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Modernization of a peasant crop in Colombia: evidence and implications

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Abstract

The survival of the small-farm sector in the process of agricultural modernization in Latin America has been a concern for many authors and institutions. It is generally believed that the small-farm sector is bypassed in the process of agricultural development. The authors analyze modernization of bean/maize cropping systems in Southern Colombia. Prices, production practices and profitability are compared for 1975 and 1989. By means of a production function, the effects of allocative efficiency, technical efficiency and technical change on productivity and profitability are analyzed. The observed changes reflect very well the price trends over the period. Between 1975 and 1989, total factor productivity increased by 50%. Bean/maize producers almost doubled returns to land and labor. Increased technical efficiency had most effect on profitability, followed by technical change. Allocative efficiency had more impact on yields than on profitability because it was associated with high input costs. Considerable opportunities for further productivity increases were identified. Conclusions on the nature of the modernization process are drawn. Implications for agricultural policy, research and the role of the small farm in agricultural development are derived.

1. Introduction

Agricultural modernization has received considerable attention in Latin America. Most studies find rapid change in the large farm sector, but only slow change or stagnation on small farms (Piñeiro and Trigo, 1983). Many authors concluded that agricultural modernization and technical change were achieved at the cost of the small farm sector (de Janvry, Sadoulet and Wilcox Young, 1989; CEDAL, 1983; Grindle, 1986; Gonzalez C. et al., 1987; Hintermeister, 1985). As FAO (1988) indicated: "[with] the emergence of a modern sub-sector of large- and medium-size farms, progress largely bypassed the numerous small peasant farms."

The equity problems that this would cause were widely recognized (de Janvry and Sadoulet, 1990). Land reform programs were one solution (Binswanger and Elgin, 1990), but in Latin America land reform often did not have sufficient political support to effectively address the equity

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problem. Integrated rural development programs became widely spread during the 1970s (Zandstra et al., 1979) as an alternative, supplying to the poor better living conditions and more technical assistance, but not more land.

More recently, modernization is also associated with reduced sustainability (Altieri and Hecht, 1990). Genetic erosion, excessive pesticide use, soil acidification, salinization and compaction are often mentioned in the same breath with modernization.

In the debt crisis of the 1980s, the need for Latin American agriculture to become more productive was strongly felt in order to compete in world markets and obtain foreign exchange (Krueger et al., 1988; Knutsen, 1990). The small-farm sector could potentially be very competitive because of its low capital intensity (Piñeiro, 1988; Janssen and Sanint, 1991); however, its ability to modernize was often thought of poorly.

In this paper we provide evidence on the process of modernization of small-scale bean/maize production in Colombia from before the debt crisis (1975) to roughly its end (1989). Maize and even more so beans are traditional peasant crops (Crouch and de Janvry, 1980; Lopez Cordovez, 1982), even though by now most production is marketed.

2. Characteristics of agricultural modernization

We distinguish three components in the modernization process: (1) Allocative efficiency, which concerns movements along the production isoquant, substituting capital for land or labor or (occasionally) vice-versa (Fig. 1, movement A). Allocative efficiency is principally driven by changing factor or input prices. When inputs become cheaper or more readily available, allocative efficiency results in intensification. (2) Technical efficiency which concerns the trial and error process of combining inputs and production factors more effectively. Technical efficiency (or learning) shifts the average production isoquant on which farmers operate more closely to the isoquant that represents the production frontier (Fig. 1, movement B). (3) Technical change, which concerns the application of previously unknown and unavailable production techniques. Technical change shifts both the average production isoquant and the frontier production isoquant closer to the origin (Fig. 1, movement C).

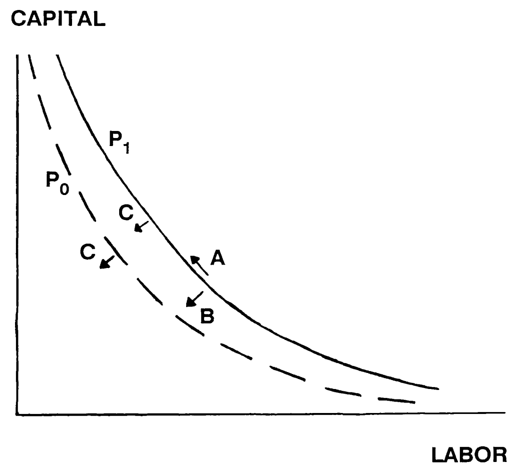

Fig. 1. Allocative efficiency, technical efficiency and technical change. Production isoquant P_0 represents the average production isoquant on which farmers operate. P_1 represents the technically most efficient isoquant (the frontier isoquant). A, changing allocative efficiency; B, increased technical efficiency; C, technical change.

Piñeiro and Trigo (1983) conclude that modernization was most effective when farmers' interests were guiding the supply of technology through a process of social articulation. Pomareda (1991) mentions social organization as a condition for successful change. Social organization improves farmer access to innovations and supports their diffusion. Simultaneously, modernizing farmers normally become market-dependent and more integrated in society's structure.

