca leaf at the farm gate as is, 35% grow coca and process coca paste, and 2% grow coca and transform it into cocaine base.

The illicit coca industry is driven by the monopsony power of insurgency that controls coca growers and prices. They control production, processing, and export of cocaine and impose their own tax on other businesses and agricultural producers as a source of finance (Dube & Vargas, 2006, p. 7). Since the price of coca leaf that is paid to peasants represents only small proportion of the final product retail price (Morales, 1986, p. 158), cocaine traffickers hold a strong power to lure farmers to supply illicit coca by compensating farm-gate prices when effective anti-drug policies take place. According to UNODC estimates, the average price of harvested coca leaf for 2013 in Colombia was about 1.1 US$/kg compared to 2,521 US$/kg of final cocaine retail price in the country's main cities. They estimate that one metric ton of fresh coca leaf is required to produce on average 1.8 kg of cocaine base (81% pure cocaine alkaloid).

The illicit coca industry is largely interconnected across Colombian, Peruvian, and Bolivian borders. Although coca cultivation can decrease in one of the three neighboring countries, cultivation tends to increase in the counterparts' borders sometimes resulting in similar coca levels in the region (Moreno-Sanchez et al., 2003; Rolles et al., 2010). Consequently, effective coca reduction policies in Colombia will likely increase cultivation in Bolivia and Peru in the long run. According to Lee and Clawson (1993), during 1989 and 1992, the success of coca reduction policies in Bolivia was offset by expansion of coca cultivation in Peru (p. 19). Prior to early 1990s, Colombia imported and transformed into cocaine most of the coca leaf grown in the leading producing countries, Bolivia and Peru (UNODC, 2010). Afterward, however, the structure of the illicit coca industry in Colombia changed. By 1994 Colombia substituted most of the coca leaf imports from Bolivia and Peru with expansion of coca cultivation within its borders (Angrist & Kugler, 2008). By the late 1990s, eradication policies in Peru and Bolivia had generated a balloon effect that shifted most coca cultivation to Colombia, which in turn became the world's principal source of coca (Bishop, 2003). Indeed, while Colombia has almost always been the world's principal manufacturer and exporter of cocaine, extensive coca cultivation is fairly recent within its borders (Angrist & Kugler, 2008, p. 193).

Recent coca production trends reveal an overall decrease of about 39% in the Andean region between 2000 and 2012. This decrease has been significant because Peru and Bolivia have not completely offset Colombian supply reduction. Despite the overall regional reduction in coca cultivation, Bolivia and Peru significantly increased cultivation. While cultivation in Colombia decreased by 70% between 2000 and 2012, it increased by 39% in Peru and 73% in Bolivia during the same period (Figure 1).

Figure 1. Regional coca cultivation (hectares) 1994-2012



Source: UNODC.

Weak governance, poverty, and unemployment favor the consolidation of the illicit coca industry. Although peasants are not significantly improving their standard of living through coca cultivation (Kennedy et al., 1993; Morales, 1986, p. 158; Steiner, 1998), the coca industry represents the most attractive cash source in most of the coca growing regions. In Colombia, virtually all coca is cultivated in rural areas plagued by poverty and largely controlled by armed insurgent groups (Ibañez et al., 2013; UNODC 2014; Dube & Vargas, 2006; Holmes et al., 2006). Nevertheless, coca cultivation is more likely to occur in areas with moderate poverty index raging between 50 and 60 (Dion & Russler, 2008, p. 418). This assertion supports the idea that coca industry requires some levels of infrastructure and assets to operate.

It is very unlikely that coca cultivation will be eliminated in all South American Andes because of the large acceptability, income provision, historical significance, and the quasi-legal protection it embraces in certain countries. Although continuous efforts to defend ancestral use of coca are legitimate, separating illicit and licit markets is not a simple task. Governments have to compete with illicit industries to control and regulate coca supply in the efforts to discourage extensive coca cultivation. This task requires continuous monitoring, extensive cooperation, and government intervention. Perchance, governments can effectively affect illicit coca industries by constraining regional coca cultivation to certain levels. Given the miniscule proportion of cocaine alkaloid per coca leaf and the cost associated with its illicitness, illicit industry most likely requires significant supply levels to bring in profits. Therefore, traffickers could be willing to provide incentives for farmers to grow coca more extensively in exchange for protection and higher returns. In particular, cocaine traffickers could easily increase incentives like higher coca price at farm gate since the percentage of coca price compared to that of the final product is insignificant. In terms of long-term anti-drug policies, governments also need to take into consideration that coca bushes grow relatively fast. Consequently, preventing rapid expansion of coca cultivation requires continuous supervision, institutional support for legal agriculture, and cooperation of coca cultivators to reach agreements upon tolerable levels of coca cultivation for traditional non-drug purposes.

2.2. Related Policies

In their efforts to discourage coca cultivation, producing countries have implemented a so-called "*carrot* and *stick"* policy. The carrot is to incentivize farmers to abandon coca cultivation through economic incentives and investment in rural development infrastructure. The stick is to destroy coca crops through manual eradication and aerial spray of herbicides over planted fields (Lee & Clawson, 1993; Veillette & Navarrete-Frías, 2005; Vargas, 2005).

The carrot policy of crop substitution and alternative development was adopted in the Andean countries as an alternative policy to discourage coca cultivation. Governments undertook the programs supported by international assistance led by the United States Agency for International Development (USAID) (Lee & Clawson, 1993; United States General Accounting Office (GAO), 2003). As pointed out by Farrell (1998), this policy started in the 1970s as a crop substitution policy, turning into a broader alternative economic development approach in the 1990s. At first glance, crop substitution programs provided farmers with materials and technical support to adopt alternative crops and substitute income from illegal coca. However, the policy turned into a broader approach that embraced the development of social and physical infrastructure a long with agricultural support (Lee & Clawson, 1993; Tabares & Rosales, 2005).

Lee and Clawson (1993) identify five important elements of the alternative development approach. The first element is related to identifying and promoting crops that can provide reasonable income in replacement of coca. The second one involves strengthening the markets for these alternative crops. The third one involves industrialization and increase of value added processes. The fourth one includes developing social infrastructure such as schools, roads, clinics, and potable water. The fifth one encompasses promoting organizational development including cooperatives and other producers' association. However, the alternative development approach has failed occasionally in the pursuit of discouraging illicit coca cultivation. Sometimes the projects are not well planned or implemented. As pointed out by Lupu (2004), this approach has improved infrastructure in the past that indirectly benefited drug traffickers, also has implemented non-traditional alternative crops with little international market or deficient domestic capacity of absorption. Nonetheless, the continuity of this policy is often justified on the grounds that it is less punitive and far more politically acceptable than eradication in the coca producing countries (Farrell, 1998, p. 396).

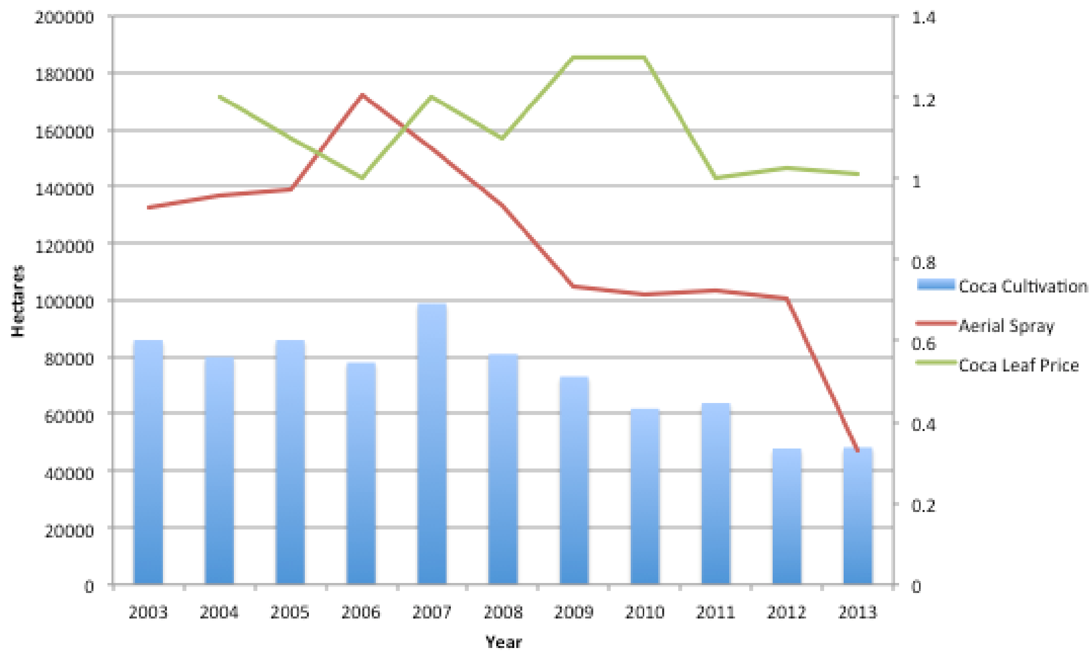
The stick policy has been designed to kill or lessen yields of cultivated coca fields. The eradication policy embraces two components, aerial spray of Glyphosate over planted fields and manual destruction of plants (UNODC, 2008). The two components may be implemented independently or together depending on the conditions that take place in particular areas. Conditions involve insurgent retaliation, financial costs, geographic access, community cooperation, and others.

