The War on Illegal Drug Production and Trafficking: An Economic Evaluation of *Plan Colombia*.*

Daniel Mejía† Pascual Restrepo‡

December 2008
Preliminary version, comments welcome.

Abstract

This paper provides a thorough economic evaluation of the anti-drug policies implemented in Colombia between 2000 and 2006 under the so-called *Plan Colombia*. The paper develops a game theory model of the war against illegal drugs in producer countries. We explicitly model illegal drug markets, which allows us to account for the feedback effects between policies and market outcomes that are potentially important when evaluating large scale policy interventions such as *Plan Colombia*. We use available data for the war on cocaine production and trafficking as well as outcomes from the cocaine markets to calibrate the parameters of the model. Using the results from the calibration we estimate important measures of the costs, effectiveness, and efficiency of the war on drugs in Colombia. Finally we carry out simulations in order to assess the impact of increases in the U.S. budget allocated to *Plan Colombia*, and find that a three-fold increase in the U.S. budget allocated to the war on drugs in Colombia would decrease the amount of cocaine that succesfully reaches consumer countries by about 17%.

Keywords: Hard drugs, conflict, war on drugs, Plan Colombia.
JEL Classification Numbers: D74, K42.

*The authors wish to thank seminar participants at Brookings, Brown U., IADB, Lacea 2008, Tufts U., Universidad de los Andes, Universidad del Rosario, the Colombian Ministry of Defense, and the second NEAT workshop in Brussels for useful discussions. The first author acknowledges financial support from Fedesarrollo's "German Botero de los Ríos" 2008 Prize for Economic Research and the Open Society Institute.

†Corresponding author. Fedesarrollo and Universidad de los Andes, e-mail: dmejia@uniandes.edu.co.
‡Universidad de los Andes, e-mail: p.restrepo23@uniandes.edu.co.

1 Introduction

Despite the large amount of resources spent over the current decade on the so-called "war on drugs" in cocaine consumer and producer countries,[1] most available measures show that consumption trends have not shown any decreasing tendency, nor have prices increased significantly.[2] On the one hand, "there is increasing acceptance that the fundamental problem for rich countries is their inability to control domestic demand for drugs"; on the other, "the search for ways of controlling production (and trafficking) continues, with rich countries both aiding and coercing poor producer nations in their efforts." (Reuter, 2008, p. 1).

While the general impression is that programs aimed at reducing the production and trafficking of illegal drugs have proved to be relatively ineffective in reducing the amount of drugs that reach consumer countries, little of a systematic nature is known about the effects, costs, effectiveness, and efficiency of these programs.[3] The main objective of this paper is at filling this gap. In particular, this paper provides a thorough economic evaluation of anti-drug policies implemented in Colombia between 2000 and 2006 under *Plan Colombia*. *Plan Colombia* is the official name of a program that, among other things, provides the institutional framework for the military alliance between the U.S. and Colombia in the war against illegal drug production, trafficking, and the organized criminal groups associated with these activities.

In Colombia, where about 70% of the cocaine consumed in the world is produced, the

[1] According to the Office for National Drug Control Policy (ONDCP, 2007, Table 1), the U.S. Federal Government alone spent approximately $12.5 billion dollars per year between 2005 and 2007 on the war on drugs. Slightly more than 60% of this budget was spent on policies aimed at reducing the supply of drugs (i.e. law enforcement, interdiction and subsidies for the war on drugs in producer countries), and slightly less than 40% on policies aimed at reducing the demand for drugs (i.e. treatment and prevention policies). Colombia, the main cocaine producer country in the world, has spent about $1 billion dollars per year for the last 7 years on the war on drugs and in combatting the organized criminal organizations associated with illegal drug production and trafficking (see DNP, 2006).

[2] Mejía and Posada (2008) provide a thorough description of the main stylized facts of the cocaine markets, both in producer and consumer countries. One of the main stylized facts is that despite the recent intensification of the war on cocaine, market prices at the wholesale and retail levels have remained relatively stable during the last 7 years, and consumption trends do not show any decresing tendency. See also the evidence cited in Caulkins and Hao (2008, p. 253), as well as the United Nations Office for Drug and Crime (UNODC) yearly reports.

[3] See Caulkins (2004), Reuter (2008), and Mejía and Posada (2008).

United States and the Colombian governments have allocated large amounts of resources to the war on drugs during the current decade under *Plan Colombia*. According to the Colombian National Planning Department (DNP), between 2000 and 2005, the U.S. government disbursed about $3.8 billion dollars in subsidies to the Colombian government for its war against illegal drug producers and traffickers. Colombia for its part spent about $6.9 billion during the same period. About one half of Colombian expenses (about $3.4 billion) and about three quarters of U.S. subsidies (about $2.8 billion) have gone directly to the military components of the war against drug production, trafficking, and the organized criminal organizations associated with these activities (DNP, 2006, Table 2). Nevertheless, most available data show that the availability of cocaine in consumer countries has not gone down significantly, nor has the price of cocaine shown any increasing tendency, as might have been anticipated given the intensification of this war (see Mejía and Posada, 2008). While the number of hectares of coca crops cultivated in Colombia has decreased by about half (from about 163,000 hectares in 2000 to about 80,000 hectares in 2006) as a result of aerial eradication campaigns, potential cocaine production in Colombia has only decreased from 687,500 kilograms per year in 2000 (right before *Plan Colombia* was initiated) to about 645,000 kilograms per year in 2006. This apparently paradoxical outcome - that is, the large decrease in the cultivation of the coca crops necessary to produce cocaine chlorhydrate, the relatively small decrease in potential cocaine production, and the relatively stable trend in the wholesale and retail prices for cocaine - can be explained, to a large extent, by a significant increase in the yields per hectare resulting from the adoption of certain measures aimed at increasing the productivity in the production of cocaine.[4] These increases in productivity have taken many different forms. Among others, the use of stronger and bigger coca plants, a higher density of coca plants per hectare, better planting techniques, the use of coca plants that have been modified to make them resistant to the active ingredients of the herbicide used in aerial eradication campaigns,[5] and the spraying of coca plants with molasses in order to prevent the active component of the herbicides used in the eradication campaigns from destroying the leaves of the coca plants. There is

[4] Caulkins and Hao (2008) provide an alternative explanatuion for this apparently paradoxical result. Namely, they argue that reductions in source country supply would affect different downstream markets in different ways depending on each market's elasticity of demand for exports. However, for the case of the war on drugs in Colombia, the large reductions observed in coca cultivation have not directly translated into reductions in the supply of cocaine, as drug producers have responded strategically to the aerial eradication campaigns by increasing the yields per hectare of land cultivated with coca crops.

[5] McDermott (2004).

also evidence that illegal drug producers intermingle coca plants with legal crops in order to avoid the aerial eradication campaigns; likewise, the illegal drug producers have reduced the size of coca plantations in order to avoid their being detected by satellite images used to detect illegal crops. As a result of these strategic responses to the intense eradication campaigns implemented under *Plan Colombia*, drug producers in Colombia have found ways to increase the yields per hectare from about 4.2 kilograms of cocaine per hectare per year in 2000 to more than 7.8 kilograms of cocaine per hectare per year in 2006. Thus, cocaine production in 2006 was almost the same as in 2000, right before *Plan Colombia* was initiated. The large productivity increases induced by the endogenous strategic responses of drug producers as described above are not surprising once one looks at the profit margins associated with the production and trafficking of cocaine: in consumer countries, at the retail level, a pure gram of cocaine is worth as much as ten times its weight in gold; in producer countries, however, the same gram is worth, on average, only slightly more than one tenth its weight in gold.

The stylized facts described in the previous paragraph have led many observers to assert that the war against drugs is "self-defeating." Whether this is true or not, however, is not the relevant policy question. Instead, we argue that the relevant policy question is, at what cost? - that is, what is the cost of making "significant" advances in the war on drugs?

Most of the available literature on the effects of anti-drug policies has focused on partial equilibrium analysis.[6] However, the market for illegal drugs hides complex interactions that should be addressed using models that can account for the feedback effects between policies, prices, and the consequent strategic reactions of the actors involved in this war, specially when one is evaluating large scale policy interventions such as *Plan Colombia.* Important exceptions are Chumacero (2007), Costa-Storti and De Grauwe (2008), and Mejía (2008). These papers explicitly model illegal drug markets when analyzing the effects of anti-drug policies. While the focus of Chumacero (2007) is on the effects of three alternative anti-drug policies (making illegal activities riskier, increasing the penalties to illegal activities, and legalization), Costa-Storti and De Grauwe (2008) and Mejía (2008) focus on the inter-relationship between anti-drug policies aimed at reducing the demand for drugs (such as

[6]See Rydell et al. (1996) and Tragler et. al (1991) for partial equilibrium studies on the trade-off between treatment vs. enforcement policies in reducing the consumption of illegal drugs. Grossman and Mejía (2008) study the relative efficiency and effectiveness of eradication and interdiction efforts in a partial equilibrium game theory model. For a thorough survey of the literature on the effects of source country control interventions and the effects of treatment and prevention policies in reducing the demand for illegal drugs, see Caulkins (2004).

treatment and prevention policies) and policies aimed at reducing the supply of drugs (by means of interdiction and increased enforcement).[7] However, none of these contributions focuses on evaluating the costs, effectiveness, and future prospects of the war on illegal drugs, as this paper does, nor are they aimed at evaluating actual anti-drug policies, as this paper is.

In this paper, we construct a model of the war against illegal drug production and trafficking which incorporates strategic interactions between the actors involved. We also explicitly model illegal drug markets, in the producer and the consumer countries, which allows us to account for the feedback effects between policies, market outcomes, and the strategic responses of the actors involved that are potentially important when evaluating such large-scale policy interventions as *Plan Colombia*. Importantly, we use data from the war on drugs in Colombia (before and after *Plan Colombia*) as well as the observed outcomes from the cocaine markets in order to calibrate the unobservable parameters of the model. We then use the results from the calibration exercise to estimate important variables that are relevant for policy purposes. Among others, we estimate variables such as the marginal cost, both for the U.S. government and for Colombia, of reducing the supply of cocaine in consumer countries by 1 kilogram, the relative effectiveness of the resources allocated by the Colombian government to the war on illegal drugs, and the costs to the Colombian government arising from the production and trafficking of cocaine. The results from the calibration of the model are then used to carry out simulation exercises, wherein we assess the effects of increasing the U.S. and Colombian budgets allocated to the war against cocaine production and trafficking. The results from these simulations shed some light on the costs of making "important advances" on the war on drugs in the future. Based on the theoretical model as well as the calibration results, we identify the key factors behind the high costs/low effectiveness of the war on drugs.

The paper is organized as follows: section 2 presents the model; section 3, the calibration strategy, results, robustness checks, as well as the results from the simulations; section 4 discusses the key factors that make the war against illegal drug production and trafficking more costly/less effective, together with other interesting results; section 5 concludes.

[7] Costa-Storti and De Grauwe (2008) also address the issue of how globalization has reduced the retail price of illegal drugs during the last few decades, thus stimulating consumption.

2 The Model

We model the war against drug production and trafficking as a sequential game, in which there are $4 + n$ actors involved. These actors are the government of the drug producing country (henceforth the government), the government of the drug consumer country (henceforth the interested outsider), the drug trafficker, n illegal drug producers, and a wholesale buyer who is located at the border of the consumer country.

We assume that the government faces a net cost per unit of income that drug producers are able to obtain from illegal drug production; additionally, that it also faces a (perhaps different) net cost per unit of income that the drug trafficker is able to obtain from illegal drug trafficking.[8] We also assume that the interested outsider grants the military forces of the government two types of subsidies in an attempt to strengthen their resolve in the war against illegal drug production and against illegal drug trafficking. These subsidies consist of a fraction $(1 - \omega) \in [0, 1)$ of the resources that the government spends on the conflict with drug producers over the control of land suitable for cultivating illegal crops, and a fraction $(1 - \Omega) \in [0, 1)$ of the resources that the government spends trying to interdict the illegal drug shipments.

The war against drug production and trafficking proceeds as follows:

1. The interested outsider grants subsidies $1 - \omega$ and $1 - \Omega$ to strengthen the resolve of the government in the war against illegal drug production and trafficking, respectively.

2. The government engages the n illegal drug producers in a conflict over the control of arable land suitable for cultivating the crop necessary to produce the illegal drug. We assume that, initially, there are n disjoint pieces of land of size L/n, each of which is contested by each one of the n drug producers with the government.

3. The n drug producers fight against each other over the control of the land that the government does not control.

4. Once the illegal drug producers know how much land they control (that is, how much raw material they have to produce illegal drugs), they have to decide the amount of resources they invest in those factors that are complementary to land in the production of illegal drugs, such as chemicals, workshops, and other materials necessary for their

[8] These costs need not be the same for many different reasons. For instance, drug producers, as it is the case in Colombia, finance their terrorist activities against the government (at least in part) from the income they receive from illegal drug production. Drug traffickers, on the other hand, might use a different fraction of the proceeds from illegal drug trafficking to corrupt politicians, bribe the anti-narcotics police, and so forth.

production. Combining these complementary factors with the land they control, they are able to produce illegal drugs.

5. At this stage of the game, the drug trafficker and the government engage in an interdiction sub-game, whereby the government tries to capture illegal drug shipments by blocking the routes used by the drug trafficker to transport them, and the drug trafficker tries to avoid the interdiction of its drug shipments.

6. Once the drug trafficker knows the expected probability that a drug shipment will survive the government's interdiction efforts, he has to decide how much illegal drugs to buy from the drug producers.