Modernization may concern changes in the use of inputs forthcoming from the private sector (often fertilizer, pesticides, machinery) or changes forthcoming from the public sector (often improved varieties or crop management). Some authors, such as Arnon (1987), suggest that modernization takes place more rapidly if a package of complementary changes is offered, because the package enhances the individual effect of each change. Other authors (see Tripp, 1991) argue that it is very difficult to design an optimal package, because of cash flow considerations, unforeseen constraints or opportunities, or sensitivity of the package results to small changes in production conditions. They state that farmers evaluate possible improvements one by one, though they may be adopted stage-wise (Graf et al., 1991).

3. Methodology

In 1975, the bean production regions of Huila and Nariño, both in South Colombia (Fig. 2), were surveyed as part of the process to establish a research strategy for the Bean Program of the International Center for Tropical Agriculture (Spanish acronym: CIAT). In Huila, 60 bean farmers were interviewed and in Nariño, 64. Farms were visited four times: shortly after planting; before the bean plants were flowering; at pod formation; and at the moment of harvest. Most farmers were using a maize/bean intercropping system. Data were gathered on farm characteristics, area planted with beans, yields, varietal use, disease and pest incidence, input use, labor requirements, credit, marketing, and production costs. Soil and seed samples were taken (Ruiz de Londoño et al., 1978).

In 1989, the same regions were surveyed again. This time in Huila 79 farmers were interviewed and in Nariño 62. Three visits were made: at the moment of planting; at pod filling; and at the moment of bean harvest. Data were gathered on the same subjects as in 1975, with the exception of disease and pest incidence.

Due to the absence of a complete list of bean producers that could be used for random sampling, a three-stage sampling procedure was used on both occasions. First the most important bean producing municipalities were selected. Within these municipalities, hamlets were chosen at random. Within each hamlet, five or six farmers were randomly approached. When it was impossible to complete all the three or four interviews, the observation was excluded from the analysis. The 1989 sampling was done strictly independent of the 1975 sample.

When analyzing the 1989 survey, the individual observations of the 1975 study were no longer

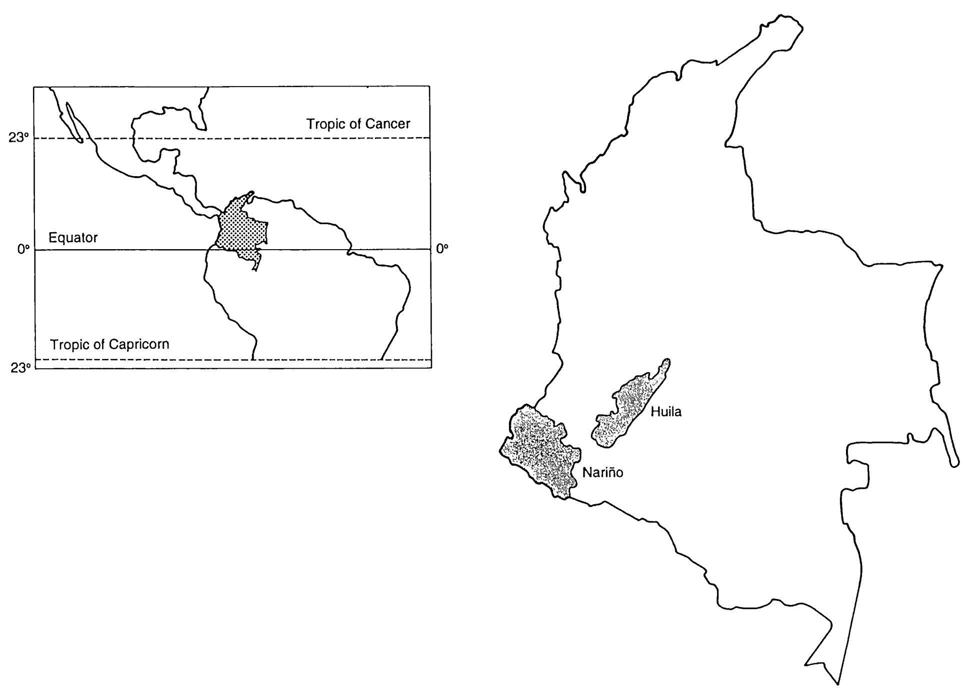

Fig. 2. Location of Huila and Nariño bean production zones in Colombia.

available. The results of the 1975 study presented here were obtained from the paper by Ruiz de Londoño et al. (1978) and from the appendix tables that were never published. For 1989, the same results as for 1975 were calculated and a linear bean production function was estimated.

The information on prices of inputs, land, labor, beans and maize obtained in the questionnaire was complemented with data collected by the Cauca Valley Corporation (CVC, various years). Prices for 1975 and 1989 in Colombian pesos were deflated to the December 1985 base month and afterwards converted to US dollars at the average exchange rate of that month.

