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

Daniel Mejía† Pascual Restrepo‡

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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*. First, we develop a game theory model of the war against illegal drugs in producer countries where we explicitly model illegal drug markets. then, we calibrate the model using available data for the war on cocaine production and trafficking as well as outcomes from the cocaine markets. Using the results from the calibration we estimate important measures of the costs, effectiveness, and efficiency of the war on drugs in Colombia. Also, we assess the impact of changes in the U.S. budget allocated to *Plan Colombia*, finding that a three-fold increase in the U.S. budget allocated to the war on drugs in Colombia would decrease the amount of cocaine reaching consumer countries by about 19.5%. Finally, we pin down four key aspects that help explain the innefectiveness (and high costs) of supply side interventions in the so-called "war on drugs" in Colombia.

Keywords: Hard drugs, Conflict, War on Drugs, *Plan Colombia*.

JEL Classification Numbers: D74, K42.

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1 Introduction

In September 1999, the Colombian government announced a strategy known as *Plan Colombia* to (1) reduce the production of illegal drugs (primarily cocaine) by 50% in 6 years and (2) improve security in Colombia by re-claiming control of areas held by illegal armed groups (see U.S. Government Accountability Office - GAO, 2008). Since 2000, *Plan Colombia* has provided 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 U.S. and the Colombian governments have allocated large amounts of resources to the war on drugs during the current decade. According to the Colombian National Planning Department (DNP), between 2000 and 2005, the U.S. government disbursed about $3.8 billion in assistance to the Colombian government for its war against illegal drug production and trafficking. Colombia for its part spent about $6.9 billion during the same period. About one half of Colombian expenses (about $3.4 billion) and three quarters of U.S. assistance (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). The total expenditure per year in the military component of *Plan Colombia* has been, on average, about $1.2 billion between 2000 and 2006, which corresponds to about 1.5% of Colombia's yearly GDP during the same period (see GAO, 2008 and DNP, 2006). Nevertheless, and despite the large amount of resources invested on the war on drugs since 2000, 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), potential cocaine production in Colombia has only decreased by about 11% (from 687,000 kg per year in 2000 to about 610,000 kg per year in 2006). This apparently paradoxical outcome 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.[1] These increases in productivity have taken many different forms. Among others, the use of stronger and bigger coca plants,

[1] Caulkins and Hao (2008) provide an alternative explanation for the stable trend in drug prices. Namely, they argue that reductions in source country supply would affect 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 been translated into reductions in the supply of cocaine.

a higher density of coca plants per hectare, better planting techniques, and the use of more efficient chemical precursors in the processing of coca leaf into cocaine. As a result, yields per hectare increased from about 4.3 kg of cocaine per hectare per year in 2000 to more than 7.7 kg of cocaine per hectare per year in 2006. Furthermore, consistent with the observed patterns of potential cocaine production in Colombia, the price of coca paste and cocaine have remained relatively stable between 2000 and 2006.[2]

With the above stylized facts in mind, the general impression is that programs aimed at reducing the production and trafficking of illegal drugs have proved to be relatively ineffective. For instance, a recent report by the GAO recognizes that although security in Colombia has improved significantly during the current decade, the drug reduction goals of *Plan Colombia* were, after almost 6 years of its implementation, not fully met. However, and despite the large amount of resources spent by Colombia and the U.S. during the current decade, little of a systematic nature is known about the effects, costs, and efficiency of the anti-drug policies implemented under *Plan Colombia*.[3] In short, the main objective of this paper is to fill this gap.

In this paper, we construct a model of the war on drugs in producer countries. This war takes place in two main fronts, the war against drug production and the war against drug trafficking. We explicitly model illegal drug markets in producer and 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 different measures of the costs, effectiveness, and efficiency of the anti-drug policies implemented in Colombia between 2000 and 2006. The results from the calibration of the model are then used to carry out simulation exercises, wherein we assess the effects of exogenous changes in the

[2]See Mejía and Posada (2008) for a thorough description of the main stylized facts of the cocaine markets, both in producer and consumer countries. 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]Dube and Naidu (2009) explore a related question. In particular, they examine the impact of U.S. military assistance on the intensity of conflict in Colombia. They find that U.S. military assistance in Colombia has lead to increases in paramilitary attacks and has had no effect on guerrilla attacks.

U.S. budget allocated to the war against cocaine production and trafficking under *Plan Colombia.*

On the one hand, we estimate that the marginal cost to the U.S. of decreasing by one kilogram the amount of cocaine reaching its wholesale markets is about \$163,000 if the U.S. assistance is used in the war against drug producers over the control of arable land, whereas the marginal cost is about \$3,700 if the assistance is used for interdiction efforts aimed at detecting and blocking illegal drug shipments in its way to consumer countries. On the other hand, we estimate that the elasticity of cocaine reaching consumer countries with respect to changes in the amount of resources invested in the war against illegal drug production is about 0.007%, whereas the elasticity with respect to changes in the amount of resources invested in the war against illegal drug trafficking is about 0.296%. In other words, if the main objective is to reduce the amount of cocaine reaching consumer countries, targeting drug trafficking activities is much more cost effective than targeting drug production activities. In particular, we find that the optimal allocation of resources (from the point of view of the U.S., whose objective is to minimize the amount of cocaine reaching its borders), implies that all the U.S. assistance to *Plan Colombia* should be allocated to subsidize Colombia's interdiction efforts. Under an efficient allocation of subsidies we estimate that the marginal cost to the U.S. of decreasing by one kg the amount of cocaine reaching consumer countries would be about \$8,800. We estimate that under an efficient allocation of subsidies, a three-fold increase in the U.S. assistance for *Plan Colombia* (from about \$465 million per year to \$1.5 billion per year) would lead to a reduction of about 19.5% (about 60,000 kg) in the amount of cocaine reaching consumer countries.

From the point of view of Colombia, whose objective is to minimize the total cost of internal conflict fueled by the drug business, the optimal allocation of subsidies between the two fronts of the war on drugs would imply that all the U.S. assistance for *Plan Colombia* should be allocated to the war against drug production. In particular, we find that one extra dollar of U.S. assistance to *Plan Colombia* used in the war against illegal drug production reduces the cost of conflict in Colombia by about \$1.4, whereas one extra dollar of U.S. assistance used in the war against illegal drug trafficking reduces the cost of conflict in Colombia by about \$0.09. The main reason for this result is that, according to our findings, Colombia faces a larger cost from illegal drug production activities as compared to the cost from drug trafficking activities. In particular, we estimate that for each dollar received by the drug producers, Colombia perceives a net cost of about \$0.55, whereas the net cost to Colombia per dollar received by the drug traffickers is roughly \$0.02.

Finally, we identify four key aspects that are behind the high costs/low effectiveness of the war on drugs in producer countries: a low price elasticity of demand for drugs (as also identified by Becker et al., 2006); a low relative effectiveness of the resources invested in the two fronts of the war on drugs; a low relative importance of the factors being targeted by the two fronts of the war on drugs (land in the case of the war against illegal drug production and drug routes in the case of the war against illegal drug trafficking); and finally, the strategic responses of drug producers and traffickers to the specific types of anti-drug policies implemented under the war on drugs in producer countries. For example, drug producers in Colombia have responded to eradication campaigns by using more intensively other factors complementary to land in the production of illegal drugs, such as planting techniques, chemical precursors, workshops, etc. As a result, productivity per hectare has increased, thus rendering eradication campaigns relatively ineffective in reducing the amount of illegal drugs produced. Although at a smaller scale, drug traffickers have also responded to interdiction policies by making the transportation of illegal drugs more efficient.

Most of the available literature on the effects of anti-drug policies has focused on partial equilibrium analysis.[4] 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 Becker et al. (2006), Naranjo (2007), Chumacero (2008), Costa-Storti and De Grauwe (2008), and Mejía (2008). These papers explicitly model illegal drug markets when analyzing the effects of anti-drug policies. Becker et al. (2006) show how the social costs of fighting against drugs crucially depends on the price elasticity of demand for drugs. In particular, they show that if the demand for drugs is highly inelastic, policies aimed at reducing the supply of drugs by punishing dealers are not socially optimal unless the negative externalities associated with drug consumption are high enough. Naranjo (2007) develops a model where insurgent groups provide security for drug producers in

[4]See Rydell et al. (1996) and Tragler et. al (2001) 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), Reuter (2008), and Mejía and Posada (2008).

exchange for a fraction of the drug output, finding that supply side interventions may have a counter-productive effect on the drug industry and may increase conflict. Chumacero (2008) focuses 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 interrelationship between anti-drug policies aimed at reducing the demand for drugs (such as treatment and prevention policies in consumer countries) and policies aimed at reducing the supply of drugs (by means of interdiction and increased enforcement).[5] Finally, Jeffrey Miron analyses the costs of drug prohibition (Miron and Zwiebel, 1995) and the budgetary consequences of drug legalization in the U.S. (Miron, 2008). However, none of these contributions focuses on evaluating the costs, effectiveness, and future prospects of the war on illegal drugs in producer countries, as this paper does, nor are they aimed at evaluating actual anti-drug policies, as this paper is.

The rest of the paper is organized as follows: section 2 presents the model; section 3 contains 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 and discusses a potential asymmetry between Colombia and the U.S. in the preferred strategy to be used in the war on drugs ; section 5 concludes.

2 The Model

We model the war against drug production and trafficking as a sequential game. The model builds on previous work by Grossman and Mejía (2008) and extends that framework in many different important dimensions. First, we make the game sequential; second, we explicitly model illegal drug markets; third, we modify the objective function of the government of the drug producing country in order to make it more general; and fourth, we use production and trafficking technologies that admit strategic responses in the choice of inputs, which, in turn, allows us to account endogenously for the observed productivity increases in both production and trafficking activities observed after *Plan Colombia.*

There are $4 + n$ actors involved in this war. These are the government of the drug producing country (henceforth the government); the government of the drug consumer

[5] 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.

country (henceforth the interested outsider); a group of n illegal drug producers; the drug trafficker; and a wholesale buyer located at the border of the consumer country. The latter plays no active role other than demanding drugs (at the wholesale level).

The two main fronts of the war on drugs in producer countries are the war against drug production and the war against drug trafficking. While the war against drug production is modelled as a conflict between the government and the producers over the control of arable land, which is necessary to grow illegal crops,[6] the war against drug trafficking is modelled as a conflict between the government and the traffickers over the control of the routes necessary to transport illegal drugs to consumer countries.

In order to rationalize the government's incentives in the war on drugs, we assume that it faces a net cost, $c_1 > 0$, per unit of income that drug producers are able to obtain from illegal drug production, and a net cost, $c_2 > 0$, per unit of income that the drug trafficker is able to obtain from illegal drug trafficking.[7] The intuition behind this modelling assumption is that illegal groups engaged in the production and trafficking of illicit drugs use part of the proceeds from these activities to finance terrorist attacks against the government and civilians, corrupt politicians, weaken local institutions and the rule of law, etc., whereas another fraction is used in other, perhaps legal, activities that do not generate direct costs to the government of the drug producing country. Thus, c_1 and c_2 capture the net cost to the government arising from illegal drug production and trafficking activities, respectively.

Furthermore, we 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 war against production, and a fraction $(1 - \Omega) \in [0, 1)$ of the resources that the government spends on the war against trafficking.

The timing of the game is as follows.

1. The interested outsider grants subsidies $1 - \omega$ and $1 - \Omega$ to strengthen the resolve of

[6] The model is motivated by the case of Colombia, where coca is the raw material for producing cocaine. However, it can also be used to interpret other cases, such as the one in Afganisthan, where opium poppies are the raw material for producing heroin.

[7] These costs need not be equal 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.

the government in the war against illegal drug production and trafficking, respectively.

2. In the war against drug production, 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. L denotes the total land that can potentially be used for the cultivation of illicit crops.

3. The n drug producers fight against each other over the control of the land that the government does not control.[8]

4. Once the 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 production. At this stage we obtain the supply of drugs in the producer country.

5. In the war against drug trafficking, the drug trafficker and the government engage in an interdiction sub-game, whereby the government invests resources to try to detect the routes used by the drug trafficker to transport illegal drugs, and the drug trafficker invests resources in order to avoid being detected.

6. Once the drug trafficker knows the expected probability that a drug shipment will survive the government's interdiction efforts (that is, the probability that a route and mean of transportation will not be detected), he has to decide how much illegal drugs to buy from the drug producers. At this stage we obtain the demand for drugs in the producer country.

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

We now turn to a description of each one of the stages of the game described above, wherein we briefly describe the problem faced by each agent involved in the game, their

[8] This stage of the game matches the Colombian experience quite well. In particular, there are numerous examples of military confrontations between illegal drug producers for the control of land not controlled 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). However, all the results that we obtain do not depend on the inclusion of this stage of the game.

objective functions and restrictions, as well as the production, conflict, and trafficking technologies. 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 wholesale drug dealer's 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 (wholesale) price elasticity of demand for drugs.

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, 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 just one or many

[9] See Mejia (2008) for a model that extends the framework developed in this paper by introducing the role of prevention and treatment policies in consumer countries aimed at reducing the demand for drugs.

[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.

drug traffickers, as long as they are all of equal size and they do not fight against each other for the control of the drug routes.[11]

2.2.2 The interdiction technology

The interdiction technology is such that h, the fraction of routes that 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 efforts 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 efficiency of the resources invested by the drug trafficker in avoiding the government's interdiction efforts.[13]

2.2.3 The drug trafficker's problem

The drug trafficker's profits are given by:

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

[11] If we had N drug traffickers, each contesting with the government disjoint sets of κ/N routes, then, 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] If we assume that all illegal drug shipments are homogeneous in terms of size, then h can also be thought as the fraction of illegal drugs that survive the government's interdiction efforts.This is 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 boats, airplanes, drug mules, etc.). However, given our interest in looking at the aggregate problem of drug trafficking, the assumption of equally-sized drug shipments is innocous.