7. Finally, in the last stage of the game, the drug trafficker sells the illegal drugs that survive the government's interdiction efforts at the border of the consumer country to a wholesale drug dealer.

While the objective of drug producers and the drug trafficker is to maximize the profits from their activities (which are described in detail below), the government's objective is to minimize the costs associated with illegal drug production, trafficking, and the war against these two activities. In turn, the interested outsider's objective is to minimize the amount of illegal drugs reaching the consumer country.

We now turn to a description of each one of the stages of the game described above, wherein we describe in detail the problems faced by each agent involved in the game, their objective functions and restrictions, as well as the production, conflict, and trafficking technologies. As it is usual in the analysis of sequential games, we start with the last stage of the game.

2.1 The demand for drugs at the border of the consumer country

In order to simplify the analysis that follows, and inasmuch as the main purpose of this paper is to study the war on illegal drug production and trafficking,[9] we assume that the

[9] Mejia (2008) develops a model of the war on drugs in both consumer and producer countries, and studies how anti-drug policies implemented in consumer countries affect the effectiveness of anti-drug policies in producer countries. Specifically, the main argument in that paper is that those policies aimed at reducing the demand for drugs in consumer countries (treatment and prevention policies) reduce the price of illegal drugs, thus making anti-drug policies implemented in producer countries more effective and less costly; conversely, policies aimed at reducing the supply of drugs in consumer countries (enforcement, stiffer penalties for dealers and consumers, etc.) render the policies implemented in producer countries less effective and more costly, as they increase the price of illegal drugs, as well as the incentive for more illegal drug production and trafficking.

demand for drugs at the border of the consumer country is given by a general demand function of the form:

$$Q_f^d = \frac{a}{P_f^b}, \tag{1}$$

where Q_f^d denotes the demand for drugs, $a \geq 0$ is a scale parameter of the demand function, P_f is the wholesale price of the illegal drug at the border of the consumer country, and b is the price elasticity of the demand for drugs at the border of the consumer country.

In this paper, we abstract from modelling the war on drugs inside the consumer country, and instead assume that the demand function in equation 1 corresponds to the demand for drugs of a wholesale drug dealer, who buys at the wholesale price at the border of the consumer country, P_f, and then distributes the illegal drug to cities where they are sold at retail levels (and prices).

2.2 The drug trafficking sub-game

2.2.1 The drug trafficking technology

We assume that the drug trafficker combines routes, κ, with the illegal drugs bought in the producer country, Q_d, to "produce" illegal drug shipments to the border of the consumer country, Q_f . However, we assume that only a fraction $h \in [0, 1]$ of the possible routes are not interdicted by the government.[10] Formally, we assume that the drug trafficking technology is given by:

$$Q_f = (\kappa h)^{1-\eta} Q_d^{\eta}, \tag{2}$$

where $\eta \in (0, 1)$ captures the relative importance of the the illegal drugs bought in the producer country in the trafficking technology, and $1 - \eta \in (0, 1)$ captures the relative importance of the drug trafficking routes. The trafficking technology in equation 2 implies that, at the aggregate level, it does not make a difference whether there is only one or many drug traffickers, as long as they are all of equal size.[11]

[10] The drug trafficker might be thought of as being located in the middle of a circle with a given number, κ, of lines (routes) connecting the middle of the circle with its circumference; the latter might be interpreted as representing the border of the consumer country. The drug trafficker sends drug shipments along these routes and, *ex-post*, a fraction, $1 - h$, of these routes are discovered by the government authorities.

[11] If we have N drug traffickers, each contesting with the government disjoint sets of κ/N routes, then,

2.2.2 The interdiction technology

The interdiction technology is such that h, the fraction of routes that, *ex-post,* survive the government's interdiction efforts, is determined endogenously by a standard context success function,[12] by:

$$h = \frac{\gamma t}{\gamma t + s}, \tag{3}$$

where s is the amount of resources that the government invests in interdiction such as radars, airplanes, go-fast boats, etc.; t is the amount of resources that the drug trafficker invests in trying to avoid the interdiction, for instance, in submarines, go-fast boats, airplanes, pilots, drug mules, corrupting government officials to avoid being captured, etc.; $\gamma > 0$ is a parameter that captures the relative effectiveness of the resources invested by the drug trafficker in avoiding the government's interdiction efforts. Note that the fraction h in equation 3 is an increasing and concave function of the ratio $\frac{\gamma t}{s}$.

If we assume that all illegal drug shipments are of the same size, then h can also be thought as the fraction of illegal drugs that survive the government's interdiction efforts.[13]

2.2.3 The drug trafficker's problem

We first start with the second choice that the drug trafficker has to make, namely, the amount of drugs to buy from the drug producers. The drug trafficker takes as given the government's choices and drug market prices, both in the producer country, P_d, and in the consumer country, P_f. More formally, the drug trafficker's problem is given by:

---

at the aggregate level, their demand for drugs in the producer country and the supply of drugs in the consumer country would be exactly the same, as in the case where there is only one drug trafficker. The details of this claim are available from the authors upon request.

[12] A contest success function (CSF) is "a technology whereby some or all contenders for resources incur costs in an attempt to weaken or disable competitors" (Hirshleifer, 1991). In this particular case, the CSF determines the fraction of illegal drugs that is succesfully exported to the consumer country as a function of the government's interdiction efforts and the drug trafficker's efforts to avoid the government's interdiction of drug shipments. See Skaperdas (1996) and Hirshleifer (2001) for a detailed explanation of the different functional forms of CSF.

[13] This is, of course, a simplifying assumption that we make for tractability. In reality, different illegal drug shipments have a different size that depends, in turn, on the size of the vehicles being used to transport them (go-fast boat, airplane, drug mule, etc.). However, given our interest in looking at the aggregate problem of drug trafficking, the assumption of equally-sized drug shipments is innocous.

$$\max_{\{Q_d\}} \pi_T = P_f Q_f - P_d Q_d - t. \tag{4}$$

The first term in equation 4 is the total income derived from drug trafficking, where P_f is the wholesale price of drugs in the consumer country and Q_f is the quantity of drugs successfully exported. The second term is the cost of buying drugs in the producer country, where P_d is the price of drugs at the farm gate in the producer country. The last term, t, is the amount of resources invested by the drug trafficker in trying to avoid the interdiction of illegal drug shipments.

Using equations 2 and 3, the demand for illegal drugs from the drug trafficker in the producer country is determined by the following first order condition:

$$\frac{\partial \pi_T}{\partial Q_d} = 0 \Longleftrightarrow Q_d^* = \kappa h \left(\frac{\eta P_f}{P_d} \right)^{\frac{1}{1-\eta}} \tag{5}$$

Inserting the optimal demand for drugs in the producer country, Q_d^*, from equation 5 back into the expression for the drug trafficker's profits (equation 4), we get that the drug trafficker's problem regarding the choice of resources for avoiding interdiction efforts, t, is given by:

$$\max_{\{t\}} \pi_T^* = \frac{\rho \kappa h P_f^{\frac{1}{1-\eta}}}{P_d^{\frac{\eta}{1-\eta}}} - t, \tag{6}$$

where $\rho = \eta^{\frac{\eta}{1-\eta}} - \eta^{\frac{1}{1-\eta}}$. Replacing h from equation 3 in equation 6, the optimal amount of resources invested by the drug trafficker in trying to escape the interdiction of drug shipments is determined by the following first order condition:

$$\frac{\partial \pi_T^*}{\partial t} = 0 \Longleftrightarrow t^* = \sqrt{\frac{\rho \kappa P_f^{\frac{1}{1-\eta}} s}{\gamma P_d^{\frac{\eta}{1-\eta}}}} - \frac{s}{\gamma} \tag{7}$$

Note that equations 5 and 7 describe the best reaction functions for the drug trafficker with respect to every possible choice of resources by the government in its interdiction efforts, s.

2.2.4 The government's problem: interdiction

Recall that at the beginning of the game, the interested outsider grants a subsidy to the producer country's government in an attempt to strengthen its resolve in the war against illegal drug trafficking. This subsidy corresponds to a fraction, $1-\Omega \in [0,1)$, of the resources that the government allocates to interdiction efforts.

We will assume that the government faces a net cost, c_2, per unit of income that the drug trafficker is able to obtain from trafficking illegal drugs.

The government's problem in the game as a whole is to minimize the costs associated with illegal drug production, drug trafficking and the overall expenses of the two fronts of the war on drugs. At this stage of the game, however, the government's objective is to determine the amount of resources that should be allocated to interdiction efforts in order to minimize only the sum of the costs associated with illegal drug trafficking. The government takes as given the choices made by the drug trafficker, Q_d and t, the price of drugs at the border of the consumer country, P_f, the net cost to the government of illegal drug trafficking, c_2, and the subsidy from the interested outsider, $1-\Omega$, and determines the amount of resources to invest in interdiction efforts, s, so as to minimize the costs associated with illegal drug trafficking. More precisely, the government's problem at this stage of the game is:

$$\min_{\{s\}} \ C_T = \ c_2 P_f Q_f + \Omega s \tag{8}$$

where Q_f is determined by equation 2. Solving the problem in equation 8, the government's optimal choice of resources allocated to interdiction efforts is determined by the following first order condition:

$$\frac{\partial C_T}{\partial s} = 0 \Longleftrightarrow s^* = \sqrt{\frac{\eta^{\frac{\eta}{1-\eta}} c_2 \kappa P_f^{\frac{1}{1-\eta}} \gamma t}{P_d^{\frac{\eta}{1-\eta}}}} - \gamma t. \tag{9}$$

Equation 9 denotes the government's best reaction function to every possible choice made by the drug trafficker with respect to Q_d and t.

2.2.5 The drug trafficking equilibrium

Using the reaction functions for the drug trafficker and the government (equations 5, 7 and 9), the Nash equilibrium for the drug trafficking sub-game is described by the following equations:

$$t^* = \frac{h^{*2} c_2 \eta^{\frac{\eta}{1-\eta}} \kappa P_f^{\frac{1}{1-\eta}}}{\gamma \Omega P_d^{\frac{\eta}{1-\eta}}}, \tag{10}$$

$$s^* = \frac{h^{*2} c_2^2 \eta^{\frac{\eta}{1-\eta}} \kappa P_f^{\frac{1}{1-\eta}}}{(1-\eta)\gamma \Omega^2}, \tag{11}$$

$$h^* = \frac{\gamma \Omega (1-\eta)}{c_2 + \gamma \Omega (1-\eta)}, \tag{12}$$

$$Q_d^d(P_d, P_f) = h^* \kappa \left(\frac{\eta P_f}{P_d} \right)^{\frac{1}{1-\eta}}, \text{ and} \tag{13}$$

$$Q_f^s(P_d, P_f) = h^* \kappa \left(\frac{\eta P_f}{P_d} \right)^{\frac{\eta}{1-\eta}}. \tag{14}$$

Equations 10 and 11 describe the amount of resources that the drug trafficker and the government, respectively, spend on the interdiction sub-game as a function of market prices and technology parameters. Equation 12 is the fraction of drug routes that are not interdicted. Recall that h^* also represents the fraction of illegal drugs successfully exported to the consumer country in equilibrium. Equation 13 is the demand for drugs of the drug trafficker in the producer country, and equation 14 is the supply of drugs from the drug trafficker at the border of the consumer country.

A few things are worth noting at this stage. First, a higher subsidy from the interested outsider for the government's interdiction efforts (that is, a lower Ω) decreases the fraction of drugs that the drug trafficker is able to successfully export to the consumer country. Additionally, the result regarding the cost faced by the government per unit of income that the drug trafficker is able to obtain from his activity is not surprising - namely, given the market prices, a higher c_2 will induce the government to fight relatively harder against illegal drug trafficking; as a result, the equilibrium fraction of drugs successfully exported will be lower. Note that the wholesale price of drugs at the border of the consumer country, P_f, does not affect the fraction of drugs successfully exported. This is because both the government's loss and the drug trafficker's profits depend on this price in exactly the same way (equations 10 and 11). As a result, P_f does not affect h, as the two effects (of t and s on h) cancel each other out. A higher γ (that is, a higher relative effectiveness of the resources that the drug trafficker allocates to the avoidance of interdiction efforts) increases the fraction of drugs successfully exported in equilibrium.

2.3 The drug production sub-game

2.3.1 The technology of conflict over arable land: The government versus drug producers

One of the main fronts in the war against drugs is the conflict over the control of arable land suitable for cultivating the crops necessary to produce illegal drugs.[14] We assume that each one of the n drug producers initially controls $L_i = L/n$ hectares of land, and that L_i and L_j comprise disjoint sets of land $\forall\, i, j$. L is the total land that can potentially be used to cultivate illegal crops in the producer country.

We assume that the outcome of the conflict over arable land between the government and each drug producer is such that the government controls a fraction g_i of the land L_i, where the fraction g_i is determined according to a standard contest success function, by:

$$g_i = \frac{z_i}{z_i + \phi x_i}, \tag{15}$$

where z_i and x_i denote the resources that the government and drug producer $i-th$ allocate to the conflict over the control over arable land, respectively. $\phi > 0$ captures the relative efficiency of the resources that drug producer $i-th$ allocates to the conflict with the government over the control of arable land. Note that the fraction of land controlled by the government is an increasing and concave function of the ratio $\frac{z_i}{\phi x_i}$.

2.3.2 The technology of conflict over arable land: drug producers versus drug producers

After the conflict over land between the government and drug producers, the latter also engage in a dispute with each other over the control of land that the government does not control.[15] This land consists of $\sum_{i=1}^{n}(1-g_i)L_i$ hectares. We denote the fraction of land not under the government's control by q, which is given by:

[14] For instance, cocaine is produced from the alkaloid extracted from the leaves of coca plants, whereas heroin is produced from oppium poppy seeds.

