POLITICAL VIOLENCE AND FARM HOUSEHOLD EFFICIENCY IN COLOMBIA

María A. González* and Rigoberto A. Lopez**

- *Centro de Investigación y Tecnología Agroalimentaria, Zaragoza, Spain (mgonzalezalv@aragob.es)
- **Department of Agricultural and Resource Economics, University of Connecticut, Storrs, CT (Rigoberto.Lopez@uconn.edu)

Abstract

This paper estimates farm household levels of technical efficiency and their determinants in Colombia, with particular reference to political violence (i.e., guerilla fronts, assassinations, kidnappings, and displaced population). An input-oriented stochastic frontier is estimated simultaneously with a technical inefficiency model that incorporates violence at the local level, using survey data from 822 farm households. The findings show that household productivity is lower in areas of high political violence, particularly with high incidence of guerrilla fronts and kidnappings. Should political violence be eliminated, the average Farrell's technical efficiency index of farm households in the sample would increase by an average of 6.4%, favoring households in small farms the most.

Key words: Distance function, farm efficiency, Colombia, Violencia

JEL codes: Q74, O13, O54, D24

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Introduction

Political violence is a fact of life in much of the developing world, especially in many countries in Latin America, Sub-Saharan Africa, the Middle East, and Asia.[1] For instance, civil wars alone embroil one in eight countries and are much more prevalent in poor, stagnant developing economies where 90% of the victims are civilians (The Economist, 2003).

One of the well-established premises in economics and political science is that political violence leads to slower or negative economic growth via destruction of property, disruption of economic activities (e.g., extortion, kidnappings, disinvestment, and displacement of the productive population), and diversion of resources into directly unproductive activities (Brunetti, 1997; Azam, Berthelemy, and Calipel, 1996; Giugale, Lafourcade, and Luff, 2003; Alesina and Perotti, 1993; Gupta, 1990; Collier, 1999).

On the other hand, one of the most prescribed solutions for fueling the economic engine in rural areas of the developing world is increasing farm household efficiency, given prevailing resource endowments, through the removal of economic and institutional constraints (e.g., Bravo-Ureta and Pinheiro, 1997; Nyemeck-Binam, et al, 2003; Liu and Zhuang, 2000; Bhaduri and Skarstein, 1997). Yet nearly all studies of efficiency of farm households ignore the importance of political violence in their analyses (even in countries like Colombia where political violence is rampant) while studies of the economic effects of political violence are conducted at the national level without a micro insight into the effects on farm households, which are particularly vulnerable to political violence.

This article assesses the impact of political violence on the productive efficiency of farm households in Colombia.[2] To this end, it simultaneously estimates an input-oriented stochastic frontier along with a household inefficiency model that incorporates violence indicators at the local level using survey data from 822 farm households. Findings show that the political violence indicators significantly explain farm household deviations from the best practice (farm and off-farm) production frontier and that the pay-off that could come from a peace process that eliminates political violence can be substantial, particularly for small size farmers.

The Case of Colombia

Colombia provides a useful case study for the analysis of the impact of political violence on farm household efficiency. First, Colombia is one of the most politically violent countries in the world (Krug et al, 2002). Second, political violence mostly affects rural areas in Colombia. In fact, 93% of the municipalities affected by guerrilla activities are typically rural, with particularly adverse effects on agricultural activities (Bejarano, 1997). Third, there is a wide variation in the incidence of political violence across rural areas, which permits analyzing the impact of political violence on farm household productivity within the same country (Echandia, 2002).

Figures 1, 2 and 3 illustrate the extent of political violence in Colombia. Figure 1 shows that there has been a steady increase of the number of new guerrilla fronts between 1978 and 1998.[3] Figure 2 presents the number of displaced population between 1990 and 2000, which mainly occurred in the rural areas in conflict. By both accounts, political violence has been on a steady increase since the 1990s. Figure 3 presents the number of assassinations at the national level from 1990 to 2000, which peaked in 1991. Regardless of changes in the level of homicides, Colombia has one of the highest homicide rates in the world (80 per 100,000 inhabitants) among the countries covered in the U.N. Demographic Yearbook in 2001. Note that homicides include common crime and cannot all be attributed to political causes, although it is often used in national level studies examining the link between political violence and economic growth.

Several studies at the national level have analyzed the impact of violence on productivity and economic growth in Colombia. Cardenas (2001) attributes the slowdown in economic growth in Colombia after 1980 to the expansion of drug trafficking and the related crime and violence. Poveda (2001), using a Solow-type model and 1992-2000 data, concludes that political instability has negatively affected productivity growth at the national level. Dinar and Keck (1997) show that violence (measured by homicide and assassination cases) has a negative effect on investment in irrigation projects in Colombia. Jaramillo and Bonnet (1993) point out that violence is one of the key factors explaining the agricultural crisis in Colombia in the 1990s.

Political violence has both direct and indirect effects on the productivity of farm households. The direct effects, which result from farm households being caught in the armed conflict (among the State, the guerrillas, the paramilitaries, and the drug mafia), can be categorized into disruption, distortion of market incentives, and capital assets effects.[4]

Disruption effects refer to interruptions in access to buying inputs and to marketing outputs in the areas of conflict. The opportunities for off-farm employment may be reduced as transportation channels are disrupted or insecurity prompts employers to reduce hiring. Also, farm households must apply increasing management resources to obtain inputs or sell their outputs when freedom of movement is restricted by the conflict. In more extreme cases, fear of death from political violence plays a key role in individual migration decisions and in displacement of the rural population (Morrison, 1993). In fact, since the 1990s, Colombia officially reported nearly three million persons displaced to date in the combat areas (Figure 2).

Distortion of market incentives occurs as political violence changes costs and profitability of alternative farm household activities. Production costs increase due to guerrilla or paramilitary 'taxes,' extortion and kidnapping for self-financing and for rent seeking purposes (Rangel, 2000). In addition, illicit crop cultivation in marginal lands offers a relatively lucrative alternative to traditional agriculture for many peasant farmers. In fact, although drug trafficking helps support the rebels, Jaramillo (2001) points out that it may also exert a positive influence on rural incomes in Colombia. Land markets have also been distorted by the acquisition of significant amounts of farmland by drug traffickers for investment. Land takes on the characteristics of a financial asset, and its use as a productive input may be less responsive to agricultural market conditions. This has resulted in lower agricultural productivity as farmers use land for livestock in areas suitable for crops or are disinterested in the rate of return of their investment (Republic of Colombia, 2000).

Capital assets effects involve the erosion of capital assets, including destruction of property in the areas of conflict. Vandalism is a major concern of farm households in the areas of conflict. The most common forms of vandalism from political violence include the destruction of crops and damage to farm equipment. For instance, with the government's implementation of Plan Colombia since 2000, aerial herbicide spraying of coca plantations, and unintentionally neighboring legal crops, has accelerated, which has rendered many agricultural areas, particularly peasant ones, unfit for agricultural production.[5] This reduces the technical efficiency in farming. Figure 4 illustrates that the amount of land where illegal crops (e.g., cocaine and poppy seeds) have been eradicated is rather substantial, from a minimum of 30,000 hectares in 1995 to a maximum of 98,000 hectares in 2001, a year after the start of Plan Colombia. In addition, farm households may become reluctant to invest heavily in new technology because planning horizons are shortened as uncertainty increases. Finally, Political violence also erodes human and social capital. Granada and Rojas (1995) put the cost of lost human capital at 5% of the GDP.