The first term in equation 4 is the total income derived from drug trafficking activities, where P_f is the wholesale price of drugs in the consumer country and Q_f is the quantity of drugs successfully exported (see 2 and 3). 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.

The drug trafficker takes as given P_d, P_f, and s and first chooses Q_d and then t in order to maximize π_T (equation 4).

2.2.4 The government's problem: The war against drug trafficking

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.

Furthermore, we assume that the government faces a net cost, c_2, per unit of income that the drug trafficker obtains 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 in 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 the sum of the costs associated with illegal drug trafficking, C_T , where:

$$C_T = c_2 P_f Q_f + \Omega s. \tag{5}$$

Q_f is determined by equations 2 and 3.

At this stage of the game, the government anticipates the drug trafficker's demand for drugs in the producer country, Q_d; takes as given P_d, P_f, t and Ω; and chooses the amount of resources to invest in interdiction efforts, s, so as to minimize C_T (equation 5).

2.2.5 The drug trafficking equilibrium

The Nash equilibrium for the drug trafficking sub-game is described by the following equations:[14]

[14] All the derivations are presented in the appendix.

$$t^* = \frac{h^{*2} c_2 \eta^{\frac{\eta}{1-\eta}} \kappa P_f^{\frac{1}{1-\eta}}}{\gamma \Omega P_d^{\frac{\eta}{1-\eta}}}, \tag{6}$$

$$s^* = \frac{h^{*2} c_2^2 \eta^{\frac{\eta}{1-\eta}} \kappa P_f^{\frac{1}{1-\eta}}}{(1-\eta)\gamma \Omega^2 P_d^{\frac{\eta}{1-\eta}}}, \tag{7}$$

$$h^* = \frac{\gamma\Omega(1-\eta)}{c_2 + \gamma\Omega(1-\eta)}, \tag{8}$$

$$Q_d^d(P_d, P_f) = h^* \kappa \left(\frac{\eta P_f}{P_d}\right)^{\frac{1}{1-\eta}}, \text{ and} \tag{9}$$

$$Q_f^s(P_d, P_f) = h^* \kappa \left(\frac{\eta P_f}{P_d}\right)^{\frac{\eta}{1-\eta}}. \tag{10}$$

Equations 6 and 7 describe the amount of resources allocated by the drug trafficker and the government, respectively, to the interdiction sub-game (as a function of drug prices, yet to be determined, and technology parameters). Equation 8 is the fraction of drug routes that survive the government's interdiction efforts. Equation 9 is the drug trafficker's demand for drugs in the producer country, and equation 10 is the drug trafficker's supply of drugs at the border of the consumer country (again, as a function of drug prices, yet to be determined).

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 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. 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 denotes 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:

$$g_i = \frac{z_i}{z_i + \phi x_i}. \tag{11}$$

z_i and x_i denote the resources that the government and the $i-th$ drug producer allocate to the conflict over the control over arable land, respectively. $\phi > 0$ captures the relative efficiency of the resources that drug producer i allocates to the conflict with the government over the control of arable land.

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. 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:

$$q = \frac{1}{L}\sum_{i=1}^{n}(1 - g_i)L_i = \frac{1}{n}\sum_{i=1}^{n}(1 - g_i). \tag{12}$$

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:

$$f_i = \frac{y_i}{y_i + \sum_{k \neq i} y_k}, \tag{13}$$

where y_i and y_k denote the resources allocated by the $i - th$ and the $k - th$ drug producers respectively, to this conflict. The contest success function in equation 13 implicitly assumes that each drug producer is equally efficient in this conflict.

2.3.3 The drug production technology

We assume that the $i-th$ drug producer combines arable land, l_i, necessary for cultivating the illegal crop, and other material resources (workshops, chemicals, microwaves, labor, etc.), r_i, in order to produce drugs, $Q_{d,i}$, according to the following production technology:

$$Q_{d,i} = \lambda r_i^{\alpha} l_i^{1-\alpha}, \quad \text{where } 0 < \alpha < 1, \tag{14}$$

where $\lambda > 0$ is a scale parameter; α and $1-\alpha$ are the relative importance of the complementary factors and land respectively in the production of illicit drugs; and l_i is the amount of land that the $i-th$ drug producer controls and is determined endogenously by:

$$l_i = q f_i L, \tag{15}$$

where q and f_i are determined by equations 12 and 13, respectively.

2.3.4 The drug producers' problem

The $i-th$ drug producer's profits are given by:

$$\pi_i = P_d Q_{d,i} - (x_i + y_i + r_i), \tag{16}$$

where $Q_{d,i}$ is given by equations 14 and 15. The $i-th$ drug producer takes as given P_d, z_i, and y_j, and first chooses x_i, then y_i, and finally r_i in order to maximize π_i (equation 16).

2.3.5 The government's problem: The war against drug production

Recall that the interested outsider grants a subsidy to the government that corresponds to a fraction $1-\omega \in [0,1)$ of the resources that the latter allocates to the conflict over the control of land with the drug producers.

Also, we assume that the government faces a net cost, c_1, per unit of income that the drug producers are able to obtain from drug production activities.

At this stage the government's objective is to minimize the total cost from drug production activities and the war against drug production, C_P, where:

$$C_P = c_1 P_d \sum_{i=1}^{n} Q_{d,i} + \omega \sum_{i=1}^{n} z_i, \tag{17}$$

where $Q_d = \sum_{i=1}^{n} Q_{d,i}$, and $Q_{d,i}$ is given by equations 14 and 15.

At this stage, the government anticipates the drug producers' allocation of resources to y_i and r_i; takes as given P_d, P_f, x_i and ω; and chooses the amount of resources to invest in the conflict over the control of arable land, z_i, so as to minimize C_P (equation 17).

2.3.6 The drug production equilibrium

The Nash equilibrium for the drug production sub-game is described by the following equations:[15]

$$x_i^* = \frac{q^{*2} c_1 \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} L}{n\phi\omega}, \tag{18}$$

$$z_i^* = \frac{q^{*2} c_1^2 n \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} L}{(1-\alpha)\phi\omega^2}. \tag{19}$$

$$q^* = \frac{\phi\omega(1-\alpha)}{c_1 n^2 + \phi\omega(1-\alpha)}. \tag{20}$$

$$y_i^* = \frac{q^*(n-1)\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} L}{n^2}, \tag{21}$$

$$f_i^* = \frac{1}{n}, \tag{22}$$

$$r_i^* = \frac{q^*(\alpha\lambda P_d)^{\frac{1}{1-\alpha}} L}{n}. \tag{23}$$

and,

$$Q_d^s(P_d) = \sum_{i=1}^{n} Q_{d,i} = q^* \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_d^{\frac{\alpha}{1-\alpha}} L, \tag{24}$$

Equations 18 and 19 describe the amount of resources allocated by each drug producer and the government, respectively, to the conflict over the control of arable land; equation 20 denotes the equilibrium fraction of land under the producers' control. Equation 21 denotes the amount of resources spent by each drug producer in the conflict with the other $n-1$ drug producers over the control of the land that the government does not control and equation 22 denotes the equilibrium fraction of land that the government does not control that is under each drug producer's control. Given the assumptions about symmetry between drug producers, each one of them ends up controlling an equal share, $1/n$, of the land that the government does not control. Finally, equation 24 describes the supply of drugs by the drug producers inside the producing country. All variables are functions of market prices, yet to be determined.

[15] All the derivations are presented in the appendix.

2.4 The drug market equilibrium

On the one hand, the drug market equilibrium condition in the producer country implies that $Q_d^s(P_d)$ (equation 24) must be equal to $Q_d^d(P_d, P_f)$ (equation 9). Equating the supply and the demand for drugs in the producer country we get:

$$q^* \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_d^{\frac{\alpha}{1-\alpha}} L = h^* \kappa \left(\frac{\eta P_f}{P_d} \right)^{\frac{1}{1-\eta}}, \tag{25}$$

On the other hand, the drug market equilibrium condition in the consumer country implies that $Q_f^s(P_d, P_f)$ (equation 10) must be equal to $Q_f^d(P_f)$ (equation 1). Equating the supply and the demand for drugs at the border of the consumer country we get:

$$h^* \kappa \left(\frac{\eta P_f}{P_d} \right)^{\frac{\eta}{1-\eta}} = \frac{a}{P_f^b}, \tag{26}$$

The analytic solution for the system of equations 25 and 26, P_d^* and P_f^* , as well as the corresponding quantities Q_d^* and Q_f^*, 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 subsidies for the conflict over the control of arable land, $1 - \omega$, and for interdiction efforts, $1 - \Omega$. We assume that the interested outsider anticipates the response of market prices (quantities) to changes in $1 - \omega$ and $1 - \Omega$. The total cost to the interested outsider, M_o, is given by:

$$M_o = n(1 - \omega) z^* + \Omega s^*. \tag{27}$$

Additionally, as we show in the appendix, 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:

$$Q_f^* = C q^{\zeta} h^{\chi}, \tag{28}$$

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

We assume that the interested outsider's problem is to choose the optimal allocation of subsidies between 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).[16] More precisely, the interested outsider's problem in the first stage of the game is:

$$\begin{aligned} & \min_{\{\omega,\Omega\}} Q_f^* \\ \text{subject to} \quad & M_o \leq \overline{M}. \end{aligned} \tag{29}$$

where Q_f^* is given by equation 28, M_o by equation 27, 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.

In any internal solution, the optimality condition for the interested outsider problem (presented in the appendix) implies that the marginal cost of reducing the amount of drugs reaching consumer countries by, say, one kg, must be equal in the two fronts of the war on drugs. Nevertheless, the two marginal costs need not be equal if the solution to the interested outsider's problem is a corner solution, with either $\omega^* = 1$ or $\Omega^* = 1$.

3 Calibration strategy and results: Baseline scenario

In order to calibrate the parameters of the model we use data from the cocaine markets (in both, producer and consumer countries) as well as available data on the outcomes of the well documented war on drugs under *Plan Colombia* (henceforth PC).

3.1 A brief description of the data used in the baseline scenario[17]

Table 1 presents the data used in the baseline calibration exercise. For each variable used in the calibration exercise, we define its value before PC as the average of the observed

[16] Although we recognize that there might be other objectives from the interested outsider's point of view, minimizing the amount of drugs reaching consumer countries is a first order objective. Furthermore, this setup will allow us to estimate the costs and effectiveness of anti-drug policies implemented in producer countries.

[17] For a thorough description of the available data on cocaine production, trafficking, and drug markets, as well as the collection metodologies and main biases see Mejia and Posada (2008).

outcomes between 1999-2000, and its value after PC as the average of the observed outcomes between 2005-2006.[18]

[Insert Table 1 here: Data used in the baseline calibration exercise].

According to UNODC, the price of a kilogram of cocaine at the wholesale level in consumer countries, P_f, was about $38,250 before PC and about $34,290 after PC.[19] The wholesale price in the U.S., $P_{f,US}$, was about $35,950 before PC and $25,850 after PC. In Colombia, the price of a kilogram of cocaine at the farm gate, P_d, was approximately $1,540 before PC and $1,811 after PC. Using satellite images, UNODC estimates that the number of hectares cultivated with coca crops, qL, before PC was about 161,700; 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,[20] 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 productivity per hectare per year is estimated by UNODC using field studies in a sample of workshops in cocaine producing regions in Colombia. On average, one hectare of land cultivated with coca crops before PC produced about 4.25 kg of pure cocaine per year; after PC this number was estimated at about 7.6 kg per hectare per year. Multiplying the estimates of productivity times the hectares of land cultivated with coca crops, we estimate that potential cocaine production in Colombia was about 687 metric tons before PC and 625 metric tons after PC.[21] Reported seizures of pure cocaine by Colombian authorities were about 50 metric tons before PC and about 120 metric tons after PC.[22] Furthermore, if we make the simplifying assumption that, on average, all drug routes are equal, then the fraction of routes not interdicted, h, equals the fraction of cocaine not seized by Colombian authorities (see footnote 13). Thus, h was about 92.7% before PC and about 80.9% after PC. Assuming that Colombian cocaine

[18] In the robustness checks we include different reference years for before and after PC.

[19] For these price figures at the wholesale level in consumer countries we take a weighted average of reported prices in Europe and the US, with the weights before PC being 28% for Europe and 72% for the US. The weights we use for after PC are 36% and 64% respectively. We approximate these weights using the share of total cocaine consumers in Europe and the US before and after PC respectively from UNODC (see UNODC, World Drug Report 2000-2008).

[20] This figure is taken from Grossman and Mejia (2008). In some of the robustness checks that we present below, we allow the value of L to vary, confirming that the obtained results are very robust to large variations in the value of L.

[21] These methodologies as well as possible biases in the collection of the data are also discussed in some detail in Mejia and Posada (2008).

[22] This estimation assumes a 60% purity level for drug seizures in Colombia.

has the same probability of being seized in transit countries as cocaine from other source countries, we estimate that seizures of Colombian cocaine in transit countries were about 46 metric tons before PC and 78 metric tons after PC.[23] Once we take into account the cocaine seizures in transit countries, the Colombian supply of cocaine in the border of consumer countries, Q_f, was about 592 metric tons before PC and about 428 metric tons after PC. According to GAO, the cocaine flowing to U.S. markets from all source countries was about 460 metric tons before PC and 625 metric tons after PC. Taking into account the seizures in transit countries we obtain that the supply of cocaine in the U.S. (from all source countries), Q_{US}, was about 400 metric tons before PC and 495 metric tons after PC.

