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Private irrigation investment in Colombia: effects of violence, macroeconomic policy, and environmental conditions

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Abstract

This paper identifies and estimates the effects of several determinants on private investment in irrigation in Colombia. It attempts to quantify macroeconomic policy, environment, and violence variables that have been identified in previous studies as significantly affecting investment in agriculture in general, and in irrigation in particular. Variables such as violence, climate, and governmental price and credit policies are used to explain changes in private investment in irrigation across regions and over time. Violence negatively affects private investment. Climate affects the investment such that in regions with favorable climate conditions, investment in irrigation is less attractive, and appropriate government crop-price and credit policies promote investment in irrigation.

1. Background

Water policies have been designed in many countries around the world, including Latin American countries such as Colombia, as a means to promote development and to provide the poor in rural areas with affordable land and water resources (World Bank, 1988). The long-term heavy investments needed to carry out these policy objectives have necessitated the direct involvement of the state. This has been done via several water-resources administration systems characterized mainly by heavy public investment and management (UN, 1991).

Recently, several countries, including countries in Latin America (e.g. Chile, Colombia, Mexico), realizing local water shortages and inefficiencies of existing water management arrangements, have considered changes in their existing water resources institu-

tions. Such changes include promoting a greater involvement of users, and encouraging private investments in the water-supply and irrigation sectors. In Colombia, for example, the new water law (HIMAT, 1993a) reorganizing the roles of the private sector in irrigation and drainage provides additional incentives for private investment, and addresses increased responsibility and management of user associations. Although the public sector is still involved in major investments, in such projects as water resource development and conveyance systems, the private sector is increasingly taking over investments in secondary and tertiary irrigation-water conveyance systems, and in farm-level investment.

Making private investment in irrigation more attractive may be one of the government's policy objectives. Previous research on private investment in irrigation referred to economic, environmental, and especially farm-level organizational parameters. Apparently, there are additional factors that may affect irrigation investment decisions. Factors such

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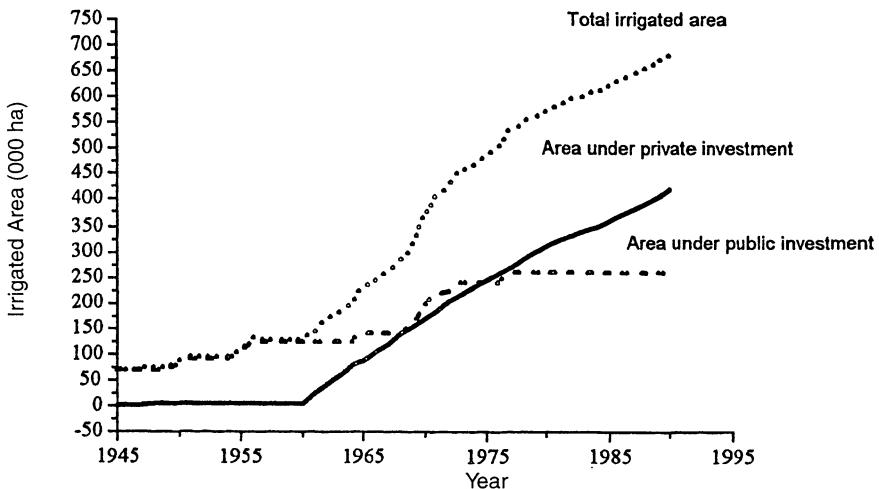


Fig. 1. Total irrigated area, and area of projects under public and private investment in Colombia (1945–1990).

as violence, leading to uncertainty in the investment and the production process, may be the overarching determinants in the investment-decision process in many countries. Evidence that violence is an important factor in investment decisions, and data to support it, exist in Colombia.

Although the existing body of empirical studies, to date, provides a better fundamental explanation of the determinants of private investment in developing countries, there is still no consensus on the theoretical framework to guide the empirical work (Levine and Renelt, 1992). In addition, as Green and Vilanueva (1990) argue, empirical research in the area of private investment behavior has been limited mainly because information on private investment has been scarce or unreliable. Thus, accumulation of empirical findings is necessary to reach a critical mass on which a comprehensive theory can be based.

This paper contributes to the body of literature on private investment by using a comprehensive and reliable data set at a country level, supporting and adding to the results of previous studies that used data at the field or farm level. The purpose of this paper is to explore empirically the possible determinants of private investment in irrigation in Colombia, and to suggest related policy measures to enhance it. Section 2 reviews private and public investment activities in irrigation in Colombia over the last three decades. Drawing on existing literature, a framework for the analysis is developed in Section 3. The

variables to be included in the analysis are discussed and defined in Section 4. Section 5 presents the results, and Section 6 concludes the paper and discusses policy implications.

2. Public and private investment in irrigation in Colombia

Agriculture is one of the major sectors in Colombia's economy. For example, in 1988–1992 it accounted for about 22% of the GDP (CEGA, 1993). Employment in agriculture accounted for nearly 25% of the country's workforce (World Bank, 1989). The GDP of the agricultural sector (excluding coffee) has risen from $20\,544 \times 10^6$ pesos in 1950 to $80\,762 \times 10^6$ pesos in 1992 (in 1975 values¹).

Based on DNP's (1991) data, the total irrigated area in Colombia as of 1990 was 681 000 ha. Of this area, 421 000 ha (62%) were irrigated by projects funded by private investment and 263 000 ha (38%) were irrigated by 27 publicly funded projects. Fig. 1 depicts the changes over time of the total irrigated area in Colombia and its breakdown by publicly and privately funded projects.