Indirect effects include what Collier (1999) calls diversion of resources, i.e., allocation of private and public resources that could have been used for social programs in the rural areas to directly unproductive activities, such as foreign aid and increases in government expenditures on police and military control In fact, including all types of crime, Colombia spends nearly 15% of the GDP on security-related measures (Rubio, 1995). Estimates of the cost of violence in the national economy range from 5% (Bejarano, 1997) to 15% (Kalmanovitz, 1990) to a maximum of nearly 25% of the GNP (Londono and Guerrero, 1999).

The net effect of political violence on farm household productivity is expected to be negative. Furthermore, as political violence is not the only environmental factor that may affect technical efficiency and as technical efficiency depends on farm and off-farm activities, the following section presents a comprehensive framework to empirically measure technical efficiency of farm households and the effects of political violence indicators on their technical efficiency.

Methodology

The empirical framework utilized in this study involves a stochastic input-oriented distance function and an equation for the determinants of inefficiency, where the explanatory variables of the inefficiency model include local violence and other environmental household indicators.

Measurement of Inefficiency

When multiple inputs are used to produce multiple outputs, distance functions (first introduced by Shephard, 1953), which basically measure deviations from the best production frontier and treat them as technical inefficiency, provide an appropriate representation of household production technology (Kumbhakar and Lovell, 2000).

An input distance function (IDF) orientation assumes that producers (i.e., farm households) are capable of allocating resources when outputs are exogenous, i.e., it denotes the maximum amount by which a producer's input vector can be reduced and the output still remain feasible (Cuesta and Zofio, 2003).[6] Assuming that producers use a vector of *n* inputs, $x = (x_1, ..., x_N) \in R_+^N$, to produce *m* outputs, $y = (y_1, ..., y_M) \in R_+^M$, the IDF can be defined as (Shephard, 1970):

$$D_I(x, y) = \max\{\lambda : (x/\lambda) \in L(y)\}, \qquad (1)$$

where the input set *L(y)* represents the set of all input vectors *x* that are feasible for each output vector *y*, so that $L(y) = \{x \in R_+^N : x \text{ can produce } y\}$. The IDF will take a value greater than or equal to 1 if the input vector *x* is an element of *L(y)*, and will take the value 1 if *x* is located on the inner boundary of *L(y)*.

The *stochastic* IDF (SIDF) can be defined as (Hatori, 2002):

$$1 = D_I(x, y)\exp(-u + v), \qquad (2)$$

where the error term is composed of *v*, which is a symmetric random disturbance term accounting for noise, and the term *u*, which is an asymmetric error term that accounts for production inefficiency.[7]

Following Coelli and Perelman (1999), a second-degree approximation to the true input distance function in (1) can be represented by the translog form with symmetry and homogeneity imposed, given by:[8]

$$\ln\left(\frac{D_I(x,y)}{x_N}\right) = \alpha_0 + \sum_{m=1}^{M}\alpha_m \ln y_m + \frac{1}{2}\sum_{m=1}^{M}\sum_{k=1}^{M}\alpha_{mk}\ln y_m \ln y_k + \sum_{n=1}^{N-1}\beta_n \ln\left(\frac{x_n}{x_N}\right) + \frac{1}{2}\sum_{n=1}^{N-1}\sum_{l=1}^{N-1}\beta_{nl}\ln\left(\frac{x_n}{x_N}\right)\ln\left(\frac{x_l}{x_N}\right) + \sum_{n=1}^{N-1}\sum_{m=1}^{M}\delta_{nm}\ln\left(\frac{x_n}{x_N}\right)\ln y_m, \tag{3}$$

where x and y are Nx1 and Mx1 vectors of inputs and outputs respectively, and *ln* is the natural log operator.

Applying (2) to (3), one obtains:

$$\ln\left(\frac{1}{x_N}\right) = \ln\left(\frac{D_I(x,y)}{x_N}\right) - u + v = TL\left(\frac{x}{x_N}, y, \alpha, \beta, \delta\right) - u + v, \tag{4}$$

where *TL* stands for the translog function in equation (3).

To allow for logarithmic estimation with a considerable number of zero values of input and output observations, we follow the procedure proposed by Battese (1997), who uses dummy variables associated with the incidence of these observations to minimize or eliminate bias in estimating a production frontier.[9]

Determinants of Inefficiency

To identify non-random sources of inefficiency, we investigate the relationship between the indexes of efficiency and environmental indicators, including those denoting political violence.

One common but often unrealistic assumption in efficiency analysis is that all units share the same technology and face similar environmental conditions. Since there is a wide variation in environmental factors-household heterogeneity, violence, and agro-ecological conditions-which influence resource allocation (Coelli, Perelman, and Romano, 1999), these factors can be regarded as directly influencing technical inefficiency without shaping the frontier (Battese and Coelli, 1993; Bravo-Ureta and Pinheiro, 1997; Fried et al, 2002). By extension, political violence is assumed to affect the farm household's deviations from the best practice frontier, but not the frontier itself.[10]

This article follows Battesse and Coelli (1993), who estimated a stochastic frontier production function incorporating a second equation where the technical inefficiency effects are a linear function of a set of environmental indicators.[11] Here, these effects are treated as normal random variables truncated at zero, i.e., $u \sim \left[N\left(\mu, \sigma_u^2\right) \right]$, where μ is a linear combination of the vector of variables which may influence the efficiency of the household, $\mu = \sum_{i=1}^{S} \rho_i Z_i$. Therefore the inefficiency deviation from the best practice frontier for the *jth* farm household is expressed as:

$$u_j = \sum_{i=1}^{S} \rho_{ij} Z_{ij} + w_j , \qquad (5)$$

where Z is a (1xS) vector of environmental variables influencing efficiency, and ρ is a (Sx1) vector of parameters to be estimated. The parameter ρ_i indicates the impact of variable Z_i on technical inefficiency deviation from the frontier for farm household *j*. A negative value of the parameter suggests a positive influence on efficiency and vice versa. The terms w_j are unobservable random variables, assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and variance σ_u^2. Farrell's (1957) technical efficiency index for the *jth* farm household is thus defined by:

$$TE_j = \exp(-u_j) = \exp(-\sum_{i=1}^{S} \rho_{ij} Z_{ij} - w_j) . \qquad (6)$$

Simultaneous estimation of the distance function (equation 4) and the inefficiency determinants (equation 5) can provide consistent and efficient estimates of the parameters.

Data and Empirical Estimation

The main data source is a survey undertaken by the Colombian *Departamento Nacional de Planeación* (DNP) in collaboration with the *Instituto Interamericano de Cooperación para la Agricultura* (IICA) and the World Bank, conducted between July 1998 and June 1999.

The survey consists of two modules. Module 1: Agricultural information, implemented at the Agricultural Production Unit (APU), provided data on all agricultural outputs and inputs, including land, family and hired labor, and farm assets.[12] Module 2: Household information, implemented at the agricultural producer's household level, provided non-agricultural information such as household characteristics, off-farm labor, non-farm assets, and non-farm family business. The sample includes 55 municipalities that were stratified into 11 zones of similar agro-ecological characteristics and systems of production.[13] After matching the data in modules 1 and 2 and eliminating incomplete observations, the sample consisted of 822 farm household observations.[14]

For the distance function in equation 4, farm households are assumed to produce three outputs (y_m): (1) crops; (2) livestock; and (3) off-farm income (which includes wage labor earned off the farm and income received from other businesses). Households utilize seven inputs

(x_n): (1) hired labor, measured as the amount paid to temporal and permanent workers; (2) farm family labor, measured as the total number of weeks that family members work at the farm; (3) off-farm family labor, measured as the total number of weeks that family members work at non-farm activities; (4) amount spent on variable inputs (seeds, fertilizers and other chemicals, purchased feed, breeding, and other expenses); (5) value of machinery; (6) value of livestock assets; and (7) hectares of cultivated land.