According to Colombia's National Planning Department (DNP, 2006), the U.S. military assistance for PC, M_o, has been about \$465 million per year since 2000. Most of this assistance has taken the form of military equipment (helicopters, airplanes, chemicals for spraying the illegal crops, radars, etc.) and training. According to DNP (2006), the total amount of Colombian military expenses in the war on drugs under PC has been about \$567 million per year since 2000. Although we don't have an official estimate for the amount of Colombian expenses in the war against drug production and trafficking before PC, we have an estimate for the number of flying hours in anti-narcotics missions before and after PC. The increase in this variable between 2000 and 2006 was about 35% (see DNP, 2006). If we take the number of flying hours in anti-narcotics missions as a good proxy for the level of Colombian expenses in the war on drugs, and apply its growth rate to the level of 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. 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

[23] Total seizures reported in transit countries were about 60 metric tons before PC and 130 metric tons after PC, again assuming reported seizures have a purity of roughly 60%. Colombian cocaine represented 75% of the cocaine going through transit countries before PC and aabout 60% after PC. Therefore, we assume that 75% of the 60 metric tons seized before PC in transit countries came from Colombia and about 60% of the 130 metric tons seized in transit countries after PC came from Colombia.

[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.

the Autodefensas Unidas de Colombia (AUC), notwithstanding their historical origins as left-wing guerrillas and right-wing paramilitaries respectively, act now as the new drug producers and residual claimants of the profits from cocaine production.

3.2 Results and discussion

The appendix describes in detail the main equations that are used in the calibration of the model.[25] We first calibrate the model without using the condition for the optimal allocation of subsidies between the two fronts of the war on drugs for the interested outsider (e.g. the U.S. government). In other words, we allow the data to determine whether the subsidies granted by the U.S. government for the war on drugs in Colombia satisfy the optimality condition for the interested outsider; if not, we estimate the efficiency cost of the misallocation of subsidies between the two fronts of the war on drugs.

Table 2 summarizes the results of the calibration of the parameters of the model in the baseline scenario, where we use the best available data, described in Table 1, to estimate the parameters of the model .

[Insert Table 2 here: Calibration results for the baseline exercise].

According to the results in the baseline scenario, the U.S. government has funded, on average, about 41% $(1-\omega)$ of Colombia's expenses in its conflict over the control of arable land with drug producers, and about 67% $(1-\Omega)$ of Colombia's interdiction efforts in the war against drug trafficking. We estimate that the demand for cocaine at the wholesale level is relatively inelastic to price changes. More precisely we estimate that b is about 0.64, which means that a 1% increase in the price of cocaine at the wholesale level reduces the demand for cocaine by about 0.64%. Our estimation of the parameter α implies that the relative importance of land in the production of cocaine in Colombia, $1-\alpha$, is about 22%, whereas that of other inputs (chemicals, workshops, energy, the "cook," etc.) is about 78%. An alternative way of estimating the parameter $(1-\alpha)$ is by calculating the ratio of the market value of the amount of coca leaf necessary to produce one kilogram of cocaine

In a recent interview, Salvatore Mancuso, once the head of the AUC and now serving prison in the US for drug charges, admits that the AUC and the FARC now control the business of cocaine production (and part of the trafficking) in Colombia. He also explicitly 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).

[25] As the reader shall see in the appendix, the calibration of the model follows recursively.

and the price of one kilogram of cocaine in Colombia. If we follow this way of calculating the share of land in the production of cocaine we arrive at an estimate for $1 - \alpha$ of about 20.8%.[26] Regarding the share of the inputs of the trafficking technology, we estimate that the relative importance of cocaine in the trafficking technology, η, is about 8%, whereas the relative importance of the routes for transporting illegal drugs is about 92%.

Turning now to the net cost perceived by Colombia from illegal drug production activities, we estimate that Colombia perceives a net cost of about \$0.55 for each dollar received by the drug producers (c_1). This estimate implies that, with the price in Colombia of one kilogram of cocaine at \$1,811, the Colombian government perceives a net cost of about \$990 per kilogram of cocaine successfully produced ($0.55 \times \$1,811$). With potential cocaine production after PC at about 625,000 kg, the total cost to the Colombian government arising from cocaine production activities has been roughly \$620 million per year. If we add to the cost of drug production activities the cost of fighting against the two drug producers, we get a total cost of production activities of about \$1.14 billion per year. Turning to the other front of the war on drugs (the interdiction front), we estimate that Colombia perceives a net cost of about \$0.02 for each dollar that the drug traffickers receive (c_2). With the price of one kilogram of cocaine at the wholesale level in consumer countries at about \$34,300, the Colombian government faces a net cost of about \$587 per kilogram of cocaine successfully exported ($0.02 \times \$34,300$). If about 430,000 kg of cocaine per year were successfully exported after PC, the total cost to the Colombian government arising from illegal drug trafficking has been about \$252 million per year. Once we add the cost of fighting the drug traffickers, we get a total cost to Colombia of drug trafficking of about \$300 million per year. Thus, the total cost to the Colombian government from drug production, drug trafficking and the war against these two activities is about \$1.44 billion per year (or about 1.3% of GDP in 2006).

On the one hand, the estimated value for γ, 0.24, implies that the resources that the

[26] About 255 kg of dry coca leaf are needed to process one pure kg of cocaine. The price of each kg of coca leaf is about \$2.5 (see UNODC, 2008). Thus, the total income from coca leaf necessary to produce 1 kg of cocaine is about \$635. On average, one hectare of land produces the coca leaf necessary to process slightly more than 7 kg of pure cocaine per year, and about one peasant is employed per hectare in the cultivation of coca leaf. Thus, if we substract from the total income from coca leaf per year (\$635 x 7) the peasant's income (about \$130 x 12 months), then the total payment for coca leaf per hectare per year is about \$2,650. This number divided by 7 kg of cocaine per hectare per year is about \$380. If the price of a pure kg of cocaine at the farmgate in Colombia is about \$1,820, then the share of land in the production of cocaine, $1 - \alpha$, is about 0.208.

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, 3.4, 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 4.2 times more efficient (1/0.24) in interdicting drug shipments than the drug trafficker is in escaping the interdiction, whereas the drug producers are about 3.4 times more efficient than the government in the conflict over the control of arable land.[27]

Having calibrated all the parameters of the model, we can now recover other important variables of the model for which we don't have data on. Among others, the equilibrium level of expenses for each of the actors involved in the war on drugs, the profits and profit margins from illegal drug production and trafficking activities, the intensity of conflict under the war on drugs in Colombia, and the total costs of the war on drugs in Colombia.

According to our estimates, after PC, each illegal drug producer spends about \$26 million per year fighting the Colombian government for the control of arable land, and about \$62 million fighting against other illegal drug producers. Furthermore, each drug producer spends about \$443 million per year on those factors that are complementary to land in the production of cocaine (chemicals, workshops, "cooks", etc.). Colombia and the U.S., on the other hand, spend about \$886 million per year in the conflict over the control of arable land against the two illegal drug producers, out of which Colombia pays for about \$519 million and the U.S. for about \$367 million. The drug traffickers spend about \$2.6 billion per year trying to avoid the interdiction of cocaine shipments (go-fast boats, submarines, small airplanes, drug mules, corrupting the authorities, etc.). This large magnitude is not surprising given the huge profit margins associated with illegal drug trafficking activities. We estimate that Colombia and the U.S. together spend about \$146 million trying to interdict illegal drug shipments in Colombia, out of which Colombia pays for about \$48 million and the U.S. for about \$98 million.

Using the information above, we can now estimate the sum of the resources allocated to the war on drugs by all actors involved (the government, the interested outsider, the drug producers, and the drug trafficker). This sum, here denoted by IC, can be interpreted as a

[27] 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.

measure of the intensity of the war on drugs in Colombia. 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 war on drugs, but rather an investment in a factor of production of cocaine. Our estimates imply that the intensity of the war on drugs in Colombia, IC, is about \$3.8 billion per year (about 4.4% of Colombia's average GDP between 2000 and 2006).

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 about \$36 million per year.[28] 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 6.7%. Our estimate for the drug trafficking profits is about \$11 billion per year. 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 294%.[29]

3.3 Costs, effectiveness and efficiency of *Plan Colombia*

In this sub-section we provide estimates of the costs, effectiveness and efficiency of the anti-drug policies implemented under PC.

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

Our estimate for FARC drug profits of \$36 million for 2005-2006, which includes only those profits from cocaine production and not those from drug trafficking activities, 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 \$115. Again, this figure does not include FARC profits from cocaine trafficking.

[29] It should be noted that this rate of return is overestimated since it does not take into account the drug trafficker's expenses to counteract transit countries' interdiction efforts.

Using equations A28 and A29 (see the appendix), we estimate the marginal cost to the U.S. government of reducing the supply of cocaine reaching consumer countries by one kilogram by subsidizing the war against drug producers (i.e. by reducing ω) and by subsidizing the war against drug trafficking (i.e. by reducing Ω). The estimates for these two marginal costs are:

$$MC_{\omega}^{U.S.} \simeq \$162,800 \quad \text{and} \quad MC_{\Omega}^{U.S.} = \$3,670.$$

Another way of measuring the costs and effectiveness of anti-drug policies under PC is to estimate the elasticity of the amount of cocaine reaching consumer countries to changes in the U.S. assistance allocated to each one of the two fronts of the war on drugs in Colombia. We find that a 1% increase in the assistance (an increase of about \$4.6 million per year) would decrease the amount of cocaine reaching consumer countries by about 0.007% (50 kg) if the increase in the assistance is used to subsidize the Colombian government in its conflict with the drug producers over the control of arable land (ϵ_{ω}); but, if the 1% increase in the budget is used to subsidize the Colombian government in its interdiction efforts, the amount of cocaine reaching consumer countries would decrease by about 0.3% (1,075 kg) (ϵ_{Ω}).

Given the large difference in the estimated marginal costs (and elasticities), and the fact that the calibrated values for both, $1-\omega$ 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]The first column of Table 3 ('Actual') summarizes the results for some of the variables of interest obtained for the baseline calibration exercise under the current allocation of subsidies by the U.S. to the war on drugs in Colombia.

In addition to presenting the actual subsidies, the fraction of land under the drug producers' control and the fraction of routes under the drug traffickers' control, and the costs and elasticities just described, the first column in Table 3 ('Actual') also reports the quantities and prices of cocaine (in Colombia and abroad) and the total costs to Colombia arising from cocaine production, C_P, from cocaine trafficking, C_T, and the total cost, $C_P + C_T$. According to our estimations in the baseline exercise, Colombia perceives a cost from cocaine production activities of about \$1,140 million per year and a cost of about \$300

[30]Note that the two marginal costs could in principle be different, even if the interested outsider allocates subsidies efficiently. However, this would be the case only if the solution to the interested outsider's problem is a corner (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 ($\omega = 0.79$ and $\Omega = 0.35$).

million from drug trafficking activities. Thus, under the current allocation of U.S. subsidies to PC, the total cost to Colombia is about \$1,440 million per year, which corresponds to about 1.3% of Colombian GDP in 2006.

[Insert Table 3 here: Actual and efficient allocation of subsidies].

A few questions naturally follow from the result described above about the inefficient allocation of U.S. subsidies between the two fronts of the war on drugs in Colombia. In particular, 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 $1-\omega \simeq 0.42$ and $1-\Omega \simeq 0.67$. Using the optimality condition for the interest outsider's problem (see equations A24, A28, and A29 in the appendix) as well as its budget constraint (equation 27) we calibrate the efficient allocation of subsidies to the two fronts of the war on drugs in Colombia, finding that the solution would be a corner solution. Under an efficient allocation, we find that 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 84% ($1-\Omega^* = 0.84$) of the resources spent by the Colombian government on the interdiction of illegal drug shipments.

With these optimal subsidies, the relevant marginal cost to the U.S. becomes \$8,820, which is the marginal cost of reducing by 1 kg the amount of cocaine reaching consumer countries by subsidizing interdiction efforts. Under an efficient allocation of subsidies between the two fronts of the war on drugs, a 1% increase in the U.S. budget allocated to interdiction efforts would reduce the amount of cocaine reaching consumer countries by about 0.14%.

In order to measure the efficiency loss due to the misallocation of subsidies, 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 $1-\Omega^* = 0.84$. Had the subsidies been allocated efficiently, we find that cocaine supply in consumer countries would have been 14.4% lower (about 60,000 kg lower) than it actually was. That is, instead of being about 428,100 kg, it would have been about 366,400 kg. However, the domestic supply of cocaine in Colombia would be higher (733,000 kg instead of 625,000 kg) because, under the efficient allocation of subsidies, the U.S. would not subsidize the conflict against drug production. Also, while the price of 1 kg of cocaine in consumer countries would increase from about \$34,300 to about \$43,600, the price in Colombia would decrease from \$1,800 to about \$1,680. Finally, while under the current (inefficient) allocation of subsidies the total cost to Colombia from illegal drug production and trafficking activities is \$1,440 million, under an efficient allocation (from the U.S. perspective) the total cost to Colombia would be about \$105 million higher. This last result will be discussed in detail in the final section of the paper.

The second column of Table 3 ('Efficient Allocation') summarizes most of the results discussed above.

3.4 Robustness checks

In the previous section we presented the results of the calibration of the model in the baseline scenario, where we use the best available data on drug market outcomes and the inputs and outputs of the war on drugs under PC. In order to verify the robustness of our results, we calibrate the model using alternative data sources. For instance, the White House Office for National Drug Control Policy (ONDCP) also collects data on coca cultivation and interdiction of illegal drug shipments.[31] We also have an alternative data source for cocaine prices from the System to Retrieve Information from Drug Evidence (STRIDE), collected by the DEA and Arkes et al. (2008).[32]

Because we are aware that many of the variables used in the calibration of the model might be measured with error, we also conduct robustness checks by changing (upward and downward) most of the variables that are used in the baseline calibration exercise. Among others, we change L (the total amount of land that can potentially be used for coca cultivation in Colombia), the U.S. and Colombian budgets for the military components of

[31]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 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.

[32]STRIDE contains price data of acquisitions of illegal drugs by undercover agents in the District of Columbia. Although STRIDE price data mostly captures retail transactions in the U.S., it also produces a price series for transactions of cocaine that are greater than 50 grams (with a median of about 118 grams per transaction). Unfortunately, the STRIDE data is only available through 2004, though Arkes et al. (2008) produced a price series based on STRIDE price data through 2005.