Forced eradication has been institutionally promoted and supported by the United States authorities. This policy, however, besides its widely acknowledged futility represents a sensitive political issue (Andreas & Youngers, 1989; Ledebur & Youngers, 2006; Dion & Russler, 2008; Sherret, 2005; Ceballos, 2003). Forced eradication has historically been the predominant anti-drug policy although it largely ignores the causes of coca cultivation due to its punitive nature. According to Andreas and Youngers (1989), eradication policies in Bolivia received the most attention from the United States before 1989 spending about half of the anti-drug budget in eradication and only 3.6 % in crop substitution. In accordance, Reyes (2014) asserts that forced eradication in Colombia has received the great majority of funding and systematic evaluation compared to alternative methods of reducing coca production. Between 2000 and 2003, the United States provided more than $2.5 billion in assistance to the Colombian war on drug programs, which in turn was largely dedicated to militarization equipment and roughly 15% in alternative development programs (GAO, 2003).

It has been widely acknowledged that forced eradication far from directly affecting cocaine traffickers, predominantly targets the impoverished and most vulnerable segment of the population involved in the illicit coca trade (Andreas & Youngers, 1989; Reyes, 2014). Preponderance of evidence suggests that the eradication policy alone does not contribute to solving the coca cultivation problem. Instead, what is needed is larger investment in more promising approaches such as alternative development that inherently encompasses voluntary and negotiated eradication with peasants (Reyes, 2014; Moreno-Sanchez et al., 2003; Holmes et al., 2006, Dion & Russler, 2008).

The general tendencies in coca cultivation appear to indicate that aerial spray and coca cultivation hold a positive correlation. The trends suggest that when aerial spray is intensified coca cultivation increases rapidly. Likewise, when aerial spray is reduced less coca is cultivated (Figure 2). Although these trends show an incomplete picture of the complex relation between the two factors, they support the findings by Moreno-Sanchez et al. (2003) and Reyes (2014).

Figure 2. Aerial spray and coca cultivation in Colombia (hectares)



Data Source: UNODC.

In sum, the coca industry in South America requires making a clear distinction between cultivation for licit and illicit markets to design more effective anti-drug policies. These policies, however, will more likely require a deeper cooperative approach than a punitive one between producers and governments. Although neither policy has proven to a better solution per se, the relevance of each policy will depend on the purpose of coca cultivation. Cooperation holds more promise than punishment in generating long-term solutions. Building trust and economic development represent a key factor in war against drug trade.

CHAPTER 3: LITERATURE REVIEW

There has been a dearth of empirical research on coca cultivation and supply control policies. The available body of empirical research on coca cultivation has primarily addressed the effectiveness of the supply control policies. Most of the available empirical studies focus on the econometric analysis of eradication and alternative development. Little research is available on the behavioral responses of famers to the application of supply control policies.

Riley (1993) presents a dynamic general equilibrium that assesses the impact of voluntary and forced eradication, development assistance, and interdiction on the production and export of cocaine from Bolivia, Colombia, and Peru. His findings suggest that the policies of the source control programs are by themselves incapable of solving the national cocaine problem. According to his results, cocaine production defies regulation in the long run. In the short run, however, source country control programs can prove disruptive. He further suggests that such disruptions in conjunction with other elements of the national drug policy including treatment and prevention may be combined to yield progress toward national drug objectives. Kennedy, Reuter, and Riley (1993), build a simple general equilibrium model of the cocaine industry in Peru, Bolivia, and Colombia. Their model concludes that crop substitution programs to disrupt coca cultivation will have a negligible impact on the world cocaine market.

Most of the econometric studies on coca cultivation and supply control find little efficacy of eradication as an effective policy for controlling coca cultivation. Using United Nations data on annual coca cultivation in Colombia, Moreno-Sanchez et al. (2003) estimate an econometric model of Colombian coca cultivation for the period

1988-2001. They include farm-gate coca price, farm-gate price of plantain as alternative crop, coca eradication level, and area of coca cultivation in Bolivia and Peru to explain coca cultivation in Colombia. Their findings suggest that the coca eradication policy in Colombia does not reduce coca cultivation. On the contrary, they find that eradication increases total coca cultivated area after farmers compensate for the risk of eradication by planting more extensively. Also, they find that the price of plantain and the level of coca cultivation in neighboring countries are negatively correlated with coca cultivation in Colombia. Dion and Russler (2008), use a time series cross-sectional dataset of 32 sub-national departments to explain the determinants of coca cultivation in Colombia including aerial fumigation and traditional agriculture during the period 2001 and 2005. Their results suggest that eradication as the primary policy during the analyzed period had a small and marginal impact on coca cultivation. They find that the effects of aerial fumigation on total coca cultivation are not a direct result of fumigation on coca fields but rather a combination of side effects of fumigation; namely: violence, displacement and indiscriminate disruption of agriculture in coca growing regions.

Ibanez and Carlsson (2010), conduct a survey-based choice experiment on coca cultivation in Colombia. They use household level data from a hypothetical choice experiment to assess the effectiveness of eradication and alternative development on coca cultivation reduction. They account for monetary and non-monetary factors such as profitability of alternative crops, moral cost of cultivating coca, and compliance with the law, on farmers' land allocation decision. They find that increasing the risk of eradication and the relative profitability of alternative crops reduces the proportion of farmers and the area involved in coca cultivation. They conclude that a 1% increase in the risk of eradication decrease the area cultivated with coca in 0.66%, while 1% increase in relative profitability of alternative crops decrease the area cultivated with coca by 0.47%.

Ibanez and Matinsson (2013) assess farmers' behavioral responses implementing field experiments to mimic coca cultivation decisions Colombia. They evaluate the efficiency of carrot and stick policies to reduce coca cultivation when producers are heterogeneous in terms of risk and moral cost of cultivating coca and estimate their respective willingness to accept monetary compensation to stop coca cultivation. They find a considerable number of farmers with a high moral cost cultivating coca. According to their findings, about one third of participants in the experiment have a high moral cost and would require no compensation to stop cultivating coca. However, two fifths of the participants would require that the relative return of the legal activity were 1.8 times that of coca, or that the risk of eradication were above 60% to stop cultivating coca.

An econometric study by Reyes (2014) estimated the causal effect of coca forced eradication in Colombia. He analyzes a 6-year panel of municipality coca cultivation and eradication data. He uses an instrumental variable approach to account for the eradication endogeneity. He uses as an instruments the variation in expected coca eradication level relative to the distance that spraying aircrafts have to travel outside safety zones determined as 80 miles perimeter around their operation airports. Similar to most previous studies, his findings suggest that eradication increases coca cultivation. According to his results, a 1% increase in eradication increases the area cultivated with coca by 1%.

Based on the existing research, there seems to be little support to assert that the eradication policy alone can completely discourage coca cultivation. In this study, we contribute to the body of literature by developing a policy model that takes into account the intuition provided by the literature about the interplay of eradication and alternative crops to shift coca cultivation.

CHAPTER 4: ECONOMIC MODEL

4.1 Model Formulation

To examine the interplay between the eradication policy (aerial spray) and price support policy for coffee and cocoa as alternative crops competing for land allocation, I consider a three-commodity model with two legal commodities (coffee, cocoa) and one illicit commodity (coca). Each commodity uses land as the major factor to produce output that is sold in the national and international markets. Coffee and cocoa are widely cultivated across the country and they have a large international market that can absorb any increase in supply due to the domestic price support policy.