[15] This is an assumption that matches the Colombian experience quite well. There are numerous examples in Colombia of military confrontations between illegal drug producers for the control of land not controlle by the government. For instance, in the Catatumbo and Sierra Nevada regions, the FARC and the AUC (the two main illegal drug producers) had military confrontations in 2004 for the control of more than 30.000 hectares of land planted with coca bushes (see *Revista Cambio*, "Tiempo de muerte y de cosecha," 8/8/2004, and *El Tiempo*, 18/01/2005).

$$q = \frac{1}{L}\sum_{k=1}^{n}(1-g_k)L_k = \frac{1}{n}\sum_{k=1}^{n}(1-g_k). \tag{16}$$

In the conflict between drug producers for the land that the government does not control, we assume that drug producer i ends up controlling, on average, a fraction f_i, where f_i is determined by the following contest success function:

$$f_i = \frac{y_i}{y_i + \sum_{k\neq i} y_k}, \tag{17}$$

where y_i and y_k denote the resources allocated by $i-th$ and $k-th$ drug producers respectively, to this conflict. The contest success function in equation 17 implicitly assumes that each drug producer is equally efficient in this conflict.

2.3.3 The drug production technology

We assume that illegal drugs are produced by combining two factors - arable land, l, necessary for cultivating the illegal crop; and other material resources (workshops, chemicals, microwaves, labor, etc.), r. These two factors are combined according to the following production technology in order to produce the illegal drug:

$$Q_{d,i} = \lambda r_i^{\alpha} l_i^{1-\alpha}, \quad \text{where } 0 < \alpha < 1, \tag{18}$$

where $Q_{d,i}$ is the amount of drugs produced by the $i-th$ drug producer, $\lambda > 0$ is a productivity parameter, r_i is the amount of resources complementary to land such as chemicals, workshops, etc., and l_i is the amount of land that the $i-th$ drug producer controls. The latter, in turn, is determined by:

$$l_i = q f_i L, \tag{19}$$

where q and f_i are determined by equations 16 and 17, respectively.

2.3.4 The drug producers' problem

We assume that there is a competitive market for illicit drugs in the producer country, where each one of the producers takes the price of drugs in the producer country, P_d, as given. The $i-th$ drug producer first chooses the amount of resources that to allocate to the conflict with the government over the control of arable land, x_i; he then has to choose the amount of resources to allocate to the conflict with the other drug producers over the control of the arable land that the government does not control, y_i;finally, once he knows how much land he controls, he has to choose how much to invest in those factors that are complementary to land in the production of illegal drugs, r_i.

We start with the last stage of the drug production sub-game, where the drug producer already knows how much land he controls and has to choose r_i. The drug producer's problem at this stage is given by:

$$\max_{\{r_i\}} \pi(x_i, y_i, r_i) = P_d Q_{d,i} - (x_i + y_i + r_i). \tag{20}$$

The optimal choice of r_i, given the amount of land that he controls, is determined by the following first order condition:

$$\frac{\partial \pi_i}{\partial r_i} = 0 \iff r_i^* = (\alpha \lambda P_d)^{\frac{1}{1-\alpha}} q f_i L. \tag{21}$$

Plugging equation 21 back into the profits for the $i-th$ drug producer (equation 20), we have:

$$\pi_i^* = \sigma(\lambda P_d)^{\frac{1}{1-\alpha}} q f_i L - (x_i + y_i), \tag{22}$$

where $\sigma = \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}} > 0$.

In step 3 of the game, illegal drug producer i has to choose the optimal allocation of resources to the conflict he is engaged in with other producers over the control of arable land that the government does not control, y_i, in order to maximize profits (equation 22). The first order condition associated with the choice of y_i is given by:

$$\frac{\partial \pi_i^*}{\partial y_i} = 0 \iff y_i^* = \sqrt{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} q L \sum_{j \neq i} y_j} - \sum_{j \neq i} y_j. \tag{23}$$

Equation 23 describes the best reaction function for drug producer i to every possible choice of resources by other drug producers, $y_j \; \forall j \neq i$, in the conflict over the control of land that the government does not control.

Inasmuch as we have assumed that all drug producers are equally effective in the conflict over arable land that the government does not control, the optimal choice of y_i will be the same for all drug producers (that is $y_i^* = y^* \; \forall i$), where:

$$y^* = \frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} qL(n-1)}{n^2}. \tag{24}$$

Plugging the optimal choice of y_i from equation 23 into equation 22, the profits of drug producer $i-th$ at this stage are given by:

$$\pi_i^{**} = \frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} qL}{n^2} - x_i. \tag{25}$$

In the conflict over the control of arable land with the government, each drug producer chooses x_i to maximize profits at this stage (equation 25). The optimal choice of resources allocated by drug producer $i-th$ to this conflict with the government, x_i, is determined by the following first order condition:

$$\frac{\partial \pi_i^{**}}{\partial x_i} = 0 \iff x_i^* = \sqrt{\frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} L z_i}{\phi n^3}} - \frac{z_i}{\phi}. \tag{26}$$

Equation 26 is the best reaction function for drug producer $i-th$ in the conflict over arable land with the government to all possible allocations by the latter in this conflict.

2.3.5 The government's problem: the conflict over the control of arable land

In the conflict with drug producers over the control of arable land, the government chooses the amount of resources to allocate to this conflict, z_i, in order to minimize the sum of the costs associated with illegal drug production and the costs of fighting against the n drug producers over the control of arable land. The government takes as given the drug producers' choices of r_i, x_i and y_i, the price of illegal drugs in the producer country, P_d, the cost associated with each unit of resources that drug producers are able to obtain from illegal drug production, c_1, and the subsidy from the interested outsider towards the government's expenses on this front of the war on drugs, $1-\omega$. The government's problem at this stage is given by:

$$\min_{\{z_i\}} C_P = c_1 \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} qL + \omega \sum_{i=1}^{n} z_i, \tag{27}$$

where $\alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} qL$ is the drug producers' income at this stage of the game. The government's optimal choice of z_i is determined by the following first order condition:

$$\frac{\partial C_P}{\partial z_i} = 0 \Longleftrightarrow z_i^* = \sqrt{\frac{c_1 \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} L \phi x_i}{n\omega}} - \phi x_i. \tag{28}$$

Equation 28 is the government's best reaction function in the conflict over the control of arable land with each illegal drug producer.

2.3.6 The drug production equilibrium

The Nash equilibrium of the drug production sub-game is given by the intersection of the reaction functions of the drug producers (equation 26) and the government (equation 28), and the equilibrium outcome of the conflict between drug producers for the control of land that the government does not control. On the one hand, the conflict between producers is characterized by an equilibrium outcome whereby each drug producer ends up controlling an equal fraction, $1/n$, of the land that the government does not control. This is because we have assumed that all drug producers are equally efficient in this conflict. On the other hand, the equilibrium allocation of resources to the conflict over arable land between the government and drug producers is obtained using equations 26 and 28, and is characterized by the following allocation of resources by drug producers and the government, respectively:

$$x_i^* = \frac{q^{*2} c_1 \sigma^2 (\lambda P_d)^{\frac{1}{1-\alpha}} L}{\alpha^{\frac{\alpha}{1-\alpha}} n \phi \omega (1-\alpha)^2}, \tag{29}$$

and,

$$z_i^* = \frac{q^{*2} c_1^2 n \sigma (\lambda P_d)^{\frac{1}{1-\alpha}} L}{\phi \omega^2 (1-\alpha)^2}. \tag{30}$$

Correspondingly, the equilibrium fraction of land not under the government's control is given by:

$$q^* = \frac{\phi\omega(1-\alpha)}{c_1 n^2 + \phi\omega(1-\alpha)}. \tag{31}$$

According to equation 31, the fraction of land that the government does not control is an increasing function of the drug producers' relative efficiency in the conflict for land, ϕ; the relative importance of land in the production of illegal drugs, $1-\alpha$; a decreasing function of the subsidy from the interest outsider to the drug producer country's government in the conflict over land, $1-\omega$; the cost to the government from illegal drug production, c_1; and the number of illegal drug producers, n.

Substituting equation 31 into equations 24 and 21, we obtain the equilibrium values for the drug producers' allocation of resources to the conflict over arable land with other drug producers, as well as to the resources complementary to land in the production of illegal drugs:

$$y_i^* = \frac{q^*(n-1)\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} L}{n^2}, \tag{32}$$

and:

$$r_i^* = \frac{q^*(\alpha\lambda P_d)^{\frac{1}{1-\alpha}} L}{n}. \tag{33}$$

Finally, replacing the value of r_i from equation 33 and $f_i = 1/n$ into equation 18 (and adding over the n drug producers), we get an equation that describes the total supply of illegal drugs in the producer country:

$$Q_d^s(P_d) = \sum_{i=1}^{n} Q_{d,i} = q^* \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_d^{\frac{\alpha}{1-\alpha}} L, \tag{34}$$

where, again, q^* is determined by equation 31.

2.4 The drug market equilibrium

In this section of the paper we close the model by deriving the drug market equilibrium conditions. These market equilibrium conditions, together with the Nash equilibrium derived above for each one of the two sub-games, characterize the equilibrium of the model as a whole.

From the drug production sub-game, we get the supply of drugs in the producer country as a function of the price of drugs in the producer country, $Q_d^s(P_d)$ (equation 34). From the drug trafficking sub-game, we get the demand for drugs in the producer country (from the drug trafficker) as a function of the price of drugs in both the producer country and the consumer country, $Q_d^d(P_d, P_f)$ (equation 13). Equating the supply and the demand for drugs in the producer country, we get the following the drug market equilibrium condition in the producer country:

$$q^* \Delta P_d^{\frac{\alpha}{1-\alpha}} = h^{*1-\frac{1}{\eta+b(1-\eta)}} \Lambda P_d^{\frac{-b}{\eta+b(1-\eta)}}, \tag{35}$$

where $\Delta = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} L$, and $\Lambda = \left(a\eta^b \kappa^{\eta+b(1-\eta)-1}\right)^{\frac{1}{\eta+b(1-\eta)}}$.

From the drug trafficking sub-game, we get the supply of illegal drugs in the consumer country as a function of the price of drugs in both the producer country and the consumer country, $Q_f^s(P_d, P_f)$. Equating the supply of drugs in equation 14 with the demand for drugs in the consumer country (equation 1), we get the drug market equilibrium condition at the border of the consumer country:

$$h^{*\frac{1-\eta}{1-\alpha\eta}} q^{*\frac{\eta(1-\alpha)}{1-\alpha\eta}} \Pi P_f^{\frac{\alpha\eta}{1-\alpha\eta}} = \frac{a}{P_f^b}, \tag{36}$$

where $\Pi = \left(\alpha^{\alpha\eta}\lambda^{\eta}L^{(1-\alpha)\eta}\eta^{\alpha\eta}\kappa^{1-\eta}\right)^{\frac{1}{1-\alpha\eta}}$.

The analytic solution to these two equations, and the corresponding quantities of drugs transacted in equilibrium in both producer and consumer countries, are presented in the appendix.

2.5 The interested outsider's problem

In the first stage of the game, the interested outsider determines the optimal allocation of subsidies to the two fronts of the war on drugs - namely, the conflict over the control of arable land and the interdiction front. The total cost to the interested outsider, M_o, is given by:

$$M_o = n(1-\omega)z^* + \Omega s^*. \tag{37}$$

Replacing the equilibrium values of z^* and s^* (from equations 30 and 11, respectively) as well as the equilibrium values for P_d^*, P_f^*, and Q_f^*, derived in the appendix, the total cost to the interested outsider can be expressed as a function of q, h, and the parameters of the model. After some algebraic manipulation, the total cost to the interested outsider can be written as:

$$M_o = A(1-q)\left(\frac{\Upsilon(1-q)}{q} - 1\right) q^{-\Gamma}h^{-\psi} + B(1-h)\left(\frac{\Theta(1-h)}{h} - 1\right) q^{-\Gamma}y^{-\psi}, \tag{38}$$

where: Γ, ψ, Υ, Θ, A, and B are themselves functions of the parameters of the model (presented in the appendix).

Additionally, the quantity of drugs successfully produced and exported in equilibrium can be expressed as a function of q, h, and the parameters of the model, by:

$$Q_f^* = Cq^{\zeta} h^{\chi}, \tag{39}$$

where, again, ζ, χ, and C are combinations of the structural parameters of the model (presented in the appendix).

The interested outsider's problem in the first stage of the game is to choose the optimal allocation of subsidies to the two fronts of the war on drugs in order to minimize the supply of drugs reaching the consumer country subject to a budget constraint. More precisely, the interested outsider's problem is given by:

$$\begin{aligned} & \min_{\{\omega,\Omega\}} Q_f^* && (40) \\ \text{subject to} \quad & M_o \leq \overline{M}. \end{aligned}$$

where Q_f^* is given by equation 39, M_o by equation 38, and $\overline{M}$ is the total budget for subsidies aimed at strengthening the government's resolve in its war against illegal drug production and trafficking.