PC, market prices, purity levels used to adjust drug seizures, reference years for before and after PC, cocaine seizures, and yields per hectare.

Finally, in some robustness checks we exogenously impose different values for b, the price elasticity of demand for drugs at the wholesale level.

Table 4 describes the main variations that we make in each group of robustness checks as well as the number of scenarios in each sub-group of robustness checks. In total we carry out 238 robustness checks.

[Insert Table 4 here: Description of robustness checks]

Table 5 reports the average results obtained for all robustness checks. The standard deviation for each of the calibrated parameters is presented in parenthesis. As the reader shall see in this table, the results are very robust to the use of different data sources, years of reference for before and after PC, and variations in b, L, prices, yields, etc. Also, all the qualitative results regarding the inefficiency in the allocation of subsidies are maintained. Moreover, all the robustness checks confirm that an efficient allocation of subsidies would imply that all U.S. assistance to PC should be allocated to subsidize interdiction efforts.[33]

[Insert Table 5 here: Results of robustness checks: Parameters]

Table 6 presents the average estimated value (and standard deviation) of different endogenous variables of the model across all 238 robustness checks. For comparison purposes, the results of the baseline scenario are presented in the left-hand-side of this table. While the marginal costs to the U.S. of decreasing by one kg the amount of cocaine reaching consumer countries by subsidizing the Colombian government in the conflict over the control of arable land with the drug producers ($MC_{\omega}^{U.S.}$) was about \$163,000 in the baseline scenario, the average of all robustness check for this variable is about \$140,000 (s.d. \$41,600). The corresponding marginal cost to the U.S. when subsidizing interdiction efforts ($MC_{\Omega}^{U.S.}$) is about \$3,700 in the baseline scenario and \$6,900 across all robustness check (s.d. \$4,600). The elasticity of cocaine reaching consumer countries with respect to a 1% increase in the U.S. assistance to PC used for the war against drug producers (ϵ_{ω}) is 0.007% in the baseline scenario and 0.011% across all robustness checks (s.d. 0.008). The corresponding elasticity when the increase in the funds is used to subsidize interdiction efforts (ϵ_{Ω}) is 0.3% in the baseline exercise and 0.25% across all robustness checks (s.d. 0.17). Finally, while the

[33] The results for each sub-group of robustness checks are available from the authors upon request.

efficiency gain (EG) from allocating the U.S. assistance to PC efficiently is 14.4% in the baseline exercise, it is 11.6% across all robustness checks (s.d. 8.6%).

Table 6 also presents the average estimated value (and standard deviation) of different endogenous variables when we calibrate the model under an efficient allocation subsidies. On the one hand, while the marginal cost to the U.S. of decreasing by one kg the amount of cocaine reaching consumer countries, $MC_{\Omega}^{U.S.}$, is about $8,800 in the baseline exercise, the average across all robustness checks is about $12,000 (s.d. $6,000). On the other hand, the elasticity of cocaine reaching consumer countries with respect to a 1% increase in the U.S. assistance for PC (allocated to subsidize Colombia's interdiction efforts) is about 0.144% in the baseline exercise, and on average about 0.13% (s.d. 0.046%) across all robustness checks.

[Insert Table 6 here: Results of RC: Actual and efficient subsidies].

3.5 Simulations

We now study the response of the endogenous variables of the model to exogenous changes in the U.S. military assistance for PC. In order to do this, we conduct numerical simulations under the assumption that the U.S. subsidies to the two fronts of the war on drugs are allocated efficiently.[34] These simulation exercises are aimed at estimating the costs of making "significant advances" in the war on drugs under Plan Colombia. More precisely, we exogenously increase and decrease $\overline{M}$ (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 such as the amount of cocaine reaching consumer countries, the intensity of the war on drugs in Colombia, and drug market outcomes. When doing these simulations we also assume that production in the other producing countries (Peru and Bolivia) remains constant and that the amount of cocaine interdicted in transit countries also remains constant.

Figures 1 and 2 show the results of the simulations for an exogenous change in $\overline{M}$, from 0 to about $1,500 million, using the calibration results obtained in the baseline scenario under an efficient allocation of U.S. subsidies between the two fronts of the war on drugs in Colombia. The vertical line in each one of the graphs denotes the actual U.S. allocation of resources to PC (about $465 million).

[34] Although we don't present the results of the simulations under the current (inneficient) allocation of subsidies, the results of these simulations are available from the authors upon request.

We find that an efficient allocation of subsidies still implies (for all levels of $\overline{M}$ between 0 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). The domestic quantity of cocaine slightly increases due to the fact that no funding is being assigned to fight against production under an efficient allocation of subsidies and drug traffickers increase their demand for cocaine in the producer countries in response to higher prices in the consumer country. However, the supply of cocaine in consumer countries (U.S. and Europe) decreases from roughly $368,000$ kg to about $296,000$ kg (panel B) due to the intensification of interdiction efforts. In other words, more cocaine is produced in Colombia but a smaller amount successfully reaches consumer countries. The simulation results imply that 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 19.5%.[35] This implies that the average cost to the U.S. of decreasing the supply of cocaine by 1 kg is about \$14,400.[36] While the fraction of land under the drug producers' control remains constant at roughly 25% (about 125,000 hectares), productivity per hectare increases from about 5.8 kg of cocaine per hectare per year to about 6.4 kg of cocaine per hectare per year (panel C). This productivity increase is an endogenous response of the drug producers to higher domestic drug prices (see panel E, described below) resulting from the increase in the drug traffickers' demand for cocaine. Also, while the fraction of routes under the drug traffickers' control falls from about 75% to less than 60% as a result of a 1 billion increase in the U.S. assistance to PC, the productivity of drug routes increases slightly (panel D). Cocaine prices (domestic and foreign) also react to the increase in the U.S. assistance for PC. Domestic cocaine prices in Colombia do not increase by much because under an efficient allocation of subsidies the U.S. does not fund the war against drug production. However, cocaine prices at the border of the consumer country increase by about 30%, from about \$42,000 per kg under the current total assistance to about \$60,000 per kilogram when the assistance to PC increases to \$1.5 billion per year (panels E and F).

The marginal cost to the U.S. of reducing the supply of cocaine by 1 kilogram increases from about \$8,800 per kilogram to about \$21,800 per kilogram (panel G).[37] In other words,

[35] The average for this variable accross all robustness checks is 17.5% (s.d. 5.1%).

[36] Under an efficient allocation of subsidies, where all the U.S. assistance for PC is allocated to funding Colombia's interdiction efforts.

[37] In panel G we also report the marginal cost to the U.S. of reducing the amount of cocaine by 1 kg by subsidizing the conflict over the control of arable land, MC_{ω}^{US}. This panel shows that the U.S.

as the war on drugs intensifies, the marginal cost of reducing supply even further increases. This happens because the price of cocaine in consumer countries rises and so does the value of drug routes, which encourages drug traffickers to fight harder for the control of the latter. The sum of the resources invested in the war on drugs by all the actors involved (our measure for the intensity of conflict associated with the war on drugs) increases from slightly less that $5.8 billion to about $10.2 billion (panel H).[38] Colombian expenses on the war on drugs also increase by about 22%, mainly due to the increase in the subsidies granted by the interested outsider which causes a decrease in the marginal cost to Colombia of investing resources in interdiction efforts (panel I). 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 U.S. budget for PC increases producers' profits but decreases those of the drug trafficker. The increase in producers' profits is about 12% (about $5 million), whereas the decrease in the drug trafficker's profits would be about 14% (about $1 billion) (panels J and K).

[Insert Figure 1 here: Simulation Exercise: Efficient subsidies].

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. In particular, we identify four key factors underlying the magnitude of the costs of the war on illegal drug production and trafficking.

After a few algebraic steps (see the appendix), we can 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:

optimal allocation of subsidies between the two fronts of the war on drugs in Colombia would still be a corner solution (where the U.S. would only subsidize Colombia's interdiction efforts) even if the total U.S. assistance increases three-fold.

[38] This result is in line with the finding in Naranjo (2008) regarding the intensification of conflict as a result of supply side interventions in producer countries.

$$MC_{\omega}^{U.S.} = \frac{M_o}{Q_f}\left[\frac{1-b}{b} + \frac{b+\alpha\eta - b\alpha\eta}{b(1-\alpha)}\left(\frac{c_1(\Upsilon - \Upsilon q^2 - q^2)}{q(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)\right] \tag{30}$$

We can also express (see the appendix) 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 interdiction efforts, as:

$$MC_{\Omega}^{U.S.} = \frac{M_o}{Q_f}\left[\frac{1-b}{b} + \frac{b+\alpha\eta - b\alpha\eta}{b(1-\eta)}\left(\frac{c_2(\Theta - \Theta h^2 - h^2)}{h(c_1\eta(1-q)(\Upsilon(1-q)/q-1)+c_2(1-h)(\Theta(1-h)/h-1))}\right)\right] \tag{31}$$

Using the previous expressions, we are able to identify the four key factors underlying the answer to our question, why is it so costly to make important advances in the war against drugs? Or, in other words, why are the marginal costs in expressions 30 and 31 large?[39]

While under the current allocation of subsidies between the two fronts of the war on drugs we estimate $MC_{\omega}^{U.S.}$ to be roughly $\$163,000$ and $MC_{\Omega}^{U.S.}$ to be about $\$3,700$, under the most efficient allocation of subsidies (one where only interdiction efforts were subsidized by the U.S.) the marginal cost to the U.S. would be about $\$8,800$ per kilogram. So, then, why are these marginal costs so high (especially $MC_{\omega}^{U.S.}$) and different?

First, notice that both costs depend positively on b, the price elasticity of demand for cocaine at the wholesale level.[40] The intuition for this result is that, with an inelastic demand function, any attempt to shift the supply of drugs to the left by curtailing the supply of illegal drugs using anti-drug policies in producer countries would only have minor effects on the quantities transacted in equilibrium. Furthermore, a lower b implies that drug prices are going to increase more in response to supply reductions. These price increases, in turn, fuels conflict and, as will be explained below, induces a larger strategic response by the drug producers and the drug traffickers to the specific types of anti-drug policies implemented under PC.

Second, the two marginal costs depend positively on ϕ and γ. Namely, if the resources invested by the government in the conflict over the control of arable land with drug producers and in interdiction efforts against the drug trafficker are less efficient (relative to

[39] Alternatively, we could have focused on the elasticity of cocaine reaching consumer countries to changes in the U.S. assistance for PC in each of the two fronts. However, the four key factors that increase the marginal costs in expressions 30 and 31 are exactly the same factors that increase the two elasticities.

[40] This first determinant of the cost of the war on drugs in producer countries is in line with the conclusion arrived at by Becker et al. (2006).

the resources invested by the drug producers and the drug trafficker respectively), then the costs of reducing Q_f are increasing on ϕ and γ (that is, as the drug producers or the drug traffickers become more efficient than the government in the war on drugs). According to our estimates, $\gamma < \phi$ ($\gamma \simeq 0.24$ and $\phi \simeq 3.4$). That is, the Colombian government is relatively much more efficient fighting the drug traffickers than fighting the drug producers. This large difference between ϕ and γ is one of the main determinants for the large difference observed between $MC_{\omega}^{U.S.}$ and $MC_{\Omega}^{U.S.}$.

Third, the two marginal costs depend negatively 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. These are the two factors targeted by the war against illegal drug production and trafficking, respectively. While we found a relatively high value for $1 - \eta$ (about 0.92), the estimated value of $1 - \alpha$ was relatively low (about 0.21). In other words, while the war against illegal drug production is mainly a dispute over a relatively unimportant factor, arable land, the war against illegal drug trafficking focuses on the most important factor of the trafficking technology, the drug routes. The difference between the relative importance of each of the factors being contested in the two fronts of the war on drugs is yet another reason why the two marginal costs, $MC_{\omega}^{U.S.}$ and $MC_{\Omega}^{U.S.}$, are so different.

Finally, the two marginal costs increase as the scope for strategic responses by the drug producers and the drug traffickers increases. More precisely, drug producers and traffickers respond to anti-drug policies by using the non-targeted factor (that is, the complementary factors to land in the case of drug production and cocaine in the case of drug trafficking) more intensively. In particular, this strategic response is reflected in an increase in the productivity of the targeted factor. Note that equations 23 and 9 show that r_i^* and Q_d^d depend positively on P_d and on P_f/P_d respectively. In other words, both producers and traffickers respond to the relative prices of their goods and inputs when choosing their optimal investments. Also, r_i^* and Q_d^d depend positively on q and h respectively. If demand for drugs is inelastic, a fall in q or h due to an intensification of the war on drugs, increases relative prices enough to offset the negative effects of the fall of q and h on r^* and Q_d^*, thus resulting in a net increase in the demand for the non-targeted factor. Overall, the ratio between complementary factors and land and the ratio between domestic cocaine and routes increase. As a result, if the demand for drugs is inelastic, the productivity of land and routes increase in response to a more intense war on drugs in producer countries. That is, drug producers use more complementary factors per hectare in response to stronger eradication efforts while drug traffickers demand more drugs per route in response to stronger interdiction efforts. According to our estimates in the baseline calibration exercise, a 1% decrease in the amount of land under the drug producers' control resulting from a more intense war against drug production leads to an increase of about 0.79% in the productivity of land (that is, in the amount of cocaine produced from one hectare of land in one year) implying a net decrease in domestic production of 0.21%. On the other hand, a 1% decrease in the fraction of drug routes not detected by government leads to an increase of about 0.11% in the productivity of drug routes, implying a net decrease in final drug supply of 0.89%. Thus, while the war against drug production activities leads to relatively large increases in productivity, the increase in the productivity of drug trafficking activities resulting from the war against illegal drug trafficking is relatively small. The difference in the size of the strategic response arises because $\eta < \alpha$, and hence, the scope for a strategic response is larger in drug production activities than in drug trafficking activities.