The respective production functions for the three crops are:

$$q_1 = A_1 \cdot l_1^{\alpha_1} \tag{1}$$

$$q_2 = A_2 \cdot l_2^{\alpha_2} \tag{2}$$

$$q_3 = A_3 \cdot \eta \cdot l_3^{\alpha_3} \tag{3}$$

where q_j, l_j, α_j, for $j = 1, 2,$ and $3,$ denote the output, the land input, and the elasticity of production for coffee, cocoa, and coca crops, respectively. The constants A_1, A_2, and A_3 capture all the other factors that shift the coca, cocoa, and coffee production functions.

The shifter η is a variable that measures the degree of effectiveness of spraying in shifting coca output. Specifically,

$$\eta = e^{-r\rho} \text{ with } r \geq 0\ \rho > 0 \tag{3a}$$

where $r = (\frac{l_\varepsilon}{l_3})$ is the ratio of total area sprayed to the area that remains cultivated with coca. Hence, as l_ε increases from zero (no eradication) relative to l_3, η increases from one (no effect of output) towards zero (total eradication of output). The parameter ρ captures farmers' production response to eradication. Lower values of ρ diminish the effectiveness of spraying as farmers internalize the eradication factor by cultivating coca more extensively or by intercropping (planting different crops in a field) to minimize the damage of aerial spray (Moreno-Sanchez et al., 2003). Planting more extensively, however, does not necessarily translate into higher yields per hectare. Thus, it is assumed that while the area cultivated with coca will remain relatively steady after aerial spray, the overall coca production will decrease because of extensive cultivation, replanting or intercropping.

The equations for the three crops supply of land are:

$$l_1 = S_1 \cdot w_1^{\beta_1} \tag{4}$$

$$l_2 = S_2 \cdot w_2^{\beta_2} \tag{5}$$

$$l_3 = S_3 \cdot w_3^{\beta_3} \tag{6}$$

where l_j represent the total land cultivated for each crop; S_j is a supply shifter; w_j is the value of land; and β_j is the price elasticity of land supply for the *jth* crop.

Assuming that farmers maximize profits from the three crops, subject to a fixed total land area, i.e.,

$$MAX\,\pi = p_1 A_1 l_1^{\alpha_1} + p_2 A_2 l_2^{\alpha_2} + p_3 A_3 e^{-\frac{l_\varepsilon}{l_3}\rho} l_3^{\alpha_3} - l_1 w_1 - l_2 w_2 - l_3 w_3 - F$$

Subject to $L_T = l_1 + l_2 + l_3$

where p_j is the output price for jth crop, and L_T is total area, z represents the Lagrangian multiplier, and F is fixed cost. The profit-maximizing land areas planted for each crop can be determined from the following first-order conditions:

$$\alpha_1 p_1 A_1 l_1^{\alpha_1 - 1} - z = w_1 \tag{7}$$

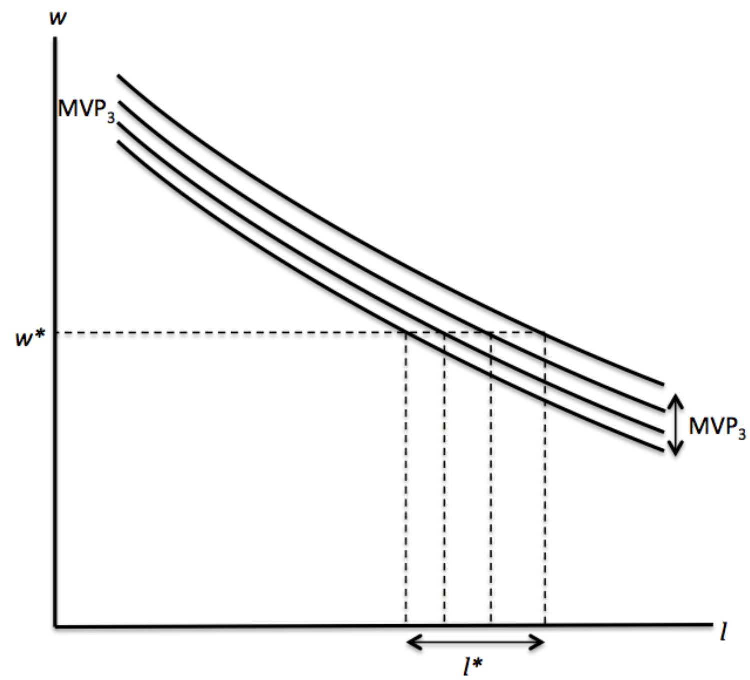
$$\alpha_2 p_2 A_2 l_2^{\alpha_2 - 1} - z = w_2 \tag{8}$$

$$\alpha_3 l_3^{\alpha_3 - 1} p_3 A_3 e^{-(\frac{l_\varepsilon}{l_3})\rho} + p_3 A_3 e^{-\left(\frac{l_\varepsilon}{l_3}\right)\rho} l_3^{\alpha_3} \left(\frac{l_\varepsilon}{l_3^2}\right) \rho - z = w_3 \tag{9}$$

These conditions imply that farmers will use land for each crop up to the point where the marginal value product of land in each crop is equal to the price of land devoted to that crop. These conditions also imply that the demand curve for the land factor is negatively sloped. Therefore, all else equal, more land is used for production as its price declines. Also, farmers will adjust output and land input seeking to maximize their profit when the equilibrium circumstances change. Because it is assumed that land can be freely substituted between each crop, the opportunity cost of land and profits determine the amount of land that is allocated to each crop and the output that is produced assuming that other factors of production remain constant. Introducing an output price change for one crop will cause substitution of land between these activities to adjust the change in profits. Similarly, shifting the output restriction caused by the eradication factor will shift the coca demand for land because of change in profit from this activity.

The eradication factor in coca production shifts the input factor demand curve as described in Figure 3. At a certain input price, the total area of land demanded for coca changes in relation to the level of eradication that affects output. Assuming that eradication can significantly affect coca output, the shift in demand for the land factor will depend on how output price changes with respect to quantity of coca supplied given output demand.

Figure 3. Input factor demand shift due to eradication in coca



Output demand of each crop is assumed to be in constant elasticity form:

$$q_1 = D_1 \cdot p_1^{\gamma_1} \tag{10}$$

$$q_2 = D_2 \cdot p_2^{\gamma_2} \tag{11}$$

$$q_3 = D_3 \cdot p_3^{\gamma_3} \tag{12}$$

where q_j represents the total demand for each crop, D_j is a scalar that represents all other factors that shift final demand; p_j represents the domestic price for each crop; γ_j represents the price elasticity of demand, all assumed to be negative.

Given values for the constants A_j, S_j, D_j, for $j=1,2,3$; α_j, β_j, γ_j, for $j=1,2,3$; and the area subjected to eradication, l_ε, the system of equations 1-12 can be solved for the equilibrium values of the 13 endogenous variables p_j, w_j, q_j, l_j and z, for $j=1,2,3$. The effect of price supports for coffee and cocoa on the supply of coca under alternative eradication levels can be simulated by treating p_1, p_2, as parameters and assuming different levels of sprayed area l_ε.

4.2 Model Calibration

Model calibration is performed in two steps. The first step generates the values for the constants A_j (equations 1-3), S_j (equations 4-6), D_j (equations 10-12) for $j=1,2,3$ by using exogenous estimates of elasticities, α_j, β_j, γ_j, for $j=1,2,3$, and observed prices and quantities in 2013. The observed quantity and price data are presented in Table 1.

I use the elasticities available in the literature for the price elasticities of demand for coffee and cocoa. The price elasticity of demand for coffee ranges from -0.2 to -0.4 (Feuerstain, 2002; Bettendorf & Verboven, 2000; Durevall, 2005; Mehta & Chavas, 2008). The price elasticity of demand for cocoa is reported approximately -0.3 (Gilbert, 2012). Therefore this study uses -0.3 for price elasticity of demand for coffee and cocoa. The rest of the elasticities are assumed to be similar to those of neighboring countries, assigned arbitrary but reasonable values, or simulated over a range of values. The elasticity of production with respect to land is taken to be similar to that of Brazil. Avila and Evenson, (1995) report land and structures production elasticity for Brazil of 0.22. Also, the USDA Economic Research Service reports land production elasticity for Brazil of 0.2.[1] I use 0.2 as the elasticity of production with respect to land for Colombia. The land supply elasticity is assumed to be 0.5, a reasonable assumption for a scarce factor like land.