¹ The exchange rate between the peso and the US\$ in 1975 was 26.06, and in 1990 it was 502.20.

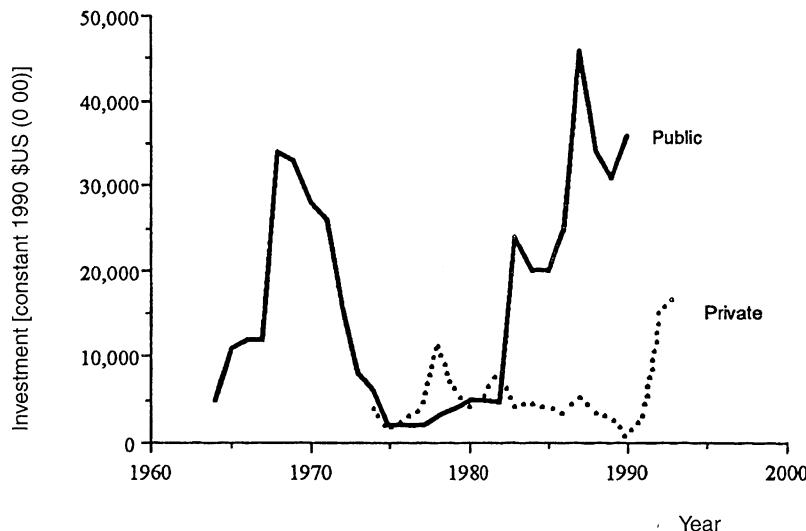


Fig. 2. Public and private investment in irrigation projects in Colombia (1964–1993).

Table 1

Area under public and private irrigation by region in 1992

Region	Potential irrigated area (ha)	Public irrigated area (ha)	Private irrigated area (ha)	Total irrigated area (ha)
Antioquia	328 921	0	3625	3625
Atlántico	203 080	24 618	1206	25 824
Bolívar	329 785	9293	3915	13 025
Boyacá	436 328	11 202	1300	12 502
Caldas	55 216	0	2765	2765
Caquetá	150 822	0	0	0
Cauca	87 924	0	34 496	34 496
Cesar	860 600	0	45 860	45 860
Córdoba	224 092	52 871	3170	56 041
Cundinamarca	409 475	21 000	18172	39 172
Guajira	217 830	0	15 714	202 116
Huila	99 450	4 601	24 831	29 432
Magdalena	467 728	47 594	8177	55 771
Meta	571 700	0	56 515	56 515
Nariño	173 029	0	40	40
N. de Santander	294 954	11 619	5000	16 619
Quindío	0	0	0	0
Putumayo ^a	na	na	na	na
Risaralda	49 680	0	0	0
Santander	156 114	8698	7000	15 698
Tolima	322 226	55 790	25 700	81 490
Valle del Cauca	303 635	10 700	202 113	212 813
Total (incl. others) ^b	6 509 200	287 454	463 059	750 513

^a No data available prior to 1989.^b Totals in Table 1 are slightly different than those cited in the text, because it includes some additional regions with marginal areas under irrigation. Source: HIMAT (1993c).

Fig. 1 suggests that irrigated agriculture is a relatively new practice in Colombia. The total irrigated area in this country was around 50 000 ha until 1950 and then started climbing to its present value. Until 1960, private-sector investment in irrigation projects was negligible. From 1960 through 1990, private irrigated area expanded at an average annual rate of 15 000 ha.

Public and private investment in irrigation projects in Colombia for the period 1964 to 1993, in constant 1990 US\$ are depicted in Fig. 2. It can be seen from Fig. 2 that between 1970 and 1990, the value of private investment declined, and that in the last 3 years (1991–1993) it increased dramatically. It can also be seen from Fig. 1 that between 1975 and 1982 there was almost no public investment in new irrigation projects. All public investment after 1982 was allocated to rehabilitation of existing irrigation systems. The areas under public and private irrigation projects, as of 1992, by the various regions, are presented in Table 1.

3. Conceptual framework

Private investment in irrigation can usually be classified at the farm and at the regional level. Investment at the regional level is mainly in water head works (dams, reservoirs) and major distribution systems. Given the relatively expensive investment in this type of infrastructure, it is usually undertaken by governments, or in some cases by groups of farmers such as regional user associations. Irrigation investment at the farm level includes investment in wells, in secondary or tertiary canals, and in new or improved irrigation and drainage technologies.

Public investment in non-water infrastructure projects such as roads and electric power, and in major water head works, is often required to trigger additional private investment in the water sector. Sometimes the crowding-out effect at relatively high levels of public investment may reduce the likelihood of private investment. Private investment in irrigation is also affected by a set of economic, social, and environmental variables, similar to those affecting investment decisions in other sectors.

The analysis in this paper draws on empirical findings in the literature on private investment in

general, and on private investment and adoption of irrigation technologies in particular that are reviewed below in Section 3.1.

3.1. Previous relevant studies and hypotheses

Several studies have attempted to explain private investment levels (including investment in agriculture) in developed and developing countries, as affected by several variables. These variables include macroeconomic policies, public investment, environmental and agroclimatic conditions, human capital, and political instability (Tun Wai and Wong, 1982; Wheeler, 1984; Cherif and Montes, 1986; Solimano, 1989; Musalem, 1989; Green and Villanueva, 1990; Barro, 1991; Levine and Renelt, 1992; Binswanger et al., 1993; Cardoso, 1993; Bleaney, 1994).

The conclusions of these studies that are relevant to the analysis in this paper suggest that trade and credit policies provided robust explanation for levels of private investment and growth. Political instability (measured either directly or through proxies) was found to be inversely related to investment and growth, although without providing robust results. In addition, it was found that appropriate agroclimatic conditions enhance private investment in agriculture.

