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**Daniel Mejía**
**Pascual Restrepo**

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Calle 19A No. 1 – 37, Bloque W.
Bogotá, D. C., Colombia
Teléfonos: 3394949- 3394999, extensiones 2400, 2049, 3233
*infocede@uniandes.edu.co*
*http://economia.uniandes.edu.co*

Ediciones Uniandes
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Bogotá, D. C., Colombia
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*infeduni@uniandes.edu.co*

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# THE WAR ON ILLEGAL DRUGS IN PRODUCER AND CONSUMER COUNTRIES: A SIMPLE ANALYTICAL FRAMEWORK*

Daniel Mejía† Pascual Restrepo‡

**Abstract**

This paper develops a simple model of the war against illegal drugs in producer and consumer countries. Our analysis shows how the equilibrium quantity of illegal drugs, as well as their price, depends on key parameters of the model, among them the price elasticity of demand, and the effectiveness of the resources allocated to enforcement and prevention and treatment policies. Importantly, this paper studies the trade-off faced by drug consumer country`s government between prevention policies (aimed at reducing the demand for illegal drugs) and enforcement policies (aimed at reducing the production and trafficking of illegal drugs in producer countries). We use available data for the war against cocaine production and trafficking in Colombia, and that against consumption in the U.S. in order to calibrate the unobservable parameters of the model. Among these are the effectiveness of prevention and treatment policies in reducing the demand for cocaine; the relative effectiveness of interdiction efforts at reducing the amount of cocaine reaching consumer countries; and the cost of illegal drug production and trafficking activities in producer countries.

*Key words*: war on drugs, conflict, enforcement, treatment and prevention policies, *Plan Colombia*.

*JEL Classification*: D74, K42.

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† Department of Economics, Universidad de los Andes, e-mail: dmejia@uniandes.edu.co
‡ Department of Economics, Universidad de los Andes, e-mail: p.restrepo23@uniandes.edu.co

# LA GUERRA CONTRA LAS DROGAS EN LOS PAÍSES PRODUCTORES Y CONSUMIDORES: UN MARCO ANALÍTICO SENCILLO[§]

Daniel Mejía[**] Pascual Restrepo[††]

**Resumen**

Este artículo desarrolla un modelo económico de la guerra contra las drogas en los países productores y consumidores. Los resultados muestran cómo la cantidad de drogas transadas en equilibrio, así como su precio, dependen de los parámetros estructurales del modelo tales como la elasticidad precio de la demanda, la efectividad de los recursos asignados a las políticas de reducción de oferta en los países productores y a la reducción de la demanda en los países consumidores . El artículo estudia el *trade-off* que enfrenta el gobierno del país consumidor entre invertir recursos en las políticas de reducción de la demanda (políticas de prevención y tratamiento), e invertir recursos para financiar al gobierno del país productor en las políticas de reducción de oferta (i.e. financiar la guerra contra las drogas en los países productores). Una vez resuelto el modelo, utilizamos los datos disponibles sobre la guerra contra las drogas en Colombia y los datos de gasto en prevención y tratamiento del consumo de cocaína en EE.UU. para calibrar los parámetros no observables del modelo. Entre otros, calibramos la efectividad de las políticas de prevención y tratamiento en reducir la demanda por cocaína en los mercados mayoristas en EE.UU., la efectividad relativa del gasto del gobierno colombiano en la guerra contra las drogas en Colombia y el costo percibido por el gobierno colombiano de las actividades de producción y tráfico de drogas y la guerra contra estas actividades ilegales.

*Palabras clave*: Guerra contra las drogas, conflicto, políticas de prevención y tratamiento, *Plan Colombia*.

*Clasificación JEL*: D74, K42.

[§] Este artículo fue preparado como un capítulo del libro *Illicit Trade and the Global Economy* (Paul De Grauwe and Claudia Costa-Storti, editores), a publicarse en 2011 por CESIfo y MIT Press. Los autores agradecen los comentarios de Rosalie Pacula, Roberto Steiner, Rodrigo Suescún y Juan Fernando Vargas, así como también los comentarios y sugerencias de los participantes en el CESIfo Summer Institute en Venecia, Fedesarrollo, y LACEA en Buenos Aires. Alejandro Ordóñez y Nicolás Idrobo hicieron una excelente labor como asistentes de investigación en la elaboración de este artículo. Los autores agradecen también el apoyo financiero del premio de investigación "Germán Botero de los Ríos" de Fedesarrollo y del Open Society Institute.
[**] Facultad de Economía, Universidad de los Andes, e-mail: dmejia@uniandes.edu.co
[††] Facultad de Economía, Universidad de los Andes, e-mail: p.restrepo23@uniandes.edu.co

## 1. Introduction

During the last decade, there has been a drastic intensification of the war against cocaine production and trafficking, not only in Latin American producer countries, but also in some of the main consumer countries, such as the United States. For instance, in Colombia, where roughly 70% of the cocaine consumed in the world is produced, over the last eight years, the U.S. and the Colombia have allocated huge amounts of resources to combat production and trafficking under the so-called *Plan Colombia*.[1] According to the Colombian National Planning Department (DNP, 2006), between 2000 and 2005, the U.S. government spent roughly $3.8 billion dollars in subsidies to the Colombian government for its war against illegal drug producers and traffickers. Colombia for its part spent about $6.9 billion during the same period. About half of the Colombian expenses (amounting to about $3.4 billion) and about three-quarters of the U.S. subsidies (about $2.8 billion) have gone directly to financing the military component of the war against drug production, trafficking, and targeting the organized criminal organizations associated with these activities (DNP, 2006, Table 2). Nevertheless, most available measures show that the availability of cocaine in consumer countries has not gone down significantly, nor has the price of cocaine shown any tendency to increase, as one might expect given the intensification of the war on drugs (see Mejía and Posada, 2010). While the number of hectares of coca crops cultivated in Colombia has decreased from about 163.000 in 2000 to about 80.000 in 2006 - as a result of intense aerial eradication campaigns- potential cocaine production in Colombia has only decreased from 695,000 kilograms per year in 2000 (right before the initiation of *Plan Colombia*) to roughly 610,000 kilograms per year in 2006 (see UNODC, 2007).[2] Consistent with the observed data just described on potential cocaine production and the relatively stable figures for consumption trends, the price of cocaine at the wholesale and retail levels in consumer countries has remained relatively stable since 2000.[3]

In the U.S., where about half of the cocaine produced in the world is consumed, the Federal Government currently spends close to $12.5 billion per year on different components of the war on drugs. Approximately $7.7 billion (about 60%) is spent on policies aimed at reducing the supply of

[1] *Plan Colombia* is the official name of a program that, among other things, provides the institutional framework for a strategic alliance between the Colombia and United States to combat the production and trafficking of illegal drugs (mainly cocaine), likewise, the organized criminal organizations associated with these activities.

[2] During the same period, coca cultivation and cocaine production increased slightly in the other two major producer countries, Bolivia and Peru. As a result, the total figures for potential cocaine production have remained relatively constant for the last 6-7 years (see UNODC, 2007; and Mejía and Posada, 2008).

[3] The wholesale and retail prices of cocaine decreased rapidly between 1990 and 2000, but since then have remained relatively stable. See Costa-Storti and De Grauwe (2007) for an explanation of this phenomenon based on the increased globalization of illegal drug markets.

illegal drugs, among them domestic law enforcement, interdiction and the provision of subsidies to drug producer countries. The other $4.8 billion (about 40%) is spent on policies aimed at reducing the demand for drugs, among them, prevention campaigns and the treatment of drug addicts (see ONDCP, 2007, Table 1).

This paper develops a simple model of the war against illegal drugs in producer and consumer countries that accounts for strategic interaction between the actors involved in this war. These actors include: an illegal drug producer and trafficker; the government of the drug producer country; the government of the drug consumer country; and a wholesale drug dealer located along the border of the consumer country. We explicitly model the (wholesale) illegal drug market, which allows us to account for the feedback effects between anti-drug policies and market outcomes (quantities and prices) likely to arise as a consequence of such large-scale policy interventions as *Plan Colombia*.