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 under PC.[41] This is because $MC_{\omega}^{U.S.} > MC_{\Omega}^{U.S.}$ even when $\omega = 1$.

Despite the fact that both the U.S. and Colombia have an incentive to jointly fight the war on drugs, they do not necessarily coincide in the preferred allocation of subsidies between the two fronts of this war. This is specially the case since the two countries have different objective functions. While the U.S. objective is to minimize the amount of drugs reaching its borders, Colombia's objective is to minimize the total cost of illegal drugs and the war against them.

So why should Colombia be concerned about the U.S. only allocating resources to subsidize 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 total costs to Colombia from illegal drug production and trafficking is lower under the current, relatively inefficient allocation of subsidies, than under an efficient (from the U.S. perspective) allocation . The reason for this is that, although the income derived by drug producers, $P_d Q_d$, is much lower

[41] This is true, of course, if the only U.S. objective under PC is to minimize the amount of cocaine reaching its borders.

than the income derived by the drug trafficker, $P_f Q_f$, the marginal cost to Colombia from drug production activities is much larger than that fro drug trafficking activities. In other words, c_1 is much higher than c_2; the difference between these two costs to Colombia more than counteracts the difference between the income of drug producers and drug traffickers. Furthermore, the large difference in the net (marginal) cost perceived by Colombia from drug production activities (55 cents per dollar received by the drug producers) *vis-à-vis* drug trafficking activities (2 cents per dollar received by the drug traffickers), more than counteracts the fact that Colombia is more efficient attacking trafficking than attacking production activities and that the factor being targeted by the war on production is relatively unimportant in the production of cocaine whereas the factor being targeted by the interdiction front of the war on drugs (the drug routes) is very important in the "production" of illegal drug shipments.[42] Thus, Colombia is better off under the current, inefficient allocation, where more resources are being spent targeting production activities. It should be stressed that 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 drug traffickers, respectively. However, if the U.S. were to stop subsidizing Colombia in its war against drug producers, drug production would increase, the income of drug producers would go up and, thus, the net cost to Colombia from this activity would increase. In fact, our results suggest that under an efficient allocation of subsidies, the total cost (including the costs of fighting in each of the fronts of the war on drugs) from illegal drug production would go up by about \$42 million and the total cost from illegal drug trafficking would go up by about \$63 million. Thus, the total cost to Colombia under the current, inefficient allocation is about \$105 million lower than it would be under an efficient (from the U.S. government point of view) allocation .

We go one step forward and explore the optimal allocation of subsidies that Colombia would implement if it were allowed to choose on its own the allocation of the U.S. assistance for PC between the two fronts of the war on drugs (see the appendix).[43] We find the conditions for the optimal allocation of subsidies from the Colombian perspective, whose objective is not to minimize the amount of cocaine reaching consumer countries but, rather, to minimize the total costs from illegal drug production and trafficking, and the costs of

[42] These last two forces would, in principle, lead Colombia to prefer to only prefer to attack trafficking activities.

[43] In this hypothetical exercise, Colombia, as in the model, takes drug prices as given (see the appendix for details).

fighting the two fronts of the war on drugs. When we calibrate the model using the optimality conditions for Colombia, we find that Colombia would choose to allocate all the U.S. assistance for PC to subsidizing its conflict with the drug producers over the control of arable land and nothing to subsidize its interdiction efforts. The main driving force behind this result, yet again, is that Colombia faces a much larger cost (at the margin) from illegal drug production than from illegal drug trafficking activities. In particular, we find that one extra dollar of U.S. assistance for PC invested in the conflict over the control of arable land with the drug producers decreases the total cost to Colombia by about \$1.37, whereas one extra dollar of U.S. assistance invested in interdiction efforts decreases the total cost to Colombia by only \$0.09.

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 war.

In this paper, we developed a game-theory model of the war against illegal drug production 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 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 in producer countries. The paper also provides estimates for the marginal cost to the U.S. 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 decrease the supply of cocaine that successfully reaches the consumer countries by about 19.5%, with an average cost to the U.S. of decreasing the exportation of cocaine by one kilogram of about $14,400.

Furthermore, we estimate that under an efficient allocation of subsidies from the U.S. perspective (the one that minimizes the amount of cocaine reaching the U.S. markets), the U.S. should only subsidize Colombia in its interdiction efforts. However, from the point of view of Colombia, whose aim is not necessarily to minimize the amount of cocaine reaching consumer countries but the total costs associated with the war on drugs, the optimal allocation of U.S. subsidies would imply spending all the U.S. assistance in the war against drug producers, as this is the group that generate the largest cost to Colombia. Thus, while both the U.S. and Colombia have an interest in fighting the war on drugs, we find that they do not necessarily coincide in the preferred means to do so.

Finally, we identify the key fundamentals that help explain the costs of fighting the war on drugs in producer countries. Namely, the price elasticity of demand for drugs in consumer countries; the relative importance of the factors targeted in the war against drug production and trafficking; the relative effectiveness of the resources invested in each of the two fronts of the war on drugs; and the scope for strategic responses by the drug producers and traffickers that counteract their effectiveness.

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.

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6 Appendix

6.1 A1: Solution of the model

Drug trafficking equilibrium:

We solve the game by backward induction. When choosing the demand for drugs in the producer country, the drug trafficker's problem is:

$$\max_{Q_d} \pi_T = P_f Q_f - P_d Q_d - t, \tag{A1}$$

taking P_f, P_d, t, s and h as given. The optimal choice of Q_d is given by the following first order condition:

$$\frac{\partial \pi_T}{\partial Q_d} = 0 \Longleftrightarrow Q_d^* = \kappa h \left(\frac{\eta P_f}{P_d}\right)^{\frac{1}{1-\eta}} \tag{A2}$$

When choosing t the trafficker anticipates his choice of Q_d and therefore the optimal choice must solve the following problem:

$$\max_t \ \pi_T^* = \rho h \kappa \frac{P_f^{\frac{1}{1-\eta}}}{P_d^{\frac{\eta}{1-\eta}}} - t, \tag{A3}$$

where $\rho = \eta^{\frac{\eta}{1-\eta}} - \eta^{\frac{1}{1-\eta}} > 0$. π_T^* is obtained by plugging Q_d^* into the original drug trafficker's problem. Using the expression for h from equation 3, the optimal choice of t is given by the following first order condition:

$$\frac{\partial \pi_T^*}{\partial t} = 0 \Longleftrightarrow t^* = \sqrt{\frac{\rho \kappa P_f^{\frac{1}{1-\eta}} s}{\gamma P_d^{\frac{\eta}{1-\eta}}}} - \frac{s}{\gamma}. \tag{A4}$$

Equation A4 describes the drug trafficker's reaction function in the conflict against the government over the control of the drug routes.

When choosing s, the government anticipates the subsequent choice of Q_d by the trafficker, and therefore its optimal choice must solve the following problem:

$$\min_s \ C_T = \ \eta^{\frac{\eta}{1-\eta}} c_2 h \kappa \frac{P_f^{\frac{1}{1-\eta}}}{P_d^{\frac{\eta}{1-\eta}}} + \Omega s, \tag{A5}$$

obtained by replacing $Q_f = (h\kappa)^{1-\eta} Q_d^{*\eta}$ into the government's original problem. Using the expression for h from equation 3, the optimal choice of t is given by the following first order condition:[44]

$$\frac{\partial C_T}{\partial s} = 0 \Longleftrightarrow s^* = \sqrt{\frac{\eta^{\frac{\eta}{1-\eta}} c_2 \kappa P_f^{\frac{1}{1-\eta}} \gamma t}{P_d^{\frac{\eta}{1-\eta}}}} - \gamma t. \tag{A6}$$

Solving equations A4 and A6 simultaneously, we find the equilibrium values for t^* and s^*. Together with Q_d^d, Q_f^s and h^*, these values constitute the Nash Equilibrium of the drug trafficking subgame $(t^*, s^*, h^*, Q_d^d(P_d, P_f), Q_f^s(P_d, P_f))$ presented in the paper in equations 6, 7, 8, 9 and 10.

Drug production equilibrium:

When choosing the demand for complementary factors to land in the production of illicit drugs, each drug producer solves the following problem:

$$\max_{r_i} \pi_i = P_d Q_{d,i} - (x_i + y_i + r_i). \tag{A7}$$

Drug producers take as given P_d, x_i, y_i, f_i, z_i and q. The optimal choice of r_i is given by the following first order condition:

$$\frac{\partial \pi_i}{\partial r_i} = 0 \quad \Longleftrightarrow \quad r_i^* = (\alpha \lambda P_d)^{\frac{1}{1-\alpha}} q f_i L. \tag{A8}$$

When choosing y_i, drug producer i anticipates his choice of r_i and therefore the optimal choice must solve the following problem:

$$\max_{y_i} \pi_i^* = \sigma(\lambda P_d)^{\frac{1}{1-\alpha}} q f_i L - (x_i + y_i), \tag{A9}$$

where $\sigma = \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}} > 0$. π_i^* is obtained by plugging r_i^* into the original drug producer's problem. Using the expression for f_i from equation 13, the optimal choice of y_i is given by the following first order condition:

$$\frac{\partial \pi_i^*}{\partial y_i} = 0 \quad \Longleftrightarrow \quad y_i^* = \sqrt{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} q L \sum_{j \neq i} y_j} - \sum_{j \neq i} y_j. \tag{A10}$$

[44] Since the functions $P_f Q_f - P_d Q_d - t$ and $\rho h \kappa \frac{P_f^{\frac{1}{1-\eta}}}{P_d^{\frac{\eta}{1-\eta}}} - t$ are strictly concave in Q_d and t respectively, and $\eta^{\frac{\eta}{1-\eta}} c_2 h \kappa \frac{P_f^{\frac{1}{1-\eta}}}{P_d^{\frac{\eta}{1-\eta}}} + \Omega s$ is a strictly convex function of s, the first order condition is sufficient to guarantee an absolute maximum (or minimum) for all functions.

Since this reaction function is the same for all the n drug producers, we must have a symmetric Nash equilibrium for this subgame[45] (that is $y_i^* = y^* \ \forall i$), with:

$$y^* = \frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} qL(n-1)}{n^2}, \tag{A11}$$

which is obtained by solving the system of equations given by A10 for $i = 1, 2, \ldots, n$, which also implies that $f_i^* = 1/n$.

When choosing x_i, drug producer i anticipates his choice of r_i and y_i, and also the equilibrium value for $f_i^* = 1/n$, therefore the optimal choice must solve the following problem:

$$\max_{x_i} \pi_i^{**} = \frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} qL}{n^2} - x_i, \tag{A12}$$

where π_i^{**} is obtained by plugging r_i^*, y_i^* and f_i^* into the original drug producer's problem. Using the expression for q from equation 12, the optimal choice of x_i is given by the following first order condition:

$$\frac{\partial \pi_i^{**}}{\partial x_i} = 0 \iff x_i^* = \sqrt{\frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} L z_i}{\phi n^3}} - \frac{z_i}{\phi}. \tag{A13}$$

When choosing z_i, the government anticipates the subsequent choice of r_i and y_i by the drug producers, and therefore its optimal choice must solve the following problem:

$$\min_{z_i} C_P = c_1 \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{\alpha}{1-\alpha}} P_d^{\frac{1}{1-\alpha}} qL + \omega \sum_{i=1}^{n} z_i, \tag{A14}$$

which is obtained by replacing $Q_d = \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{\alpha}{1-\alpha}} qL$ into the government's original problem. Using the expression for q from equation 12, the optimal choice of z_i is given by the following first order condition[46]

$$\frac{\partial C_P}{\partial z_i} = 0 \iff z_i^* = \sqrt{\frac{c_1 \alpha^{\frac{\alpha}{1-\alpha}} (\lambda P_d)^{\frac{1}{1-\alpha}} L \phi x_i}{n\omega}} - \phi x_i. \tag{A15}$$

[45] In this case, it can be shown that the equilibrium must be symmetric since, letting $Y = \sum_{i=1}^n y_i$, the function $f(y) = \sqrt{A(Y-y)} - Y + y$ has only one fixed point with $y = \frac{AY - Y^2}{A}$ and therefore all y_i must be equal in order to satisfy $f(y_i) = y_i$.

[46] Since the functions $P_d Q_{d,i} - (x_i + y_i + r_i)$, $\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} q f_i L - (x_i + y_i)$ and $\frac{\sigma(\lambda P_d)^{\frac{1}{1-\alpha}} qL}{n^2} - x_i$ are strictly concave in r_i, y_i and x_i respectively, and the function $c_1 \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{\alpha}{1-\alpha}} P_d^{\frac{1}{1-\alpha}} qL + \omega \sum_{i=1}^n z_i$ is strictly convex in $z = (z_1, \ldots, z_n)$, the first order conditions guarantee the existence of a global maximum or minimum for all of these functions.

Solving equations A13 and A15 simultaneously for x_i^* and z_i^* we find their equilibrium values. Together with equation A8 and the implied values for y_i, f_i and q, these values constitute the Nash Equilibrium of the drug production subgame $(x_i^*, z_i^*, q^*, y_i^*, f_i^*, r_i^*, Q_d^s(P_d))$, presented in the paper in equations 18, 19, 20, 21, 22, 24.