The relationships between public and private investment were not always robust. Possible reasons include the crowding-out effect, and the fact that public investment in agriculture, driven also by political interest, is not always in locations with appropriate agroclimatic conditions.

The literature on irrigation technology adoption (dealing with private decision makers) supports the findings of the above mentioned studies. A synthesis of the conclusions of the relevant studies on adoption in Feder et al. (1985), Negri and Brooks (1990), Caswell (1991), Dinar and Zilberman (1991), Dinar et al. (1992), and Feder and Umali (1993) suggests similar effects on adoption from credit and trade policies, and from agroclimatic conditions.

Political instability, which has been used in some of the previous studies, does not capture the effects of domestic violence. Several studies exist that account for the effects of domestic violence on economic activity, investment, and growth. Shami (1990) describes short- and long-term effects of violence on the economy in Pakistan. Short-term impacts include

loss of working days that lead to reductions in production and in tax revenues. Long-term impacts include stagnation of private local and foreign investment (despite government assurances), shifting of the skilled labor force to safer regions, and capital flight from the country.

Morrison (1993) claims that there is strong reason to believe that noneconomic social variables such as violence play a key role in many decisions, including investment decisions, and that "this is almost certainly the case in Guatemala, El Salvador,... Colombia,... and Peru". Violence was measured as the number of reported homicide cases in the country.

Two studies exist that address violence in Colombia. Medina (1989) describes the history of violence in Colombia in two critical periods during the 1940s and the 1980s, and the negative effects of violence in urban and rural areas on the economic situation in the country. Jaramillo and Junguito Bonnet (1993) used a measure for violence in an econometric study aimed at determining whether or not the new trade policy (Apertura) of 1990 caused the agricultural crisis in Colombia. Violence explained part of the changes in agricultural production over the period 1968–1987.

3.2. The empirical models

Based on the reviewed work, it is assumed here that three sets of variables affect the level of private investment in irrigation and drainage. One set of variables, including environmental variables such as weather, climate, and soil type, may explain differences in investment levels over time and across regions. While weather variables measure seasonal (daily, monthly, yearly) changes, climate variables represent the long-term weather conditions in a particular region. Therefore, it is likely that both climate and weather conditions will affect irrigation investment decisions. Another set of variables, including macroeconomic policy variables such as crop prices (which affect agricultural profitability) or improved credit conditions for irrigation loans (which make investment in irrigation more attractive), may affect the propensity of entrepreneurs to invest in irrigation projects.

Based on the studies reviewed earlier, investors are more likely to invest in projects associated with

agricultural technologies as the profit margin in farming grows wider, and when the investment is less risky, assuming that the investment either saves water and other inputs or increases yield. In the case of irrigation in Colombia, the profit margin for agricultural products that are either exported, or for which import substitutes can be found, has been determined until recently by a macroeconomic policy of price protection. The opening of the economy (Apertura), including the agricultural sector, in 1990 to international competition had negatively affected the profitability of several agricultural crops (Jaramillo and Junguito Bonnet, 1993), and, therefore, may have had a direct effect on private investment in irrigation.

Government lending policies may positively affect investment by providing attractive credit lines for investors and by adjusting them for specific types of irrigation projects. Another macroeconomic intervention, public investment in irrigation infrastructure such as head works and main conveyance systems, is expected to have positive effects on private investment, keeping in mind the crowding-out effect. Public investment in infrastructure such as roads, energy facilities etc., may explain a good deal of the private investment when the entire economy is considered. In the case of irrigation in Colombia, when the analysis is a cross-section, some of the public investment in infrastructure (in water and other sectors) in one region may not be relevant to private investment decisions in irrigation in another region. We did not have data on public investment that could be used to test this hypothesis. Our public investment data is aggregated at the national level. We, therefore, estimate the effect of public investment on private investment in irrigation using national-level data only.

Finally, a variable measuring violence is introduced. Farmers, who are risk averse, might be less likely to invest in expensive irrigation equipment if it might be subject to vandalism, or if local farm output might not reach the market because of violent attacks on roads. The violence effect can be interpreted as a threat to private property and capital. A higher level of violence may, therefore, negatively affect private investment in irrigation.

Private investment in irrigation (I^P and I^R , depending whether it is a regional analysis or a national analysis, respectively) will be explained by the

three groups of variables: environmental conditions, violence, and government macroeconomic policy. Environmental conditions (E) are represented by several variables. The first variable is an aggregated climate variable (C^L) that is fixed at the regional level. The aggregated climate variable is comprised of several climate indicators (annual rainfall, rainfall days, humidity, and temperature). The effect of C^L on private investment is not known a priori; while increases in annual rainfall, rainfall days, and humidity are expected to negatively affect private investment in irrigation, higher values of temperature are likely to positively affect irrigation investment. The ultimate effect of this variable depends on the interactions among the four climate indicators. A weather variable of total annual rainfall (R), which varies across regions and over time, is expected to negatively affect private investment since higher amounts of rainfall reduce the need for irrigation. The second variable which expresses violence (v), is expected to negatively affect private investment. The last group of variables for explaining private investment is government macroeconomic policy intervention, which is represented by the following variables: (1) an aggregated agricultural crop price (p or P , for regional and national analyses, respectively); (2) a real interest rate for investment projects in irrigation and drainage (ϕ); and (3) a dummy variable distinguishing between periods with different credit conditions for agricultural and irrigation projects (D). Higher crop prices, lower real interest rates, and improved credit conditions are each expected to positively affect private investment.