Choosing $\omega \in [0,1]$ and $\Omega \in [0,1]$ is equivalent to choosing $q \in [0, \dfrac{\phi(1-\alpha)}{c_1 n^2 + \phi(1-\alpha)}]$ and $h \in [0, \dfrac{\gamma(1-\eta)}{c_2 + \gamma(1-\eta)}]$.[16] Hence, the problem for the interested outsider can be rewritten as:

$$\begin{aligned} & \min_{\{q,h\}} Q_f^* && (41) \\ \text{subject to} \ : \quad & M_o \leq \overline{M}, && (42) \\ & 0 < q < \frac{\phi(1-\alpha)}{c_1 n^2 + \phi(1-\alpha)}, \text{ and} && (43) \\ & 0 < h < \frac{\gamma(1-\eta)}{c_2 + \gamma(1-\eta)}. && (44) \end{aligned}$$

In any internal solution, the following optimality condition must hold:

$$\left(\frac{\partial Q_f}{\partial M_o}\right)_q = \left(\frac{\partial Q_f}{\partial M_o}\right)_h = \frac{1}{\Lambda}, \tag{45}$$

[16]Note that $q(w)$ is a continuous biyection from $[0,1]$ to $[0, \frac{\phi(1-\alpha)}{c_1 n^2 + \phi(1-\alpha)}]$; likewise, $h(\Omega)$ is a continuous biyection from $[0,1]$ to $[0, \frac{\gamma(1-\eta)}{c_2+\gamma(1-\eta)}]$.

or, equivalently:

$$\left(\frac{\partial M_o}{\partial Q_f}\right)_q = \left(\frac{\partial M_o}{\partial Q_f}\right)_h = \Lambda, \tag{46}$$

where, Λ is the marginal cost of reducing Q_f^* by one unit when the subsidies to the two fronts of the war on drug production and trafficking are allocated efficiently.[17]

On the one hand, we have that $\left(\frac{\partial M_o}{\partial Q_f}\right)_q = \frac{\partial M_o/\partial q}{\partial Q_f^*/\partial q}$ is the marginal cost of reducing the production and trafficking of illegal drugs by one unit by marginally increasing $1-\omega$ (decreasing ω), which is the subsidy that the interested outsider grants to the government in its war against drug producers for the control of arable land.

On the other hand, the term $\left(\frac{\partial M_o}{\partial Q_f}\right)_h = \frac{\partial M_o/\partial h}{\partial Q_f^*/\partial h}$ is the marginal cost of reducing the production and trafficking of illegal drugs by one unit by marginally increasing $1-\Omega$ (decreasing Ω), which is the subsidy that the interested outsider grants to the government in its efforts to interdict illegal drug shipments.

Using expressions 39 and 38 we can explicitly calculate each one of these terms. On the one hand, the marginal cost of reducing the quantity of drugs that reach the consumer country by one unit by marginally increasing $1-\omega$ is given by:

$$\left(\frac{\partial M_o}{\partial Q_f}\right)_q = \frac{q^{-\Gamma-\zeta+1}h^{-\psi-\chi}}{\zeta C}\left(\frac{-\frac{A\Gamma(1-q)}{q}\left(\frac{\Upsilon(1-q)}{q}-1\right)}{-A\left(\frac{\Upsilon(1-q)}{q}-1\right)-\frac{A\Upsilon(1-q)}{q^2}-\frac{B\Gamma(1-h)}{q}\left(\frac{\Theta(1-h)}{h}-1\right)}\right). \tag{47}$$

On the other hand, the marginal cost of reducing the quantity of drugs that reach the consumer country by one unit by marginally increasing $1-\Omega$ is given by:

$$\left(\frac{\partial M_o}{\partial Q_f}\right)_h = \frac{q^{-\Gamma-\zeta}h^{-\psi-\chi+1}}{\chi C}\left(\frac{-\frac{B\psi(1-h)}{h}\left(\frac{\Theta(1-h)}{h}-1\right)}{-B\left(\frac{\Theta(1-h)}{h}-1\right)-\frac{B\Theta(1-h)}{h^2}-\frac{A\psi(1-q)}{h}\left(\frac{\Upsilon(1-q)}{q}-1\right)}\right). \tag{48}$$

3 Calibration strategy

To calibrate the parameters of the model we use data from the market for cocaine as well as available data on the well documented *Plan Colombia* (henceforth PC). Under this

[17] $1/\Lambda$ is the Lagange multiplier associated with the restriction $M_o \leq \overline{M}$ of the problem in equation 41.

Plan the U.S. government has provided about \$600 million per year since 2000 to the Colombian government for its fight against illegal drug production and trafficking. Most of these subsidies have taken the form of military equipment (helicopters, planes, chemicals to spray the illegal crops, radars, etc.) and training. We take some observed outcomes of the cocaine markets from the United Nations Office for Drug Control (UNODC) such as the number of hectares cultivated with coca crops, the price of cocaine at the farm gate in Colombia and the wholesale price of cocaine in consumer countries, data on drug seizures before and after PC, and available estimates on productivity per hectare. We also use data from the Colombian Government for estimates of U.S. and Colombian military expenditures under PC. We will take an average of the outcomes observed between 1999 and 2000 as the reference point before PC and averages for 2005 and 2006 as the reference point after PC.[18]

We will denote all variables before PC (that is, all average for years 1999 and 2000) with a subscript B. In order to keep the notation as simple as possible, all variables after PC (averages for years 2005 and 2006) will not have a subscript. In the remaining of this section we describe the main equations from the model that we will use to recover the parameters of the model. As it will become clear, the calibration strategy follows recursively.

3.1 A brief description of the data

Using satellite images, UNODC estimates that the average number of hectares cultivated with coca crops, q^*L, before PC was about 161,700 and, after PC, this number had decreased to about 82,000 hectares. Using an estimated value for $L \simeq 500.000$, which is the number of hectares that can potentially be used to cultivate coca (from Grossman and Mejía, 2008) and the figures for coca cultivation just described, the percentage of land under the effective control of the drug producers, q^*, was about 32,3% before PC and 16,4% after PC.

The figures on productivity per hectare are estimated by UNODC using field studies in a sample of workshops in the cocaine producing regions.[19] Although there is a large variance in productivity per hectare across different regions in Colombia, on average, one

[18] Although there is available data for 2007, UNODC usually makes revisions to their estimates of the illegal drug markets for the previous year and therefore it is more convinient to use data that has already been thoroughly revised.

[19] See UNODC's crop monitoring reports for different years.

hectare of land cultivated with coca crops before PC produced about 4.25 kilograms of pure cocaine. After PC this number was estimated at about 7.8 kilograms per hectare per year. Potential cocaine production in Colombia was about 687,500 kilograms before PC and about 645,000 kilograms after PC.[20] Using the estimates of drug seizures in Colombia calculated by UNODC as well as the data on potential cocaine production, we can recover the fraction of drugs that are note seized (in Colombia). Reported seizures of pure cocaine were about 87 metric tons before PC and about 116 metric tons after PC.[21] This implies that before PC the fraction of cocaine not seized, h^*, was about 87.3% whereas after PC it was about 81.9%. Once one takes into account drug seizures of Colombian cocaine outside of Colombia, the Colombian supply of cocaine, net of total interdiction, was about 561,000 kilograms before PC and about 474,000 kilograms after PC. When estimating some of the parameters of the model we need to control for the fact that Colombia is not the sole supplier of cocaine in the world. In fact, potential cocaine production in the world, that is adding to Colombian production that of Bolivia and Peru, was about 902,000 kilograms and 982,000 kilograms before and after PC respectively. In other words, while Colombian potential cocaine production decreased between 2000 and 2006, the production of Bolivia and Peru together increased. Before PC the share of total cocaine supplied by Colombia was about 78%, whereas after PC this share had decreased to about 63%.

According to UNODC, the average price of a kilogram of cocaine at the wholesale level in consumer countries, P_f^*, was about \$37,900 before PC and, after PC, about \$35,800.[22] In Colombia, the price of a kilogram of cocaine at the farm gate, P_d^*, was approximately \$1,500 before PC and \$1,860 after PC.

According to Colombia's National Planning Department (DNP, 2006), the total military component of Colombian expenses in the war on drugs under PC has been about \$566

[20] UNODC estimates potential cocaine production multiplying the estimates for productivity per hectare per year (kilograms of cocaine obtained from one hectare of land cultivated with coca crops in one year) obtained from samples of filed work in workshops in producer countries, and the estimated number of hetares of land cultivated with coca crops. For a thorough description of these estimates see UNODC crop monitoring reports for Colombia fro different years. These methodologies as well as possible biases are also discussed in some detail in Mejia and Posada (2008).

[21] These are estimates for seizures of pure cocaine inside Colombia.

[22] For these price figures at the wholesale level in consumer country we take a weighted average of reported prices in Europe and the US, with the weights before PC being 1/4 for Europe and 3/4 for the US. The weights we use after PC are 45% and 55% respectively. These weights are approximately equal to the share of total cocaine consumers in Europe and the US before and after PC.

million per year since 2000.[23] Although we don't have direct estimates for every year, we take this average as the baseline for the expenses in the war on drugs after PC. We don't have an official estimate for the level of Colombian expenses in the war against drug production and trafficking before PC. However, we do have estimates for military and defense expenditures as a share of GDP. Before PC this share was about 3.25% and, after PC, this share had increased to about 4.3%. That is, between 1999-2000 and 2005-2006 total military and defense expenditures as a share of GDP increased by about 32%. We also have an estimate for the number of members of the military forces per 1.000 inhabitants in Colombia. Before PC this number was about 3,5 and after PC it had increased to about 4.7, that is, a 37% increase between 1999-2000 and 2005-2006. Based on these two proxies we make the assumption that Colombian expenses in the war on drugs increased by about 35% between 1999-2000 and 2005-2006. Combining this assumption and the figure for Colombian expenses in the war on drugs after PC, we arrive at an estimate for Colombian expenses in the war on drugs before PC of about $420 million. The United States, on the other hand, has spent about $465 million per year in subsidies to the military forces of Colombia in order to strengthen their resolve in the war against illegal drug production and trafficking (see DNP, 2006).

Finally, we take $n = 2$, to be the number of illegal drug producers after PC. There is wide agreement among Colombian and foreign observers[24] that Fuerzas Armadas Revolucionarias de Colombia (FARC) and the Autodefensas Unidas de Colombia (AUC), notwithstanding their historical origins as left-wing guerrillas and right-wing paramilitaries respectively, act as the new drug producers and are the residual claimants of the profits from cocaine

---

[23] The other two broad components on Plan Colombia (in addition to the military component) are institutional strenghthening and social programs.

[24] Rabasa and Chalk (2001), Echeverry (2004), Thoumi (2003), and UNODC (2003). Bottía (2003) and Diaz and Sanchez (2004) use data from municipalities to confirm the high correlation between cocaine production and the control of arable land by the FARC and the AUC. Rangel (2000) tells us that at one time the FARC only taxed and provided security for those stages related to drug production and exportation — the cultivation of coca, the manufacturing of cocaine from coca base, and the trafficking of cocaine — but that subsequently, the FARC began, as it does now, to organize and direct the production and exportation of cocaine.

In a recent interview Salvatore Mancuso, once the head of the AUC and now serving prision in the US for drug trafficking, admits that the AUC and the FARC now control the business of cocaine production (and part of the trafficking) in Colombia. He also explicily states, while mentioning some facts, that the split of production between the two groups is about equal (see Revista Semana, 'Las Cuentas de Mancuso,' available at: http://www.semana.com/wf_InfoArticulo.aspx?idArt=115092).

production and from cocaine trafficking (at least in the initial stages of the trafficking network).

Table 1 summarizes the main stylized facts described above about the cocaine market and the war on drugs in Colombia before and after PC that will be used in the calibration of the model.

[Insert Table 1 here].

3.2 Results and discussion

We now consider the calibration of the model. As the reader shall see, the calibration follows recursively. That is, using the observed data described in the previous section, we start with the equations of the model where we can estimate parameters with the information that we have and then turn to other equations of the model in order to estimate the remainder parameters. We first calibrate the model without the assumption that the interested outsider (i.e., the U.S. government) chooses an efficient allocation of subsidies between the two fronts of the war on drugs. In other words, we allow the available information to determine whether the subsidies granted by the U.S. government for the war on drugs in Colombia have been assigned efficiently; if not, we estimate the efficiency cost of this misallocation. As discussed in the previous section, the condition for an efficient allocation of subsidies is that the marginal cost (again, to the U.S.) of decreasing the successful production and exportation of drugs by one kilogram through subsidizing the Colombian military's efforts against illegal drug production (equation 47) should be equal to the marginal cost (to the U.S.) of decreasing the successful production and exportation of drugs by one kilogram through subsidizing the Colombian military's efforts against illegal drug trafficking (equation 48).

We first estimate the parameters of the drug trafficking technology.[25] From equation 2, we get:

$$(h\kappa)^{1-\eta} Q_d^{\eta} = Q_f \tag{49}$$

Also, from equation 5, the drug trafficker's demand for drugs becomes:

[25] In order to keep the notation as simple as possible, we abstract from including and * to the endogenous variables in equilibrium. Of course, all endogenous variables observed in the data (prices, quantities, h, q, etc.) are equilibrium values.

$$Q_d = h\kappa \left(\frac{\eta P_f}{P_d} \right)^{\frac{1}{1-\eta}} . \tag{50}$$

Replacing equation 50 into equation 49, simplifying, and then solving for η, we get:

$$\eta = \frac{P_d Q_d}{P_f Q_f} \quad \Rightarrow \quad \eta \simeq 0.07 \ . \tag{51}$$

This estimate of the parameter η implies that the relative importance of cocaine in the trafficking technology is about 7%, whereas the relative importance of the route for transporting the illegal drugs is about 93%.