In the producer country, the government comes into conflict with the drug producer and trafficker over the fraction of illegal drugs successfully produced and exported to the consumer country. In modeling the conflict between the government and the drug producer and trafficker, we abstract from explicitly modeling the conflict over the control of arable land necessary for the cultivation of illicit crops.[4]

Following the analysis of Grossman and Mejía (2008), we assume that the drug consumer country`s government uses both sticks and carrots to strengthen the resolve of the drug producer country`s government in its war against illegal drugs. Additionally, the drug consumer country`s government uses prevention policies and provides subsidies to the drug producer country`s government in an attempt to minimize the amount of illegal drugs transacted in the market. While the former are aimed at reducing the demand for drugs through educational campaigns and by providing treatment to drug addicts, the latter aim at reducing the supply of illegal drugs coming from the drug producer country. Importantly, we study how anti-drug policies implemented in consumer and producer countries interact and affect one another's effectiveness. Our analysis shows how the equilibrium allocation of resources between these two alternative policies crucially depends on the price elasticity of the demand for illegal drugs in the consumer country; on the effectiveness of prevention and treatment policies in reducing the demand for illegal drugs; and on the effectiveness of anti-drug policies in the producer country. In particular, we show how the relative allocation of resources to subsidies for the war on drugs in producer countries should be smaller when the following conditions exist: the demand for illegal drugs

[4] See Grossman and Mejía (2008), and Mejía and Restrepo (2010) for models in which this particular front on the war on drugs is explicitly studied.

is relatively inelastic; prevention and treatment policies are relatively more effective; and the anti-drug policies being implemented in producer countries are relatively less effective.

We calibrate the model using the available data on the cocaine markets as well as data on the war against cocaine production, trafficking and consumption in Colombia and the U.S. This calibration exercise allows us to recover some important unobservable parameters, such as the relative effectiveness of interdiction efforts, the effectiveness of prevention policies in reducing the demand for cocaine, and the cost facing Colombia from illegal drug production and trafficking activities.

One of this paper`s main contributions is that it provides a formal analytical framework for understanding the interaction between anti-drug policies implemented in producer and consumer countries. Importantly, by explicitly modeling the illegal drug market, we are able to account for the feedback effects between policies and market outcomes likely to arise as a result of large-scale policy interventions, such as those implemented under the war on drugs in producer and consumer countries. While there have been some important attempts at developing models of the war on drugs in producer countries (Grossman and Mejía, 2008; and Mejía and Restrepo, 2008) and consumer countries (Becker, Grossman and Murphy, 2006; Rydell et al., 1996; and Caulkins, 1993, among others) there is no model in the literature that studies the interaction between anti-drug policies implemented in both consumer and producer countries. An important exception is the recent contribution by Chumacero (2006), who develops a dynamic general equilibrium model of the war against illegal crops cultivation on the one hand, and that against illegal drug production, trafficking and consumption, on the other.[5] His main contribution relies on the calibration of some of the key parameters of the model, that are then used to assess the effects of three alternative policies - making illegal activities riskier, increasing the penalties for illegal activities, and legalization.

This paper consists of four sections, inclusive of this introduction. The second section, which constitutes the core of the paper, develops the model and explains the motivations and choices of the actors involved in the war on drugs. This section also derives the equilibrium of the model. Section three presents the results of the calibration of the model using the available data on the cocaine market, some key figures reflective of the war against cocaine production and trafficking in Colombia, and data on the allocation of resources for prevention and treatment policies in the U.S. The fourth section concludes.

[5] The title of his paper, "Evo, Pablo, Tony, Diego, and Sonny," is quite suggestive of the fact that, in it, he studies the war on drugs at almost every stage: illegal crop cultivation (Evo), drug production (Pablo), drug trafficking (Tony), and drug consumption (Diego).

## 2. The Model

We model the war against illegal drugs as a sequential game. In the first stage of the game, the the drug consumer country`s government chooses the optimal allocation of resources between prevention and treatment policies on the one hand, and enforcement policies on the other. The latter take the form of a subsidy the drug producer country`s government in order to strengthen its resolve in the war against illegal drug production and trafficking. Both sets of policies have the same objective, namely to reduce the amount of illegal drugs transacted in the consumer country at the wholesale level. While prevention and treatment policies target a reduction in demand, enforcement policies (subsidies to the producer country's government) aim at thwarting the availability of drugs in the consumer country - that is, at reducing the supply of illegal drugs. In the second stage of the game, the drug producer country`s government comes into conflict with drug producers and traffickers over the fraction of illegal drugs successfully exported.

We start with the second stage of the game - that is, with the conflict between the drug producer country's government and the illegal drug producer and trafficker over the fraction of illegal drugs successfully produced and exported.

### 2.1 The drug trafficking game

#### 2.1.1 The interdiction technology

Let $q$ be the fraction of drugs that survive the government's interdiction efforts. The interdiction technology is such that $q$ is determined endogenously by a standard contest success function,[6]:

$$q = \frac{s}{s+\varphi r}, \tag{1}$$

where $r$ is the amount of resources the government invests in the interdiction of drug shipments (radars, airplanes, speed boats, etc.); $s$ is the amount of resources that the drug trafficker invests in trying to avoid the interdiction of drug shipments (submarines, speed boats, airplanes, etc.); and $\varphi > 0$ is a parameter capturing the relative effectiveness of the resources invested by the government in trying to interdict illegal drug shipments. Note that the fraction $q$ of illegal drugs that

[6] A contest success function (CSF) represents "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 successfully exported to the consumer country as a function of the government's interdiction efforts and the drug trafficker's efforts to avoid such efforts. See Skaperdas (1996) and Hirshleifer (2001) for a detailed explanation of the different functional forms of CSF.

the drug trafficker successfully exports (equation 1) is an increasing and concave function of the ratio $\frac{s}{\varphi r}$.

### 2.1.2 The drug trafficker

The problem of the drug trafficker is to choose the amount of resources to invest in trying to avoid the interdiction of drug shipments so as to maximize his profits, $\pi_T$. More precisely, the drug trafficker's problem is given by:

$$\max_{\{s\}} \ \pi_T = p_c q \lambda L - s \ . \qquad (2)$$

The first term in equation 2 is the price of drugs at the border of the consumer country, $p_c$, times the fraction of drugs that survives interdiction efforts, $q$, times the amount of drugs produced in the consumer country, $\lambda L$. This last term is the product of the productivity per hectare of land per year, $\lambda$ (for instance, the number of kilograms of illegal drugs that can be produced through the cultivation of the illegal crop on one hectare of land in one year[7]), times the number of hectares of land under the drug producer's control, $L$.[8] The last term, $s$, denotes the amount of resources invested by the drug trafficker in trying to avoid the interdiction of illegal drug shipments.[9]

The first order condition of the drug trafficker's problem in equation 2 is:

$$\frac{\partial \pi_T}{\partial s} = 0 \quad \Leftrightarrow \quad \frac{\varphi r}{(s+\varphi r)^2} p_c \lambda L \ = 1. \qquad (3)$$

Equation 3 describes the best reaction function of the drug trafficker to every possible choice of resources employed by the government in its interdiction efforts, $r$.

### 2.1.3 The drug producer country`s government

Following Grossman and Mejía (2008), we assume that the drug consumer country's government uses both sticks and carrots in attempting to strengthen the resolve of the drug producer country's

[7] In the case of Colombian cocaine, the yield/hectare/year ratio was, for 2006, about 7.4 kg of cocaine per hectare (see UNODC, 2006).

[8] See Grossman and Mejía (2008), and Mejía and Restrepo (2010) for models that include conflicts between the government and drug producers over the control of arable land suitable for cultivating illegal crops.