Two versions of the cross-section model were estimated. The first version assumes that investment decisions in Year t depend on information available during the same year. The second version assumes that effects are lagged; that is, decisions in Year t are based on information from Year $t-1$.

The cross-section models to be estimated are:

$$I^p = g(E, v, p, D, \phi) \quad (1)$$

The cross section time-series lagged models are

$$I_t^p = h(E_{t-1}, v_{t-1}, p_{t-1}, D, \phi_{t-1}) \quad (2)$$

A model based on time-series data at the national level was also estimated. This model attempts to verify the hypothesis that public investment boosts

private investment in the sector. The model assumes that private investment in irrigation at the national level (I_t^P) is affected by public investment in irrigation (I_{t-1}^B), violence (V_{t-1}), crop prices (P_{t-1}), and credit conditions (D).

$$I_t^P = e(I_{t-1}^B, V_{t-1}, P_{t-1}, D) \quad (3)$$

where $V = \sum_{\text{regions}} v$, and P is a weighted average of the regional crop prices p .

The empirical relationships to be estimated assume profit-maximizing private investors. Therefore, based on the conceptual framework described above, private investment decisions will respond to policy and state variables in the manner shown below. In these relationships, I_x^p or I_x^P represents the first-order derivatives of I^p or, I^P and I_{xx}^p or I_{xx}^P (time index is ignored for simplicity) stands for the second order derivatives of I^p or I^P with respect to the relevant components of X ($X = C^L, R, I^B, p, P, \phi, v, V$).

$$\begin{aligned} I_{C^L}^p &\geq 0 & I_{C^L C^L}^p &\leq 0 & I_R^p &\leq 0 & I_{RR}^p &\leq 0 \\ I_p^p &\geq 0 & I_{pp}^p &\leq 0 \\ I_D^p &\geq 0 & I_{DD}^p &\leq 0 & I_\phi^p &\leq 0 & I_{\phi\phi}^p &\leq 0 \\ I_v^p &\leq 0 & I_{vv}^p &\leq 0 \end{aligned} \quad (4)$$

The aggregated private investment responds in a similar way, and in addition,

$$\begin{aligned} I_B^P &\geq 0 & I_{Bt}^P &\leq 0 & I_D^P &\geq 0 & I_{DD}^P &\leq 0 \\ I_V^P &\leq 0 & I_{VV}^P &\leq 0 & I_p^P &\geq 0 & I_{pp}^P &\leq 0 \end{aligned} \quad (5)$$

The model assumes substitution between policy and environmental variables, or between policy variables and violence. For example, if government would consider a certain level of private investment in a given region as a policy objective (e.g. for enhancing development in the region), then the influence of policy-variable levels, such as crop prices and credit conditions, on private investment could compensate for less desirable regional conditions, such as weather or climate and violence. Possible substitution between policy and environmental or violence variables can be estimated from the results of this analysis. For example, a government might consider supporting private investment until it reaches a certain level, \bar{I}^p , in productive regions with high levels of violence. Since violence negatively affects private investment, a premium for private investment

in selected regions that are characterized by high violence could be provided, ignoring the additional institutional costs associated with this intervention. This premium can be in the form of improved credit conditions (e.g. extended repayment and grace periods that result in lower real interest rates). The rate of substitution between the real interest rate and violence, as an example, is provided by

$$\frac{d\varphi}{dv} = \frac{\partial I^p}{\partial \varphi} \frac{\partial v}{\partial I^p} \text{ for } I^p = \bar{I}^p \quad (6)$$

A similar substitution could be considered between climate and interest rate to reflect support for regions with unfavorable climate conditions. Government assistance, via special credit conditions, for private investment in irrigation projects is practiced in Israel (Dinar and Yaron, 1992). Government policy there is intended to support farmers living in border regions, where they experience hostility risk, by providing them with special credit conditions for investment in improved irrigation technologies (as well as other agricultural projects).

4. Data and empirical specifications

The analysis uses pooled cross-section and time-series data combined with fixed regional effects. In preparing the data for the analysis, several sources have been available. These sources provided information on the major agricultural production regions in Colombia over the last three decades. The main information sources are listed below, including the years for which data was available.

Twenty one regions (actually, 22 regions exist, but Putumayo region was created in 1989, and therefore, not included in the analysis) were included in the analysis (see Table 1). Production data in DNP (1993a,b) that include cultivated area and production for all crops grown in each region for the period 1981–1992, are used in the analysis. Major crops under irrigation that together capture 60–100% of the harvested land include beans, maize, caña panela, plantain, cotton, sorghum, cassava, barley, potato, wheat, soybeans, sugarcane, rice, palm oil, and banana. Three to five major irrigated crops, accounting for 60–70% of the reported cultivated area in each region, were selected.

Private investment in irrigation projects is defined in this paper as the sum of loans provided by the public agencies FFAP and FINAGRO to private-sector investors (farmers, farm corporations) for irrigation and drainage projects and for wells. Data on private investment (in current pesos) in irrigation and drainage projects and in wells, at the regional level for the period 1974–1989 were taken from Banco de la Republica (various years). Data for the period 1990–1993 (in current pesos) was provided directly by FINAGRO (FINAGRO, 1994). FINAGRO loans are assumed to represent 60–70% of the loans available to the private sector for investment in irrigation and drainage projects (Ramirez, 1993), and will therefore be used as an estimate of private irrigation investment for the period 1990–1993. The data were converted to constant 1990 US\$ and categorized by region and year. To avoid scale bias, the analysis measures private investment as the value of regional investment per hectare of potential irrigated land (Table 1).