Rearranging the equation for the equilibrium fraction of drugs that survives the government's interdiction efforts (equation 12), we get:

$$\frac{h_B}{(1-h_B)(1-\eta_B)} = \frac{\gamma}{c_2} \qquad \text{and} \qquad \frac{h}{\Omega(1-h)(1-\eta)} = \frac{\gamma}{c_2}, \tag{52}$$

before and after PC respectively. Recall that before PC, $\Omega = 1$ (that is, before PC there were no subsidies for Colombia for its war on drugs). Using the two expressions in equation 52, and the UNODC's estimates for the fractions of drugs seized before and after PC, we get:

$$\Omega = \frac{h(1-h_B)(1-\eta_B)}{h_B(1-h)(1-\eta)} \quad \Rightarrow \quad \Omega \simeq 0.67. \tag{53}$$

The estimate of the subsidy from the U.S. government to the Colombian government implies that the former paid for about 33% $(1-\Omega)$ of the expenses for the interdiction efforts of the latter.

Using the estimate for η from equation 51, together with the expression for the trafficking technology (equation 2) and the observed data on drug production and seizures, we can recover κ :

$$\kappa = \frac{1}{h} \left(\frac{Q_f}{Q_d^{\eta}} \right)^{\frac{1}{1-\eta}} \quad \Rightarrow \quad \kappa \simeq 565,601 \ \cdot \tag{54}$$

Using the expression for the demand for drugs in the consumer country (equation 1), we have:

$$\frac{a}{P_{fB}^b} = Q_{fB} \qquad \text{and} \qquad \frac{a}{P_f^b} = Q_f, \tag{55}$$

before and after PC respectively.

Combining the two expressions in equation 55, and controlling for the fact that Colombia's potential cocaine production before PC was about 78% of worldwide potential cocaine production and, after PC, this share decreased to about 63%, we obtain:

$$\left(\frac{P_{fB}}{P_f}\right)^b = \frac{0.78Q_f}{0.63Q_{fB}}. \tag{56}$$

Solving the previous expression for b, and using the available data on the quantities and prices of cocaine before and after PC, we get:

$$b = \frac{\ln\left(\frac{0.78Q_f}{0.63Q_{fB}}\right)}{\ln\left(\frac{P_{fB}}{P_f}\right)} \quad \Rightarrow \quad b \simeq 0.67. \tag{57}$$

It should be noted that the price elasticity of demand for cocaine that we are calibrating is not that for final consumers, but rather that for drug dealers at the wholesale level in the consumer country. As Becker et al. (2006) show, the price elasticity of demand is a crucial parameter behind the effectiveness of the war on drugs. A relatively inelastic demand for cocaine implies that a large increase in the resources allocated to the war on illegal drug production and trafficking will only decrease the amount of drugs transacted by a relatively small amount.

Using the estimated value for b and equation 1 we estimate the scale parameter of the demand function, a, as:

$$a = Q_f P_f^b. \quad \Rightarrow \quad a \simeq 820,395,752. \tag{58}$$

In order to recover the parameters of the drug production technology, we use available data for the productivity per hectare of land used in the cultivation of coca crops - that is, the number of kilograms of cocaine produced on one hectare of land in one year. According to UNODC, the productivity per hectare in Colombia increased from about 4.25 kg per hectare per year before PC to about 7.8 kg per hectare per year after PC. This large increase in productivity has been attributed to better planting techniques and to the use of more productive intermediate inputs. Using equation 34, the productivities per hectare per year before and after PC can be expressed as:

$$\left(\frac{Q_i}{l_i}\right)_B = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_{dB}^{\frac{\alpha}{1-\alpha}} \qquad \text{and} \qquad \left(\frac{Q_i}{l_i}\right) = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_{d}^{\frac{\alpha}{1-\alpha}} \ . \tag{59}$$

Using the two expressions in equation 59, and solving for α yields

$$\alpha = \frac{\ln\left(\frac{(Q_i/l_i)_B}{(Q_i/l_i)}\right)}{\ln\left(\frac{P_{dB}}{P_d}\right) + \ln\left(\frac{(Q_i/l_i)_B}{(Q_i/l_i)}\right)} \quad \Rightarrow \quad \alpha \simeq 0.73 \ . \tag{60}$$

The estimated value of α implies that the relative importance of land in the production of cocaine is about 27%, whereas that of other inputs (chemicals, workshops, the "cook," etc.) is about 73%.

Having found an estimate for α, the scale parameter of the cocaine production technology can be obtained from the expression for the productivity per hectare per year (the second expression in equation 59) as:

$$\lambda = \frac{(Q_i/l_i)^{1-\alpha}}{(\alpha P_d)^{\alpha}} \quad \Rightarrow \quad \lambda \simeq 0.01 \ . \tag{61}$$

We now turn to the calibration of the costs faced by the Colombian government per unit of income obtained by illegal drug producers and traffickers, c_1 and c_2 respectively. Rearranging equations 12 and 31, we get:

$$\frac{c_2}{\gamma} = \frac{\Omega(1-\eta)(1-h)}{h} \qquad \text{and} \qquad \frac{c_1}{\phi} = \frac{\omega(1-\alpha)(1-q)}{qn^2} \ . \tag{62}$$

In order to calibrate $c_1$and c_2, as well as other parameters, we use the equation describing the government's total expenses for the war on drugs before and after PC (equations 64 and 65 below).

The Colombian budget for the war against drugs after PC is the sum of the costs for each front of this war. If we let M_s denote the government's total budget for the war on drugs, we have:

$$M_s = n\omega z^* + \Omega s^*. \tag{63}$$

Replacing the values for z^* and s^* in equation 63 and simplifying, we get:

$$M_s = (1-q^*)P_d Q_d c_1 + (1-h^*)P_f Q_f c_2. \tag{64}$$

The expression in equation 64 corresponds to total Colombian expenses on the war on drugs after PC. The corresponding expression for before PC is given by:

$$M_{sB} = (1 - q^*_B)P_{dB}Q_{dB}c_1 + (1 - h^*_B)P_{fB}Q_{fB}c_2. \tag{65}$$

We have values for all the variables in equations 64 and 65 except $c_1$and c_2. Solving for these two unknowns in equations 64 and 65, we get:

$$c_1 = \frac{M_{sB}(1 - h^*)P_fQ_f - (1 - h^*_B)P_{fB}Q_{fB}M_s}{(1 - q^*_B)P_{dB}Q_{dB}(1 - h^*)P_fQ_f - (1 - h^*_B)P_{fB}Q_{fB}(1 - q^*)P_dQ_d} \quad \Rightarrow \quad c_1 \simeq 0.40 \ , \tag{66}$$

and,

$$c_2 = \frac{M_{sB}(1 - q^*)P_dQ_d - (1 - q^*_B)P_{dB}Q_{dB}M_s}{(1 - q^*_B)P_{dB}Q_{dB}(1 - h^*)P_fQ_f - (1 - h^*_B)P_{fB}Q_{fB}(1 - q^*)P_dQ_d} \quad \Rightarrow \quad c_2 \simeq 0.05 \ . \tag{67}$$

These estimates imply that, with the price in Colombia of one kilogram of cocaine at \$1,860, the Colombian government perceives a cost of about \$760 per kilogram of cocaine successfully produced ($0.4 \times \$1,860$). With potential cocaine production after PC at about 645,000 kilograms, the cost to the Colombian government arising from cocaine production has been roughly \$490 million per year. This cost does not include yet the costs of fighting the war against drugs, which will be estimated and discussed below. Turning to the other front of the war on drugs (the interdiction front), we find that, with the price per kilogram of cocaine at the wholesale level in consumer countries at about \$35,800, the Colombian government faces a cost of about \$1,790 per kilogram of cocaine that is successfully exported ($0.05 \times \$35,800$). If about 474,000 kilograms of cocaine per year were successfully exported after PC, the cost to the Colombian government arising from illegal drug trafficking has been about \$848 million per year. This cost does not include the cost of fighting the war against illegal drug trafficking, which, again, will be estimated and discussed below.

The total subsidies from the interested outsider (the U.S. government) to the producer country, M_o, equals the sum of the subsidies allocated to the war against production and those allocated to the war against drug trafficking. That is:

$$M_o = (1 - q)\frac{1 - \omega}{\omega}Q_dP_dc_1 + (1 - h)\frac{1 - \Omega}{\Omega}Q_fP_fc_2. \tag{68}$$

We now use equation 68 to estimate the subsidy from the interested outsider to the drug producer country's government in its war against drug producers, $1-\omega$. Solving equation 68 for ω, and using the data on prices, quantities, and the parameters estimated so far yields:

$$\omega = \frac{M_o - (1-h^*)\frac{1-\Omega}{\Omega} Q_f P_f c_2}{(1-q^*) Q_d P_d c_1 + M_o - (1-h^*)\frac{1-\Omega}{\Omega} Q_f P_f c_2} \quad \Rightarrow \quad \omega \simeq 0.51 \ . \tag{69}$$

The calibrated value of ω implies that, after PC, the U.S. government has funded about half (49%) of Colombia's expenses in its conflict over land with illegal drug producers.

Having estimated ω, c_1, and c_2, we can now use the two expressions in equation 62 to calibrate the relative efficiency of the resources allocated by drug producers in their conflict with the government for the control of arable land, ϕ, and the relative efficiency of the resources that the drug trafficker allocates in order to avoid the interdiction of drug shipments, γ. Solving for γ in the first expression of equation 62, and using the estimations obtained so far, yields:

$$\gamma = \frac{h^* c_2}{\Omega(1-h^*)} \quad \Rightarrow \quad \gamma \simeq 0.36 \ . \tag{70}$$

Solving for ϕ in the second expression of equation 62 and, again, using the estimations obtained so far, we get:

$$\phi = \frac{q^* c_1 n^2}{\omega(1-\alpha)(1-q^*)} \quad \Rightarrow \quad \phi \simeq 2.33 \ . \tag{71}$$

On the one hand, the estimated value for γ implies that the resources that the drug trafficker allocates to evade the interdiction of drug shipments are less efficient than the resources allocated by the Colombian government to the interdiction front of the war on drugs. On the other hand, the value of ϕ resulting from the calibration of the model implies that the resources allocated by drug producers to the conflict over arable land are much more efficient than those allocated by the Colombian government to this conflict. In sum, the results imply that the government is 2.7 times more efficient (1/0.36) in interdicting drug shipments than the drug trafficker is in escaping the interdiction, whereas the drug producers are about 2.3 times more efficient than the government in the conflict over the control of arable land.[26]

[26] Although the Colombian army has access to better technologies and equipment, the fact that the illegal armed groups associated with illegal drug production are able to use guerrilla tactics in its war against the government's armed forces may help counteract the first factor.

Table 2 summarizes the main results from the calibration of the model.

[Insert Table 2 here].

3.3 Other variables of interest

Having estimated all the parameters of the model, we can now recover other important variables of the model. Among others, the equilibrium level of expenses for each of the actors involved in the war on drugs, the profits and profit margins for drug producers and the drug trafficker, the intensity of conflict, and the total cost of fighting the war on drugs in Colombia.

First, we estimate the level of expenses for each actor involved in the war on drugs. These estimates are:

Variable	**Estimated value**
x_i	\$33.6 million
y_i	\$80.3 million
z_i	\$399.0 million
r_i	\$439.1 million
t	\$2.86 billion
s	\$233 million

According to our estimates, after PC, each illegal drug producer spends about \$33.6 million dollars per year fighting the Colombian government for the control of arable land, and about \$80.3 million fighting against other illegal drug producers. Furthermore, each drug producer spends about \$439.1 million dollars on those factors that are complementary to land in the production of cocaine (chemicals, workshops, "cooks", *raspachines*,[27] etc.). Colombia and the U.S., on the other hand, spend about \$399 million per year in the conflict over the control of arable land against each one of the drug producers. The drug trafficker spends about \$2.86 billion per year trying to avoid the interdiction of cocaine shipments (go-fast boats, submarines, small airplanes, drug mules, corrupting the authorities, etc.). This is not surprising, given the huge profit margins associated with illegal drug trafficking activities. Colombia and the U.S. together spend about \$233 million trying to interdict

[27] This is the name in Spanish for those workers in charge of cultivating and harvesting illegal crops.

illegal drug shipments.

Using the information in Table 3, we can estimate the sum of the resources allocated to the war on drugs by all actors involved (the government, the interested outsider, drug producers, and the drug trafficker). This sum, here denoted by IC, can be understood as a measure of the intensity of the war on drugs. This measure does not include investments in r (the complementary factors to land in the production of cocaine) by the drug producers, as this variable does not capture investments in the conflict, but rather an investment in a factor of production of cocaine. IC is given by:

$$IC = t + s + \sum_i (x_i + y_i + z_i) \simeq 4.1 \text{ billion dollars.} \tag{72}$$

Having estimated the level of expenses for each front of the war on drugs in Colombia, we can now obtain an estimate for the profits from illegal drug production (for each drug producer) and from cocaine trafficking. The profits for each individual drug producer are given by:

$$\pi_i \simeq 46.7 \text{ million per year.} \tag{73}$$

This figure denotes the profits obtained by each illegal drug producer per year. According to a press release from the Office of National Drug Control Policy (ONDCP), FARC drug profits in 2005 ranged between \$60 and \$115 million.[28] Our estimate for FARC drug profits of \$46.7 million for 2005-2006, which includes only those profits from cocaine production and not those from drug trafficking, is not too far from that obtained by other sources, especially if one takes into account that the FARC are also involved in the very initial stages of cocaine trafficking inside Colombia. The same press release also mentions that FARC drug profits per kilogram of cocaine produced are between \$195 and \$320. Our estimate for FARC drug profits per kilogram of cocaine successfully produced is \$160. Again, this figure does not include FARC profits from cocaine trafficking.[29]

[28] See http://www.whitehousedrugpolicy.gov/pda/060407.html.