[1] Trindade and Fulginiti (2015) calculate 0.1 as the average land productivity factor for South America.

Table 1. National data and sources (2013)

Parameter	Source	Amount
Domestic Area of Coca	UNODC, 2014	48189 (Hectares)
Aerial Spray (Coca Eradication)	UNODC, 2014	47053 (Hectares)
Domestic Area of Coffee	AGRONET	771731 (Hectares)
Domestic Area of Cocoa	AGRONET	151930 (Hectares)
Domestic Price of Coca	UNODC, 2014	1100 ($/Ton)
Domestic Price of Coffee	International Coffee Organization	2500 ($/Ton)
Domestic Price of Cocoa	FEDECACAO	2100 ($/Ton)
Domestic Output of Coca	UNODC, 2014	229497 (Tons)
Domestic Output of Coffee	AGRONET	653160 (Tons)
Domestic Output of Cocoa	AGRONET	79686 (Tons)

Using the above elasticities and data in Table 1, model calibration is conducted under three different assumptions about elasticity values. :

- **Assumption 1:** α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3

All land production elasticities are assumed to be 0.2, land supply elasticities to be 0.5, and the output demand elasticities to be -0.3.

- **Assumption 2:** α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1

Because coca cultivation is illicit, land supply elasticity for this activity is likely to be more inelastic than other crops. Also, because prices and demand for coca leaf are controlled entirely by the Colombian armed insurgents and drug cartels, the price elasticity of demand for coca is difficult to approximate. It is assumed that the elasticity of demand for coca is very inelastic because of its illicit nature. This scenario assumes a price elasticity of demand for coca that is more inelastic than that of coffee and cocoa.

- **Assumption 3**: α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5

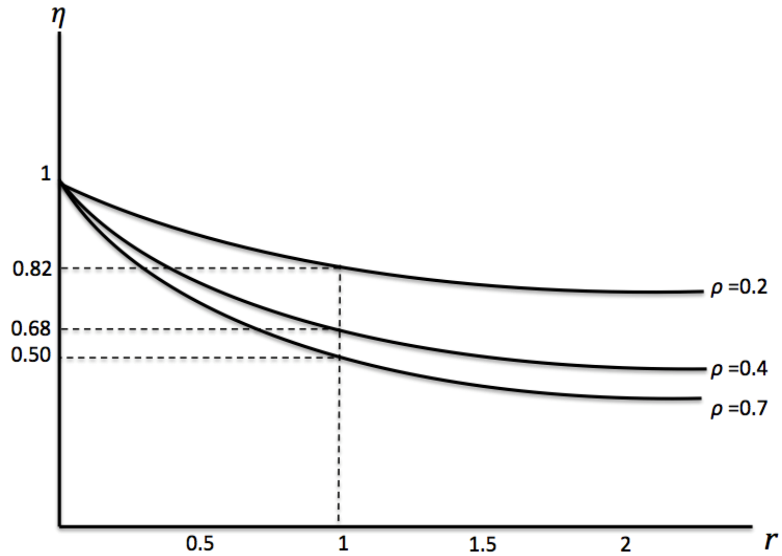
This assumption is the same as assumption 2 except that the demand for coca is assumed to be more elastic than the demand for coffee and cacao.

The parameter ρ in equation 3a is simulated over a range of values. The parameter summarizes farmers' response to eradication. A low (high) value for ρ is interpreted as low (high) effectiveness of the eradication policy because of farmers respond to eradication by expanding (reducing) the land area devoted to coca cultivation, intercropping, replanting, etc. Alternative values for ρ result in alternative levels of η, which, as shown in equation 3a, shifts the production function for coca. The assumed values for ρ and the resulting estimates for η using equation 3a are shown numerically in Table 2 and graphically in Figure 4.

Table 2. Values of η under alternative assumptions of ρ and r (2013)

ρ	l_3	l_e	r	η
0.2	48189	47053	0.976	0.82260
0.4	48189	47053	0.976	0.67667
0.7	48189	47053	0.976	0.50485

Figure 4. Behavior of *η* under alternative assumptions of *ρ* and *r*



When, for example, the ratio of area affected by eradication (48189) to land that remains on cultivation (47053) is 0.97, the production shifts by 0.82, 0.68, or 0.50 as ρ decreases from 0.2 to 0.7. In other words, as ρ gets larger, eradication becomes less effective. Similarly, as the ratio r (example from r=1 to r=2) becomes larger the shift in coca production function becomes smaller. For different regions with different ρ, the same ratio of eradication r can have a different effect on coca output depending on the farmers' response. Since each value of ρ calibrates a different value for production shifter A_3, eliminating eradication will shift coca production differently.

The calibrated values for A_j, (equations 1-3) S_j (equations 4-6), D_j (equations 10-12) for $j=1,2,3,$ and associated equilibrium prices and quantities for the three assumptions are given in Tables 3, 4, and 5. The equilibrium prices and quantities will be used as benchmarks for comparing the equilibrium prices and quantities induced by the policy scenarios considered in the next section.

Table 3. Calibrated constants and equilibrium quantities and prices: Assumption 1

Variables	Coefficients		
	ρ=0.2	*ρ=0.4*	*ρ=0.7*
A_1	43403.66	43403.66	43403.66
A_2	7329.15	7329.15	7329.15
A_3	32284.85	39247.32	52604.99
D_1	6829699.30	6829699.30	6829699.30
D_2	790765.69	790765.69	790765.69
D_3	1875835.79	1875835.79	1875835.79
S_1	37514.93	37514.93	37514.93
S_2	10236.46	10236.46	10236.46
S_3	1058.97	866.366	708.328
η	0.82260	0.67667	0.50485
l_1	771731.1	771731.1	771731.8
l_2	151930	151930	151930.3
l_3	48189.1	48189	48188.9
w_1	423.2	423.2	423.2
w_2	220.3	220.3	220.3
w_3	2070.8	3093.8	4628.3
q_1	653160	653160	653160.1
q_2	79686.1	79686.1	79686.1
q_3	229497.1	229496.8	229497.9
p_1	2500	2500	2500.0
p_2	2100	2100	2100.0
p_3	1100.0	1100	1100

Table 4. Calibrated constants and equilibrium quantities and prices: Assumption 2

Variables	Coefficients		
	ρ=0.2	ρ=0.4	ρ=0.7
A_1	43403.66	43403.66	43403.66
A_2	7329.15	7329.15	7329.15
A_3	32284.85	39247.32	52604.99
D_1	6829699.30	6829699.30	6829699.30
D_2	790765.69	790765.69	790765.69
D_3	462291.90	462291.90	462291.90
S_1	37514.93	37514.93	37514.93
S_2	10236.46	10236.46	10236.46
S_3	22456.12	21572.40	20720.74
η	0.82260	0.67667	0.50485
l_1	771731.8	771731.7	771731.9
l_2	151930.2	151930.2	151930.3
l_3	48189	48189	48188.9
w_1	423.2	423.2	423.2
w_2	220.3	220.3	220.3
w_3	2070.8	3093.8	4628.2
q_1	653160.1	653160.1	653160.1
q_2	79686.1	79686.1	79686.1
q_3	229497	229496.8	229497.9
p_1	2500	2500	2500
p_2	2100	2100	2100
p_3	1100	1100	1100

Table 5. Calibrated constants and equilibrium quantities and prices: Assumption 3

Variables	Coefficients		
	ρ=0.2	ρ=0.4	ρ=0.7
A_1	43403.66	43403.66	43403.66
A_2	7329.15	7329.15	7329.15
A_3	32284.85	39247.32	52604.99
D_1	6829699.30	6829699.30	6829699.30
D_2	790765.69	790765.69	790765.69
D_3	7611554.40	7611554.40	7611554.40
S_1	37514.93	37514.93	37514.93
S_2	10236.46	10236.46	10236.46
S_3	22456.12	21572.40	20720.74
η	0.82260	0.67667	0.50485
l_1	771731.8	771731.8	771731.8
l_2	151930.2	151930.2	151930.2
l_3	48189	48189	48189
w_1	423.2	423.2	423.2
w_2	220.3	220.3	220.3
w_3	2070.8	3093.8	4628.3
q_1	653160.1	653160.1	653160.1
q_2	79686.1	79686.1	79686.1
q_3	229497	229496.7	229498.0
p_1	2500	2500	2500
p_2	2100	2100	2100
p_3	1100	1100	1100

4.3 Model Simulations

In this section I simulate 4 policy scenarios:

1) **No eradication (η=1)**

For this scenario, I set the level of eradication l_ε=0. The no eradication scenario shifts the production function of coca upward by different degrees depending on the effectiveness of eradication determined by the hypothesized values of ρ and the assumed elasticities.