Climate data for the regions analyzed were found in HIMAT (1993b). Weather data for the indicated regions were provided by HIMAT (1994) for the period 1974–1993. Several climate and weather variables were available for the analysis at the regional level. These variables include rainfall (measured in millimetres per month), rainfall days (per month), temperature (monthly average centigrades), and humidity (monthly average percent). To capture the overall climatic effect of these variables, and to prevent multicollinearity between some variables (such as humidity and precipitation), a principal component analysis (PCA) of the four variables was performed to generate a single climate variable, which was subsequently used in the correlation analysis. The weather data spans the period 1974 through 1993 and consists of data points for the same four climate variables (temperature, humidity, rainfall, and rainfall days). Although multiple weather stations exist in some regions, to maintain consistency, only one weather-station figure per region was used in the analysis. It was assumed that this station (as reported in HIMAT, 1993b) represents the region.

Violence is reported on a cross-section and a time-series basis. The data are used to scale violence by the number of inhabitants in each region. Regional population figures were estimated using data

from the 1973, 1985, and 1993 censuses (DANE, 1985, 1989, 1993). Regional data on homicides and assassinations are taken from Losada Lora (1991) for 1975–1988 and from Revista Criminalidad for 1989–1992. The data do not allow for disaggregation of rural and urban violence, so it is assumed that there is a crossover effect of urban violence on rural investment choices.

Regional population growth estimates were obtained by fitting a semilog growth curve to available data points in 1973, 1985, and 1993, for each region, in order to calculate population figures for years for which census data was not available. Growth curves for the 21 regions (not presented) suggest annual growth rates ranging between 0.83% in Quindío to 4.07% in Meta. *R*-square values were 0.904 and above. Although census data exist for previous years, they were not used since some regional boundaries were changed in the period prior to 1973, which does not allow a basis for comparison.

Annual regional violence was calculated as the sum of all homicide and assassination cases in the police homicide statistics for the period 1975–1992. In order to account for different population scales that affect violence in the different regions, a violence figure per 100 000 inhabitants is used in the analysis.

Public investment in irrigation projects, and maintenance of existing projects, in Colombia is reported in DNP (1991). Public investment in monetary values is reported at the national level only. The data, in constant 1990 pesos, have been converted to constant 1990 US\$, based on the inflation- and exchange-rate figures in DNP (1993c). Exchange rates between the Colombian peso and the US\$, and inflation rates for the period 1970–1993, are provided in DNP (1993c).

Crop prices paid to producers were used in the analysis. Domestic price data are taken from Colombian Department of Agriculture statistics, and international prices are from IMF statistics, as provided in DNP (1993c). The prices are largely producer prices, with the exception of caña panela, plantain, potato, and yucca, for which only consumer prices were available.

The aggregated crop price is calculated using different variables. Crop-price data for the period 1970–1993 are provided by DNP (1993a,b,c) and by Valdés and Scheffer (1993). The data include domes-

tic prices (in pesos) for all crops included in the analysis, and international prices (in US\$) for a subgroup of crops that have been affected by the government's 1990 trade-liberalization policy. Yield data and cultivated area, by crop, are provided for the period 1980–1991 in DNP (1993b).

The crop prices represent, for some crops, throughout part of the period (1981–1989) the governmental 'price protection policy.' This policy set tariff and non-tariff protection against imported crops, and price stabilization and discriminated exchange rates for exported crops. Since 1990, a trade-liberalization policy that introduced international prices into the local price system (Apertura) has been in effect.

In order to capture the price effect, an aggregated price variable was calculated for each region (*p*), and also at the national level (*P*). The variable *p* is a cross-section and time-series variable, since each region is characterized by a different set of major crops, and assuming (based on observations) that these crops do not vary over the time span of the analysis, except in their shares. These crops together account for 60–70% of the cultivated areas. All other crops, individually accounting for marginal areas, and also not cropped every year, were not included in the analysis, assuming that they have marginal effects on farmers' investment decisions. A PCA was applied to each region and an aggregated price (*p*) calculated for each region in every year. All price values are expressed in constant 1990 US\$.

A regional revenue variable was also calculated by multiplying the cultivated area by the yield and the crop-yield price, and by aggregating over the various crops in the region. This variable replaces the price variable in some of the estimates. All revenue values are expressed in 1990 US\$.

Credit data for private investment in irrigation and drainage projects, and for drilling wells, were provided by Vaca (1994). The data include nominal interest rates and grace periods for different loan programs for the period 1974–1993. Nominal interest-rate data were taken from government sources (FFAP and FINAGRO), and from Vaca (1994). Where more than one rate was identified (e.g. a short-term and a medium-term rate of interest), the rates were summed and an average calculated. Based on Vaca (1994), representative loan conditions were calculated for each year. This includes nominal inter-

est rates, repayment periods, and grace periods, to calculate more precise real interest rates. Using the annual inflation information, a real interest rate was calculated using a numerical solution to the equation

$$X \frac{\varphi(\varphi + 1)^T}{(1 + \varphi)^T - 1} = \sum_{i=t_g+1}^T \times \frac{X \frac{\phi(\phi + 1)^{T-t_g}}{(1 + \phi)^{T-t_g-1}}}{\left(\prod_{i=t_g+1}^T (1 + \xi_i) \right)} \cdot \frac{1}{(1 + \phi)^i} \quad (7)$$

In the equation X is the loan (it can be set to 1 and eliminated from the equation); ϕ is the loan's nominal interest rate; T is the repayment period; t_g is the last year of the grace period; ξ_i is the inflation rate in year i ; and φ is the real interest rate of that same loan. Since all variables are known except φ , it can be calculated from the equation. The real interest rate (φ) is a time-series variable, but it is fixed at the regional level. The results (not presented) indicate that real interest rates for these investments have been consistently negative over the past 20 years.