[9] Equation 2 implicitly assumes that the cost of producing illegal drugs is zero. In reality, the main costs of illegal drug production and trafficking are those associated with avoiding the eradication of illegal crops and the interdiction of drug shipments; the cost of actually producing illegal drugs is negligible. This assumption is made for analytical simplicity, and does not modify the main results obtained below.

government in its war against illegal drugs. The stick is the threat that the interested outsider will label the country a narco-state, resulting in its being ostracized by the international community.

Let us assume that, from the perspective of the drug producer country's government, the drug consumer country`s decision to apply the label narco-state includes a stochastic element[10]. To allow for this stochastic element, we assume that the drug producer country's government perceives the probability of its being labeled a narco-state to be equal to the ratio $D/\lambda L$, where $\lambda L$ is the amount of drugs that could potentially be produced and exported annually, and $D = q\lambda L$ is the actual production and exportation of illegal drugs. Let $c$ denote the annual cost in dollars that the drug producer country's government anticipates would result from being labeled a narco-state. Thus, the expected annual cost associated with the possibility of being labeled a narco-state equals the product of $c$ and $q$ ($D/\lambda L = q$).

The carrot employed by the drug consumer country is the subsidizing of the drug producer country's armed forces. This subsidy is a fraction, $1 - \omega$, of the resources that the drug producer country allocates to interdicting drug shipments, $r$.

The objective of the drug producer country's government is to minimize the sum of the costs associated with illegal drug production and trafficking. These costs are given by the sum of the expected cost of being labeled a narco-state and the cost of fighting the war against drug production and trafficking. They equal the amount of resources invested by the government in interdiction efforts, $r$, times the fraction actually paid by the government, $\omega$. The problem for the drug producer country`s government is:

$$\min_{\{r\}} C_T = cq + \omega r, \tag{4}$$

where $q$ is determined by equation 1.

The first order condition for the government's problem is given by:

$$\frac{\partial C_T}{\partial r} = 0 \quad \Leftrightarrow \quad \frac{-\varphi s}{(s+\varphi r)^2} c + \omega = 0. \tag{5}$$

[10] What we have in mind is the Drug Certification Process, established in 1986 and whereby each year the U.S. government evaluates the level of cooperation and measures taken by all illegal drug producer and transit countries against illegal drug production and trafficking. Those countries not certified face a number of consequences with direct and indirect costs. For instance, non-certification "requires the U.S. to deny sales or financing under the Arms Export Control Act; to deny non-food assistance under Public Law 480; to deny financing by the Export-Import Bank, and to withhold most assistance under the FAA with the exception of specified humanitarian and counternarcotics assistance. The U.S. must also vote against proposed loans from six multilateral development banks." See: http://www.usembassy-mexico.gov/bbf/bfdossier_certDrogas.htm.

Equation 5 is the government's best reaction function to every possible choice of resources employed by the drug trafficker in avoiding the interdiction of illegal drug shipments, $s$.

## 2.2 The drug trafficking equilibrium

Using equations 3 and 5, we can find a LOCUS of points in the space $(\frac{r}{s}, p_c)$ for which the drug trafficking game is in equilibrium[11].

**Definition 1 (GE LOCUS)**: All pairs $\left(\frac{r}{s}, p_c\right)$ that satisfy the following expression represent possible equilibria for the drug trafficking game:

$$\frac{r}{s} = \frac{c}{p_{c\lambda L\omega}} \tag{6}$$

According to the expression for the GE LOCUS, a higher price for the illegal drug in the consumer country will lead to lower relative spending by the drug producer country's government on the war on drugs. This is so because a larger $p_c$ increases the marginal returns for the drug trafficker of allocating resources to avoiding interdiction; this naturally induces the trafficker to fight relatively harder than the government.[12]

Using the expression in equation 6, and inserting it into the drug trafficker's reaction function (equation 3), we are able to derive an explicit expression for the government's and the drug trafficker's level of expenses in the war on drugs (both as functions of the parameters of the model and the price of drugs in the consumer country, yet to be determined). These two allocations are given respectively by:

$$r = \frac{\varphi c^2(\lambda L\omega p_c)^2}{\lambda L\omega^2 p_c(\lambda L\omega p_c+\varphi c)^2} \tag{7}$$

and,

$$s = \frac{\varphi c(\lambda L\omega p_c)^2}{\omega(\lambda L\omega p_c+\varphi c)^2} \tag{8}$$

[11] Recall that $r$, $s$, and $p_c$ are endogenous variables of the model.

[12] This result arises from the assumption that the cost from illegal drug trafficking to the drug producer country's government does not depend on the price of the drugs, but rather on the amount of drugs successfully produced and exported relative to potential production.

In turn, if we insert $r$ and $s$ from equations 7 and 8 into equation 1, the fraction of illegal drugs that survives the government's interdiction efforts in equilibrium (that is, the fraction of drugs exported successfully) is given by:

$$q = \frac{\lambda L \omega p_c}{\lambda L \omega p_c + \varphi c} \qquad (9)$$

The fraction of drugs that survives the government's interdiction efforts is an increasing and concave function of the price of drugs; of the fraction of the drug producer`s government`s expenses paid for interdiction efforts, $\omega$; and of potential cocaine production, $\lambda L$. A higher relative efficiency in the government's interdiction efforts, $\varphi$, or a larger cost for being labeled a narco-state, $c$, decreases the fraction of drugs successfully exported.

We now turn to a description of the drug market equilibrium.

### 2.3 The drug market equilibrium

First, let us assume that the demand for drugs along the border of the consumer country is given by a general demand function of the form:

$$Q_c^d = \frac{a(l)}{p_c^b} \qquad (10)$$

where $Q_c^d$ denotes the demand for drugs by drug dealers along the border of the consumer country, and $a(l) \geq 0$, with $l$ denoting the allocation of resources to prevention policies (educational campaigns, treatment programs for drug addicts, etc.) aimed at reducing the demand for illegal drugs in the consumer country. Naturally, we assume that $a'(l) < 0$ - that is, as more resources are allocated to prevention and treatment policies, the demand for illegal drugs decreases (i.e., the demand for drugs shifts to the left). $p_c$ is the price of illegal drugs along the border of the consumer country, and $b$ is the price elasticity of demand for illegal drugs at the wholesale level along the border of the consumer country.

Second, the supply of drugs in the consumer country is given by:

$$Q_c^s = \frac{s}{s + \varphi r} \lambda L. \qquad (11)$$

According to equation 11, the supply of drugs in the consumer country is equal to potential drug production, $\lambda L$, multiplied by the fraction of the production not interdicted, $q$ (see equation 1). Note that equation 11 expresses the supply of drugs in the consumer country as a function of the ratio of the expenses for the war on drugs in the producer country, $\frac{r}{s}$.

In the drug market equilibrium, we must have $Q_c^d = Q_c^s$. Equating expressions 10 and 11 and rearranging them, we are now able to define a LOCUS of points in the space $(\frac{r}{s}, p_c)$ for which the illegal drug market along the border of the consumer country is in equilibrium.

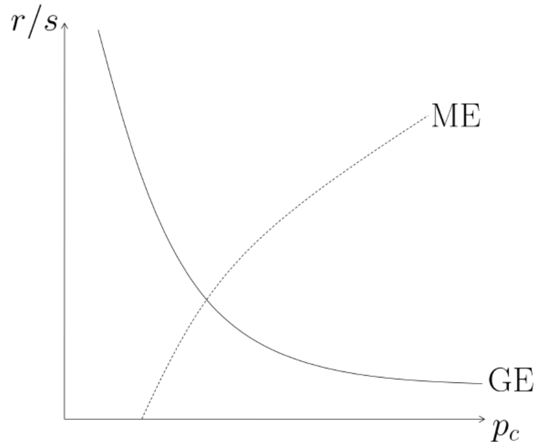
**Definition 2 (ME LOCUS):** All pairs $(\frac{r}{s}, p_c)$ satisfying the following expression represent possible equilibria of the drug market along the border of the consumer country:

$$\frac{r}{s} = \frac{\lambda L p_c^b}{\varphi a(l)} - \frac{1}{\varphi}. \tag{12}$$

In contrast with the GE Locus, under the ME Locus, a higher price for illegal drugs along the border of the consumer country will lead to greater relative spending by the drug producer country`s government on the war on drugs. This positive relationship between the ratio of spending on the war on drugs and the price of illegal drugs in the consumer country arises because a higher ratio $\frac{r}{s}$ means a smaller supply of drugs; given the demand, the price of illegal drugs, $p_c$, has to increase in order for the drug market to remain in equilibrium.