2) **A price support for coffee equivalent to a 10% increase from the benchmark equilibrium price of coffee with and without eradication**

For this scenario I increase the price of coffee by 10%. I also increase the benchmark equilibrium price of coffee by 10% and simultaneously eliminate eradication exogenously (l_ε=0). This shock generates different outcomes for coca production that are determined by the hypothesized values of ρ and the assumed elasticities.

3) **A price support for cocoa equivalent to a 10% increase in the benchmark equilibrium price of cocoa with and without eradication**

For this scenario I increase the price of cocoa by 10%. I also increase the benchmark equilibrium price of cocoa by 10% and simultaneously eliminate eradication exogenously (l_ε=0). This scenario generates different outcomes for coca production that are determined by the hypothesized values of ρ and the assumed elasticities.

4) **Scenarios 2 and 3 combined**

4.3.1 Simulation Results and Discussion

- **Scenario one: No eradication (l_ε=0, η=1)**

Using the hypothesized values of ρ and elasticity assumptions 1, 2, and 3, Tables 6, 7, and 8 display the respective equilibrium prices and quantities with no eradication followed by percent changes in the price and quantities relative to their benchmark values.

Table 6. No eradication: Assumption 1

Equilibrium Variables	α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3, η=1					
	ρ=0.2		ρ=0.4		ρ=0.7	
	Value	Δ%	Value	Δ%	Value	Δ%
l_1	781377.6	1.2	786844.3	2.0	792087.2	2.6
l_2	155587.2	2.4	157666.7	3.8	159664.7	5.1
l_3	34885.4	-27.6	27339.1	-43.3	20099.2	-58.3
w_1	433.8	2.5	439.9	3.9	445.8	5.3
w_2	231	4.9	237.2	7.7	243.3	10.4
w_3	1085.2	-47.6	995.8	-67.8	805.2	-82.6
q_1	654784.7	0.2	655698.4	0.4	656569.9	0.5
q_2	80066	0.5	80278.9	0.7	80481.4	1.0
q_3	261533.6	14.0	302807.6	31.9	381647.6	66.3
p_1	2479.4	-0.8	2467.9	-1.3	2457	-1.7
p_2	2067	-1.6	2048.7	-2.4	2031.6	-3.3
p_3	711.6	-35.3	436.6	-60.3	201.9	-81.6

Table 7. No eradication: Assumption 2

Equilibrium Variables	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1, η=1					
	$\rho=0.2$		$\rho=0.4$		$\rho=0.7$	
	Value	Δ%	Value	Δ%	Value	Δ%
l_1	777712.6	0.8	781868.4	1.3	785266.1	1.8
l_2	154195.7	1.5	155773.7	2.5	157065.9	3.4
l_3	39942.6	-17.1	34208.9	-29.0	29519	-38.7
w_1	429.8	1.6	434.4	2.6	438.2	3.5
w_2	226.9	3.0	231.6	5.1	235.4	6.9
w_3	317	-84.7	100.6	-96.7	34.4	-99.3
q_1	654169.3	0.2	654867	0.3	655435.1	0.3
q_2	79922.3	0.3	80085.2	0.5	80217.7	0.7
q_3	268711.4	17.1	316692.5	38.0	412142.4	79.6
p_1	2487.2	-0.5	2478.3	-0.9	2471.2	-1.2
p_2	2079.4	-1.0	2065.3	-1.7	2054	-2.2
p_3	227.1	-79.4	43.9	-96.0	3.2	-99.7

Table 8. No eradication: Assumption 3

Equilibrium Variables	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5, η=1					
	$\rho=0.2$		$\rho=0.4$		$\rho=0.7$	
	Value	Δ%	Value	Δ%	Value	Δ%
l_1	774348.4	0.3	776013.6	0.6	777840.9	0.8
l_2	152920.5	0.7	153551.5	1.1	154244.4	1.5
l_3	44582.1	-7.5	42285.9	-12.2	39765.7	-17.5
w_1	426.1	0.7	427.9	1.1	429.9	1.6
w_2	223.2	1.3	225	2.1	227	3.0
w_3	951.2	-54.1	837.5	-72.9	677.7	-85.4
q_1	653602.4	0.1	653883.3	0.1	654190.9	0.2
q_2	79789.7	0.1	79855.4	0.2	79927.4	0.3
q_3	274682.5	19.7	330406.9	44.0	437450.2	90.6
p_1	2494.4	-0.2	2490.8	-0.4	2486.9	-0.5
p_2	2090.9	-0.4	2085.2	-0.7	2078.9	-1.0
p_3	767.9	-30.2	530.7	-51.8	302.8	-72.5

Under the no-eradication policy, Tables 6, 7, and 8 show that when ρ=0.2, the area cultivated with coca decreases from 7.5% to 27% and output increases from 14% to 19.7%. When ρ=0.4, the area cultivated with coca decreases from 12.2% to 43.3% and output increases 31.9% to 44%. When ρ=0.7, the area cultivated with coca decreases from 17.5% to 58.3% and output increases from 66.3% to 90.6%. The magnitudes of the ranges are driven by the assumed elasticities. Results in Table 6 assume the values of each triplet of elasticities are the same. Results in Table 7 assume the same elasticities as in Table 6, except that the price elasticities of supply and demand for coca are more inelastic elasticities for coffee and cocoa. Results in Table 9 assume the values as Table 8, except the price elasticity of demand for coca is less inelastic that the corresponding elasticities for coffee and cocoa.

In all three cases, output increases even though the area cultivated with coca declines indicating higher yields per hectare and farmers intensifying coca cultivation per the area. Both the respective areas and outputs for coffee and cocoa increase, but the increase is very small in magnitude relative to the changes in coca. Using the assumptions of Table 6, coca cultivation decreases by a larger amount and coca output increases by a smaller amount than when using the assumptions of Tablets 7 and 8. Also, the magnitude of the percentage change is larger for coca output and smaller for coca cultivation when assuming the elasticities of Table 8 than when using the assumptions of Table 7.

The results imply that due to the illicit nature of coca cultivation, peasant farmers compensate for the punishment of aerial spray by intercropping, planting expansively, replanting, and implementing other strategies that minimize the damage of aerial spray of herbicide over coca plantations. This response suggests that coca eradication affects agricultural productivity because it affects legal crops and farmers' initial land allocation. In the absence of eradication, there would be a small increase in production and area cultivated for alternative crops relative to equilibrium.

In the absence of accurate elasticities and ρ values, I assumed different values that cause a large variability in the results. However, the large drop in coca price p_3 when ρ is greater than 0.2 may suggest that ρ is more likely to be small. Historically, coca prices have not changed dramatically when eradication changes significantly relative to area cultivated (Figure 2).

- **Scenario two: A 10% increase in the price of coffee**

The partial effects of an exogenous 10% increase in the benchmark equilibrium price of coffee with and without eradication of coca (l_ε=0) are summarized in Tables 9, 10, and 11 using assumptions 1, 2, and 3 about the elasticities.

Under a price support policy for coffee, with eradication, the results show that when ρ=0.2 and ρ=0.4, coca output and area under coca cultivation decreases by less than 1%. With no eradication, the results show that when ρ=0.4 the area cultivated with coca decreases from 7.8% to 27.3% and output increases from 13.7% to 19.6%. When ρ=0.4, the area cultivated with coca decreases from 12.6% to 40.6% and output increases 29.2% to 43.9%. When ρ=0.7, the area cultivated with coca decreases from 17.9% to 58.8% and output increases from 65.9% to 90.4%.