5. Results

The regional private investment values suggest that, in absolute values, private investment in irrigation is intensive in only a few of the 21 regions included in the analysis. For example, only Antioquia, Cesar, Córdoba, Cundinamarca, Magdalena, and Valle del Cauca each have total annual investment values that exceed US\$ 800 000. However, it is clear that the potential amount of irrigable land affects the investment values, as can be seen from the individual per-hectare private investment values that range between US\$ 250 and US\$ 2000.

The trend in violence at the national level in Colombia is presented in Fig. 3.

Several observations can be made at this point. First, except for three short periods (1977–1978, 1981–1983, and 1991–1992), the level of violence in Colombia (at the national level) is steadily in-

creasing. Second, the regional data (not presented) indicate wide variation in violence levels over time and across regions.

The regional data on violence (not presented) reveal several interesting general results. First, it is clear that violence (in absolute terms) varies significantly across regions and over time. The variation over time is explained partially as affected by political events (Medina, 1989). For example, in 1988 there was a significant increase in the level of violence in many regions. The variation in absolute values of violence across regions is probably also affected by population increases. Regions with relatively greater populations also have a higher incidence of violence.

Another observation obtained from the data is that in all regions, there is an increase in the number of violence cases over time. Some regions have a moderate increase, while other regions have a dramatic increase. For example, in Valle del Cauca total violence cases increased from 534 in 1975 to 3022 in 1992. In Antioquia total violence cases increased from 1082 to 9127 over the same period. Since 1989, only six regions have experienced a decrease in the level of recorded violence. Table 2 presents changes in violence from 1975 to 1992 in the regions that are included in the analysis. Results show that for most regions, violence has increased by several hundred percent over that period, but with a lower rate of increase between 1989 and 1992.

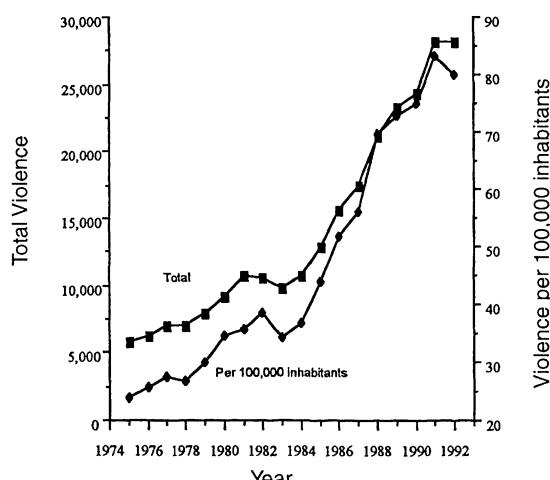


Fig. 3. Violence in Colombia (1975–1992).

Table 2

Change in cases of violence from 1975 to 1992 in Colombia

Region	Change in total cases of violence (%)		Change in cases of violence per 100 000 inhabitants (%)	
	1975–1992	1989–1992	1975–1992	1989–1992
Antioquia	744	18	500	11
Atlántico	178	30	67	19
Bolívar	307	37	198	30
Boyacá	131	6	92	3
Caldas	375	2	269	–3
Caquetá ^a	134	39	77	29
Cauca	276	69	189	61
Cesar	331	8	184	1
Córdoba	313	–15	188	–20
Cundinamarca	412	30	183	17
Guajira	74	–6	31	–10
Huila	354	30	202	21
Magdalena	319	73	240	67
Meta	159	–19	30	–28
Nariño	148	–1	86	–6
N. de Santander	295	28	181	21
Putumayo ^b	na	–17	na	–28
Quindío	467	75	392	71
Risaralda	90	–63	33	–65
Santander	173	7	112	3
Tolima	171	31	126	27
Valle del Cauca	466	31	312	24

^a Data available for 1981 through 1992 only.^b No data available prior to 1989.

Regression analyses that included each climate variable (temperature, rainfall, rainfall days, and humidity) separately did not provide good results. This makes sense since the climate effect is combined. Therefore, a PCA analysis was performed on the climate variables. Using PCA, the first eigenvector explaining 55% of the standardized variance among the four climate variables are, respectively, –0.437, 0.453, 0.620 and 0.467. Based on these values, a global climate variable was calculated and used in the correlation analyses. The climate variable, as defined here, is easy to interpret. Higher temperature values increase the likelihood for investment in irrigation, and all other variables work in the other direction. Therefore, the negative sign of the first weight (–0.437) corrects for the temperature effect, and the overall effect of the climate variable depends on the interaction among the four variables. The overall effect of the climate variable in the analysis yielded a negative coefficient. That is, higher values for the climate variable are negatively correlated

with investment in irrigation. This makes sense since higher humidity, higher rainfall and more rainfall days decrease the need for investment in irrigation projects.

At the aggregate level, one can observe from Fig. 2 that, after more than a decade of continuous decline in private investment in irrigation, the trend has changed, and a significant increase in investment is realized between 1991 and 1993 (and also in 1994, which is not shown in Fig. 2). What happened before 1990 and after 1990 that can explain the change in the trend?

Based on Vaca (1994), the new credit policy, in effect starting in 1990, introduced many features that should provide incentives for private investment. First, there are more credit lines that can fit special conditions and investment types (such as irrigation equipment, drainage etc.) as opposed to one credit line before 1990. Second, there are more resources available for loans, compared to the period prior to 1990. Third, loans cover 80% of the investment,

compared to 50–60% prior to 1990. Fourth, grace periods are negotiable on an individual basis, compared to a fixed grace period of 3 years prior to 1990. And fifth, loans are processed faster, in less than 6 months now, compared to 1–3 years prior to 1990.