For the inefficiency effects model in equation 5, the socioeconomic information from the survey is complemented with village-level environmental factors. The explanatory variables include: household characteristics (e.g., age, education and gender of the household head, and family composition); land tenure status; proxies for factor market endowments and institutions that affect access to land and use of resources, such as rental market activity or credit; and indicators of violence (e.g., number of assassinations, kidnappings, guerrilla attacks and of displaced population from that particular area).[15] In addition, dummy variables are used to denote agro-ecological regions and to control for other fixed effects.

The available literature does not offer a universally accepted measure of violence. Kirchhoff and Ibañez (2001) argue that violence and the perception of insecurity are important reasons motivating displacement in Colombia. Thus, the number of displaced people is included in the analysis as an indicator of the level of conflict in the expulsory location. These data were provided by the Colombian government in the Sistema Unico de Registro (SUR, unique registration system). The data base contains municipal-level data on displaced population that were matched with observations in the survey.[16]

Additional aspects of political violence included are the number of assassinations, kidnappings, and guerrilla attacks. These were obtained from the University of Los Andes in

Santa Fe de Bogotá, Colombia. Note that previous studies on political violence have relied heavily on assassinations. The number of inhabitants by municipality was obtained from the last population census (XVI Censo Nacional de Poblacion y Vivienda – 1993) provided by the National Statistic Bureau (Departamento Administrativo Nacional de Estadística – DANE). To make them comparable across municipalities, the various measures of political violence are expressed on a per capita basis.

The analysis also includes a number of other variables reflecting household heterogeneity and farm activity, which may affect decision making and control of resources within the household. These include household head age, education and gender, number of adults in the household, land tenure status, and land rental and credit activity at the village level.

Table 1 summarizes the variables used in the two-equation model. Their descriptive statistics are presented in Table 2. The equations are estimated simultaneously using maximum likelihood procedure with FRONTIER 4.1 software (Coelli, 1994). Several specification tests indicate that the most appropriate functional form for the distance function is the input-oriented translog form with inefficiency effects that have a truncated normal distribution for the inefficiency deviations.[17]

First, to determine whether or not the technical efficiency effects have a half normal distribution $u \sim \left[N\left(0, \sigma_u^2\right) \right]$ or a truncated normal distribution $u \sim \left[N\left(\mu, \sigma_u^2\right) \right]$, we tested if μ equals zero (H_0: $\mu = 0$) since the former is a special case of the latter. [18] The resultant likelihood ratio test is 16.86 and is significant at the 1% level, implying the rejection of the null hypothesis. Therefore, the truncated normal distribution is a more appropriate assumption for the inefficiency effects of the SIDF.

The second test was to determine whether or not the inefficiency deviations (*u*) are non-stochastic and equal to zero and, therefore, could be eliminated from the equation. The hypothesis of no technical inefficiencies of production is equivalent to $\gamma = \sigma_u^2 / \sigma^2$ equal to zero (H_0: $\gamma = 0$).[19] The value of the likelihood ratio test is significant at the 1% level, which implies that there are significant technical inefficiencies among farm households in Colombia.

The third test establishes whether or not the technical inefficiency effects are influenced by the level of the explanatory variables (*Z*). The null hypothesis is expressed by H_0: $\rho_0 = \rho_1 = ... = \rho_{24} = 0$. The likelihood ratio test indicates that the explanatory variables included in the inefficiency model are jointly significant at the 1% level. Out of the 25 variables (including the regional dummies), 16 are statistically significant at the1% level.

Finally, the translog functional form was tested against the null hypothesis that the Cobb-Douglas specification is an adequate approximation of the true distance function (H_0: $\alpha_{mk} = \beta_{nl} = \delta_{nm} = 0$). Again the null hypothesis was rejected, implying that the restrictions imposed by the Cobb-Douglas functional form are inappropriate and that the translog is a more suitable specification for the SDIF. The empirical results are presented and discussed in the following section.

Empirical Results

Efficiency Results

The parameter estimates of equation (4) are presented in Table 3. Of the 64 parameters estimated after the symmetry and homogeneity conditions were imposed, 38 are statistically significant at the 5% level. The significance of cross products and squared terms lends further support as to why the likelihood test rejected the Cobb-Douglas specification. As expected, the estimated SIDF is increasing in inputs and decreasing in outputs. Of the dummy variables included in the model, the coefficients associated with the zero input variables $(dx_1, \ldots, dx_6)$ are statistically significant at the 1% level, which confirms that considerable bias would be introduced in the parameters if the input distance function was estimated without addressing explicitly the problem of zero values.

The log values of the distance function variables were mean differentiated prior to estimation; therefore, the first-order coefficients in the equation can be interpreted as the elasticities of the SIDF with respect to inputs and outputs at the sample means. Furthermore, these elasticities reflect the relative importance of particular inputs and outputs in the production process. The results indicate that 5 out of 6 input elasticities are positive and statistically significant. The elasticity of off-farm family labor is the largest with a value of 0.33, and farm family labor is the second largest at 0.30. This is an indicator of the crucial role of family labor (farm and off-farm) in Colombian agriculture and of the necessity to include them in an integrated analysis at the household level.

The elasticity of the SIDF with respect to each output corresponds to the negative of the cost elasticity for that particular output. Off-farm income has elasticity statistically different from zero at the 5% level. Hence, increases in off-farm production result in considerable increases in costs. This is a consequence of the importance of off-farm family labor as reflected by its input elasticities.

The value of Farrell's technical efficiency index (from equation 5) indicates how much input usage could be proportionally reduced and still maintain the same levels of outputs. The average value of the efficiency score is 0.87, implying that, on average, input consumption of the households could be reduced by 13% and still produce the same amount of outputs. Variation of the efficiency scores across regions was very small. Therefore, it is plausible to assume that all regions share the same production frontier.

Effects of Political Violence on Inefficiency

Table 3 presents the results for the determinants of inefficiency or deviation from the farm household frontier function. Out of the 25 explanatory variables (including the regional dummies), 18 are statistically significant at least at the 10% level. The model parameters are expressed in terms of inefficiency. Consequently, variables with negative coefficients are interpreted as having a positive effect on technical efficiency and vice versa.

The indicators of violence are quite strong in explaining the inefficiency of farm households in Colombia. Two variables have a negative and significant effect on household efficiency: guerrilla attacks and kidnappings. Recall that violence variables are normalized by expressing them per 1000 inhabitants. The assassination cases are not significantly different from zero. These results seem to indicate that insecurity related to political violence, which is the case of guerrilla activity and to a certain extent kidnappings, has a greater impact on efficiency than other violent acts, such as violent homicides, which represent a more generalized type of violence. Dinar and Keck (1997) in their study on irrigation investment in Colombia found that increases in violence, measured as assassinations per capita, have a significant negative effect on investment. Our results fail to reject this proposition but do not support it either.

The percentage of displaced population from a particular municipality was used as one of the proxies for violence. This variable had a positive a significant effect on household efficiency. This result is somehow surprising, but considering that the survey used for the analysis contains only information on the people that are still farming, not on those who left, it is difficult to infer if the households that left were more productive or not than the ones remaining in their place of origin. However, it is plausible to assume that in a stressful situation, the first people who leave their place of origin will be those with a higher opportunity cost of staying. Therefore, the families leaving are likely to be the least productive farmers, people that have skills other than farming that could be easily rehired in another sector, or families occupying marginal lands. This fact could be driving the positive effect of displacement on efficiency.

One factor related to the massive displacement of the population that is not reflected in the analysis is that there is an important amount of land abandoned by internally displaced populations. One consequence is that these households are not included in the survey. Overall, the findings suggest that it is important to consider violence and insecurity in the rural areas in the design of policies aimed at increasing agricultural productivity.