[29] The similarity between our estimates and the ONDCP's figures on FARC profits per kilogram of cocaine tells us that the FARC produces about half of the total cocaine produced in Colombia, which confirms our assumption that $n = 2$, with the other group controlling the production of cocaine being the paramilitaries (AUC).

The average rate of return from illegal drug production, calculated as the ratio of total profits to total costs from illegal drug production, is estimated to be roughly 8.4%.

Using equations 87, 86, and 12 to express the drug trafficker's profits (equation 4) as a function of the parameters of the model, we can use the parameter values estimated so far in order to find an estimate for this variable:

$$\pi_T \simeq 12.9 \text{ billion per year.} \tag{74}$$

This estimate denotes the total profits from cocaine trafficking. To simplify the analysis in our model, we made the assumption of a single drug trafficker, though in fact, there are probably many groups engaged in cocaine trafficking that share these profits. Furthermore, drug trafficking activities require vertically integrated networks that operate not only in Colombia, but also along the routes towards drug consumer countries in North America and Europe. The average rate of return from illegal drug trafficking, calculated as the ratio between total profits to total costs from illegal drug trafficking, is roughly 318%.

The total costs to the Colombian government arising from illegal drug trafficking and production are, respectively:

$$C_T \simeq 1.021 \text{ billion per year,} \tag{75}$$

and,

$$C_P \simeq 900 \text{ million per year.} \tag{76}$$

According to our results, the total cost to Colombia from illegal drug production, trafficking, and the war against these activities, is about \$2 billion per year.

We now estimate the marginal cost to the interested outsider (i.e. the U.S.) of reducing the amount of cocaine reaching the consumer country by one kilogram. Using equations 47 and 48, we estimate the marginal cost to the U.S. government of reducing the supply of cocaine reaching consumer countries by one kilogram by reducing ω and by reducing Ω, respectively. The estimates for these two marginal costs are:

$$MC_{\omega}^{U.S.} \simeq \$118,438 \quad \text{and} \quad MC_{\Omega}^{U.S.} = \$4,279 \ . \tag{77}$$

The corresponding marginal costs to Colombia of reducing the quantity of cocaine successfully exported to consumer countries by one kilogram if the U.S. marginally changes ω or Ω are thus given by:

$$MC_{\omega}^{COL} \simeq \$\ 9,796 \quad \text{and} \quad MC_{\Omega}^{COL} = \$2,243\ . \tag{78}$$

The total marginal cost of reducing the amount of cocaine reaching consumer countries by one kilogram by reducing ω and Ω is given by the sum of the respective marginal costs to the U.S. and Colombia.

Table 3 (column 1) summarizes the results for the variables of interest using UNODC data for the calibration under the current (inefficient) allocation of subsidies by the U.S. to the war on drugs in Colombia.

Given the difference in the estimated marginal costs and the fact that the calibrated values for $1-\omega$ and $1-\Omega$ are strictly positive, we can infer that the allocation of subsidies to the two fronts of the war on drugs under PC has not been efficient.[30]

A few questions naturally follow from this last result. What would be the subsidies to the two fronts of the war on drugs under an efficient allocation? What is the efficiency loss due to the misallocation of subsidies? Finally, what would be the equilibrium level of the endogenous variables of the model if the subsidies were allocated efficiently? Recall that based on the calibration of the model presented above, we found that $1-\omega \simeq 0,49$ and $1-\Omega \simeq 0,33$. Using the optimality condition for the interest outsider's problem (equations 46, 47, and 48) as well as its budget constraint (equation 68) we calibrate the efficient allocation of subsidies to the two fronts of the war on drugs in Colombia. We find that the solution would be a corner solution. More specifically, we find that under an efficient allocation of subsidies, the U.S. government would allocate all its resources to subsidizing the Colombian government's interdiction efforts. Under an efficient allocation, the U.S. government would not subsidize the Colombian government in its conflict with the drug producers over the control of arable land ($1-\omega^* \simeq 0$), and it would, however, subsidize about 64% of the resources spent by the Colombian government on the interdiction of illegal drug shipments (under the current allocation the U.S. subsidizes only 33% of Colombian expenses on this front of the war on drugs). Under an efficient allocation, then, we would have the following:

$$1-\omega^* \simeq 0 \quad \text{and} \quad 1-\Omega^* \simeq 0.64. \tag{79}$$

[30]Note that the two marginal costs could in principle be different, even if the interested outsider is allocates subsidies efficiently. However, this would be the case only if the solution to the interested outsider's problem is a corner solutuion (that is, with either $1-\omega=0$, or $1-\Omega=0$). However, the calibrated values for both ω and Ω are strictly less than 1 ($\omega = 0.51$ and $\Omega = 0.67$).

With these optimal subsidies, we can now estimate the marginal cost of decreasing the supply of drugs in consumer countries. These marginal costs are now given by:[31]

$$MC_{\omega^*}^{U.S.} \simeq \$67,679 \quad \text{and} \quad MC_{\Omega^*}^{U.S.} = \$10,141 \tag{80}$$

The respective figures for Colombia would then be:

$$MC_{\omega}^{COL} \simeq \$\ 19,314 \quad \text{and} \quad MC_{\Omega}^{COL} = \$2,470\ . \tag{81}$$

Another question naturally arising from the finding that subsidies have not been allocated efficiently is, by how much would the supply of cocaine have been decreased if the U.S. had in fact allocated the subsidies to the war on drugs efficiently? We can estimate the supply of drugs using all of the parameters of the model calibrated above but, instead of using the estimated values for ω and Ω, we use the subsidies under an efficient allocation - $1-\omega^* = 0$ and $1-\Omega^* = 0.64$. Had the subsidies been allocated efficiently, we find that the cocaine supply in consumer countries would have been 11% lower than it actually was. That is, instead of being about 474,000 kilograms, it would have been about 420,480 kilograms. In other words, although the subsidies were not allocated efficiently, the efficiency loss due to the inefficient allocation was relatively low.

Table 3 (column 2) presents the results for the variables of interest using UNODC data in the calibration, but assuming an efficient allocation of subsidies to the two fronts of the war on drugs in Colombia.

3.4 Robustness check

In the previous section, we used the figures produced by the UNODC, the main data source for data on, among other things, illegal drug production, illegal crop cultivation, interdiction, and market outcomes, in order to calibrate the parameters of the model. However, there is an additional, alternative source of information for some of the data that we used in the calibration exercise. The White House Office for National Drug Control Policy (ONDCP) also collects data on coca cultivation and the interdiction of illegal drugs.[32]

[31] Note that these two marginal costs are not equal because the solution to the optimization problem for the interested outsider is in a corner. The relevan marginal cost is the lowest one, that is $MC_{\Omega^*}^{US}$.

[32] Many informed observers agree that ONDCP data is not as reliable (see, for instance, Dobbs, 2007, and Mejia and Posada, 2008). For instance, the ONDCP also produces an estimate of potential cocaine production. There are many problems with this estimation however. For one thing, the ONDCP never

Furthermore, we also have data on cocaine prices from a different data source, STRIDE. Although STRIDE price data mostly captures retail transactions in the U.S., it also produces a price series for transactions of cocaine greater than 50 grams (with a median of about 118 grams per transaction). This is the closest alternative figure we might use for the wholesale price of cocaine in the U.S. in order to check the robustness of our results. Unfortunately, STRIDE data is only available through 2004, though Arkes et al. (2008) produced a price series based on STRIDE price data through 2005.[33] It is this price data that we use in the robustness check.

Table 4 presents the data from ONDCP and STRIDE (before and after PC), as well as the other figures that we use to calibrate the model in this section.

[Insert Table 4 here]

Table 5 (column 1) reports the results from the calibration of the model using coca cultivation figures,[34] as well as the interdiction figures from the ONDCP. For the wholesale price of cocaine we use the price of a kilogram of cocaine as reported by Arkes et al. (2008) for transactions greater than 50 grams (with a mean size for transactions of about 118 grams). Because the price data is only available up through 2005, we use an average of the figures between 1999 and 2000 as a reference point for before PC, and an average of the figures between 2004 and 2005 for after PC. In column 2, we report the results we obtained before using the UNODC data so as to compare the robustness and stability of our results. As the reader will notice, the calibration results are very similar to the ones obtained using the UNODC data. While our original calibration for the price elasticity of demand, b, was about 0.67, we obtain a slightly higher value, $b \simeq 0.86$, using the alternative data sources; although higher than our original estimate, it still denotes a relatively inelastic demand for drugs. Using the ONDCP and STRIDE data, we estimate α to be about 0.7 and η about 0.13 (using the UNODC data, these values were 0.73 and 0.07, respectively). As for the costs faced by the Colombian government from illegal drug production and trafficking, we

says how it calculated these figures; furthermore, the figures themselves are very erratic, and the reported figures for a given year are changed frequently in official statements and press releases. As a result, we only use ONDCP figures for coca cultivation, while continuing to use the productivity measures from the original data source, the UNODC,in arriving at estimates of potential cocaine production.

[33] See Arkes et al. (2008) for details.

[34] ONDCP extended the surveyed area in Colombia by about 81% in 2005. Fortunately, for 2005 the coca cultivation figures they report are for both, for the originally surveyed area (before 2005) and for the extende area. We use the numbers they report for the originally surveyed area.

get $c_1 \simeq 0.26$ and $c_2 \simeq 0.18$, respectively; using the UNODC data, we had that $c_1 \simeq 0.4$ and $c_2 \simeq 0.05$. Only one parameter significantly changes when we use the alternative data sources, γ, the relative effectiveness of the resources invested by illegal drug trafficker to avoid the interdiction of drug shipments. The result obtained for this parameter using the UNODC figures was about 0.36, while that using the ONDCP interdiction data is much higher, $\gamma = 2.12$. We find then that illegal drug traffickers are more (and not less) effective than the government in the interdiction sub-game using the ONDCP data.

[Insert Table 5 here]

The values for the other endogenous variables of the model estimated using the ONDCP and STRIDE data are reported in Table 6 (column 1). Regarding the qualitative result concerning the efficiency in the allocation of subsidies between eradication and interdiction efforts, we get the same result - namely, that the U.S. should only be funding interdiction efforts, and not the conflict for the control of arable land. Using the ONDCP data and STRIDE prices, we report the results for the variables of interest under an efficient allocation of subsidies in Table 6 (column 2). Had the subsidies been allocated efficiently,the quantity of cocaine reaching the U.S. markets would have been about 10,000 kilograms less (that is, 239,785 kilograms, as compared to 250,100 kilograms under the current allocation). In other words, had the subsidies been allocated efficiently, the cocaine supply in consumer countries would have been about 4.1% lower than it actually was.

[Insert Table 6 here]

3.5 Simulations

An important policy question that one can answer within the framework developed in this paper is, by how much would the cocaine supply decrease if the total budget allocated to subsidies for the war on drugs in producer countries were increased?. This estimation would give us a measure of the costs of making "important advances" in the war on drugs, not only in terms of the monetary costs involved in reducing the amount of cocaine produced and trafficked, but also in terms of the change in the intensity of conflict that these policies might induce. We also study the response of many of the model's other endogenous variables to an increase in the U.S. budget allocated to the war on drugs in Colombia. In order to do this, we conduct numerical simulations under the assumption that subsidies to the two fronts of the war on drugs are allocated efficiently. More precisely, we exogenously increase

$\overline{M}$ (the total U.S. budget allocated to the war on drugs in Colombia) and determine the response of some of the key variables of the model.

Figures 1, 2, and 3 show the results of the simulations for an exogenous increase in $\overline{M}$, from about $400 million to about $1,500 million, using the calibration results obtained with UNODC data. We find that an efficient allocation of subsidies still implies (for all levels of $\overline{M}$ between $400 million and $1.500 billion) that the entire U.S. budget should be used to fund the Colombian government's interdiction efforts and none to fund its conflict with the drug producers over the control of arable land (panel A in Figure 1). While the fraction of drugs surviving interdiction decreases from about 72.2% to about 59%, the fraction of land under the drug producers' control stays constant at about 27% (panel B in Figure 1). The domestic quantity of cocaine slightly increases due to the fact that no funding is being assigned to fight against production; at the same time, the supply of cocaine in consumer countries (U.S. and Europe) would decrease from roughly $427,078$ kg to about $355,674$ kg (panel C in Figure 1) - that is, if the U.S. budget allocated to the war on drugs in Colombia is multiplied by a factor of about three, the quantity of cocaine reaching consumer countries would decrease by about 17%. This implies that the average cost to the U.S. of decreasing the supply of cocaine by 1 kg is about $15,405. Productivity per hectare, on the other hand, increases from about 5.58 kg per hectare per year to about 5.96 kg per hectare per year (panel D in Figure 1).

The marginal cost to the U.S. of reducing the supply of cocaine by 1 kilogram increases from about $9,235 per kilogram to about $23,207 per kilogram (panel A in Figure 2), and the marginal cost to the Colombian government increases from about $2,429 to about $2,970 (panel B in Figure 2). Colombian expenses on the war on drugs also increase by about 31% (panel C in Figure 2), due to the decrease in the subsidies granted by the interested outsider which causes a decrease in the marginal cost to Colombia of investing resources in interdiction efforts. The sum of the resources invested in the war on drugs by all the actors involved (our measure for the intensity of conflict in equation 72) increases from slightly less that $6 billion to about $10 billion (panel D in Figure 2).

While the wholesale price of a kilogram of cocaine at the border of the average consumer country increases from $41,920 to about $55,130 (that is, by about 32%), the domestic price of a kilogram of cocaine only increases by about 2% (panels A and B in Figure 3). Given that the optimality condition for the U.S. calls for no subsidies to the Colombian government in its conflict over the control of arable land, an increase in the budget increases producers' profits but decreases those of the drug trafficker (panels C and D in Figure 3).