Finally, a regression analysis was conducted, aimed at estimating the relative effect on investment of the variables discussed earlier. Since only 11 years (1981–1992) of crop-yield and price data are available for the regions under investigation, some of the investment and the violence data, existing for the years beyond that range, could not be used.

Regional effects have been introduced via dummy variables. These are special regional effects that have not been captured via other variables. Valle del Cauca was set to be the benchmark region, and all other regional effects were estimated relative to that region.

Quadratic and linear functional forms were estimated using a GLM procedure. Estimates of the quadratic functional form, with cross effects between price and violence (negative coefficient), did not provide superior results and are not presented. The lag relationships resulted in significantly superior results compared to the other relationships in only one estimate, and therefore only one lag result will be presented. The real interest rate variable was associated with a negative value, and was not significant. This result, although opposite to the theory, makes sense under the situation in Colombia as described above. The inaccessible credit programs made entrepreneurs not interested in investments, even with very low (negative) real interest rates. The aggregated climate variable was the only variable in the group of environmental variables that was associated with a significant coefficient in all regressions; therefore, it will be presented.

The results shown in Tables 3 and 4 place a dollar value on several variables found to affect private investment in irrigation in Colombia. The effect of violence on investment in all estimates is negative and should be interpreted in the following way (Table 3): An increase in violence by one case per 100 000 inhabitants reduces private investment by about US\$ 0.11/km² of arable land for the linear estimates. An increase in revenue by US\$ 1/ha of irrigated land increases private investment by US\$

0.0001/km² of arable land (this variable was found to be not significant). An increase in the value of the climate variable by 1 unit (a combination of temperature, rainfall, rainfall days, and humidity) reduces investment in irrigation by US\$ 0.0054/km² of arable land. The 21 regions differ significantly in their responses, as is reflected in the estimated coefficient values assigned to the 21 dummy regional variables.

Table 4 provides additional results for a quadratic functional forms that were estimated. Here, the price variable replaced the revenue variable, and both price and violence have a quadratic effect. In Eq. 3

Table 3
Results of the linear estimates of factors affecting private investment in irrigation projects

Variable	Dependent variable is regional private investment			
	Eq. 1		Eq. 2	
	Estimated coefficient	t-value	Estimated coefficient	t-value
Intercept	113.75	10.06	125.53	3.42
Violence	−0.107	−1.55	−0.106	−1.53
Revenue	0.000099	0.21	0.000098	0.21
Climate			−0.0054	−0.34
<i>Region</i>				
Antioquia	−91.03	−6.69	−98.03	−3.94
Atlántico	−77.34	−6.00	−86.70	−2.83
Bolívar	−108.35	−8.33	−117.15	−4.01
Boyacá	−78.40	−6.18	−87.92	−2.84
Caldas	−88.40	−7.00	−94.56	−4.25
Caquetá	−103.75	−8.20	−105.32	−7.79
Cauca	−105.64	−5.86	−111.35	−4.50
Cesar	−71.56	−5.68	−80.25	−2.80
Córdoba	−107.27	−8.41	−115.68	−4.13
Cundinamarca	−64.18	−5.04	−72.85	−2.54
Guajira	−102.38	−8.13	−112.57	−3.43
Huila	−83.95	−6.63	−91.86	−3.44
Magdalena	−95.68	−7.53	−106.03	−3.19
Meta	−102.96	−8.03	−103.86	−7.91
Nariño	−106.96	−8.31	−115.97	−3.91
N. de Santander	−98.96	−7.84	−108.23	−3.57
Quindío	−95.09	−7.53	−101.12	−4.61
Risaralda	−84.73	−6.62	−90.27	−4.33
Santander	−106.42	−8.42	−114.33	−4.28
Tolima	−79.69	−6.18	−84.91	−4.21
R-square	0.428		0.428	
N	224		224	
F	6.84		6.52	

Table 4

Results of the quadratic estimates of factors affecting private investment in irrigation projects

Variable	Dependent variable is regional private investment					
	Eq. 3		Eq. 4		Eq. 5 ^a	
	Estimated coefficient	t-value	Estimated coefficient	t-value	Estimated coefficient	t-value
Intercept	195.95	10.45	195.34	10.39	231.96	12.50
Violence	−0.798	−2.80	−0.811	−2.85	−1.22	−4.30
(Violence) ²	0.00253	2.03	0.00265	2.10	0.00402	3.23
Price	0.00117	0.77	0.0154	0.94	0.00320	0.17
(Price) ²	−0.0000172	−1.00	−0.0000190	−1.08	0.0000236	−1.22
Credit			4.18	0.60	15.42	2.18
<i>Region</i>						
Antioquia	−141.86	−7.59	−139.94	−7.37	−151.31	−7.92
Atlántico	−147.18	−8.66	−147.75	−8.66	−161.54	−9.40
Bolívar	−181.30	−10.72	−182.36	−10.70	−207.94	−12.13
Boyacá	−137.43	−7.78	−136.71	−7.71	−155.72	−8.76
Caldas	−138.13	−7.48	−136.41	−7.29	−146.83	−7.82
Caquetá	−151.95	−8.05	−149.84	−7.79	−165.38	−8.57
Cauca	−156.50	−9.88	−156.21	−9.84	−167.12	−10.38
Cesar	−117.86	−5.98	−114.97	−5.66	−135.58	−6.57
Córdoba	−171.27	−10.69	−171.69	−10.69	−188.17	−11.59
Cundinamarca	−127.86	−7.19	−127.45	−7.16	−154.08	−8.64
Guajira	−150.24	−7.68	−147.71	−7.37	−165.32	−8.21
Huila	−144.15	−8.42	−143.71	−8.37	−161.01	−9.33
Magdalena	−149.43	−8.64	−148.10	−8.48	−163.52	−9.31
Meta	−149.63	−8.11	−147.54	−7.85	−159.02	−8.43
Nariño	−175.43	−9.57	−175.22	−9.54	−201.03	−10.99
N. de Santander	−156.14	−8.46	−154.83	−8.32	−179.53	−9.66
Quindío	−146.33	−8.65	−145.45	−8.55	−156.64	−9.11
Risaralda	−106.40	−6.18	−104.36	−5.93	−116.55	−6.58
Santander	−163.92	−9.85	−163.54	−9.80	−179.85	−10.68
Tolima	−140.05	−8.56	−139.75	−8.53	−159.28	−9.53
R-square	0.514		0.515		0.549	
N	235		235		234	
F	9.25		8.87		10.11	