To analyze the extent of the effect of violence on household efficiency, Farrell efficiency indexes were simulated setting the violence indicators to zero. Table 4 shows the results from the simulation. Eliminating violence would increase farm household efficiency by 6.4 percent. Since outputs are assumed to be exogenous (and so are revenues), this translates into a 6.4 average percent increase in producer surplus.

An important issue is the impact of political violence across farm sizes. In this regard, small size farms in the sample (0-15 hectares) stand to gain the most from the elimination of political violence, with an average technical efficiency gain of 7.9%. Large farmers (>50 hectares) stand to gain the least at 4% average gain. At the same time, the regional impacts of eliminating political violence on farm household efficiency varies widely, from a negative impact in Valle del Cesar and Magdalena Alto regions to the highest impact in the Bajo Magdalena region (28% gain).

Other Effects on Inefficiency

Table 3 shows that variables representing household characteristics also have a strong impact on farm household efficiency in Colombia.

The positive impact of household head education on efficiency indicates that increases in human capital could significantly enhance productivity of households since they will be more capable of allocating inputs and selecting among available techniques (Abdulai and Eberlin, 2001; Lockheed, Jamison, and Lau, 1981). The lower household efficiency of female-headed households is normally attributed to lower access to land, capital or other financial services, although credit and land tenure were controlled for in this study. It would be useful to explore the reasons for productivity discrepancies between male-and female-headed households in Colombia. Some of the discrepancies could be spurious since non-marketed outputs (at home production, for instance) were not included in the analysis and could significantly bias the results. Another surprising result is that families with more adults appear to be less efficient than those with fewer, pointing to decreasing returns from family labor.

Not surprisingly, farm households located in areas of higher soil erosion were found to be less efficient, pointing to potential benefits of adopting soil conservation practices in these locations as well as the importance of controlling for land quality. Other variables, such as rental and credit activity, did not have a discernable effect on technical efficiency. Finally, municipal population density was found to have a negative effect on the technical efficiency of farm households.

Concluding Remarks

This paper estimates farm household levels of technical efficiency in Colombia and also identifies the variables that determine the shortfalls in efficiency with special reference to political violence. It explores why farm households often fail to achieve outcomes that can be described as efficient and measures departures from the efficient frontier, measured as a stochastic multi-output, input-oriented distance function.

Empirical results indicate that the average level of technical efficiency of farm households in Colombia is approximately 87%. Thus, the results indicate that it is possible for the households in the sample to improve their performance by using the best practice technology and overcoming constraints that might be imposed by factors such as violence. The empirical findings also show that violence has a very influential effect on farm household productivity performance. In areas where the political violence is higher, households have significantly lower productive efficiency. Simulation results show that if violence is eliminated, average technical efficiency could increase by 6.4 percent, with a particularly strong positive effect on small size farmers and in the Bajo Magdalena region.

Overall, this study shows that substantial productivity gains can be obtained by improving household productive efficiency without requiring additional inputs or without the need of new technologies. Therefore, it is important for Colombian rural development to provide an institutional environment with reduced political violence and insecurity in the rural areas as well as farm household access to education. The ensuing increases in efficiency can translate into significant increases in producer surplus and would significantly advance economic development in rural Colombia.

Footnotes

1. For the purpose of this article, we refer to political violence as guerrilla and paramilitary conflicts, assassinations, kidnappings, and displacement of population. Moser (2000) present three categories of violence: (1) political (guerrilla conflict, paramilitary conflict, political assassinations, armed conflicts between parties); (2) economic (street crime, robbery/theft, drug trafficking, kidnapping, and assaults); and (3) social (interpersonal violence like spouse and child abuse, sexual assault of women and children, and arguments out of control).

2. Political violence in Colombia is largely rooted in its unequal and exclusionary agrarian system, where unequal land ownership is a major element explaining the country's violent history (Fajardo, 2002; Grusczynski and Jaramillo, 2002; Kirchoff and Ibañez, 2001). In addition, political violence is also rooted in drug trafficking activities.

3. Although there are differences in size among the different insurgent groups, each front is formed of about 120 rebels (Cardenas, 2001).

4. Leftist guerrillas mainly consist of the FARC (Revolutionary Armed Forces of Colombia, about 18,000 fighters), the ELN (National Liberation Army, 3,000 fighters), and the smaller EPL (Popular Liberation Army). The right-wing paramilitaries are grouped into the AUC (Defense Forces of Colombia, 11,000 well-armed troops).

5. Two main objectives of Plan Colombia (2000-2005), which postdates data used in this study, are negotiating a political solution to the conflict and implementing an anti-narcotics strategy (Republic of Colombia, 2004). Critics contend that the Plan has overemphasized military support and that the peasants and civilian population, particularly in the Putumayo area, have been the most affected as their legal as well as illegal crops have been sprayed with herbicides (Cooper, 2001).

6. For simplicity, this study relies on input-oriented distance functions. As is discussed later, robustness analysis included alternative specifications of output- and input-oriented distance functions under alternative error distribution and functional forms. The output-oriented efficiency scores indicate the amount by which an output vector can be expanded and still be producible with a given input vector.

7. The term v is typically assumed to be iid N~(0, σ_v^2) and independently distributed from u. The term u is assumed either to be half-normal, truncated normal, exponential, or gamma distributed (Greene, 1993; Murty and Kumar, 2002).

8. The restrictions required for symmetry are $\alpha_{mk} = \alpha_{km}$ and $\beta_{nl} = \beta_{ln}$, while homogeneity of degree one in inputs implies $\sum_{n=1}^{N} \beta_n = 1$, $\sum_{l=1}^{N} \beta_{nl} = 0$, and $\sum_{n=1}^{N} \delta_{nm}$. To impose homogeneity, all inputs are normalized by an arbitrary input x_N. Homogeneity of degree one in inputs implies that $D_I(\lambda x, y) = \lambda D_I(x, y)$ for any $\lambda > 0$.

9. Particularly, the variables in the model are replaced by x_n*=max (x_n, D_n) and y_m*=max (y_m, F_m) , where D_n and F_m are dummy variables with a value of one if the variable is equal to zero and with a value of zero if the variable is greater than zero (Tsekouras, Pantzios and Karagiannis, 2004). That is,

$D_n = 1$ if $x_n = 0$ and $D_n = 0$ if $x_n > 0$,

$F_m = 1$ if $y_m = 0$ and $F_m = 0$ if $y_m > 0$.

10. An alternative approach is to estimate technical efficiency by introducing these environmental factors directly into the production function, assuming that they influence its shape (Good et al, 1993). Therefore, each farm faces a different production frontier and the efficiency indexes are net of environmental effects.

11. Some empirical papers adopt a two-stage approach where the first stage estimates a stochastic production function and in the second stage a regression of the estimated efficiency index is run against the set of environmental variables (Bravo-Ureta and Pinheiro, 1997; Kalirajan, 1989; Lingard, Castillo, and Jayasuriya, 1983; Page, 1984). As noted by Battese and Coelli (1993), this technique is inconsistent because the estimation of the stochastic frontier function in the first stage assumes that the inefficiency effects, measured as the error term, are identically distributed, while using these inefficiency effects as a dependent variable in the second stage implies that they are not identically distributed. Overcoming this problem, another set of papers involve the estimation of a stochastic production function incorporating a model for technical inefficiency effects into a single stage (Battese and Coelli, 1993; Coelli, Perelman, and Romano, 1999; Kumbhakar, Ghosh, and McGukin, 1991).