The increase in producers' profits is about 10%, whereas the decrease in the drug trafficker's profits would be about 10%.

[Insert Figures 1 to 3 here].

Summarizing the results obtained from the simulations of an exogenous three-fold increase in the U.S. budget allocated to the war on drugs in Colombia, we find that the decrease in the supply of cocaine in consumer countries is very small relative to the large increase in the resources invested in the war on drugs. Although the price of cocaine in consumer countries increases by about 32%, the amount of cocaine transacted at the wholesale level would only decrease by about 17%. This result is explained, at least in part, by the relatively low elasticity of demand for cocaine that we estimated. The increase in the budget allocated to the war on drugs in Colombia also causes an increase in the resources allocated by the Colombian government to the war on drugs; in general then, it leads to an intensification of the war (in terms of the sum of the resources being invested in the war by all actors involved). For the Colombian government, the total cost of the war on drugs increases, as measured by the sum of C_T and C_P.

Table 3 summarizes the results for all the endogenous variables of the model under three different scenarios: the actual observed values of the variables (first column), the values of the endogenous variables that would be obtained had the subsidies been allocated efficiently, but with the current total level of expenditures by the U.S. (second column), and the predicted values of the endogenous variables of the model if the U.S. increased the total amount of resources allocated to the war on drugs in Colombia to $1,5 billion (third column).

When we carry out the same simulations but instead use the calibration results obtained using the ONDCP and STRIDE data, we obtain a very similar pattern for all the endogenous variables of the model.[35] An interesting result emerges, however. Namely, we find that for $\overline{M} \geq \$900$ million, the optimal allocation of subsidies between eradication and interdiction efforts is no longer in a corner solution; at that point, the U.S. should begin subsidizing the Colombian government in its war against drug producers over the control of arable land. In other words, if the total budget allocated by the U.S. government to the war on drugs in Colombia is greater than $900 million, we find that the U.S. should begin subsidizing the Colombian government on both fronts of the war on drugs. Recall that when we did the simulations using the UNODC data, we found that the U.S. should not

[35] The corresponding figures for these simulations are available from the authors upon request.

subsidize the Colombian government in its conflict with drug producers over the control of arable land; this held for any level of expenses in the war on drugs between \$400 million and \$1.5 billion. Using the ONDCP and STRIDE data, we find that a three-fold increase in the U.S. budget allocated to PC (from about \$465 million to \$1.5 billion) decreases the amount of cocaine reaching the U.S. wholesale market by about 32,000 kilograms (or by about 12.7%, see Table 6, third column).[36]

4 Discussion

4.1 Why is it so costly to make "important advances" in the war on drugs? (Or, why is the war on drugs so ineffective?)

This section provides an explanation as for why the war on illegal drug production and trafficking is so costly / ineffective. We identify the key factors underlying the ineffectiveness of the war on illegal drug production and trafficking.

After a few algebraic steps, we are able to express the marginal cost to the interested outsider of decreasing by 1 kilogram the amount of drugs reaching the consumer country by subsidizing the producer country's government in its war against drug producers over the control of arable land, as:

$$CM_{\omega}^{U.S.} = \frac{M_o}{Q_f}\left[\frac{1-b}{b} + \frac{b+\alpha\eta-b\alpha\eta}{b(1-\alpha)}\left(\frac{c_1(\Upsilon-\Upsilon q^2-q^2)}{q(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)\right] \tag{82}$$

The last expression implies that the elasticity of Q_f with respect to M_0, by subsidizing the government's conflict with the drug producer over the control of arable land, is:

$$\epsilon_{\omega} = \left(\frac{\partial Q_f}{\partial M_o}\right)_{\omega}\frac{M_o}{Q_f} = \frac{1}{\frac{1-b}{b} + \frac{b+\alpha\eta-b\alpha\eta}{b(1-\alpha)}\left(\frac{c_1(\Upsilon-\Upsilon q^2-q^2)}{q(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)} \tag{83}$$

We can also express the marginal cost to the interested outsider of decreasing by 1 kilogram the amount of drugs reaching the consumer country by subsidizing producer country's government in its interdiction efforts, as:

[36] Column 3 in Table 6 reports the predicted values (using the results of the calibration of the model obtained using the ONDCP and STRIDE data) for all the endogenous variables of the model, assuming an efficient allocation of subsidies, and that the U.S. increases the total budget allocated to PC from \$465 million to \$1.5 billion.

$$CM_{\Omega}^{U.S.} = \frac{M_o}{Q_f}\left[\frac{1-b}{b} + \frac{b+\alpha\eta-b\alpha\eta}{b(1-\eta)}\left(\frac{c_2(\Theta-\Theta h^2-h^2)}{h(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)\right] \quad (84)$$

The last expression implies that the elasticity of Q_f with respect to M_o, by subsidizing the interdiction efforts, is given by:

$$\epsilon_{\Omega} = \left(\frac{\partial Q_f}{\partial M_0}\right)_{\Omega}\frac{M_o}{Q_f} = \frac{1}{\frac{1-b}{b} + \frac{b+\alpha\eta-b\alpha\eta}{b(1-\eta)}\left(\frac{c_2(\Theta-\Theta h^2-h^2)}{h(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)} \quad (85)$$

Using the previous expressions, we are able to identify the key factors underlying the answer to our question, why is it so costly to make important advances in the war against drugs?

If the marginal costs in expressions 82 and 84 are large (or the elasticities in expressions 83 and 85 are small) then the war on drugs is more costly (less effective).

Given that the key factors driving up the costs are the same factors reducing the elasticities, let us focus on the elasticities, ϵ_{Ω} and ϵ_{ω}. Our numerical results suggest that $\epsilon_{\Omega} > \epsilon_{\omega}$; that is, at the U.S.'s current level of expenditures in the war on drugs in Colombia, subsidies should only be allocated to interdiction efforts. However, both of these elasticities are relatively small. The first one, ϵ_{Ω}, is about 0.102, and the second one, ϵ_{ω}, about 0.014, both assuming an efficient allocation of subsidies to the war on drugs under PC. This implies that a 10% increase (that is, an increase of about $50 million per year in actual values) in the U.S. budget allocated to interdiction efforts under PC (the best possible alternative) would only decrease the supply of cocaine reaching consumer countries by about 1% (or about 4,600 kilograms of cocaine); things could get even worse if the subsidies are allocated inefficiently, as in fact seems to have been the case.

So, then, why are these elasticities so small?

Both elasticities depend positively on b, the price elasticity of demand for cocaine at the wholesale level. If b is low, then the war on drugs tends to become more ineffective. Conversely, if the demand for drugs is relatively elastic, then the war on drugs tends to be more effective (a higher ϵ_{Ω} and ϵ_{ω}). This first key factor, the price elasticity of demand for illegal drugs, is in line with the conclusion arrived at by Becker et al. (2006). The reason for this is that, with an inelastic demand function, any attempt to shift the supply of drugs to the left has only minor effects on the quantity transacted and a relatively large effect on prices.

Additionally, the two elasticities depend negatively on ϕ and γ. If the resources invested by the government in the conflict over the control of arable land with drug producers or in interdiction efforts against the drug trafficker are less efficient (that is, relative to the resources invested by the drug producers and the drug trafficker respectively), then the responsiveness of Q_f to marginal increases in M_o will be lower.

Finally, the two elasticities depend positively on $(1-\alpha)$ and $(1-\eta)$. These are, respectively, the relative importance of land in the production of illegal drugs and the relative importance of drug routes in the trafficking technology. While we found a relatively high value for $(1-\eta)$, the value obtained for $(1-\alpha)$ was relatively low. In other words, while the war against illegal drug production is mainly a dispute over the control of arable land - which turns out to be a relatively unimportant factor in the production of cocaine - the war against illegal drug trafficking focuses on the interdiction of drug routes - which turn out to be relatively quite important in the trafficking technology. This difference in the relative importance of each of the factors being contested in the two fronts of the war on drugs is one of the reasons why the optimal allocation of subsidies is in a corner solution. This is a topic that will be elaborated on more detail in the subsection that follows.

4.2 Why should the U.S. only fund interdiction efforts in Colombia? (And why should Colombia be concerned about it?)

One of the policy recommendations emerging from our analysis and results is that the U.S. should only be funding interdiction efforts in Colombia. As this result might seem controversial, given the huge emphasis that Colombia and the U.S. have placed on eradication measures and the conflict over the control of arable land, it deserves further analysis. Two factors are behind this result. First, the elasticity of Q_f with respect to M_0, by subsidizing the government's conflict with the drug producer over the control of arable land, is much lower than the elasticity of Q_f with respect to M_0, by subsidizing the government's interdiction efforts - that is, $\epsilon_\Omega > \epsilon_\omega$. It follows then that the U.S. should allocate the resources devoted to the war on drugs in Colombia where they are more productive - that is, in the interdiction front of the war on drugs. Second, the war against illegal drug production constitutes a conflict over the control of arable land, whereas the interdiction front is a conflict over the fraction of routes controlled by the drug trafficker. While land turns out to be a relatively unimportant factor in the production of cocaine, routes turn out to be a very important factor in the trafficking technology - that is, the war on production represents a conflict over a relatively cheap factor, land, whereas interdiction represents a conflict over a very important and costly factor of production of drug shipments, drug routes.

So why should Colombia be concerned about the U.S. only allocating subsidies to interdiction efforts and none to subsidize Colombia in its conflict with drug producers over the control of arable land? The reason is very simple, the sum of the total costs to Colombia from illegal drug production and trafficking is lower under the current, relatively inefficient allocation of subsidies, than under an efficient allocation (for the U.S.). The reason for this is that, although the income derived by drug producers, P_dQ_d, is much lower than the income derived by the drug trafficker, P_fQ_f, c_1 is much higher than c_2; the difference between these two costs to Colombia more than counteracts the difference between the respective incomes of drug producers and the drug trafficker. Thus, Colombia is better off then under the current inefficient allocation of subsidies by the U.S. to PC. Costs c_1 and c_2 are important to the U.S. only to the extent that they induce Colombia to fight harder against drug producers and against drug traffickers, respectively. However, if the U.S. were to stop subsidizing Colombia in its war against drug producers over the control of arable land, drug production would increase, the income of drug producers would go up and, thus, the cost facing Colombia from this activity would increase. In fact, our results suggest that under an efficient allocation of subsidies, the total cost from illegal drug production would go up by about \$116 million, whereas the total cost from illegal drug trafficking would only go down by about \$4 million. As a result, the sum of these two costs to Colombia would increase if the subsidies to the two fronts of the war on drugs were allocated efficiently.

To summarize, the fact that Colombia faces costs c_1 and c_2, whereas the U.S. does not, creates an asymmetry in the preferred allocation of subsidies between the two countries.[37]

5 Concluding Remarks

Modelling the motivations and choices of the actors involved in the war on drugs using economic tools (more precisely, game theory tools) is an important step towards better understanding the observed outcomes and future prospects of this apparently-ineffective war.

In this paper, we developed a game-theory model of the war against illegal drug pro-

[37] One might naturally conjecture that the observed inneficiency in the allocation of subsidies between the two fronts of the war on drugs could mean that the U.S. also cares about the costs faced by Colombia, and not only about the quantity of drugs reaching consumer countries.

duction and trafficking, and use the available evidence from the cocaine market as well as the stylized facts of the war on drugs in Colombia in order to calibrate all the unobservable parameters of the model. Importantly, we are thus able to estimate important variables that are key for evaluating the effectiveness, efficiency, and costs of the war on drugs in Colombia, as well as its future prospects. The paper provides estimates for a wide range of parameters that are key to understanding the outcomes of the war on drugs - for instance, the value of the price elasticity of demand, which, in line with the results of Becker et al. (2006), is a key parameter for understanding the response of market outcomes to an increase in the budget allocated to the war on drugs. The paper also provides estimates for the marginal cost of decreasing the production and trafficking of cocaine by one kilogram, the allocation of resources to the war on drugs by the different actors involved, the intensity of conflict, and the rates of return associated with illegal drug production and trafficking, among others. .

By means of a simulation exercise, the paper also provides an analysis of the effects of increasing the U.S. budget allocated to the war on drugs in Colombia. In particular, we find that a three-fold increase in the U.S. budget allocated to the war on drugs in Colombia would only decrease the supply of cocaine that successfully reaches the consumer countries by about 17%, with an average cost to the U.S. of decreasing the exportation of cocaine by one kilogram of about $15,405.

The framework developed in this paper, as well as the estimates of key variables, should help policy makers objectively evaluate current anti-drug policies and, hopefully, guide them in the process of shaping more sound strategies in the war on illegal drugs.

References

Arkes, J., Liccardo Pacula , R., Paddock, S., Caulkins, J., and Reuter, P., 2008. Why the DEA Stride data are still useful for understanding drug markets. NBER working paper 14224, August.

Becker, G., Murphy, K. and Grossman, M., 2006. The Market for Illegal Goods: The case of Drugs. Journal of Political Economy 114(1), 38-60.

Bottía, M., 2003. La presencia y expansión municipal de las FARC: Es avaricia y contagio, más que ausencia estatal. Working Paper 2003-03, CEDE, Universidad de los Andes.

Caulkins, J., 1993. Local Drug Markets' Response to Focused Police Enforcement. Operations Research 41(5), 848-63.

Caulkins, J., 2004. Drug Policy: Insights from mathematical analysis. In: Brandeau, M., Sainfort, F., and Pierskalla, W., *Operations research and healthcare* (pp. 297-332). Boston: Kluwer.