We can now use both LOCI described above to graphically represent the equilibrium of the second stage of the game. Recall that the GE Locus describes all pairs of points $(\frac{r}{s}, p_c)$ for which the drug trafficking game is in equilibrium, while the ME Locus describes all pairs of points $(\frac{r}{s}, p_c)$ for which the drug market is in equilibrium. The two LOCI are represented in Figure 1.

Figure 1




We can now study how changes in the structural parameters of the model shift each of the two LOCI, and how these changes in turn change the relative allocation of resources for the war on drugs and the price of illegal drugs. At this point, we focus on changes in the allocation of resources with respect to prevention and treatment policies, as well as enforcement policies in the form of subsidies to the drug producer country's government (which will be the focus of our analysis once we turn to the analysis of the first stage of the game). Figure 2 shows how the price of illegal drugs and the relative spending on the war on drugs change as l increases (i.e., as a decreases). Figure 3 shows the effect of a decrease in ω (an increase in the subsidy to the drug producer country's armed forces in its war against illegal drug production and trafficking). While an increase in spending in the consumer country on prevention policies aimed at reducing consumption reduces the equilibrium price of drugs and increases the government's relative spending on the war on drugs (thereby reducing the equilibrium fraction of drugs successfully exported), an increase in the subsidy increases the equilibrium price of drugs at the consumer country`s border and the producer county`s government`s relative spending on the war on drugs. Note that an increase in the subsidy generates two opposing forces on the ratio $\frac{r}{s}$ - it increases the price of illegal drugs, and thus increases the drug trafficker`s incentives to invest resources in evading interdiction (as the price of drugs increases); and it increases the drug producer country`s incentives to invest resources on the war on drugs, as the marginal cost of doing so goes down. The net effect is an increase in the ratio $\frac{r}{s}$ (as shown in Figure 3). Importantly, an increase in the subsidy provides by the drug consumer country induces an increase in the total resources invested on the war on drugs, $r + s$ - that is, an increase in the subsidy to the drug producer country increases the intensity of the conflict as measured by the sum of resources invested by the two actors involved in this war.

Figure 2

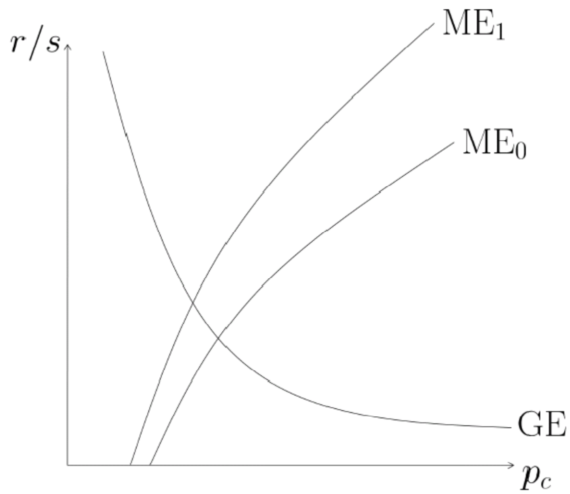
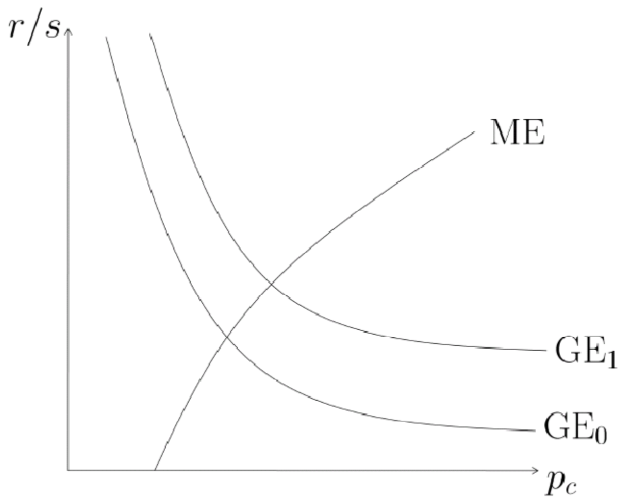



Figure 3

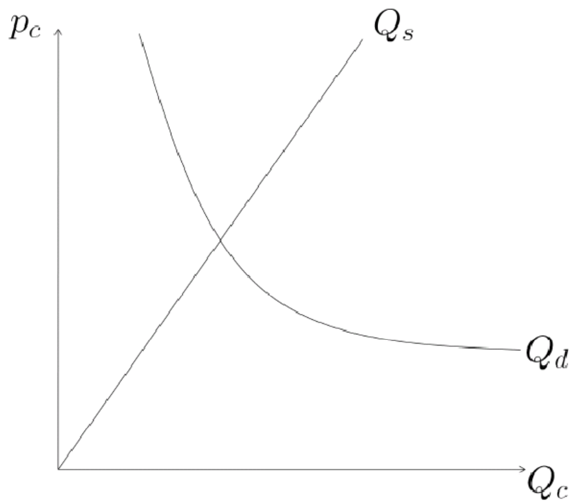



A representation of the equilibrium of the model in terms of the two LOCI described above is helpful for understanding how changes in the parameters of the model affect the relative allocation of resources to the war on drugs and, correspondingly, the fraction of drugs successfully exported. However, the equilibrium of the model can also be represented using a standard supply and demand framework. Using equation 9, the supply of drugs along the consumer country`s border (that is, the supply of drugs net of interdiction) is given by:

$$Q_c^s = \frac{(\lambda L)^2 \omega p_c}{\lambda L \omega p_c + \varphi c}. \tag{13}$$

In turn, the demand for drugs is given by equation 10. The graphical representation of the equilibrium at this stage of the game, represented in a simple supply and demand framework, is depicted in Figure 4.

Figure 4




Solving for $p_c$ in both expressions and making $Q_c^s$=$Q_c^d$, the equilibrium quantity of drugs is determined by the following implicit equation, which depends on the parameters of the model as well as on the two choice variables for the drug consumer country's government, $l$ and $\omega$ (yet to be determined in the next subsection).

$$F(Q_c, l, \omega) = Q_c^{\frac{1+b}{b}} \varphi c + a(l)^{\frac{1}{b}} \lambda L \omega (Q_c - \lambda L) = 0. \tag{14}$$

Using the expression for the equilibrium quantity of drugs in the second stage of the game, we are now able to determine the sign of the effect of changes in the parameters of the model on the equilibrium quantity of drugs. The following are the main comparative statics results at this stage:

· $\frac{\partial Q_c}{\partial l} = \frac{-\partial F/\partial l}{\partial F/\partial Q_c} \leq 0$. An increase in prevention policies aimed at reducing the demand for drugs in the drug consumer country decreases the amount of illegal drugs transacted in equilibrium. On the one hand, $\partial F/\partial Q_c > 0$; on the other, $\partial F/\partial l > 0$. This is because $Q_c - \lambda L < 0$. Recall that $\lambda L$ is potential drug production whereas $Q_c$ is the amount of drugs transacted in equilibrium. With at least some interdiction (that is, where $q < 1$, as is in fact the case in equilibrium (see equation 9)), the amount of drugs transacted in equilibrium is always less than potential drug production. Conversely, a decrease in $l$ (i.e., an increase in $a$) increases the amount of illegal drugs transacted. We elaborate more on this point in the next section of the paper, when we consider the optimal allocation of resources to prevention policies in the drug consumer country.