Table 9. Effect of a 10% price support for coffee: Assumption 1

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3						α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3, η=1					
	$\rho=0.2$ η=0.82	Δ%	$\rho=0.4$ η=0.68	Δ%	$\rho=0.7$ η=0.50	Δ%	$\rho=0.2$	Δ%	$\rho=0.4$	Δ%	$\rho=0.7$	Δ%
L_1	778227.7	0.8	778176.5	0.8	778145.1	0.8	788380.8	2.2	794203.2	2.9	799696	3.6
L_2	145621.3	-4.2	145605.6	-4.2	145595.9	-4.2	148767	-2.1	150590.6	-0.9	152323.3	0.3
L_3	48001.2	-0.4	48068	-0.3	48110	-0.2	33918.3	-27.3	27056.3	-40.6	19831.7	-58.8
W_1	430.3	1.7	430.3	1.7	430.2	1.7	441.6	4.3	448.2	5.9	454.4	7.4
W_2	202.4	-8.1	202.3	-8.2	202.3	-8.2	211.2	-4.1	216.4	-1.8	221.4	0.5
W_3	2054.6	-0.8	3078.3	-0.5	4613.2	-0.3	1025.9	-48.8	975.3	-33.2	783.9	-83.1
Q_1	654256	0.2	654247.4	0.2	654242.1	0.2	655954.3	0.4	656920.3	0.6	657826.5	0.7
Q_2	79013	-0.8	79011.3	-0.8	79010.3	-0.8	79351.5	-0.4	79545.1	-0.2	79727.3	0.1
Q_3	229317.8	-0.1	229381.4	-0.1	229422.7	0.0	267414.1	13.7	302178.6	29.2	380626.4	65.9
P_2	2160.2	2.9	2160.4	2.9	2160.5	2.9	2129.7	1.4	2112.4	0.6	2096.4	-0.2
P_3	1102.9	0.3	1101.8	0.2	1101.2	0.1	660.7	-34.8	439.6	-52.2	203.7	-81.5
z	32.1		32.1		32.2		15.8		6.7		-2.0	

Table 10. Effect of a 10% price support for coffee: Assumption 2

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	Δ%	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	778127.9	0.8	778113.2	0.8	778103.7	0.8	784643.2	1.7	789532.5	2.3	795331.8	3.1
L_2	145590.6	-4.2	145586.1	-4.2	145583.2	-4.2	147603.9	-2.8	149126.6	-1.8	150945.6	-0.6
L_3	48132.4	-0.1	48151.7	-0.1	48164.1	-0.1	39603.9	-17.8	33191.9	-31.1	25573.6	-46.9
W_1	430.2	1.7	430.2	1.7	430.2	1.7	437.5	3.4	442.9	4.7	449.5	6.2
W_2	202.3	-8.2	202.3	-8.2	202.3	-8.2	207.9	-5.6	212.2	-3.7	217.4	-1.3
W_3	2046.6	-1.2	3069.9	-0.8	4604.5	-0.5	291.1	-85.9	74.4	-64.5	8.2	-99.8
Q_1	654239.2	0.2	654236.7	0.2	654235.1	0.2	655331.1	0.3	656145.8	0.5	657106.9	0.6
Q_2	79009.7	-0.8	79009.2	-0.8	79008.9	-0.8	79227	-0.6	79389.8	-0.4	79582.5	-0.1
Q_3	229443.1	0.0	229461.2	0.0	229474.3	0.0	268254.1	16.9	314786.8	37.2	400484.1	74.5
P_2	2160.5	2.9	2160.6	2.9	2160.6	2.9	2140.8	1.9	2126.2	1.2	2109.1	0.4
P_3	1102.6	0.2	1101.7	0.2	1101.1	0.1	231	-79.0	46.7	-95.8	4.2	-99.6
z	32.2		32.2		32.2		21.9		14.2		5.0	

Table 11. Effect of a 10% price support for coffee: Assumption 3

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	Δ%	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	778133.9	0.8	778117.1	0.8	778106.2	0.8	780947.9	1.2	782711.5	1.4	784656.2	1.7
L_2	145592.5	-4.2	145587.3	-4.2	145583.9	-4.2	146459.7	-3.6	147005	-3.2	147607.9	-2.8
L_3	48124.6	-0.1	48146.5	-0.1	48160.9	-0.1	44443.5	-7.8	42134.5	-12.6	39586.9	-17.9
W_1	430.2	1.7	430.2	1.7	430.2	1.7	433.3	2.4	435.3	2.9	437.5	3.4
W_2	202.3	-8.2	202.3	-8.2	202.3	-8.2	204.7	-7.1	206.2	-6.4	207.9	-5.6
W_3	2043.3	-1.3	3066.7	-0.9	4601.4	-0.6	922	-55.5	808	-40.8	647.8	-86.0
Q_1	654240.2	0.2	654237.4	0.2	654235.5	0.2	654712.7	0.2	655008.1	0.3	655333.3	0.3
Q_2	79009.9	-0.8	79009.3	-0.8	79009	-0.8	79103.8	-0.7	79162.6	-0.7	79227.4	-0.6
Q_3	229435.7	0.0	229456.3	0.0	229471.2	0.0	274511.4	19.6	330169.9	43.9	437056.2	90.4
P_2	2160.5	2.9	2160.6	2.9	2160.6	2.9	2152	2.5	2146.6	2.2	2140.8	1.9
P_3	1100.6	0.1	1100.4	0.0	1100.2	0.0	768.8	-30.1	531.5	-51.7	303.3	-72.4
z	32.2		32.2		32.2		27.7		25.0		21.9	

The magnitudes of the ranges across the values of ρ are driven by the assumed elasticities as follows: Table 9 assumes the values of each triplet of elasticities are the same. Table 10 assumes the same elasticities as in Table 9, except that the price elasticities of supply and demand for coca are more inelastic elasticities for coffee and cocoa. Results in Table 11 assume the values as Table 10, except the price elasticity of demand for coca is less inelastic that the corresponding elasticities for coffee and cocoa.

In all cases when eradication is eliminated while simultaneously providing a price support for coffee, coca output increases even though the area cultivated with coca declines indicating higher yields per hectare and farmers intensifying coca cultivation. The outcome of providing a 10% price support for coffee while simultaneously eliminating eradication is not substantially different from the outcome of eliminating eradication alone discussed in scenario one. A 10% price support for coffee holds little promise to control coca supply from shifting upward if eradication is eliminated at the same time.

Using the assumptions of Table 9 and no eradication, coca cultivation decreases by a larger amount and coca output increases by a smaller amount than when using the assumptions of Tables 10 and 11. Also, the magnitude of the percentage change is larger for coca output and smaller for coca cultivation when assuming the elasticities of Table 11 than when using the assumptions of Table 10.

The effect of a price support for coffee is larger on cocoa than on coca. A 10% price support for coffee decreases cocoa production by 8% relative to the benchmark equilibrium (with eradication) regardless of the values of ρ and assumed elasticities. An increase in the price of coffee with no eradication changes cocoa output from -0.7% to +1% depending on the hypothesized ρ values and the assumed elasticities.

Initial farmers' land allocation changes after a price support for coffee luring them to reallocate more land between coffee and cocoa than between coffee and coca. The Lagrangian multiplier indicates that the marginal profit generated by adding one hectare of land is about 32 dollars with eradication. The marginal profit of additional hectare of land decreases with no eradication due to gain in coca productivity and yields per hectare.

- **Scenario three: A 10% increase in the price of cocoa**

The partials effect of an exogenous 10% increase in the benchmark equilibrium price of cocoa with and without eradication of coca (l_{ε}=0) are summarized in Tables 12, 13, and 14 using assumptions 1, 2, and 3 about the elasticities.

Under a price support policy for cocoa, I again consider two alternatives: 1) with eradication and 2) no eradication. Under eradication, the results indicate that coca output does not decrease and the area under coca cultivation decreases by less than 0.1% for all the hypothesized values of ρ. Under no eradication, the results show that when ρ=0.2, the area cultivated with coca decreases from 7.5% to 27.8% and output increases from 13.9% to 19.7%. When ρ=0.4, the area cultivated with coca decreases from 12.3% to 43.4% and output increases 31.9% to 43.9%. When ρ=0.7, the area cultivated with coca decreases from 17.6% to 58.4% and output increases from 66.2% to 90.6%.