Drug market equilibrium:

The domestic drug market equilibrium condition is given by:

$$q^* \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_d^{\frac{\alpha}{1-\alpha}} L = h^* \kappa \left(\frac{\eta P_f}{P_d}\right)^{\frac{1}{1-\eta}}, \tag{A16}$$

and the drug market equilibrium condition at the border of the consumer country is given by:

$$h^* \kappa \left(\frac{\eta P_f}{P_d}\right)^{\frac{\eta}{1-\eta}} = \frac{a}{P_f^b}, \tag{A17}$$

These equations form a simultaneous system of equations on P_d and P_f which turns out to be log linear. Taking logs in both equations and using Cramer's rule, we obtain:

$$P_d^* = \frac{1}{q^{*\frac{(\eta+b-b\eta)(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{(1-b)(1-\alpha)(1-\eta)}{b+\alpha\eta-b\alpha\eta}}} \left(\frac{\Lambda}{\Delta}\right)^{\frac{(1-\alpha)(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}} \tag{A18}$$

$$P_f^* = \frac{1}{q^{*\frac{\eta(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{1-\eta}{b+\alpha\eta-b\alpha\eta}}} \left(\frac{a}{\Pi}\right)^{\frac{1-\alpha\eta}{b+\alpha\eta-b\alpha\eta}}, \tag{A19}$$

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 $\Pi = \left(\alpha^{\alpha\eta} \lambda^\eta L^{(1-\alpha)\eta} \eta^{\alpha\eta} \kappa^{1-\eta}\right)^{\frac{1}{1-\alpha\eta}}$. Using P_d^* and P_f^* we also get the corresponding equilibrium quantities:

$$Q_d^* = \frac{q^{*\frac{b(1-\alpha)}{b+\alpha\eta-b\alpha\eta}}}{h^{*\frac{\alpha(1-b)(1-\eta)}{b+\alpha\eta-b\alpha\eta}}} \Delta^{1-\frac{\alpha(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}} \Lambda^{\frac{\alpha(\eta+b(1-\eta))}{b+\alpha\eta-b\alpha\eta}} \tag{A20}$$

$$Q_f^* = q^{*\frac{b\eta(1-\alpha)}{b+\alpha\eta-b\alpha\eta}} h^{*\frac{b(1-\eta)}{b+\alpha\eta-b\alpha\eta}} a^{1-\frac{b(1-\alpha\eta)}{b+\alpha\eta-b\alpha\eta}} \Pi^{\frac{b(1-\alpha\eta)}{b+\alpha\eta-b\alpha\eta}}. \tag{A21}$$

6.2 A2: The interested outsider problem.

Since the function $q(\omega)$ is a continuous biyection from $[0,1]$ to $\left[0, \frac{\phi(1-\alpha)}{c_1 n^2+\phi(1-\alpha)}\right]$ and the function $h(\Omega)$ is a continuous biyection from $[0,1]$ to $\left[0, \frac{\gamma(1-\eta)}{c_2+\gamma(1-\eta)}\right]$, we can rewrite the interested outsider problem as:

$$\begin{aligned} \min_{q,h} \quad & Q_f(q,h) \\ \text{s.t} \quad & M_o(q,h) \leq M, \quad 0 \leq q \leq q_{max}, \ 0 \leq h \leq h_{max}, \end{aligned} \tag{A22}$$

which has the associated Lagrangian function:

$$\varsigma(q,h,\Lambda,\vartheta_q,\vartheta_h) = Q(q,h) - \Lambda(M - M_o(q,h)) - \vartheta_q(q_{max}-q) - \vartheta_h(h_{max}-h) \tag{A23}$$

The Kuhn-Tucker conditions for the minimization problem are:

$$\begin{aligned} q \geq 0 \quad &, \quad q\left(\frac{\partial Q_f}{\partial q} + \Lambda\frac{\partial M}{\partial q} + \vartheta_q\right) = 0, \\ h \geq 0 \quad &, \quad h\left(\frac{\partial Q_f}{\partial h} + \Lambda\frac{\partial M}{\partial h} + \vartheta_h\right) = 0, \\ \Lambda \geq 0 \quad &, \quad \Lambda(M - M_o(q,h)) = 0, \\ \vartheta_q \geq 0 \quad &, \quad \vartheta_q(q_{max}-q) = 0, \\ \vartheta_h \geq 0 \quad &, \quad \vartheta_h(h_{max}-h) = 0. \end{aligned} \tag{A24}$$

In any internal solution we must have $\vartheta_q = \vartheta_h = 0$, and $\frac{\partial Q_f}{\partial q} + \Lambda\frac{\partial M}{\partial q} = \frac{\partial Q_f}{\partial h} + \Lambda\frac{\partial M}{\partial h} = 0$, which implies that:

$$MC_\omega = -\frac{\frac{\partial M}{\partial q}}{\frac{\partial Q_f}{\partial q}} = \frac{1}{\Lambda} = -\frac{\frac{\partial M}{\partial h}}{\frac{\partial Q_f}{\partial h}} = MC_\Omega \tag{A25}$$

where MC_ω and MC_Ω are the marginal cost of reducing the supply of drugs by one kilogram by subsidizing the conflict over the control of arable land and interdiction efforts, respectively. In this case $\Lambda > 0$ and we must also have $M = M_o(q,h)$, so the budget constraint is binding.

In a corner solution with $q = q_{max}$ (or $\omega = 1$) we must have $\vartheta_h = 0$, and $\frac{\partial Q_f}{\partial q} + \Lambda\frac{\partial M}{\partial q} + \vartheta_q = \frac{\partial Q_f}{\partial h} + \Lambda\frac{\partial M}{\partial h}$ which implies that:

$$MC_\omega = -\frac{\frac{\partial M}{\partial q}}{\frac{\partial Q_f}{\partial q}} \geq \frac{1}{\Lambda} = -\frac{\frac{\partial M}{\partial h}}{\frac{\partial Q_f}{\partial h}} = MC_\Omega \tag{A24}$$

In this case it is also true that $\Lambda > 0$ and we must also have $M = M_{(q,h)}$, so the budget constraint is binding.

From the model we obtain:

$$M_o = A(1-q)\left(\frac{\Upsilon(1-q)}{q} - 1\right) q^{-\Gamma} h^{-\psi} + B(1-h)\left(\frac{\Theta(1-h)}{h} - 1\right) q^{-\Gamma} y^{-\psi}, \qquad \text{(A26)}$$

where Γ, ψ, Υ, Θ, A, and B are themselves functions of the parameters of the model, given by:

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

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

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

Also, 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:

$$Q_f^* = C q^{\zeta} h^{\chi}, \qquad \text{(A27)}$$

where, again, ζ, χ, and C are combinations of the structural parameters of the model given by:

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

Using the previous expressions we can calculate MC_ω and MC_Ω as:

$$MC_\omega = \frac{q^{-\Gamma-\zeta+1} h^{-\psi-\chi}}{\zeta C} \left(\begin{array}{c} \frac{A\Gamma(1-q)}{q}\left(\frac{\Upsilon(1-q)}{q} - 1\right) \\ +A\left(\frac{\Upsilon(1-q)}{q} - 1\right) + \frac{A\Upsilon(1-q)}{q^2} + \frac{B\Theta(1-h)}{q}\left(\frac{\Theta(1-h)}{h} - 1\right) \end{array}\right) \qquad \text{(A28)}$$

$$MC_\Omega = \frac{q^{-\Gamma-\zeta} h^{-\psi-\chi+1}}{\chi C} \left(\begin{array}{c} \frac{B\psi(1-h)}{h}\left(\frac{\Theta(1-h)}{h} - 1\right) \\ +B\left(\frac{\Theta(1-h)}{h} - 1\right) + \frac{B\Theta(1-h)}{h^2} + \frac{A\psi(1-q)}{h}\left(\frac{\Upsilon(1-q)}{q} - 1\right) \end{array}\right). \qquad \text{(A29)}$$

6.3 A3: Calibration details.

Let any variable with a subscript B denote the value of the variable before PC. The variables which do not have subscript B denote the value of the variable after PC.

Demand parameters:

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

$$\frac{a}{P_{fB,US}^{b}} = Q_{fB,US} \qquad \text{and} \qquad \frac{a}{P_{f,US}^{b}} = Q_{f,US}, \tag{A30}$$

before and after PC respectively. By using the prices and quantities at the wholesale level in the U.S., together with the expressions in equation A30, we get:

$$b = \frac{\ln\left(\frac{Q_{f,US}}{Q_{fB,US}}\right)}{\ln\left(\frac{P_{fB,US}}{P_{f,US}}\right)} \quad \Rightarrow \quad b \simeq 0.64. \tag{A31}$$

which is our baseline estimate for the price elasticity of demand for cocaine at the wholesale level in the U.S. We use this elasticity for the generic wholesale drug dealer in our model since we don't have precise data on quantities flowing to Europe and their interdiction in transit countries. To recover the scale parameter of the demand function we use our estimated value for b and obtain:

$$a = Q_f P_f^b. \quad \Rightarrow \quad a \simeq 428,659,920. \tag{A32}$$

Trafficking parameters:

In order to estimate η, we use equations 2 and A2, and obtain:

$$\eta = \frac{P_d Q_d}{P_f Q_f} \quad \Rightarrow \quad \eta \simeq 0.08 \ . \tag{A33}$$

η equals the share of domestic drugs in the total earnings of drug traffickers, which, in turn is our baseline estimate for the relative importance of cocaine in the trafficking technology.

Rearranging the equation for the equilibrium fraction of drugs that survive the government's interdiction efforts (equation 8), we get:

$$\frac{h_B}{(1-h_B)(1-\eta)} = \frac{\gamma}{c_2} \qquad \text{and} \qquad \frac{h}{\Omega(1-h)(1-\eta)} = \frac{\gamma}{c_2}, \tag{A34}$$

before and after PC, respectively. Recall that before PC, $\Omega = 1$. Also, h_B and h are the fractions of cocaine produced in Colombia that survive interdiction efforts inside Colombia before and after PC respectively. According to UNODC, these values are $h_B \simeq 0.93$ and $h \simeq 0.81$. Using the two expressions in equation A34, and the UNODC's estimates for the fractions of drugs seized before and after PC, we get:

$$\Omega = \frac{h(1-h_B)}{h_B(1-h)} \quad \Rightarrow \quad \Omega \simeq 0.33. \tag{A35}$$

To estimate κ, we use equation 2 together with the previous estimate of η and obtain:

$$\kappa = \frac{1}{h}\left(\frac{Q_f}{Q_d^{\eta}}\right)^{\frac{1}{1-\eta}} \quad \Rightarrow \quad \kappa \simeq 512,820 \ \cdot \tag{A36}$$

Production parameters:

Using equation 24, the productivities per hectare of land before and after PC can be expressed as:

$$prod_{qLB} = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_{dB}^{\frac{\alpha}{1-\alpha}} \qquad \text{and} \qquad prod_{qL} = \alpha^{\frac{\alpha}{1-\alpha}} \lambda^{\frac{1}{1-\alpha}} P_{d}^{\frac{\alpha}{1-\alpha}} \ . \tag{A37}$$

Using the two expressions in equation A37, and solving for α yields:

$$\alpha = \frac{\ln\left(\frac{prod_{qLB}}{prod_{qL}}\right)}{\ln\left(\frac{P_{dB}}{P_d}\right) + \ln\left(\frac{prod_{qLB}}{prod_{qL}}\right)} \quad \Rightarrow \quad \alpha \simeq 0.78 \ . \tag{A38}$$

Note that another way of estimating α is by noticing that $1-\alpha$ is the share of the input land in total production. About 255 kg of dry coca leaf are needed to process one pure kg of cocaine. The price of each kg of coca leaf is about \$2.5 (see UNODC, 2008). Thus, the total income from coca leaf necessary to produce 1 kg of cocaine is about \$635. On average, one hectare of land produces the coca leaf necessary to process slightly more than 7 kg of pure cocaine per year, and about one peasant is employed per hectare in the cultivation of coca leaf. Thus, if we substract from the total income from coca leaf per year (\$635 x

7) the peasant's income (about \$130 x 12 months), then the total payment for coca leaf per hectare per year is about \$2,650. This number divided by 7 kg of cocaine per hectare per year is about \$380. If the price of a pure kg of cocaine at the farmgate in Colombia is about \$1,820, then the share of land in the production of cocaine, $1-\alpha$, is about 0.208, thus obtaining a similar estimate for α with the two alternative estimation methods.

The scale parameter λ can be obtained from equation A37 using our value of α as:

$$\lambda = \frac{(Q_i/l_i)^{1-\alpha}}{(\alpha P_d)^{\alpha}} \quad \Rightarrow \quad \lambda \simeq 0.005 \ . \tag{A39}$$

Costs perceived by the state from drug production and drug trafficking activities:

We calculate c_1 and c_2 using the Colombian government expenditures on the military component of PC. It can be shown that Colombia's equilibrium expenditure on PC are given by:

$$\begin{aligned} M_s &= (1-q^*)P_d Q_d c_1 + (1-h^*)P_f Q_f c_2. \\ M_{sB} &= (1-q_B^*)P_{dB} Q_{dB} c_1 + (1-h_B^*)P_{fB} Q_{fB} c_2. \end{aligned} \tag{A40}$$

which is a linear equation system on c_1 and c_2. Using Cramer's rule we get:

$$c_1 = -\frac{M_{sB}(1-h^*)P_f Q_f - (1-h_B^*)P_{fB} Q_{fB} M_s}{(1-q_B^*)P_{dB} Q_{dB}(1-h^*)P_f Q_f - (1-h_B^*)P_{fB} Q_{fB}(1-q^*)P_d Q_d} \quad \Rightarrow \quad c_1 \simeq 0.55 \ , \tag{A41}$$

and,

$$c_2 = \frac{M_{sB}(1-q^*)P_d Q_d - (1-q_B^*)P_{dB} Q_{dB} M_s}{(1-q_B^*)P_{dB} Q_{dB}(1-h^*)P_f Q_f - (1-h_B^*)P_{fB} Q_{fB}(1-q^*)P_d Q_d} \quad \Rightarrow \quad c_2 \simeq 0.02 \ . \tag{A42}$$

Finally, to estimate ω we use the U.S budget for PC. The U.S budget in equilibrium can be expressed as:

$$M_o = (1-q)\frac{1-\omega}{\omega} Q_d P_d c_1 + (1-h)\frac{1-\Omega}{\Omega} Q_f P_f c_2. \tag{A43}$$

Therefore, isolating ω we obtain:

$$\omega = \frac{M_o - (1-h^*)\frac{1-\Omega}{\Omega} Q_f P_f c_2}{(1-q^*) Q_d P_d c_1 + M_o - (1-h^*)\frac{1-\Omega}{\Omega} Q_f P_f c_2} \quad \Rightarrow \quad \omega \simeq 0.58 \ . \tag{A44}$$

Finally, rearranging the equations for q^* and h^* (equations 20 and 8 respectively), and isolating ϕ and γ respectively, we obtain:

$$\phi = \frac{q^* c_1 n^2}{\omega(1-\alpha)(1-q^*)} \rightarrow \phi = 3.36 \quad \gamma = \frac{h^* c_2}{\Omega(1-\eta)(1-h^*)} \rightarrow \gamma = 0.24.$$

6.4 A4: Optimal allocation of subsidies for Colombia.

Let $C_T = c_2 P_f Q_f + \Omega s$ be the total cost to Colombia from drug trafficking activities; $C_P = c_1 P_d Q_d + \omega \sum_{i=1}^{n} z_i$ be the total cost to Colombia from drug production activities; $M_T = (1-\Omega)s$ the U.S. allocation of resources for interdiction efforts; and $M_P = (1-\omega)\sum_{i=1}^{n} z_i$ the U.S. allocation of resources for the conflict over the control of arable land. If Colombia were allowed to choose the subsidies, it would choose them in order to solve the following optimization problem:

$$\min_{\omega,\Omega} \; C_T + C_P \qquad \texttt{s.t.} \qquad \begin{array}{l} M_T + M_P \leq M, \\ 0 \leq \omega, \Omega \leq 1. \end{array} \tag{A45}$$

In order to be consistent with the model, we assume that Colombia takes prices as given and therefore we take the equilibrium values for C_T, C_P, M_T and M_P as functions of market prices and the parameters of the model.