· $\frac{\partial Q_c}{\partial \omega} = \frac{-\partial F/\partial \omega}{\partial F/\partial Q_c} \geq 0$. A decrease in subsidies to the drug producer country in its war against illegal drugs (that is, a lower $1 - \omega$) increases the quantity of illegal drugs transacted in equilibrium. Again, this result follows from the fact that $Q_c - \lambda L < 0$. Intuitively, a larger marginal cost for the drug producer country's interdiction efforts will induce its government to spend less resource on the interdiction of drug shipments. As a result, the supply of drugs to the consumer country (net of interdiction) will increase. Again, this point will be elaborated in more detail in the next section of the paper.

· $\frac{\partial Q_c}{\partial \varphi} = \frac{-\partial F/\partial \varphi}{\partial F/\partial Q_c} \leq 0,$ and $\frac{\partial Q_c}{\partial c} = \frac{-\partial F/\partial c}{\partial F/\partial Q_c} \leq 0$. An increase in either the relative efficiency of the drug producer country's government in its war on drugs, or an increase in the cost to the drug producer country of being labeled a narco-state will lead to a negative shift in the supply of drugs. This is because the drug producer country's government will allocate relatively more resources to its interdiction efforts. As a result, the equilibrium fraction of drugs successfully exported (equation 9) will decrease.

· $\frac{\partial Q_c}{\partial \lambda} = \frac{-\partial F/\partial \lambda}{\partial F/\partial Q_c} \geq 0,$ and $\frac{\partial Q_c}{\partial L} = \frac{-\partial F/\partial L}{\partial F/\partial Q_c} \geq 0$. An increase in $\lambda$, the productivity per hectare of land used in the cultivation of illegal crops, or an increase in $L$, the land under the control of drug producers, will increase the amount of drugs produced and exported in equilibrium. An increase in productivity or in the amount of land controlled by drug producers shifts the supply curve outwards. As a result, the price of drugs goes down and the quantity of drugs in equilibrium goes up.

We now turn to an analysis of the first stage of the game - that is, the stage at which a choice is made between prevention policies and policies aimed at curtailing the supply of drugs by increasing subsidies for the drug producer country's interdiction efforts.

### 2.4 Anti-drug policies in the consumer country: prevention and treatment versus a supply reduction in producer countries

In the first stage of the game, the objective of the drug consumer country's government is to minimize the amount of illegal drugs transacted along its border. To achieve its objective, the drug consumer country carries out prevention and treatment policies aimed at reducing the demand for illegal drugs, together with enforcement policies, in the form of subsidies to the armed forces of the drug producer country in its war against illegal drug production and trafficking.

More formally, the objective of the drug consumer country's government is:

$$\min_{\{l,d\}} Q_c \quad \text{subject to} \quad l + d = M, \text{ and} \tag{15}$$

$$d = (1 - \omega) r^*,$$

where $Q_C$ is the quantity of illegal drugs transacted along the border of the consumer country in equilibrium; $M$ is the consumer country's total budget for treatment and prevention and supply reduction policies; $l$ is the allocation of resources to prevention policies (i.e., to the reduction of demand); and $d$ is the total amount of resources that the drug consumer country grants to the drug producer country in the form of subsidies to finance its expenses in the war against illegal drug trafficking. The total amount of subsidies, $d$, is equal to the marginal subsidy, $1 - \omega$, times the resources spent by the drug producer country on its war against drug production and trafficking, $r^*$- that is, $d$ is the total amount of resources allocated by the drug consumer country's government to reducing the supply of illegal drugs coming from the drug producer country.

Using equations 7 and 13, and the fact that $d = (1 - \omega) r^*$, we can solve for $\omega$ in terms of the model's parameters, the total amount of subsidies provided by the drug consumer country's government, $d$, and the quantity of illegal drugs transacted, $Q_C$:

$$\omega = \frac{\frac{cQ_C}{\lambda L}\left(1 - \frac{Q_C}{\lambda L}\right)}{d + \frac{cQ_C}{\lambda L}\left(1 - \frac{Q_C}{\lambda L}\right)}. \tag{16}$$

Inserting the expression for $\omega$ obtained in equation 16 into equation 14 allows us to express the quantity of drugs transacted in equilibrium (i.e., the equilibrium level $Q_C$) as a function of the model's parameters and the two instruments of the drug consumer country's government, $l$ and $d$, through the following implicit function:

$$S(Q_C, l, d) = Q_C^{\frac{1+b}{b}} \varphi c + a(l)^{\frac{1}{b}} \lambda L \frac{\frac{cQ_c}{\lambda L}\left(1 - \frac{Q_c}{\lambda L}\right)}{d + \frac{cQ_c}{\lambda L}\left(1 - \frac{Q_c}{\lambda L}\right)} = 0. \tag{17}$$

Using the implicit function in equation 17 - which defines the equilibrium quantity of illegal drugs as a function of the two instruments of the drug consumer country's government - the optimal allocation of resources between prevention and enforcement policies is determined by the following optimality condition:[13]

$$\frac{\partial Q_c}{\partial \mathrm{l}} = \frac{\partial Q_c}{\partial \mathrm{d}} \rightarrow \frac{\partial S(Q_c, l, d)}{\partial l} = \frac{\partial S(Q_c, l, d)}{\partial d}. \tag{18}$$

Intuitively, the optimally condition in equation 18 states that the drug consumer country's government will adjust the allocation of resources between prevention and deterrence policies until the two are equally effective at the margin in reducing $Q_c$; or equivalently, until the marginal cost of reducing $Q_c$ by one kilo through subsidizing deterrence policies is exactly equal to the marginal cost of reducing $Q_c$ by one kilo through an investment in treatment and prevention.

Deriving the expressions for $\partial S(.)/\partial l$ and $\partial S(.)/\partial d$ from equation 17, the optimality condition in equation 18 becomes (after some algebraic manipulations):

$$\frac{1}{b}\frac{a\prime(l)}{a(l)} = -\frac{1}{d+cq(1-q)}. \tag{19}$$

In order to find a close form solution to the problem of the drug consumer country's problem, let us assume that:

$$a(l) = \frac{A}{l^{\theta}}, \tag{20}$$

where $A > 0$, and $\theta > 0$ is a parameter capturing the efficiency of prevention and treatment policies in reducing the demand for drugs. More precisely, the parameter $\theta$ captures the percentage reduction in the demand for drugs as a result of a 1% increase in treatment and prevention policies.

Using the functional form for $a(l)$ from equation 20, the optimality condition in equation 19 becomes:

$$\frac{\theta}{b} = \frac{l}{d+cq(1-q)}. \tag{21}$$

[13] This optimality condition is obtained using the implicit function theorem to find the expressions for $\frac{\partial Q_c}{\partial \mathrm{l}}$ and $\frac{\partial Q_c}{\partial \mathrm{d}}$.

This equation implies that if $\theta$ is big and $b$ small - such that prevention policies are very effective at reducing demand and demand is very inelastic - then prevention policies become more effective at the margin in reducing $Q_c$ . On the other hand, if $\theta$ is low and $b$ is large - such that prevention policies are not very effective at reducing demand and demand is more elastic - then deterrence policies become more effective at the margin in reducing $Q_c$. The point that b reduces the effectiveness of supply reduction policies relative to prevention policies is consistent with the previous findings by Becker et al. (2006). We refer to the right hand side expression of equation 21 as the critical value for $\frac{\theta}{b}$. Values of $\frac{\theta}{b}$ larger than this threshold imply a reallocation of resources from supply reduction to treatment and prevention policies; values below this threshold imply a reallocation of resources from treatment and prevention to supply reduction policies.

## 3. Calibration strategy and results

In this section, we use data from the cocaine market at the wholesale level, as well as available data on the outcomes of *Plan Colombia,* in order to calibrate the unobservable parameters of the model.