Table 12. Effect of a 10% price increase for cocoa: Assumption 1

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3						α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	768139.4	-0.5	768129.6	-0.5	768124.1	-0.5	777323.3	0.7	782529.8	1.4	787538	2.0
L_2	155561.8	2.4	155557.3	2.4	155554.8	2.4	159713.2	5.1	162046.4	6.7	164276.7	8.1
L_3	48149	-0.1	48163.2	-0.1	48172	0.0	34813.7	-27.8	27273.8	-43.4	20036.3	-58.4
W_1	419.2	-0.9	419.2	-0.9	419.2	-0.9	429.3	1.4	435.1	2.8	440.7	4.1
W_2	230.9	4.8	230.9	4.8	230.9	4.8	243.4	10.5	250.6	13.8	257.5	16.9
W_3	2067.3	-0.2	3090.5	-0.1	4625.1	-0.1	1080.8	-47.8	991	-68.0	800.1	-82.7
Q_1	652550.9	-0.1	652549.2	-0.1	652548.3	-0.1	654103.8	0.1	654977.7	0.3	655814	0.4
Q_2	80063.4	0.5	80063	0.5	80062.7	0.5	80486.3	1.0	80720.1	1.3	80941	1.6
Q_3	229458.9	0.0	229472.1	0.0	229481.8	0.0	261426.1	13.9	302662.9	31.9	381408.5	66.2
P_1	2507.8	0.3	2507.8	0.3	2507.8	0.3	2488	-0.5	2476.9	-0.9	2466.4	-1.3
P_3	1100.6	0.1	1100.4	0.0	1100.2	0.0	712.6	-35.2	437.3	-60.2	202.3	-81.6
z	6.8		6.9		6.9		-10.6		-20.5		-29.9	

Table 13. Effect of a 10% price increase for cocoa: Assumption 2

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	768120.7	-0.5	768117.9	-0.5	768116.2	-0.5	773838.4	0.3	777888.2	0.8	781416.8	1.3
L_2	155553.3	2.4	155552	2.4	155551.2	2.4	158143.2	4.1	159967.1	5.3	161548.9	6.3
L_3	48177	0.0	48181.1	0.0	48183.6	0.0	39869.3	-17.3	33995.7	-29.5	28885.3	-40.1
W_1	419.2	-0.9	419.2	-0.9	419.2	-0.9	425.5	0.5	430	1.6	433.9	2.5
W_2	230.9	4.8	230.9	4.8	230.9	4.8	238.7	8.4	244.2	10.8	249.1	13.1
W_3	2065.6	-0.3	3088.7	-0.2	4623.2	-0.1	311.2	-85.0	94.5	-96.9	27.7	-99.4
Q_1	652547.7	-0.1	652547.2	-0.1	652546.9	-0.1	653516.3	0.1	654198.9	0.2	654791.3	0.2
Q_2	80062.6	0.5	80062.4	0.5	80062.3	0.5	80327.4	0.8	80511.8	1.0	80670.4	1.2
Q_3	229485.6	0.0	229489.2	0.0	229492.8	0.0	268612.7	17.0	316296.8	37.8	410357.5	78.8
P_1	2507.8	0.3	2507.8	0.3	2507.8	0.3	2495.5	-0.2	2486.8	-0.5	2479.3	-0.8
P_3	1100.5	0.0	1100.4	0.0	1100.2	0.0	228	-79.3	44.5	-96.0	3.3	-99.7
z	6.9		6.9		6.9		-4.0		-11.7		-18.4	

Table 14. Effect of a 10% price increase for cocoa: Assumption 3

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	768121.9	-0.5	768118.7	-0.5	768116.6	-0.5	770613.9	-0.1	772196.6	0.1	773936.7	0.3
L_2	155553.8	2.4	155552.4	2.4	155551.4	2.4	156684.8	3.1	157401.3	3.6	158187.6	4.1
L_3	48175.3	0.0	48180	0.0	48183	0.0	44552.3	-7.5	42253.1	-12.3	39726.7	-17.6
W_1	419.2	-0.9	419.2	-0.9	419.2	-0.9	422	-0.3	423.7	0.1	425.6	0.6
W_2	230.9	4.8	230.9	4.8	230.9	4.8	234.3	6.4	236.4	7.3	238.8	8.4
W_3	2064.9	-0.3	3088	-0.2	4622.6	-0.1	944.8	-54.4	831	-73.1	671.1	-85.5
Q_1	652547.9	-0.1	652547.3	-0.1	652547	-0.1	652970.7	0.0	653238.7	0.0	653532.9	0.1
Q_2	80062.6	0.5	80062.5	0.5	80062.4	0.5	80178.7	0.6	80251.9	0.7	80331.9	0.8
Q_3	229484	0.0	229488.1	0.0	229492.3	0.0	274645.7	19.7	330355.6	43.9	437364.4	90.6
P_1	2507.8	0.3	2507.8	0.3	2507.8	0.3	2502.4	0.1	2499	0.0	2495.2	-0.2
P_3	1100.1	0.0	1100.1	0.0	1100	0.0	768.1	-30.2	530.9	-51.7	302.9	-72.5
z	6.9		6.9		6.9		2.1		-0.9		-4.2	

The magnitudes of the ranges across the values of ρ are driven by the assumed elasticities in Tables 12, 13, and 14. Again, Table 12 assumes the values of each triplet of elasticities are the same. Table 13 assumes the same elasticities as in Table 12, except that the price elasticities of supply and demand for coca are more inelastic elasticities for coffee and cocoa and Table 14 assume the values as Table 13, except the price elasticity of demand for coca is less inelastic that the corresponding elasticities for coffee and cocoa.

In all cases when eradication is eliminated while simultaneously providing a price support for cocoa, output increases even though the area cultivated with coca declines indicating higher yields per hectare and farmers intensifying coca cultivation per the area. These results are similar to the results when price support was provided for coffee. A 10% price support for cocoa with no eradication is not substantially different from the effect of eliminating eradication alone as discussed in scenario one. A 10% price support for coca holds little promise to control coca supply from shifting upward if eradication is eliminated simultaneously.

Using the assumptions of Table 12 with no eradication, coca cultivation decreases by a larger amount and coca output increases by a smaller amount than when using the assumptions of Tablets 13 and 14. Also, the magnitude of the percentage change is larger on coca output and smaller on coca cultivation when assuming the elasticities of Table 14 than when using the assumptions of Table 13. There is virtually no difference in coca output and area cultivated with coca under eradication.

The effect of a price support for cocoa is larger on coffee than on coca. This result is similar to scenario two where land reallocation between alternative crops is larger than land reallocation between licit and illicit crops. A 10% price support for cocoa decreases coffee production by 1% relative to equilibrium with eradication regardless of the values of ρ and assumed elasticities. A price increase on cocoa with eradication increases coffee output up to 0.4% depending on the hypothesized ρ values and the assumed elasticities.

Initial farmers' land allocation changes after a price support for cocoa luring them to reallocate more land between coffee and cocoa rather than between cocoa and coca. The Lagrangian multiplier indicates that the marginal profit generated by adding one hectare of land is about 7 dollars with eradication. The marginal profit of additional hectare of land decreases with no eradication due to gain in coca productivity and yields per hectare.

- **Scenario four: A 10% increase in the price of coffee and cocoa**

The effects of a 10% price support for coffee and cocoa, with and without eradication are shown in Tables 15, 16, and 17 using the elasticities assumptions 1, 2, and 3.

In the price support policy for both crops coffee and cocoa I also considered two alternatives: 1) with eradication and 2) no eradication. With eradication, the results show that coca output and area under coca cultivation decreases by less than 1% regardless of the values of ρ. With no eradication, the results show that when ρ=0.2 the area cultivated with coca decreases from 7.8% to 28.4% and output increases from 13.7% to 19.6%. When ρ=0.4, the area cultivated with coca decreases from 12.6% to 43.9% and output increases 31.6% to 43.9%.