In any internal solution the following condition must hold:

$$\left(-\frac{\partial C_T^*}{\partial M_T^*}\right)_{\Omega} = \left(-\frac{\partial C_P^*}{\partial M_P^*}\right)_{\omega}. \tag{A46}$$

This optimality condition says that one extra dollar of U.S. assistance for PC invested in the conflict over the control of arable land with the drug producers should decrease the total cost of conflict to Colombia $(C_T + C_P)$ by the same amount as one extra dollar of U.S. assistance invested in interdiction efforts would do. This condition can fail to be true only if we have a corner solution with either $\omega^* = 1$ or $\Omega^* = 1$.

By using the equilibrium values for all variables but taking prices as exogenous, we get

$$C_T = h(2-h)c_2\kappa\eta^{\frac{\eta}{1-\eta}} P_f \left(\frac{P_f}{P_d}\right)^{\frac{\eta}{1-\eta}} \tag{A47}$$

and,

$$C_P = q(2-q)c_1\lambda^{\frac{1}{1-\alpha}} L\alpha^{\frac{\alpha}{1-\alpha}} P_d^{\frac{1}{1-\alpha}} \tag{A48}$$

Also:

$$M_T = \left(\frac{\gamma(1-\eta)}{c_2}h - h\right)(1-h)c_2\kappa\eta^{\frac{\eta}{1-\eta}} P_f \left(\frac{P_f}{P_d}\right)^{\frac{\eta}{1-\eta}} \tag{A49}$$

and

$$M_P = \left(\frac{\phi(1-\alpha)}{c_1 n^2}(1-q) - q\right)(1-q)c_1\lambda^{\frac{1}{1-\alpha}} L\alpha^{\frac{\alpha}{1-\alpha}} P_d^{\frac{1}{1-\alpha}} \tag{A50}$$

Therefore, we obtain:

$$\left(-\frac{\partial C_T}{\partial M_T}\right)_\Omega = -\frac{\partial C_T/\partial h}{\partial M_T/\partial h} = \frac{1}{\Theta + \frac{1-2h}{2-2h}} \tag{A51}$$

and,

$$\left(-\frac{\partial C_P}{\partial M_P}\right)_\omega = -\frac{\partial C_P/\partial q}{\partial M_P/\partial q} = \frac{1}{\Gamma + \frac{1-2q}{2-2q}} \tag{A52}$$

From our baseline calibration exercise, we obtain $\left(-\frac{\partial C_T}{\partial M_T}\right)_\Omega = 0.09$, and $\left(-\frac{\partial C_P}{\partial M_P}\right)_q =$ 1.37. This implies that in order to minimize its objective function, Colombia would choose a smaller subsidy for interdiction and a larger one for the conflict over the control of arable land, since one extra dollar of U.S. assistance for PC invested in the conflict over the control of arable land with the drug producers decreases the total cost of conflict to Colombia ($C_T + C_P$) by 1.37 dollars, while the same dollar invested in the conflict over the control of routes with the drug traffickers decreases the total cost of conflict to Colombia by only 0.09.

In fact, when we solve the problem for Colombia numerically, we obtain a corner solution with $\omega^*_{COL} = 0.51$ and $\Omega^*_{COL} = 1$, for which $\left(-\frac{\partial C_T}{\partial M_T}\right)_\Omega = 0.14$ and $\left(-\frac{\partial C_P}{\partial M_P}\right)_\omega = 1.35$.

In other words, should Colombia be allowed to choose freely the allocation of U.S. subsidies to the two fronts of the war on drugs under PC, it would choose to allocate all the U.S. assistance to PC to subsidizing its conflict against the drug producers over the control of arable land and nothing to subsidize its interdiction efforts.

However, we should note that Colombia takes drug prices as given and, thus, this hypothetical exercise does not take into account general equilibrium effects and strategic responses arising from changes in drug prices.

Table 1: Data used in the baseline calibration exercise.

Variable	Source	Before PC Average 99-00	After PC Average 05-06	Description
P_f	UNODC	\$38,250	\$34,290	Final price in consumer countries.
$P_{f,U.S.}$	UNODC	\$35,950	\$25,850	Final price in the U.S.
P_d	UNODC	\$1,540	\$1,811	Domestic price.
qL	UNODC	161,700 has.	82,000 has.	Hectares with coca.
q	UNODC	32.3%	16.4%	Percentage of land with coca crops.
	UNODC	4.25 kg/ha/year.	7.6 kg/ha/year.	Productivity per hectare.
Q_d	UNODC	687,490 kg.	625,760 kg.	Domestic potential production.
	UNODC	49,655 kg.	119,683 kg.	Seizures by Colombian authorities.
h	UNODC	92.7%	80.9%	Percentage of cocaine not seized.
	Authors' calculations	45,490 kg.	77,955 kg.	Colombian cocaine seized in transit.
Q_f	Authors' calculations	592,350 kg.	428,120 kg.	Final supply from Colombia.
	GAO	460,000 kg.	625,000 kg.	Cocaine flows to U.S. markets.
	UNODC	60,127 kg.	129,900 kg.	Total seizures in transit countries.
Q_{US}	Authors' calculations	399,870 kg.	495,100 kg.	Final supply in U.S. borders.
M_s	DNP	\$420 Million	\$567 Million	Colombian expenses on PC.
M_o	DNP	0	\$465 Million	U.S. expenses on PC.

UNODC: United Nations Office on Drugs and Crime.
GAO: Government Accountability Office, U.S.
DNP: Departamento Nacional de Planeación, Colombia.

Table 2: Calibration results for the baseline exercise

Parameter	Value	Description
ω	0.586	Fraction of total erradication expenditures paid by Colombia.
Ω	0.329	Fraction of total interdiction expenditures paid by Colombia.
a	428,659,926	Scale parameter of the wholesale demand function.
b	0.64	Price elasticity of the demand for cocaine (wholesale).
α	0.78	Relative importance of the complementary factors in production.
λ	0.005	Scale parameter of the production technology.
η	0.08	Relative importance of domestic drugs in the trafficking technology.
κ	512,821	Scale parameter of the trafficking technology.
c_1	0.55	Net cost to Colombia per dollar received by the drug producers.
c_2	0.02	Net cost to Colombia per dollar received by the drug traffickers.
ϕ	3.36	Drug producers' relative efficiency in the conflict for land.
γ	0.24	Drug traffickers' relative efficiency in the conflict for routes.

Table 3: Actual and efficient allocation of subsidies.

Variable	Actual	Efficient Allocation
ω	0.586	1
Ω	0.33	0.16
q	0.164	0.25
h	0.81	0.67
$MC_{\omega}^{U.S.}$	\$162,782	\$113,833
$MC_{\Omega}^{U.S.}$	\$3,674	\$8,825
ϵ_{ω}	0.007	0.011
ϵ_{Ω}	0.296	0.144
Q_d	625,757 kg.	733,528 kg.
P_d	\$1,811	\$1,681
Q_f	428,119 kg.	366,387 kg.
P_f	\$34,288	\$43,607
C_P	\$1,140 m.	\$1,182 m.
C_T	\$300 m.	\$363 m.
$C_P + C_T$	\$1,440 m.	\$1,545 m.

Table 4: Description of robustness checks (RC).

	Observed variable	Description and Methodology	Number of RC
RC0	Purity and years	Variations in the purity of cocaine produced in Colombia, cocaine seized in Colombia and in transit countries. Also the years 1998 and 2004 are included in some of the scenarios.	6
RC1	Purity and years	Variations in the purity of cocaine flowing and seized in source and transit countries. Also changes in the reference years for before and after PC.	29
RC2	Wholesale price	Variations in the weights (for U.S. and Europe) used for calculating the wholesale price of cocaine in consumer countries. Also, we use the wholesale price of cocaine in the U.S. from STRIDE data.	18
RC3	prices	Exogenous imputed variations in the observed domestic and final price of cocaine applied one by one to the baseline scenario.	10
RC4	Yields and land	Variations in the source of data for land with coca crops and yields per hectare using ONDCP estimates, as well as averages between UNODC and ONDCP estimates.	14
RC5	Yield and land	Exogenous imputed variations in observed land with coca crops and yields applied one by one to the baseline scenario. In some cases we vary yields and land in opposite directions mantaining potential cocaine production stable.	15
RC6	Seizures	Variations in the source of data for cocaine seizures using ONDCP estimates as well as averages between UNODC and ONDCP estimates.	13
RC7	Seizures	Exogenous imputed variations in seizures in source and transit countries, applied one by one to the baseline scenario.	20
RC8	Colombia expenses	Variations in the Colombian expenses before PC.	13
RC9	Colombia expenses	Variations in the Colombian expenses in PC.	13
RC10	U.S. expenses	Variations in the U.S expenses in PC.	13
RC11	U.S. Market	We restrict our attention to the U.S drug market. We use both UNODC, ONDCP and STRIDE data and prices for the U.S. markets.	38
RC12	b	Exogenous imputed variations on the value of the price elasticity of demand for drugs at the wholesale level. We vary b from 0.2 to 1.6.	10
RC13	L	Imputed variations in the total ammount of land available for coca cultivation L applied to the baseline scenario. We vary L from 475,000 to 700,000.	10
RC14	P_f	We scale down P_{fB} and P_f from their original level to about 20% of their original level. This allows us to account for the possibility that traffickers affected by PC get only a fraction of the final price.	16
AllRC	All observations	Includes all robustness checks.	238

UNODC: United Nations Office on Drugs and Crime.
DNP: Departamento Nacional de Planeación, Colombia.
White House, ONDCP: Office for the National Drug Control Policy.

Table 5: Results of RC: Parameters.

Parameter	Baseline	All RC	Description
ω	0.586	0.630	Fraction of total erradication expenditures paid by Colombia.
		(0.095)	
Ω	0.329	0.341	Fraction of total interdiction expenditures paid by Colombia.
		(0.068)	
b	0.648	0.620*	Price elasticity of the demand for cocaine (wholesale).
		(0.145*)	
α	0.782	0.764	Relative importance of the complementary factors in production.
		(0.063)	
η	0.077	0.098	Relative importance of domestic drugs in the trafficking technology.
		(0.041)	
c_1	0.548	0.510	Net cost to Colombia per dollar received by drug producers.
		(0.070)	
c_2	0.017	0.0372	Net cost to Colombia per dollar received by drug traffickers.
		(0.035)	
ϕ	3.37	2.95	Drug producers' relative efficiency in the conflict for land.
		(0.75)	
γ	0.24	0.47	Drug traffickers' relative efficiency in the conflict for routes.
		(0.46)	

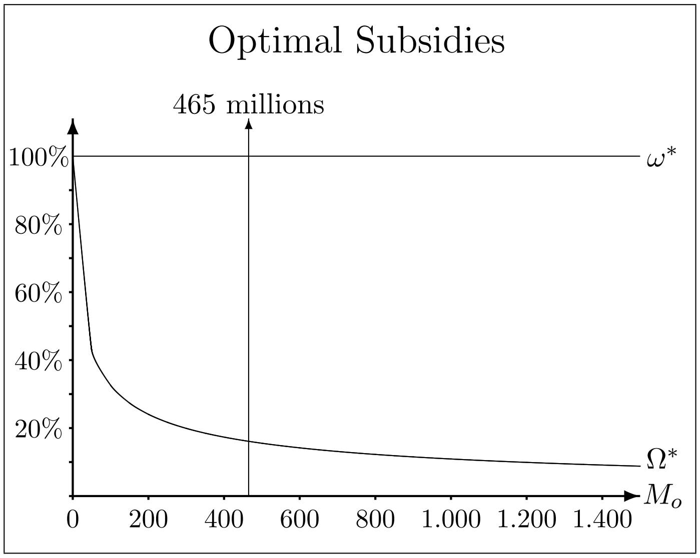
Standar errors of all robustness checks are reported in parentheses below their respective averages.
The results of all robustness checks are available from the authors upon request.
* This average (and standar deviation) does not include the robustness checks where we imputed b exogenously (RC12).

Table 6: Results of RC: Actual and efficient subsidies.