Table 1 briefly describes some of the data used in calibrating the model's parameters[14]. We use the average for all outcomes of the war on drugs in Colombia and the U.S., as well as the outcomes from the wholesale cocaine market between 2005 and 2008, in order to calibrate the parameters of the model. Although we don't have a direct estimate for the U.S. allocation of resources to prevention and treatment policies aimed at reducing the demand for cocaine, l, we do know the total amount of resources spent by the U.S. government on policies aimed at reducing the demand for illegal drugs - about $3,8 billion in 2006 (see ONDCP, 2007). We assume that roughly 7% of these resources (or about $250 million) were spent in the reduction of cocaine consumption[15].

[14] For a thorough description of the data on the cocaine markets, the war on drugs, etc., see Mejía and Posada (2008). The data used in this calibration is the same data used by Mejía and Restrepo (2010).
[15] As the reader will see below, the results are robust to changes in this assumption.

Table 1: Data used in the calibration exercise.

| Definition | Variable | Observed | Source |
|---|---|---|---|
| Drug seizures[a] (kgs) | $(1-q)\lambda L$ | 127,000 | UNODC |
| Cocaine price/kg at the U.S. border ($/kg) | $p_c$ | 32,400 | UNODC |
| Colombian cocaine in the wholesale market | $Q_c$ | 445,000 | UNODC |
| U.S. budget for prevention ($) | $l$ | 250 million | ONDCP 2007 |
| U.S. budget for Plan Colombia[b] ($) | $d$ | 593 million | GAO 2008 |
| Hectares of land with coca crops (has) | $L$ | 86,000 | UNODC |
| Kilos of cocaine/hectare/year (kgs) | $\lambda$ | 6.66 | UNODC |
| Colombian expenditures on the war on drugs | $\omega r$ | 561.6 million | DNP |

*Notes*: This table shows the data used in the calibration exercise. All numbers are averages for the year 2005, 2006, 2007 and 2008.
[a] Seizures adjusted assuming a 70% purity.
[b] See Mejía and Restrepo (2010) for an explanation of how this number was constructed.

Using the equilibrium value for the observations in our data, we are able to jointly calibrate $\theta$, $\varphi$, $\omega$, $A$ and $c$ (see the appendix for details of the calibration procedure). We assume that the price elasticity of the demand for drugs at the wholesale level, $b$, is 0.65[16]. On the other hand, $\theta$ is estimated on the assumption that the U.S. allocates resources optimally between treatment and prevention on the one hand, and supply reduction policies in Colombia on the other - that is, assuming that $\theta/b$ equals the critical ratio defined by equation 21. We also present the estimated value for this threshold as a useful policy measure, in the event that the U.S. has not allocated subsidies optimally. In such cases, and given an empirical estimation of $\theta$, one would only have to compare $\theta/b$ to the actual ratio in order to determine if more resources should be allocated to treatment and prevention, or to policies aimed at reducing the supply in producer countries. Table 2 presents the results from the calibration exercise, together with the confidence intervals for each point estimate.

[16] Given our limited data, we cannot estimate this parameter. However, the assumption that b=0.65 is in line with the results obtained in Mejía and Restrepo (2010).

Table 2: Calibration results.

| Parameter | Value |
|---|---|
| $b$ | 0.65 |
| $\theta$ | 0.14<br>[0.11-0.18] |
| Critical ratio $\theta/b$ | 0.22<br>[0.18-0.26] |
| $\phi$ | 0.79<br>[0.50-1.23] |
| $\omega$ | 0.49<br>[0.43-0.54] |
| $c$ | \$3.3 billion<br>[2.5m-4.2m] |
| $A$ | $5.8\text{x}10^9$<br>[$1.1\text{x}10^9$-$33.0\text{x}10^9$] |

*Notes:* This table shows the results for the calibration exercise. 90% confidence intervals constructed from 10.000 Montecarlo simulations are shown below each estimate in square brackets.

According to the results presented in Table 2, $\theta$, the parameter capturing the efficiency of prevention policies in reducing the demand for cocaine in the U.S., is estimated to be about 0.14. This parameter can be interpreted as the percentage of reduction in the demand for cocaine at the wholesale level that results following a 1% increase in the resources devoted to prevention and treatment policies. In other words, we estimate that a 1% increase in the funding of prevention and treatment policies would decrease the demand for illegal drugs at the wholesale level by about 0.14%. The critical ratio for $\theta/b$ for current expenditure levels is estimated to be 0.22. This estimate implies that if (contrary to our assumption about the optimal allocation of resources) $\theta \geq 0.22b$, then the U.S. should reallocate resources away from supply reduction efforts and towards prevention policies; conversely, if the opposite holds, then the U.S. government should reallocate resources from prevention to supply reduction policies in producer countries in order to reduce $Q_c$.[17]

[17] The reported value for $\theta$, given that our assumption of an optimal allocation of resources satisfies $\theta = 0.17b$.

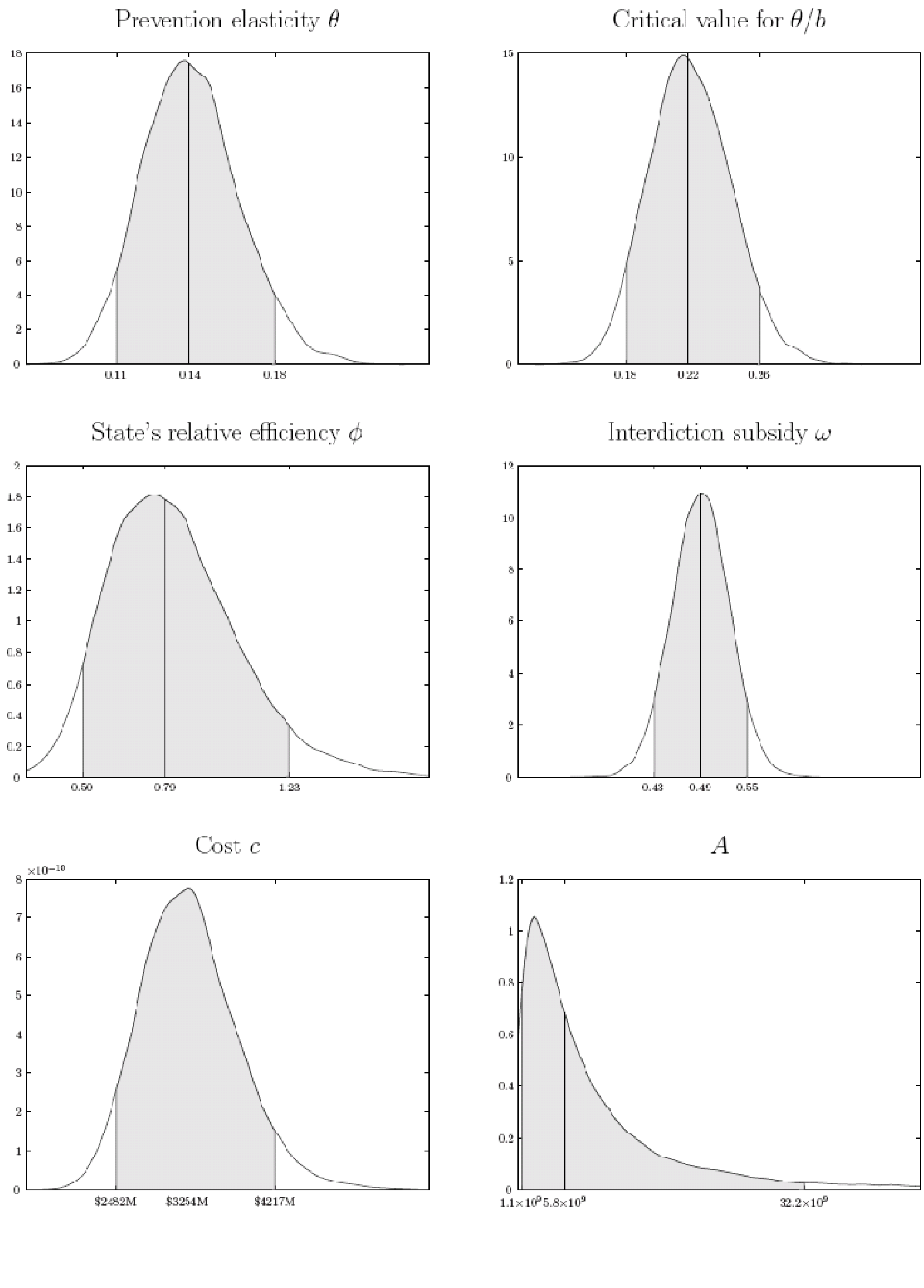
The parameter $\varphi$, which captures the relative efficiency of the drug producer country's government's efforts on the war on drugs, is calibrated at about 0.79. Conversely, the resources spent by drug producers and traffickers on the war on drugs are 1.27 times more efficient (1/0.79) than those invested by the drug producer country's government.