12. The Agricultural Productive Unit is defined as the economic unit involved in agricultural and livestock production under a unique management. The APU can have more than one plot of land as long as the plots share the same "production means," i.e. the same labor force, machinery, and buildings used for the purpose of agricultural production (Deininger, Castagnini, and Gonzalez, 2004).

13. These 11 regions are: (1) Valle del Sinú and San Jorge; (2) Valles del Bajo Magdalena; (3) Valles del Cesar and Ranchería; (4) Magdalena Medio; (5) Magdalena Alto; (6) Vertiente Nororiental; (7) Altiplanos; (8) Vertiente Central; (9) Vertiente Sur; (10) Vertiente Noroccidental; and (11) Piedemonte Llanero.

14. The data were collected for about 1,200 APUs, using a 3-stage stratified random procedure for the areas. In the first stage, 55 municipalities were selected as primary sampling units (PSU) from a universe of 604 municipalities. There are 110 secondary sampling units

(SSU) (2 for each PSU selected), constructed using the number of houses as a proxy for the number APUs in the sampling unit. In the third stage, 110 terciary sampling units (UTM) or segments, were selected, one for each SSU. The segments are groups of APUs (on average 16 APUs per segment); all households and APUs in the selected segments were interviewed (Ramirez, Prada, and Useche, 2000).

15. Multivariate analysis was also used to measure violence via a principal component analysis that captures the joint variation of these four violence indicators. Although the component violence effect on inefficiency was the expected one, the results failed to give additional insight into the violence effects or did not improve the overall results of the two equations.

16. It is important to realize that the numbers on displacement reported by SUR are a conservative estimate. Households have to explicitly register in the system to access government support that is provided only for a by limited time after the displacement; therefore households that were displaced at earlier dates are unlikely to register (Deininger, 2004).

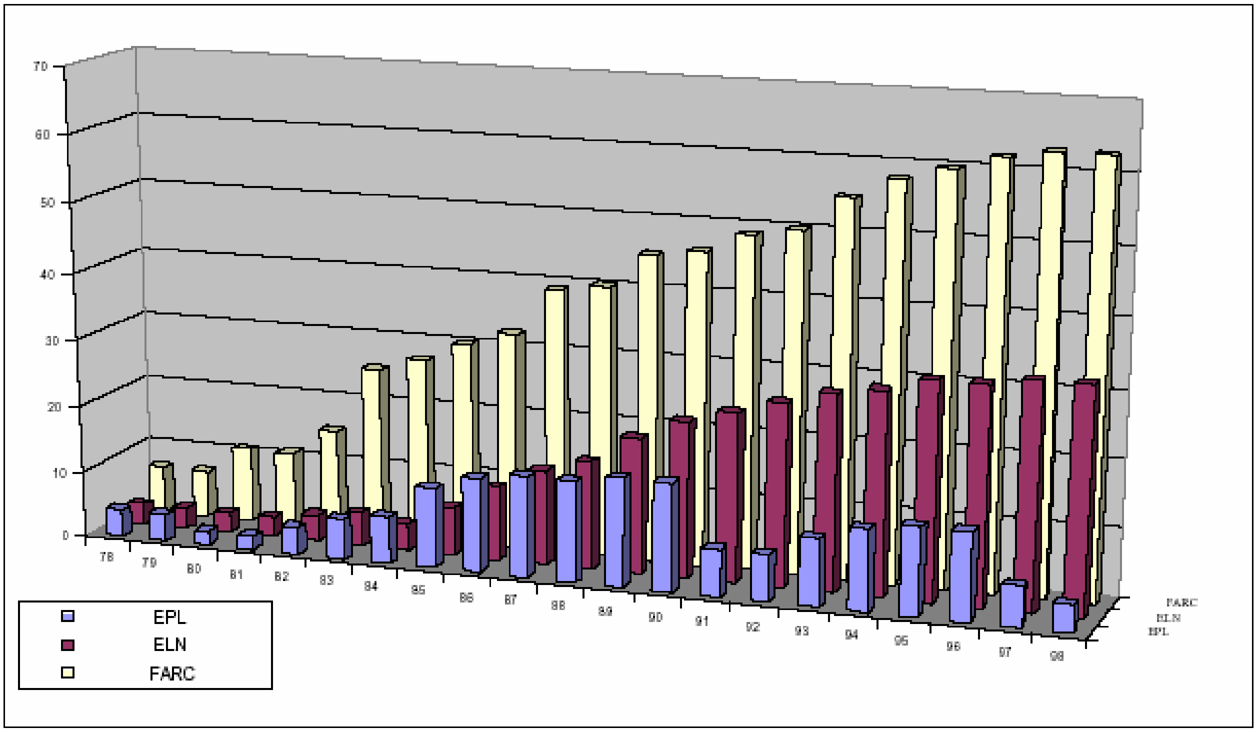
17. Accordingly, nine multi-output technical efficiency models were estimated for the Colombian households in the sample. These models are: (1) stochastic input distance function (half normal distribution), (2) stochastic output distance function (truncated normal distribution), (3) stochastic input distance function (half normal distribution), (4) stochastic output distance function (truncated normal distribution), (5) constant returns to scale DEA, (6) input oriented variable returns to scale DEA, (7) output oriented variable returns to scale DEA, (8) input oriented non-increasing returns to scale DEA, and (9) input oriented non-increasing returns to scale DEA. The Spearman rank correlation coefficient was used to compare the ranking of the efficiency indexes obtained by the different models. In all cases, the coefficient was significant at

the 1% level, implying a significant ranking relationship between the indexes calculated by the stochastic and parametric techniques. However, the SIDF yielded the most plausible results and avoided some of the restrictiveness of some of the models, such as the use of a two-step analysis with DEA or constant returns to scale.

18. The generalized likelihood ratio statistic is given by $\lambda = -2\left[\ln\left\{L(H_0)\right\} - \ln\left\{L(H_1)\right\}\right]$, where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and the alternative hypotheses. The value of λ has a chi-squared distribution with the number of degrees of freedom equal to the number of restrictions imposed.

19. Because γ is the ratio of two variances and it is necessarily positive, the test follows a mixed chi-squared distribution and the critical values for the test can be found in Kodde and Palm (1986).