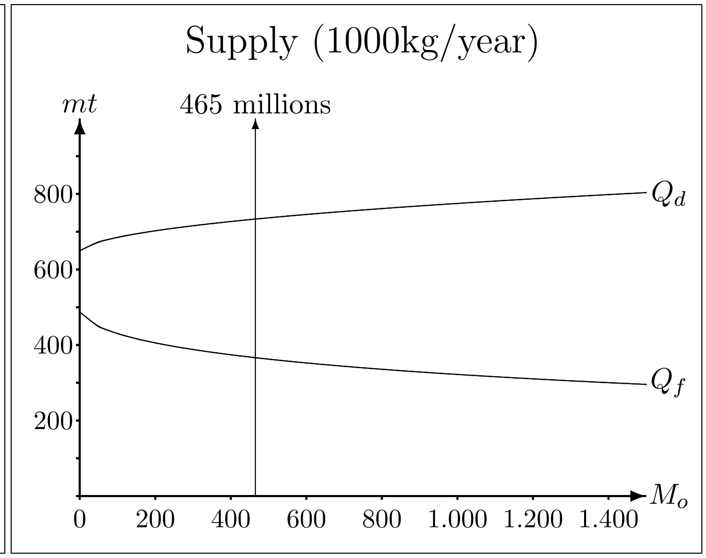
Current allocation			Efficient allocation		
	Baseline	All RC		Baseline	All RC
Ω	0.329	0.341	Ω	0.161	0.204
		(0.068)			(0.079)
ω	0.586	0.630	ω	1.000	1.000
		(0.095)			(0.004)
MC_{Ω}^{US}	\$ 3,674	\$6,716	MC_{Ω}^{US}	\$ 8,825	\$11,963
		(4,509)			(5,982)
MC_{ω}^{US}	\$ 162,782	\$135,590	MC_{ω}^{US}	\$ 113,834	\$104,220
		(42,129)			(65,863)
ϵ_{Ω}	0.296	0.255	ϵ_{Ω}	0.144	0.131
		(0.165)			(0.046)
ϵ_{ω}	0.007	0.011	ϵ_{ω}	0.011	0.016
		(0.008)			(0.010)

Standar errors of all robustness checks are reported in parentheses below their respective averages.
The results of all robustness checks are available from the authors upon request.

Simulation Exercise: Efficient subsidies.



(A)



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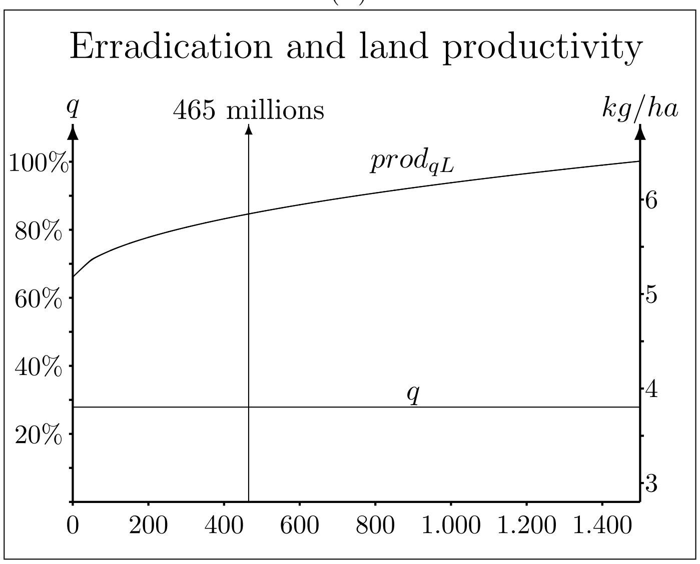

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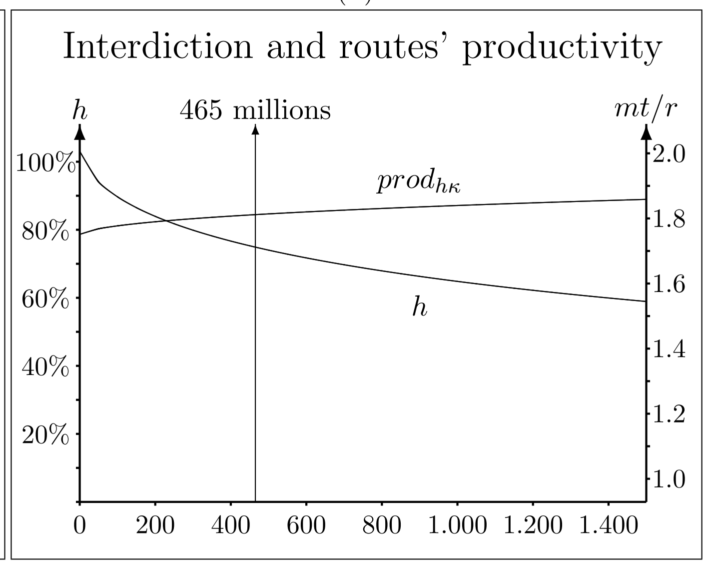

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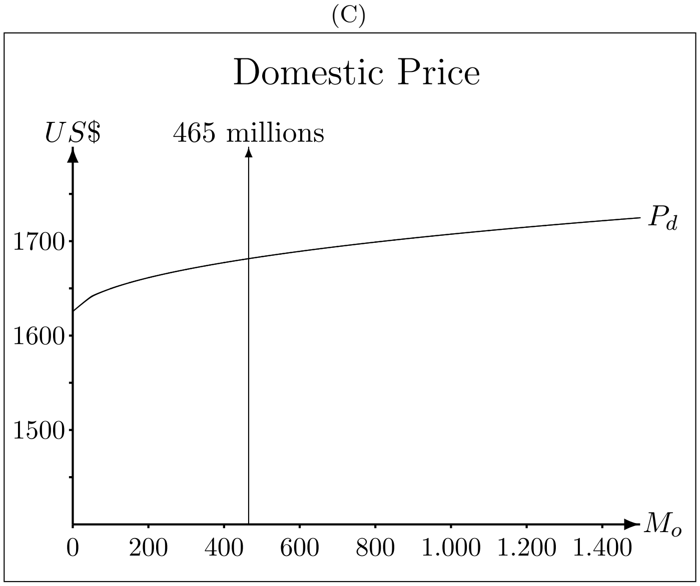

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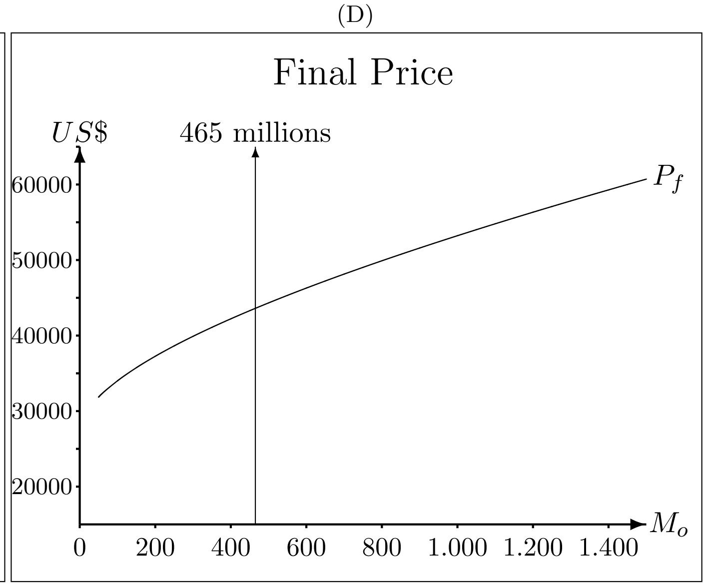
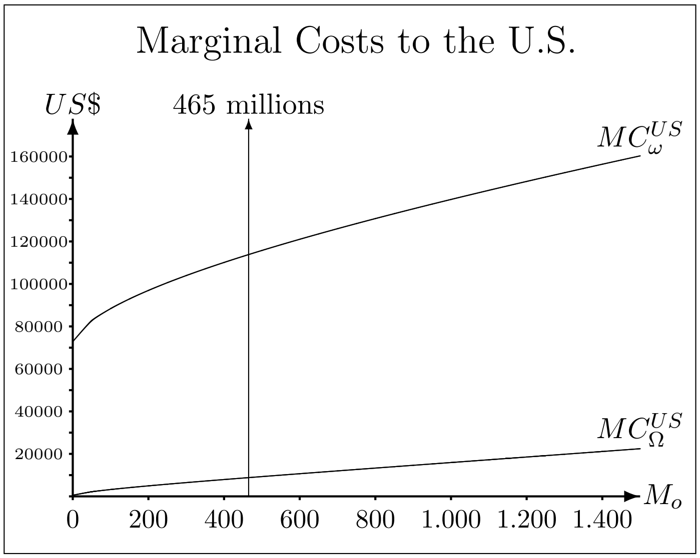
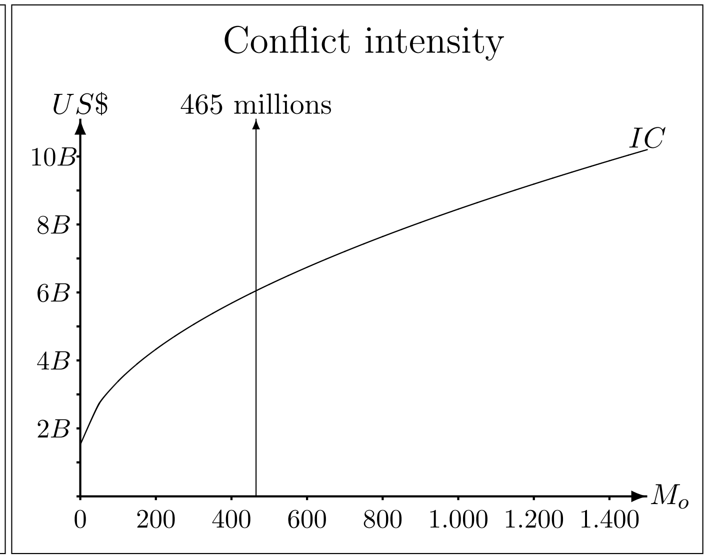


(F)

Simulation Exercise (continued): Efficient subsidies.



(G)



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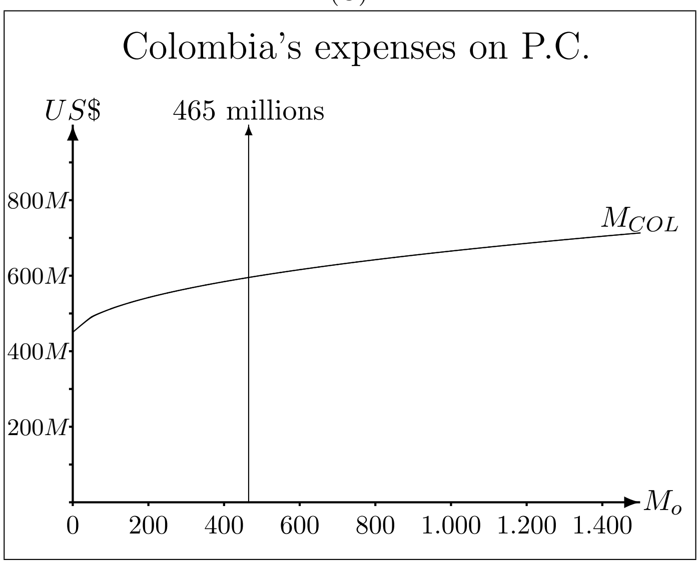
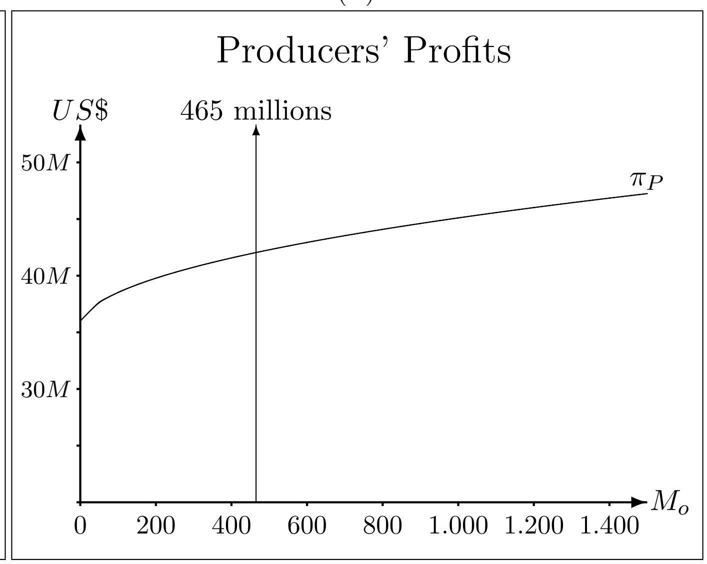
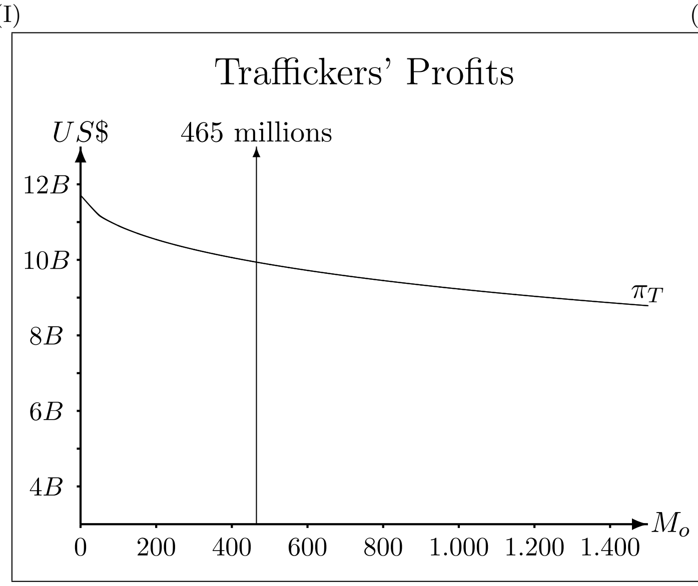


(I)



(J)



(K)