Our estimate for $\omega$ implies that the U.S. has funded about 51% $(1 - \omega)$ of Colombian (military) expenses on the war on drugs.

We calibrate the cost to the Colombian government of being labeled a narco-state, $c$, to be about $3.3 billion, about 2% of current Colombian GDP. This number lies within the range of the variable assumed in Grossman and Mejía (2008) and is in line with the total cost perceived by the Colombian government due to drug production and trafficking activities.

Finally, in order to check the robustness of the results just described, we conduct 10,000 Montecarlo simulations by adding random perturbations to the data used in the baseline calibration exercise. Using these simulations, we create a 90% confidence interval for each of the estimated parameters. Figure 5 presents the distribution of point estimates for all the calibrated parameters, along with the 90% confidence intervals (the areas in dark grey).

Figure 5: Calibration results:

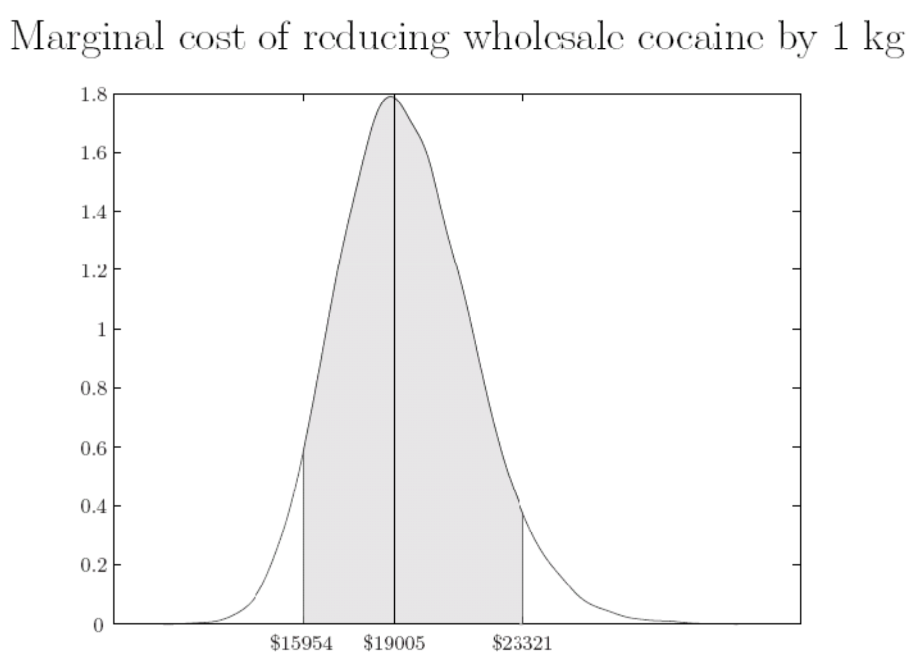


## 4. The costs of the war on drugs and the interaction between supply and demand reduction policies

Assuming that resources are optimally allocated, the marginal cost to the U.S. of reducing $Q_c$ by one kilogram by subsidizing supply reduction policies in Colombia should be the same as the marginal cost of reducing $Q_c$ by one kilogram by investing in treatment and prevention policies. These numbers can also be calculated using the inverse of the Lagrange multiplier of the budget restriction for the drug consumer country's problem (see equation 15). Using the calibrated parameters, we obtain a figure for the marginal cost of about $19.000. In other words, we estimate that the marginal cost of reducing the wholesale transaction of cocaine by one kilogram is about $19.000, either by spending on prevention and treatment policies or by subsidizing Colombia in its war against illegal drug production and trafficking.[18]

Moreover, this result is robust to small perturbations in the data used to calibrate the model, as shown in figure 6, whereby we plot the empirical distribution of these marginal costs using the 10.000 Montecarlo simulations.

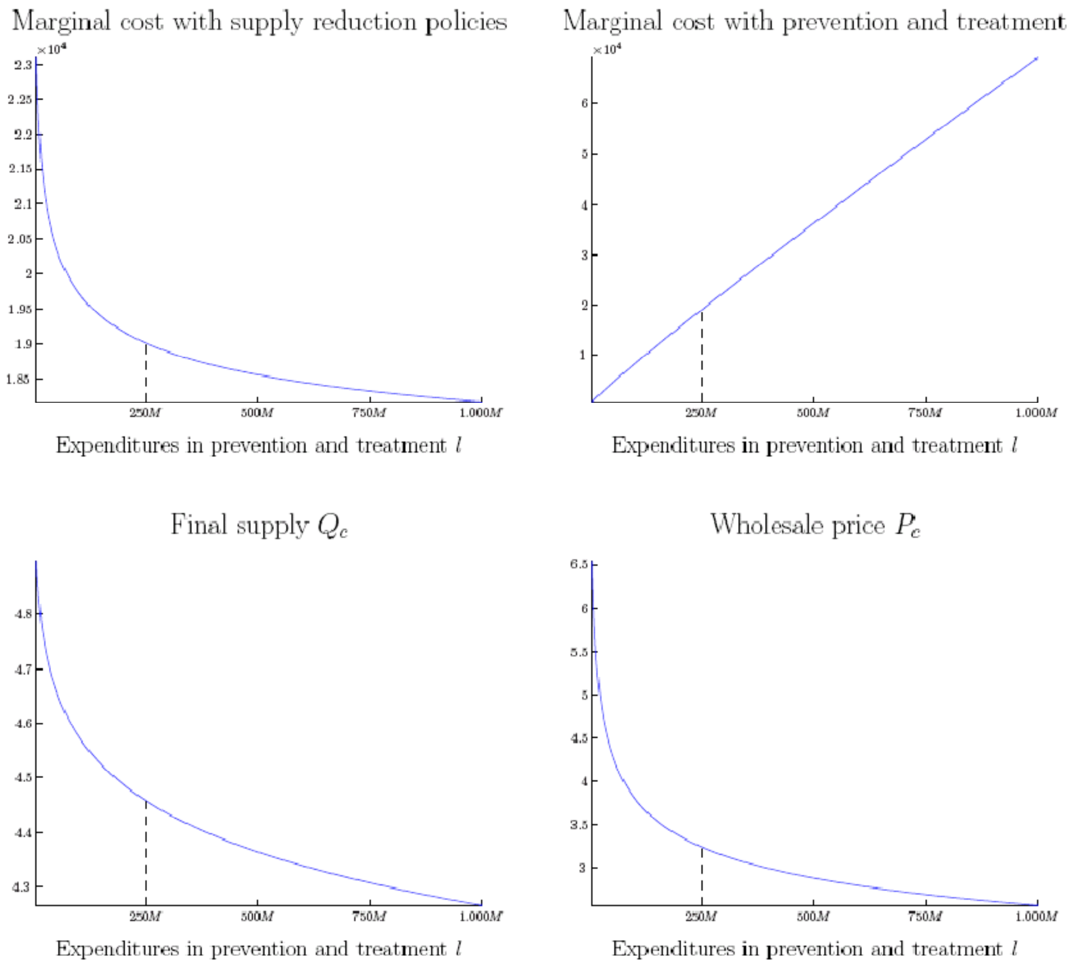
Figure 6: Marginal cost




[18] This estimate of this marginal cost is relatively close to those obtained in Mejía and Restrepo (2010).