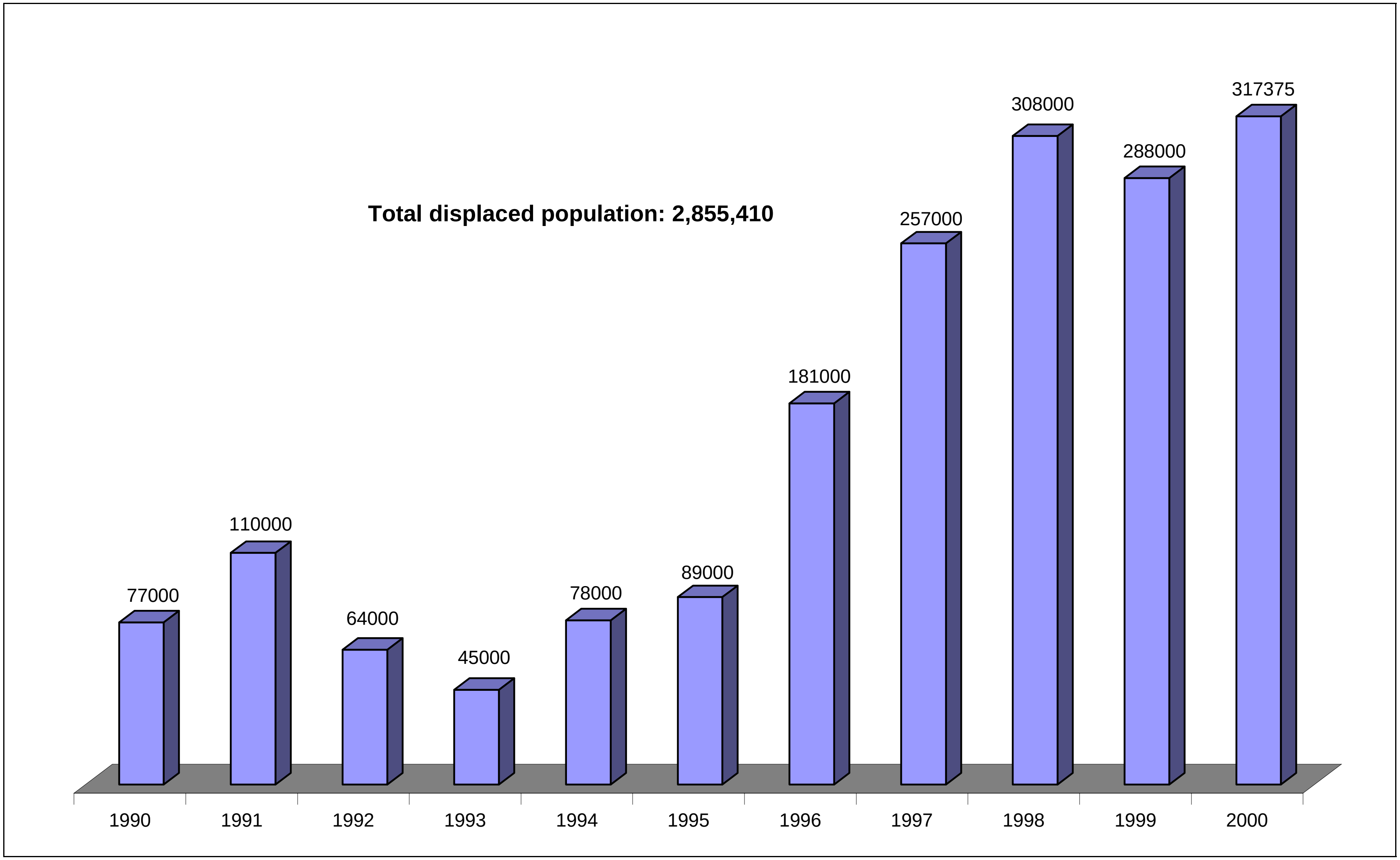
Figure 1: Number of New Guerrilla Fronts from 1978 to 1998



Source: Echandia, C. (1999)

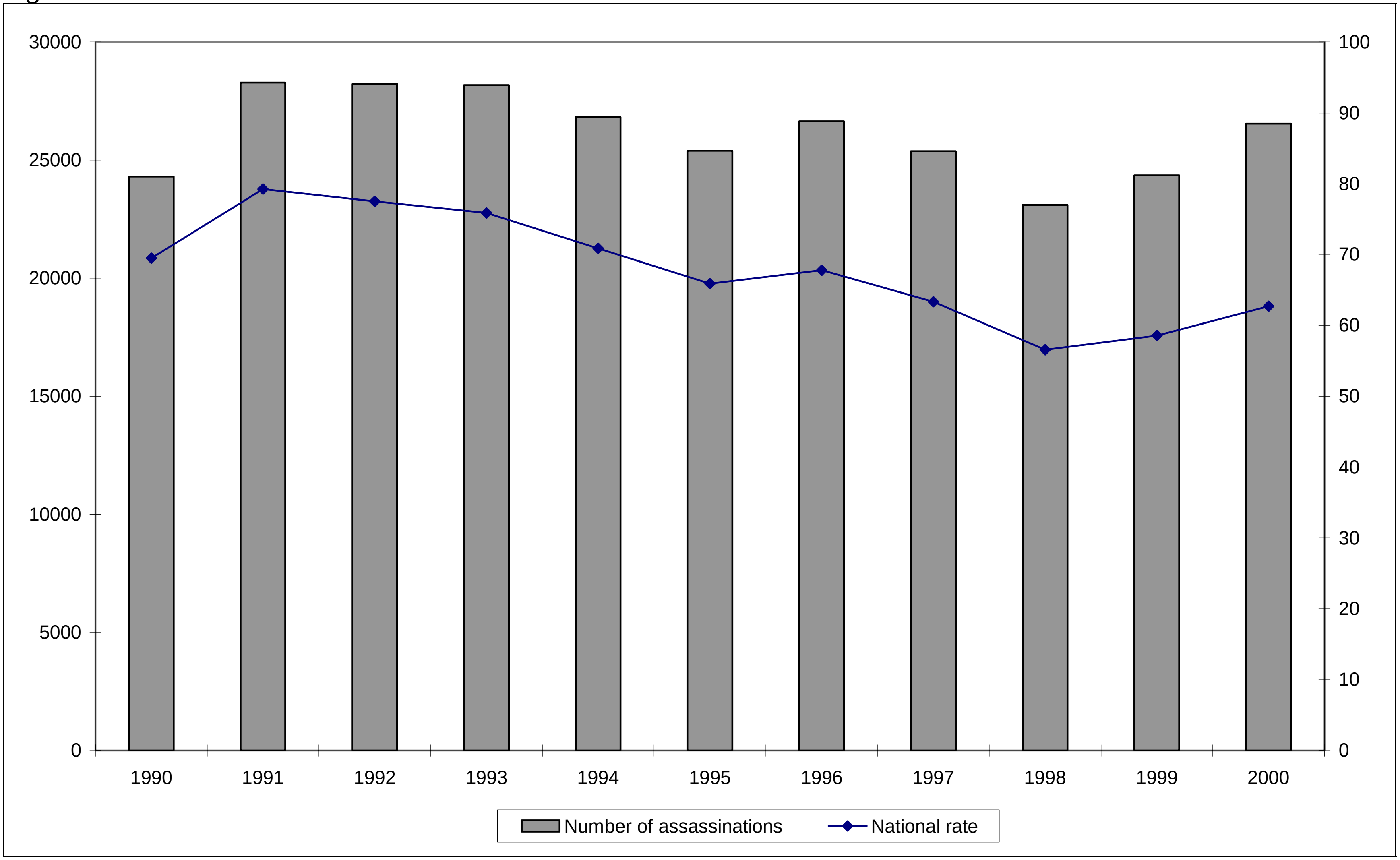
- EPL = Popular Liberation Army
- ELN=National Liberation Army
- FARC= Revolutionary Armed Force of Colombia