^a One-year lags for Violence and Price are used.^b Durbin–Watson D test was run for the lag estimates for each region.

* No autocorrelation; ** inclusive positive autocorrelation.

in Table 4, the variables are violence and price, and in Eq. 4 in Table 4, the dummy variable for credit is also included. In both equations the special regional effects are captured via the dummy regional variable. Violence has a negative effect on private investment, but the squared relationship (Violence²) has a positive effect. However, the overall effect of violence on private investment, in the range of values for the various regions, is still negative.

The aggregated price effect on private investment is positive and diminishes as prices increase. This is

also in agreement with previously published results in the field of technology adoption, and also in agreement with studies reviewed earlier that estimated price-policy effects on private investment in general, and in Latin America countries. The credit dummy variable suggests that private investment has been positively affected by the expanded package of credit programs offered by the government starting in 1990. Holding all other factors constant, private investment during 1990 to 1992 was higher than in years prior to 1990, by US\$ 4.18/km². The credit

Table 5
Results of the estimates of factors affecting private investment in irrigation projects (national level analysis)

Variable	Dependent variable is aggregated private investment in Year t			
	Eq. 6		Eq. 7	
	Estimated coefficient	<i>t</i> -value	Estimated coefficient	<i>t</i> -value
Intercept	1094.07	4.04	573.13	1.28
Violence (Year $t - 1$)	-0.784	-3.69	-0.958	-4.16
Price (Year $t - 1$)	0.020	0.058	1.575	1.37
Public investment (Year $t - 1$)	0.00658	1.22	0.0035	0.66
Credit			759.39	1.41
<i>N</i>		10		9
R-square		0.773		0.848
Durbin-Watson		1.879		1.594

variable, although having positive effect, was not significant. The special regional effects were captured by the regional dummy variable, and have magnitudes similar to the results shown in Table 3.

Eq. 5 in Table 4 presents the results of estimated relationships that include effects on private investment in Year t of violence and prices occurring in Year $t - 1$, as well as the dummy credit variable. The results for the lag estimate indicate that violence and price effects in Year $t - 1$ and credit conditions significantly affect investment decisions made in Year t .

Table 5 presents the results of estimated national-level relationships that include the effects on private investment of 1-year-lagged public investment, violence, and aggregated crop price. The results shown in Table 5 indicate that, also on an aggregated national level, the violence and price variables have significant effects on private investment. Public investment enhances private investment, and improved credit conditions, as measured by the dummy variable, increase private investment. Durbin-Watson test results suggest no autocorrelation between the lagged variables.

6. Conclusions

The available data on public and private investment in irrigation and drainage in Colombia used in this paper support the argument that private investment has declined over time (although it increased

between 1990 and 1993). The analysis in this paper focused on determining the factors affecting private investment in irrigation in Colombia. To quantify the determinants affecting private investment, the paper draws on previous literature on adoption of irrigation technologies in general, and literature on investment determinants in Latin American countries.

Three sets of variables that may affect investment decisions were considered: physical variables that represent local conditions, including climate; a social variable, violence; and economic-policy variables, including crop price and credit conditions, and public investment in irrigation projects. Several additional variables considered did not provide good results and were not presented.

The estimated relationships explain 42–55% of the variance in private investment among regions and over time, and about 80% of the variance in private investment at the national level. The climate variable affects the investment such that in regions with favorable climate conditions, investment in irrigation is less attractive. Violence is a significant factor that negatively affects private investment. Finally, agricultural profitability that reflects government crop-price policy promotes investment in irrigation. An additional important result is that there are significant differences across the analyzed regions. These differences mean that, while holding all other factors constant, there are other regional effects that influence investment decisions. Public investment in irrigation in Colombia, although relatively high, can still enhance and direct private investment.

The analysis indicates that public investment in irrigation can be used as a policy tool. Regional data, if available, could provide more specific results.

The results of this analysis could be used to guide policy makers in enhancing investment in irrigation. The results provide both quantitative measures for the different effects, and they provide some indication for regional preferences. Since regions differ significantly in climate and weather conditions, and in natural land endowments, differential credit programs could be tailored to different region types, given that all other conditions remain the same. These programs may take into account the relative advantages for irrigated agriculture in the various regions of Colombia. Public investment could, if no special social plans exist, focus only on improving and expanding the infrastructure needed to further encourage private investment, instead of developing additional, 'inefficient' irrigation projects.

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