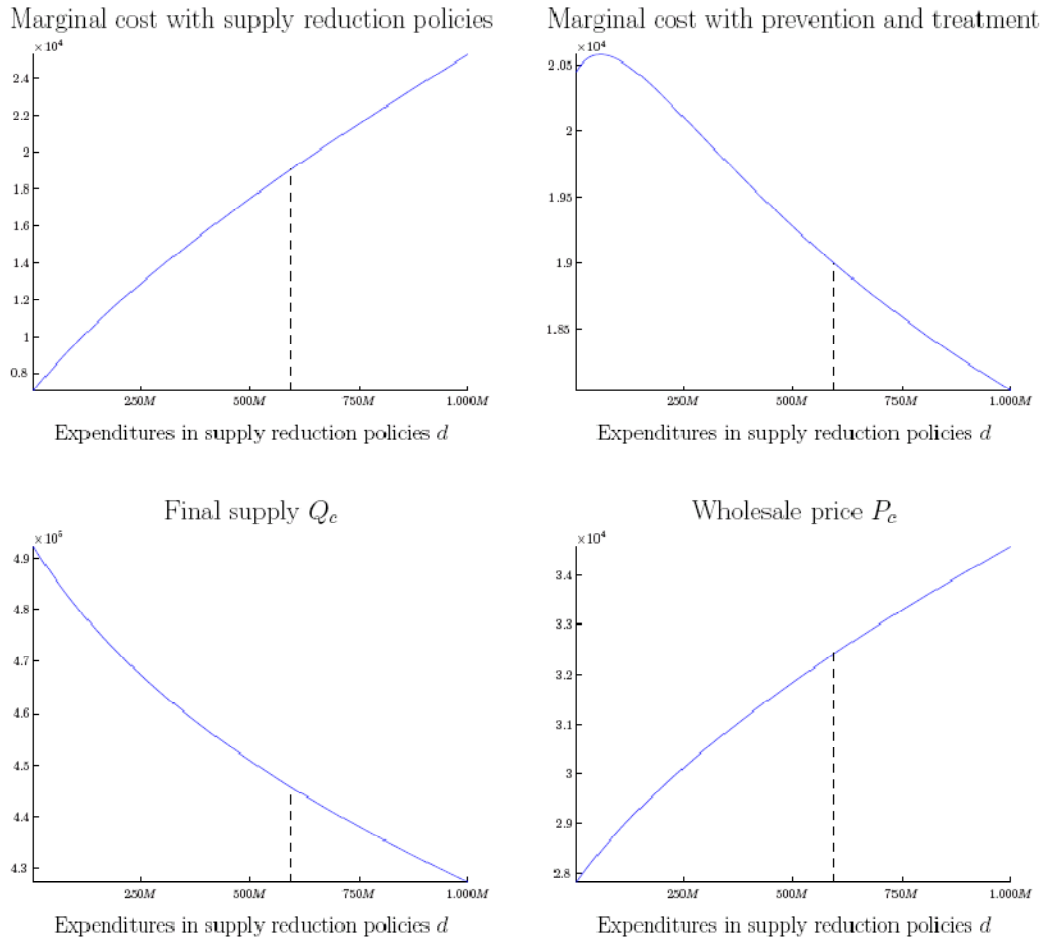
To address the interplay between supply reduction policies and prevention and treatment policies, we explore the effects of prevention on drug markets by exogenously changing the value of l while leaving the value of d constant. That is, using the calibrated parameters, we estimate the equilibrium value for all variables in the model for different values of l and a fixed value of d (d=561 million). Figure 7 shows the results of this exercise, with *l* plotted along the x axis, ranging from 0 to 1 billion, and the variables of interest plotted along the y axis.

Figure 7: Simulations of an exogenous change in *l*.




Finally, we explore the effects of supply reduction policies on drug markets by exogenously changing the value of d while leaving constant the value of l. That is, using the calibrated parameters, we estimate the equilibrium value of all the variables in the model for different values of d and a fixed value of l (l=250 million). Figure 8 shows the results of this exercise with l plotted in the x axis, ranging from 0 to 1 billion and the variables of interest in the y axis.

Figure 8: Simulations of an exogenous change in *d*:




## 5. Concluding remarks

The model developed in this paper is a first step towards understanding the interrelationship between respective anti-drug policies in consumer and producer countries. Modeling 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 understanding the outcomes of this war. This paper develops a simple model of the war on drugs in producer and consumer countries in order to explain how resources are allocated by the different actors involved in it, the equilibrium outcomes, and outcome responses to exogenous changes in some of the model's key parameters. Importantly, we explicitly model illegal drug markets, which allow us to account for the feedback effects between policy changes, prices, and the strategic responses of the different actors involved likely to arise as a result of large-scale policy interventions such as *Plan Colombia*.

We use the available data on the cocaine market at the wholesale level in consumer countries, as well as outcomes from the war on drugs under *Plan Colombia,* to calibrate the unobservable parameters of the model. More specifically, we estimate that a 1% increase in the resources invested in prevention and treatment policies in the U.S. would decrease the demand for cocaine at the wholesale level by about 0.14%. We estimate that the relative efficiency of resources spent by Colombia on the war on drugs relative to the resources spent by drug traffickers in this war is about 0.79. According to the results of the calibration exercise, the cost perceived by Colombia of being labeled as a narco-state is of about $3.3 billion (about 2% of Colombia's GDP in 2008). Also, we estimate that the marginal cost to the U.S. of reducing the amount of cocaine transacted in wholesale drug markets by 1 kilogram is about $19.000.

Finally, the paper studies the interaction between treatment and prevention policies in consumer countries on the one hand and policies aimed at reducing the supply of drugs in producer countries on the other. The results show that the marginal cost of supply reduction policies in producer countries decreases with the scale of treatment and prevention policies implemented in consumer countries and vice versa.

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## Appendix: Model calibration

In order to calibrate the subsidy granted by the U.S. for supply reduction policies, we use the following equation:

$$\omega = \frac{M_{COL}}{M_{U.S.} + M_{COL}} = 0.49,$$

in which $M_{COL} = \omega r^*$ and $M_{U.S.} = (1 - \omega) r^*$ are Colombia and U.S. expenditures, respectively on supply reduction policies in producer countries.

We calculate $q$ using the reported number of seizures by Colombian authorities, which gives

$$q = \frac{seizures}{\lambda L} = 0.78.$$

Using the equilibrium value for $\omega r^* = M_{COL}$, we can rewrite it as $M_{COL} = cq(1-q)$, and we obtain

$$c = \frac{COL}{q(1-q)} = 3.3\ billion.$$

Using the equilibrium expression for $q$, we can isolate $\varphi$ and obtain

$$\varphi = \frac{p_c \lambda L\ \omega(1-q)}{qc} = 0.79.$$

In order to obtain the elasticity of treatment and prevention parameter $\theta$, we assume the U.S. allocates resources optimally. This implies, that the ratio $\theta/b$ must be equal to the right hand side in equation 21, and assuming $b = 0.65$, we obtain

$$\theta = \frac{lb}{d + cq(1-q)} = 0.14.$$

Finally, the scale parameter is adjusted in order to reproduce the correct market size by using the equation

$$A = Q_c l^{\theta} p_c^b = 5.8 \times 10^9.$$

The above equations show how to obtain all the parameters from the observed data. In order to analyze how sensible is this calibration to the data fed into the model, we conduct 10.000 Montecarlo simulations in which we add perturbations to each of the observations used to calibrate the model. These perturbations are centered at zero and have a standard deviation equal to 10% the value of the observation. Moreover, these perturbations are independently drawn from a truncated normal distribution, so that the value of the observations for all the simulations is between half and twice the original value.