Figure 2: Displacement in Colombia from 1990-2000



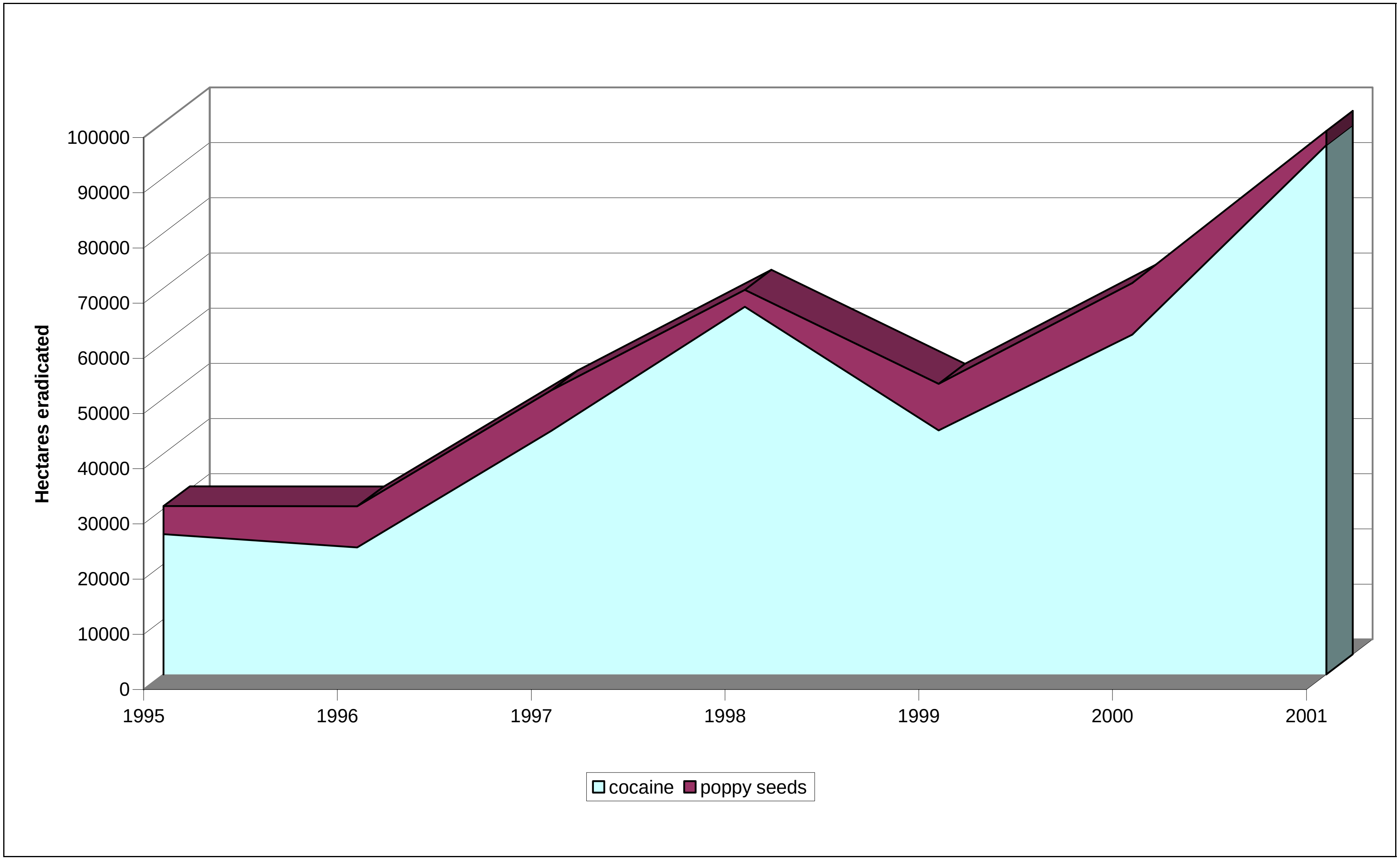
Source: CODHES, 2004

Figure 3: Evolution of National Rate and Number of Assassinations from 1990-2000



Source: Republic of Colombia. Vice-presidency of Human Rights

Figure 4: Eradicated area planted with illegal crops from 1995-2001



Source: OAS, 2001

Table 1: Definition of Variables

Variable Name	*Definition*
<u>*SIDF Equation*</u>	
y_1	Crop production ($)
y_2	Livestock production ($)
y_3	Non-farm income ($)
dy_j	Dummy variable =1 for zero y_j observation; 0 otherwise
x_1	Hired labor ($)
x_2	Farm family labor (weeks)
x_3	Off-farm family labor (weeks)
x_4	Seeds, fertilizers, and feed ($)
x_5	Value of machinery ($)
x_6	Livestock assets ($)
x_7	Cultivated land (hectares)
dx_j	Dummy variable =1for zero x_j observation, 0 otherwise
<u>*Inefficiency Determinants*</u>	
Guerrilla	Municipal Average Guerrilla attacks from 1995-1998/1000 people
Kidnappings	Municipal Average Kidnappings from 1995-1998/1000 people.
Assassinations	Municipal Average Assassinations from 1995-1998/1000 people.
Displacement	% of displaced population in a Municipality
Age	Age of household head (years)
Education	Household Head education (years)
Female	1 if the household head is female
Adults	Number of adults living in the house
Land size	Hectares of cultivated land
Landless	1 if household is pure tenant
Credit	Municipal Level of credit access
Rental	Municipal Level of rental activity
Erosion	Municipal level of erosion (index).
Pop. density	Municipal Population density (people/km^2)
dr_j	Dummy variable =1 for region j, 0 otherwise

Table 2: Descriptive Statistics of the Sample

		Mean	*Min*	*Max*	*CV*
Distance Function					
Outputs					
y_1	Crop production ($)	1907.57	0	101000	3.06
y_2	Livestock production ($)	1284.61	0	37000	2.79
y_3	Non-farm income ($)	17.56	0	6835	14.14
Inputs					
x_1	Hired labor ($)	607.29	0	49300	3.87
x_2	Farm family labor (weeks)	27.82	2	141	0.92
x_3	Off-farm family labor (weeks)	21.36	0	260	1.59
x_4	Seeds, fertilizers, and feed ($)	727.95	0	24200	2.46
x_5	Value of machinery ($)	309.70	0	31000	5.36
x_6	Livestock assets ($)	3248.02	0	85600	2.40
x_7	Cultivated land (hectares)	25.71	0.004	1600	3.33
Inefficiency Determinants (household level)					
Age	Age of household head (years)	53.59	21	95	0.27
Education	Household Head education (years)	5.56	1	15	0.58
Gender	% of female household head	20%	0	1	2.00
Adults	Number of adults living in the house	3.28	1	10	0.51
Landless	% pure tenant	8%	0	1	3.50
Inefficiency Determinants (Municipality level)					
Credit	Level of credit access	0.11	0	0.53	1.10
Rental	Level of rental activity	0.18	0	1.00	1.05
Erosion	Level of erosion (index)	2.08	0	4.10	0.48
Pop. density	Population density (people/km^2)	66.71	3.4959	265.64	0.94
Guerrilla	Guerrilla attacks per 1000 people	1.41	0	11.25	1.46
Kidnappings	Kidnappings per 1000 people.	0.05	0	0.27	1.37
Assassinations	Assassinations per 1000 people.	0.72	0.0922	4.36	0.87
Displacement	% of population displaced	0.04	0	0.34	1.37