Caulkins, J. and Hao, H., 2008. Modelling drug market supply disruptions: Where do all the drugs not go? Journal of Policy Modeling 30, 251-270.

Chumacero, R., 2006. Evo, Pablo, Tony, Diego, and Sonny. Mimeo, Universidad de Chile.

Costa Storti, C., and De Grauwe, P., 2008. Modelling the Cocaine and Heroin Markets in the Era of Globalization and Drug Reduction Policies. Paper presented at the CESifo Venice summer institute, 2008.

Díaz, A.M., and Sanchez, F., 2004. Geography of Illicit Crops and Armed Conflict in Colombia. Working Paper 2004-18, CEDE, Universidad de los Andes.

Departamento Nacional de Planeación (DNP), 2006. Balance Plan Colombia: 1999-2005. Septiembre.

Dobbs, M., 2007. Is There a Cocaine Shortage?. The Fact Checker, The Washington Post, November.

Echeverry, J.C., 2004. Colombia and the War on Drugs, How Short is the Short Run? Working Paper 2004-13, CEDE, Universidad de los Andes.

Grossman, H. and Mejia, D., 2008. The War Against Drug Producers. Economics of Governance 9(1), 5-23.

Hirshleifer, J., 1991. The Technology of Conflict as an Economic Activity. American Economic Review Papers and Proceedings 81 (2), 130-134.

Hirshleifer, J., 2001. Conflict and Rent-Seeking Success Functions: Ratio vs. Difference Models of Relative Success, in Hirshleifer, J., The Dark Side of Force, ch. 5, 89-101.

McDermott, J., 2004. New Super Strain of Coca Plant Stuns Anti-Drug Officials, The Scotsman, Scotland, August 27.

Mejia D. and Posada., C.E., 2008. Cocaine Production and Trafficking: What do we know?. Policy Research Working Paper 4618. The World Bank.

Mejia D., 2008. The War on Illegal Drugs: The interaction of anti-drug policies in producer and consumer countries. Mimeo, Universidad de los Andes.

Office of National Drug Control Policy (ONDCP), 2007. National Drug Control Strategy, FY 2007 Budget Summary.

Rabassa, A., Chalk, P., 2001. Colombian Labyrinth. RAND.

Rangel, A., 2000. Parasites and Predators: Guerrillas and the Insurrection Economy of Colombia. Journal of International Affairs 53(2). 577-601.

Reuter, P., 2008. Can Production and Trafficking of Illegal Drugs be Reduced or Merely Shifted? Policy Research Working Paper 4564. The World Bank.

Rydell, P., Caulkins, J., and Everingham, S., 1996. Enforcement or Treatment: Modelling the Relative Efficacy of Alternatives for Controlling Cocaine. Operations Research 44(5), 687-95.

Skaperdas, S., 1996. Contest Success Functions. Economic Theory 7, 283-290.

Thoumi, F., 2003. Illegal Drugs, Economy, and Society in the Andes. Woodrow Wilson Center Press and The Johns Hopkins University Press.

Tragler, G., Caulkins, J., and Feichtinger, G., 2001. Optimal Dynamic Allocation of Treatment and Enforcement In Illicit Drug Control. Operations Research 49(3), 352-62.

United Nations Office for Drug Control (UNODC), 1999 through 2007. World Drug Report.

United Nations Office for Drug Control (UNODC), 1999 through 2007. Drug Monitoring Report, Colombia.

Appendix

· Solution to the drug market equilibrium (in the producer and consumer countries).

Solving equations 35 and 36, the equilibrium price of drugs in the producer country, P_d, in the consumer country, P_f, and the corresponding drug quantities in the producing and consumer country are given by:

$$P_d^* = \frac{1}{q^{*\frac{(\eta+b-b\eta)(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{(1-b)(1-\alpha)(1-\eta)}{b+\alpha\eta-b\alpha\eta}}} \left(\frac{\Lambda}{\Delta}\right)^{\frac{(1-\alpha)(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}}, \tag{86}$$

and,

$$P_f^* = \frac{1}{q^{*\frac{\eta(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{1-\eta}{b+\alpha\eta-b\alpha\eta}}} \left(\frac{a}{\Pi}\right)^{\frac{1-\alpha\eta}{b+\alpha\eta-b\alpha\eta}}. \tag{87}$$

where: $\Delta = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} L$, $\Lambda = \left(a\eta^b \kappa^{\eta+b(1-\eta)-1}\right)^{\frac{1}{\eta+b(1-\eta)}}$, and $\Pi = \left(\alpha^{\alpha\eta}\lambda^{\eta}L^{(1-\alpha)\eta}\eta^{\alpha\eta}\kappa^{1-\eta}\right)^{\frac{1}{1-\alpha\eta}}$.

The corresponding equilibrium quantities transacted in the producer and consumer country are given by:

$$Q_d^* = \frac{q^{*\frac{b(1-\alpha)}{b+\alpha\eta-b\alpha\eta}}}{h^{*\frac{\alpha(1-b)(1-\eta)}{b+\alpha\eta-b\alpha\eta}}} \Delta^{1-\frac{\alpha(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}} \Lambda^{\frac{\alpha(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}},$$

and,

$$Q_f^* = q^{*\frac{b\eta(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{b(1-\eta)}{b+\alpha\eta-b\alpha\eta}} a^{1-\frac{b(1-\alpha\eta)}{b+\alpha\eta-b\alpha\eta}} \Pi^{\frac{b(1-\alpha\eta)}{b+\alpha\eta-b\alpha\eta}}.$$

· Parameters of the Interested Outsider's total expenses in the war on drugs (equation 38):

$$\Gamma = \frac{(1-\alpha)(\eta-b\eta)}{b+\alpha\eta-b\alpha\eta}, \quad \psi = \frac{(1-b)(1-\eta)}{b+\alpha\eta-b\alpha\eta},$$

$$\Upsilon = \frac{\phi(1-\alpha)}{c_1 n^2}, \quad \Theta = \frac{\gamma(1-\eta)}{c_2},$$

$$A = c_1\left(\frac{a\eta^b}{\kappa^{(1-b)(1-\eta)}\alpha^{\alpha\eta-b\alpha\eta}\lambda^{\eta-b\eta}L^{(1-\alpha)(\eta-b\eta)}}\right)^{\frac{1}{b+\alpha\eta-b\alpha\eta}}, \text{ and}$$

$$B = c_2\left(\frac{a}{\eta^{\alpha\eta-b\alpha\eta}\kappa^{(1-b)(1-\eta)}\alpha^{\alpha\eta-b\alpha\eta}\lambda^{\eta-b\eta}L^{(1-\alpha)(\eta-b\eta)}}\right)^{\frac{1}{b+\alpha\eta-b\alpha\eta}}.$$

· Parameters of equilibrium quantity of drugs that is successfully produced and exported in equilibrium (equation 39):

$$\zeta = \frac{b\eta(1-\alpha)}{b+\alpha\eta-b\alpha\eta},\ \chi = \frac{b(1-\eta)}{b+\alpha\eta-b\alpha\eta},\ \text{and}$$
$$C = \left(\kappa^{1-\eta}(\alpha\eta)^{\alpha\eta}\lambda^{\eta}L^{\eta(1-\alpha)}\right)^{\frac{b}{b+\alpha\eta-b\alpha\eta}} a^{\frac{\alpha\eta}{b+\alpha\eta-b\alpha\eta}}.$$

Table 1: Plan Colombia: Before and after (UNODC data).

	Before PC	After PC
Final Price	$37,900	$35,862
Domestic Price	$1,485	$1,860
Final Supply from Colombia	561,000 kgs.	474,000 kgs.
Domestic Supply	687,500 kgs.	645,000 kgs.
Hectares with cocaine	161,700 has.	82,000 has.
Productivity per Hectare	4.25 kgs/ha/year	7.86 kgs/ha/year
Percentage of Land with Cocaine Crops	32.3%	16.4%
Seizures by Colombian Authorities	87,000	113,000
Percentage Not Seized	87.2%	81.8%
Colombia Expenses	$420 million	$566 million
(Assuming a 35% increase)		
USA Expenses	0	$465 million
Supply in Consumer Countries	718,000 kgs.	745,000 kgs.
Percentage of USA Cocaine Supplied by Colombia	78%	63%

Table 2: Calibration results: Parameters (using UNODC data).

Parameter	Value
ω	0.51
Ω	0.67
κ	565,601
η	0.07
a	820,395,752
b	0.67
α	0.73
λ	0.01
c_1	0.40
c_2	0.05
ϕ	2.33
γ	0.36
σ	0.11

Table 3: Calibration results: Variables of Interest

Variable	Actual	Efficient Allocation (M=0.46 billion)	Efficient Allocation (M=1.5 billions)
ω	0.51	1	1
Ω	0.67	0.36	0.21
q	0.164	0.27	0.27
h	0.818	0.71	0.59
CM_q	$118,438	$67,679	$88,344
CM_h	$4,279	$10,141	$23,207
Q_f	474,000 kgs	420,480 kgs	355,674 kgs
P_f	$35,862	$42,909	$55,130
Q_d	645,000 kgs	774,881 kgs	823,570 kgs
P_d	$1,860	$1,643	$1,680
t	$2,864,799,573	$4,867,998,354	$7,472,030,802
s	$232,967,687	$731,081,309	$1,906,397,792
x	$33,590,080	$30,859,531	$33,538,276
y	$80,359,042	$85,292,652	$92696434
z	$399,016,156	$188,278,147	$204,621,529
r	$439,131,915	$466,092,236	$506,551,118
π_P	$46,768,963	$54,433,121	$59,158,159
π_T	$12,934,088,427	$11,900,855,776	$10,752,434,569
M_{Col}	$566,666,667	$642,983,544	$818,189,914
$CM_{Col,q}$	$9,796	$19,314	$24,982
$CM_{Col,h}$	$2,243	$2,470	$2,970
C_P	$900,156,506	$896,938,232	$974,796,466
C_T	$1,021,470,143	$1,184,192,497	$1,406,378,215
IC	$4,123,697,817	$6,207,940,323	$10,040,141,070
Land Productivity	7.87	5.61	5.96
Route Productivity	1929	1974	2009
Production Returns	8.4%	9.3%	9.3%
Trafficking Returns	318%	193%	121%

Table 4: Plan Colombia: Before and after. (ONDCP - White House data)

	Before PC	After PC
Final Price	\$56,500	\$45,000
Domestic Price	\$1,485	\$1,860
Final Supply from Colombia (in US markets)	281,357 kgs.	250,099 kgs.
Domestic Supply	556,205 kgs.	812,150 kgs.
Hectares with cocaine	129,350 has.	109,750 has.
Productivity per Hectare	4.3 kgs/ha/year	7.4 kgs/ha/year
Percentage of Land with Cocaine Crops	25,8%	21,9%
Seizures by Colombian Authorities	47,713 kgs.	97,447 kgs.
Percentage Not Seized	91,4%	88%
Colombia Expenses	\$420 million	\$566 million
(Assuming a 35% increase)		
USA Expenses	0	\$465 million
Supply in USA	398,601 kgs.	484,830 kgs.
Percentage of USA Cocaine Supplied by Colombia	70%	51%

Table 5: Calibration results: UNODC vs. ONDCP.

Parameter	Value (UNODC)	Value (White House)
ω	0.51	0.45
Ω	0.67	0.75
κ	565,601	236,767
η	0.07	0.13
a	820,395,752	4,895,642,855
b	0.67	0.86
α	0.73	0.7
λ	0.01	0.01
c_1	0.40	0.26
c_2	0.05	0.18
ϕ	2.33	2.25
γ	0.36	2.12
σ	0.11	0.12

Table 6: Calibration results: Variables of Interest (ONDCP data)

Variable	Actual	Efficient Allocation (M=0.46 billion)	Efficient Allocation (M=1.5 billions)
ω	0.45	1	0.82
Ω	0.75	0.46	0.29
q	0.22	0.38	0.34
h	0.88	0.81	0.73
CM_q	\$102,784	\$43,486	\$63,380
CM_h	\$16,437	\$33,442	\$63,380
Q_f (USA)	250,100 kgs	239,785 kgs	218,400 kgs
P_f	\$45,000	\$47,257	\$52676
Q_d	812,150 kgs	962,083 kgs	936,957 kgs
P_d	\$1,860	\$1,581	\$1,648
t	\$1,169,138,077	\$1,800,249,624	\$2,629,517,895
s	\$339,296,419	\$861,155,500	\$2,007,572,392
x	\$43,206,625	\$34,288,247	\$37,404,078
y	\$110,715,248	\$111,473,581	\$113,174,216
z	\$345,851,791	\$123,394,000	\$164,180,668
r	\$533,869,005	\$537,525,687	\$545,726,152
π_P	\$67,508,622	\$77,185,334	\$75,770,138
π_T	\$8,574,746,816	\$8,010,375,030	\$7,330,777,163
M_{Col}	\$566,666,667	\$640,500,389	\$844,286,393
$CM_{Col,q}$	\$9,390	\$17,046	\$16,939
$CM_{Col,h}$	\$9,161	\$9,001	\$9,236
C_P	\$709,411,425	\$647,950,857	\$676,497,026
C_T	\$2,386,664,764	\$2,539,283,991	\$2,753,376,681
IC	\$2,507,981,823	\$3,199,716,778	\$5,266,608,212
Land Productivity	7.40 kgs/ha/year	5.00 kgs/ha/year	5.53 kgs/ha/year
Route Productivity	947 kgs/route	978 kgs/route	989 kgs/route
Production Returns	9.8%	11.3%	10.9%
Trafficking Returns	319%	241%	175%