Table 15. Effect of a 10% price support for coffee and cocoa: Assumption 1

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3						α_j=0.2, β_j=0.5, γ_j=-0.3 for j=1,2,3, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	775415.2	0.5	775360	0.5	775326	0.5	785170.6	1.7	790615	2.4	795855.5	3.1
L_2	148459.9	-2.3	148438.9	-2.3	148426	-2.3	152160.8	0.2	154224.1	1.5	156208.3	2.8
L_3	47975.2	-0.4	48051.2	-0.3	48099	-0.2	34518.7	-28.4	27010.9	-43.9	19787.2	-58.9
W_1	427.2	0.9	427.2	0.9	427.1	0.9	438	3.5	444.1	4.9	450	6.3
W_2	210.3	-4.5	210.3	-4.5	210.2	-4.6	221	0.3	227	3.0	232.9	5.7
W_3	2052.4	-0.9	3076.1	-0.6	4611.1	-0.4	1062.5	-48.7	972	-68.6	780.4	-83.1
Q_1	653782.4	0.1	653773.1	0.1	653767.3	0.1	655419.2	0.3	656325.6	0.5	657193.4	0.6
Q_2	79318.7	-0.5	79316.4	-0.5	79315	-0.5	79710.3	0.0	79925.3	0.3	80129.9	0.6
Q_3	229293	-0.1	229365.4	-0.1	229412.2	0.0	260981.5	13.7	302077.2	31.6	380455.3	65.8
P_3	1103.3	0.3	1102.1	0.2	1101.4	0.1	716.6	-34.9	440.1	-60.0	204	-81.5
z	36.5		36.6		36.6		21.7		12.4		4.1	

Table 16. Effect of a 10% price support for coffee and cocoa: Assumption 2

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.1, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	775307.5	0.5	775291.6	0.5	775281.3	0.5	781521.9	1.3	786261.1	1.9	792444.8	2.7
L_2	148419	-2.3	148412.9	-2.3	148409	-2.3	150777.1	-0.8	152574.2	0.4	154917.2	2.0
L_3	48124.6	-0.1	48146.5	-0.1	48160.7	-0.1	39552	-17.9	33015.7	-31.5	24489.1	-49.2
W_1	427.1	0.9	427.1	0.9	427.1	0.9	434	2.6	439.3	3.8	446.2	5.4
W_2	210.2	-4.6	210.2	-4.6	210.2	-4.6	217	-1.5	222.2	0.9	229	3.9
W_3	2043.2	-1.3	3066.6	-0.9	4601.2	-0.6	287.3	-86.1	70.5	-97.7	5.3	-99.9
Q_1	653764.2	0.1	653761.5	0.1	653759.8	0.1	654808.9	0.3	655601.2	0.4	656629.1	0.5
Q_2	79314.3	-0.5	79313.7	-0.5	79313.2	-0.5	79564.7	-0.2	79753.5	0.1	79997	0.4
Q_3	229435.6	0.0	229456.2	0.0	229471	0.0	268183.8	16.9	314451.8	37.0	397028.3	73.0
P_3	1102.9	0.3	1102	0.2	1101.2	0.1	231.7	-78.9	47.2	-95.7	4.6	-99.6
z	36.7		36.7		36.7		26.8		19.3		9.5	

Table 17. Effect of a 10% price support for coffee and cocoa: Assumption 3

Variables	Including Aerial Spray						Eliminating Aerial Spray					
	α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5						α_j=0.2, β_1=0.5, β_2=0.5, β_3=0.1, γ_1=-0.3, γ_2=-0.3, γ_3=-0.5, η=1					
	ρ=0.2 η=0.82	Δ%	ρ=0.4 η=0.68	Δ%	ρ=0.7 η=0.50	ρ=0.2 η=0.8	ρ=0.2	Δ%	ρ=0.4	Δ%	ρ=0.7	Δ%
L_1	775313.9	0.5	775295.8	0.5	775284	0.5	777990.4	0.8	779666	1.0	781516.3	1.3
L_2	148421.4	-2.3	148414.5	-2.3	148410	-2.3	149437.2	-1.6	150073	-1.2	150774.9	-0.8
L_3	48115.7	-0.2	48140.6	-0.1	48157	-0.1	44423.3	-7.8	42112	-12.6	39559.8	-17.9
W_1	427.1	0.9	427.1	0.9	427.1	0.9	430.1	1.6	431.9	2.1	434	2.6
W_2	210.2	-4.6	210.2	-4.6	210.2	-4.6	213.1	-3.3	214.9	-2.5	216.9	-1.5
W_3	2039.5	-1.5	3062.9	-1.0	4597.7	-0.7	917.8	-55.7	803.7	-74.0	643.4	-86.1
Q_1	653765.3	0.1	653762.3	0.1	653760.3	0.1	654216.1	0.2	654497.6	0.2	654808	0.3
Q_2	79314.6	-0.5	79313.8	-0.5	79313.3	-0.5	79422.8	-0.3	79490.3	-0.2	79564.5	-0.2
Q_3	229427.1	0.0	229450.7	0.0	229467.5	0.0	274486.5	19.6	330134.8	43.9	436996.3	90.4
P_3	1100.7	0.1	1100.4	0.0	1100.3	0.0	769	-30.1	531.6	-51.7	303.4	-72.4
z	36.7		36.7		36.7		32.4		29.8		26.8	

When ρ=0.7, the area cultivated with coca decreases from 17.9% to 58.9% and output increases from 65.8% to 90.4%. The magnitudes of the ranges across the values of ρ are driven by the assumed elasticities as follow: Table 15 assumes the values of each triplet of elasticities are the same. Table 16 assumes the same elasticities as in Table 15, except that the price elasticities of supply and demand for coca are more inelastic elasticities for coffee and cocoa. Results in Table 17 assume the values as Table 16, except the price elasticity of demand for coca is less inelastic that the corresponding elasticities for coffee and cocoa.

In all cases when eradication is eliminated while simultaneously providing a price support for coffee and cocoa, output increases even though the area cultivated with coca declines indicating higher yields per hectare and farmers intensifying coca cultivation per the area. The result of providing a 10% price support for coffee and cocoa while simultaneously eliminating eradication is not substantially different than the effect of eliminating eradication alone discussed in scenario one. There is a small gain in decreasing coca cultivation and output by providing a price support for coffee and cocoa simultaneously than the scenarios two and three. However, the magnate of this change is very small. A 10% price support for coffee and cocoa together still holds little promise to control coca supply from shifting upward if eradication is eliminated simultaneously.

Using the assumptions of Table 15 with no eradication, coca cultivation decreases by a larger amount and coca output increases by a smaller amount than when using the assumptions of Tablets 16 and 17. Also, the magnitude of the percentage change is larger on coca output and smaller on coca cultivation when assuming the elasticities of Table 17 than when using the assumptions of Table 16. There is no significant difference in coca output and area cultivated with coca under eradication.

Under eradication, providing a simultaneous 10% price support for coffee and cocoa increases coffee output by 1% and decreases cocoa production by 0.5% relative to equilibrium regardless of the values of ρ and assumed elasticities. The policy effect on output and cultivation between alternative crops is smaller when both crops are provided a price support rather than individual crops. The Lagrangian multiplier indicates that the marginal profit generated by adding one hectare of land is about 37 dollars with eradication. The marginal profit of additional hectare of land decreases with no eradication due to gain in coca productivity and yields per hectare.

CHAPTER 5: SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

In summary, an alternative crops policy alone holds little promise to significantly reduce coca production. Although coffee is shown to be more competitive than cocoa for reducing coca production, price support on individual crops has little effect on coca cultivation and coca production. There is a small gain in reducing coca cultivation by providing a simultaneous price support to several alternatives crops. If peasant farmers seek to maximize profits, they would be lured to substitute land between alternative crops rather than taking land away from coca production. This substitution occurs because the relative profit derived from coca is larger than the relative profit from alternative crops.

Eradication policy has a negative effect on agricultural productivity. Eliminating eradication of coca increases production of both coca and traditional crops. Although eliminating aerial spray could decrease total land cultivated with coca, these gains can be offset by the increase of coca output because of increasing coca yields per hectare. However, the decrease of land cultivated with coca leads to an increase of alternative crops cultivation.

Because the volume of coca output rather than area cultivated with coca is what causes the harm, eliminating aerial spray has a negative effect in controlling coca supply in Colombia. From a policy standpoint, results suggest that alternative crops alone have low potential to prevent increase of coca supply if aerial spray is suspended in Colombia. Although alternative crops policies alone would be ineffective in controlling a shift in coca supply due to the absence of aerial spray, they will prevent the negative effect associated with externalities of this policy.

There are several limitations of this study. One limitation is associated with the assumptions about the elasticities and ρ values. This study hypothesizes a functional form to explain the effect of eradication on coca production. Assuming values for the coefficients rather than estimating and testing them generates a substantial variation in the results. Another limitation is that this analysis does not include manual eradication of coca plantations. Manual eradication is likely to play a key role in the control of cocoa cultivation if aerial spray is to be suspended in Colombia. Another limitation is that the coca industry is interconnected across the South American Andes; therefore, these results are not independent from policy measures in the other major producers like Peru and Bolivia. It is necessary to integrate cross-country effects of coca production to fully evaluate the effect of a policy change in the long run.

Combining education, moral suasion, and manual eradication policy with economic incentives to cultivate alternative crops could provide better outcomes in controlling coca supply in Colombia. Additionally, implementing alternative crops with higher returns could produce better results in controlling cocoa supply.

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