Table 3: Estimated Parameters and Selected Statistics

Variable	Coeff.	Est. Coeff.	Std. Error	T-Ratio
SIDF Equation				
Constant	α_0	-1.329***	0.055	-24.222
$\ln y_1$	α_1	0.026	0.033	0.805
$\ln y_2$	α_2	-0.074*	0.044	-1.687
$\ln y_3$	α_3	-0.064**	0.028	-2.310
$\ln x_1$	β_1	0.125***	0.018	7.052
$\ln x_2$	β_2	0.315***	0.022	14.612
$\ln x_3$	β_3	0.331***	0.021	15.782
$\ln x_4$	β_4	-0.006	0.022	-0.253
$\ln x_5$	β_5	0.063***	0.025	2.547
$\ln x_6$	β_6	0.202***	0.019	10.754
$\ln y_1 \ln y_1$	α_{11}	-0.005**	0.003	-2.070
$\ln y_2 \ln y_2$	α_{22}	0.002	0.003	0.536
$\ln y_3 \ln y_3$	α_{33}	0.015***	0.003	5.178
$\ln y_1 \ln y_2$	α_{12}	-0.002	0.002	-0.817
$\ln y_1 \ln y_3$	α_{13}	0.001	0.003	0.188
$\ln y_2 \ln y_3$	α_{23}	-0.011**	0.005	-2.380
$\ln x_1 \ln x_1$	β_{11}	-0.013***	0.002	-6.225
$\ln x_1 \ln x_2$	β_{12}	0.004**	0.002	2.193
$\ln x_1 \ln x_3$	β_{13}	0.010***	0.002	5.123
$\ln x_1 \ln x_4$	β_{14}	0.003	0.002	1.019
$\ln x_1 \ln x_5$	β_{15}	0.004**	0.002	2.197
$\ln x_1 \ln x_6$	β_{16}	0.003***	0.001	2.604
$\ln x_2 \ln x_2$	β_{22}	-0.015***	0.003	-5.387
$\ln x_2 \ln x_3$	β_{23}	0.021***	0.003	7.181
$\ln x_2 \ln x_4$	β_{24}	0.003	0.003	0.818
$\ln x_2 \ln x_5$	β_{25}	-0.005*	0.003	-1.792
$\ln x_2 \ln x_6$	β_{26}	0.005**	0.002	2.511
$\ln x_3 \ln x_3$	β_{33}	-0.026***	0.002	-12.847
$\ln x_3 \ln x_4$	β_{34}	0.005**	0.003	1.997
$\ln x_3 \ln x_5$	β_{35}	0.007***	0.003	2.581
$\ln x_3 \ln x_6$	β_{36}	0.020***	0.002	9.347
$\ln x_4 \ln x_4$	β_{44}	-0.003	0.003	-1.037
$\ln x_4 \ln x_5$	β_{45}	-0.007**	0.003	-2.260
$\ln x_4 \ln x_6$	β_{46}	0.000	0.003	-0.035
$\ln x_5 \ln x_5$	β_{55}	-0.002	0.003	-0.821
$\ln x_5 \ln x_6$	β_{56}	0.003	0.002	1.214
$\ln x_6 \ln x_6$	β_{66}	-0.018***	0.002	-8.807
$\ln y_1 \ln x_1$	δ_{11}	0.000	0.001	-0.324
$\ln y_1 \ln x_2$	δ_{12}	-0.001	0.002	-0.278
$\ln y_1 \ln x_3$	δ_{13}	-0.005**	0.002	-2.503
$\ln y_1 \ln x_4$	δ_{14}	0.005**	0.002	1.939
$\ln y_1 \ln x_5$	δ_{15}	-0.001	0.003	-0.440
$\ln y_1 \ln x_6$	δ_{16}	-0.001	0.001	-0.656
$\ln y_2 \ln x_1$	δ_{21}	-0.005**	0.002	-2.413
$\ln y_2 \ln x_2$	δ_{22}	0.002	0.003	0.841
$\ln y_2 \ln x_3$	δ_{23}	0.000	0.002	-0.160
$\ln y_2 \ln x_4$	δ_{24}	0.009***	0.003	3.073

Table 3: Estimated Parameters and Selected Statistics (cont.)				
$\ln y_2 \ln x_5$	δ_{25}	0.000	0.003	-0.070
$\ln y_2 \ln x_6$	δ_{26}	-0.005**	0.002	-2.373
$\ln y_3 \ln x_1$	δ_{31}	-0.003	0.003	-0.980
$\ln y_3 \ln x_2$	δ_{32}	0.002	0.004	0.385
$\ln y_3 \ln x_3$	δ_{33}	-0.005	0.004	-1.124
$\ln y_3 \ln x_4$	δ_{34}	0.005	0.005	1.125
$\ln y_3 \ln x_5$	δ_{35}	0.002	0.005	0.364
$\ln y_3 \ln x_6$	δ_{36}	-0.017***	0.004	-4.523
dx_1	D_1	0.532***	0.058	9.156
dx_2	D_2	1.080***	0.052	20.841
dx_3	D_3	1.100***	0.054	20.182
dx_4	D_4	0.161***	0.059	2.716
dx_5	D_5	0.200***	0.054	3.716
dx_6	D_6	0.699***	0.056	12.589
dy_1	F_1	-0.055	0.094	-0.581
dy_2	F_2	-0.333***	0.114	-2.931
dy_3	F_3	-0.068**	0.034	-2.012
Inefficiency Equation				
Constant	ρ_0	-0.936***	0.223	-4.197
Guerrilla	ρ_1	0.060***	0.017	3.581
Kidnappings	ρ_2	1.971***	0.469	4.199
Assassinations	ρ_3	-0.001	0.035	-0.038
Displacement	ρ_4	-3.361***	0.978	-3.435
Age	ρ_5	0.001	0.001	1.013
Education	ρ_6	-0.021***	0.005	-4.513
Gender	ρ_7	0.087*	0.048	1.828
Adults	ρ_8	0.113***	0.018	6.365
Farm size	ρ_9	0.0003*	0.0001	-1.837
Landless	ρ_{10}	-0.566***	0.169	-3.343
Credit	ρ_{11}	0.020	0.215	0.093
Rental	ρ_{12}	-0.103	0.136	-0.759
Erosion	ρ_{13}	0.075***	0.029	2.556
Pop. density	ρ_{14}	0.001***	0.0004	3.555
dr_2	ρ_{15}	-0.356***	0.117	-3.044
dr_3	ρ_{16}	-0.436***	0.137	-3.176
dr_4	ρ_{17}	-0.369***	0.116	-3.190
dr_5	ρ_{18}	-0.369	0.129	-2.872
dr_6	ρ_{19}	0.049	0.115	0.431
dr_7	ρ_{20}	0.023	0.085	0.275
dr_8	ρ_{21}	-0.018	0.087	-0.210
dr_9	ρ_{22}	-0.245***	0.094	-2.591
dr_{10}	ρ_{23}	-0.303***	0.117	-2.596
dr_{11}	ρ_{24}	-0.272***	0.132	-2.063
σ^2		0.090***	0.011	7.866
γ		0.646***	0.069	9.409
log likelihood		96.094		

Table 4: Actual and Zero-Violence Farrell's Efficiency Indexes across Farm Sizes and Regions

	Ineff. Index				*Ineff. Index (violence=0)*				*% Change*			
Region	*Small 0-15*	*Medium 15-50*	*Large >50*	*Total*	*Small 0-15*	*Medium 15-50*	*Large >50*	*Total*	*Small 0-15*	*Medium 15-50*	*Large >50*	*Total*
1	0.86	0.81	0.90	0.85	1.00	0.98	1.02	1.00	14.0%	17.0%	12.4%	14.5%
2	0.90	0.92	0.93	0.91	1.28	1.06	1.28	1.19	37.5%	13.6%	34.7%	28.1%
3	0.81	0.84	0.85	0.84	0.57	0.61	0.64	0.62	-24.3%	-22.5%	-20.6%	-22.0%
4	0.92	0.91	0.90	0.92	1.18	0.98	0.89	1.07	25.6%	6.7%	-0.8%	15.2%
5	0.90	0.89	0.92	0.90	0.85	0.84	0.90	0.85	-4.4%	-4.4%	-2.1%	-4.3%
6	0.87	0.83	0.77	0.86	0.93	0.89	0.81	0.92	6.0%	5.9%	3.6%	5.9%
7	0.85	0.81	-	0.85	0.89	0.78	-	0.87	3.5%	-2.8%	-	2.8%
8	0.83	0.90	0.88	0.84	0.92	1.02	0.94	0.93	8.9%	11.9%	5.6%	9.2%
9	0.88	0.86	0.84	0.88	0.95	1.00	0.84	0.95	6.8%	13.8%	0.0%	7.3%
10	0.87	0.92	0.91	0.87	0.91	0.97	0.96	0.91	4.1%	4.7%	5.3%	4.2%
11	0.87	0.89	0.91	0.89	0.77	0.98	1.05	0.96	-10.5%	9.4%	14.4%	6.3%
Total	0.87	0.87	0.89	0.87	0.95	0.89	0.93	0.94	7.9%	2.3%	4.0%	6.4%

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