4. Farm characteristics

In the departments of Huila and Nariño, a total of 40 000 ha of beans in 1975 and of 36 000 ha in 1989 were planted. The 1975 and the 1989 surveys covered farmers with approximately equal land resources and production patterns. Average farm size, area in crops and area in beans were comparable from one survey to the other. Topographic characteristics of farms were virtually the same (Table 1).

The average farm size was 18 ha in both surveys, which is slightly on the large side for peasant farms. In 1989, 30% of the land was cropped, with bean/maize systems, coffee, plantain, sugar, vegetables and a very diverse home garden. Coffee growing became more important after 1975. The remainder of the land was in pastures, fallow or wood land. Farm size and importance of pastures and fallow land were strongly biased by the presence in both surveys of a few large farms. For the 1989 survey, taking out six farms would reduce farm size with 50%. Since these farms used the same production methods as the rest, we decided to leave them in the analysis.

Bean production in both departments was a commercial activity. By 1975, already more than 90% of total production was marketed. Between 1975 and 1989 the importance of bean monocropping decreased. More frequently than before beans were planted in intercrops with maize.

Table 1
Farm characteristics in bean production surveys, 1975 and 1989, Huila and Nariño, Colombia

Farm characteristics	1975	1989
Farm size (ha)	19	17
Area in crops (ha)	5.0	5.1
Area in beans (ha)	3.0	2.6
Topography		
Plain-ondulating (%)	30	31
Mountainous (%)	70	69
Frequency of bean cropping systems		
Monoculture (%)	21	14
Beans/maize (%)	78	83
Other intercrops (%)	2	4

Source: CIAT Bean production surveys, 1975 and 1989.

5. Prices and production practices

Prices and scarcity

The prices that producers in Huila and Nariño were facing, changed drastically between 1975 and 1989. Day wages increased by 12%, and land rents by 65%. Real agricultural interest rates (nominal interest rate – inflation rate) were negative in 1975, but positive and rather high in 1989. The cost of mechanized land preparation (excluding labor) fell by 10%, while the cost for preparation with oxen was 20% below the 1975 value. Costs of inputs diminished. The average price of a basket of fertilizers in 1989 was only 50% of that of 1975. Prices of fungicides and insecticides were 103% and 88% of the 1975 prices. Bean prices went up and maize prices came down slightly. In 1989, many farmers declared that labor was difficult to hire. Credit availability improved (Table 2).

What hypotheses should be derived from the price developments? Increasing land rents would have put upward pressure on productivity per ha, otherwise bean production would have lost out to more profitable crops. Increasing day wages and the arising labor scarcity would have put pressure to increase labor productivity. Relative price trends and topography would suggest that animal traction grew in importance. Both land and labor productivity could be enhanced by input use, especially of fertilizers. Credit use should have fallen. Price trends, if any, would suggest that beans became more important in the cropping system.

Bean production practices

In 1975, production costs of the bean/maize system consisted of 61% labor costs (Table 3). The land rental cost (imputed for owners) and the cost of seed were the other important categories (17% and 12%). The total cost of agrochemicals (fertilizers, herbicides, insecticides and fungicides) was only 1% of total production costs. Only one of six farmers applied proper rotations. Almost 50% of farmers used credit.

In 1989, labor remained the most important cost component, but now it only counted for 43% of production costs. Land cost increased, absorbing 25% of production costs. The share of seed in total costs stayed the same (12%). Cost of fertilizers, herbicides, insecticides and fungicides climbed from 1% to 10%. The use of rotations doubled. Credit use diminished to one-third of the sample.

Between 1975 and 1989, the number of labor days per ha fell by one-third. Mechanization and herbicide use helped to reduce the time for land preparation. Oxen plowing increased, but tractor use remained the same. Minimum tillage methods began to be used. Other labor savings were obtained by better crop management. Planting took on average 16 labor days per ha in 1975 and 9 labor days in 1989. Harvesting took 37 days in 1975 and 30 in 1989. More even plant establishment reduced weed control by 20% (CIAT, 1991).

Lower labor cost paid for increased input costs. Fertilizer use increased roughly 34 times, use of insecticides and fungicides roughly 4 times. Herbicides were not used at all in 1975. In 1989, only 7% of farmers applied them.

Changes in production practices reflected price developments over the period. Input use increased, labor use decreased, and oxen became more important. Though cash expenditures (on inputs and mechanization) increased, the share of farmers that used credit was lower than before. The increased use of rotations cannot be related to price changes but resembles increased technical efficiency.

Varietal and seed management

In 1975, 16 varieties were identified in the study region (Table 4). Six of them were red-mottled varieties, the most important market class in Southern Colombia. The red-mottled varieties made up two-thirds of planting material. On the average farmers planted 1.8 varieties. Improved varieties represented 51% of the seed and were released by ICA, the national agricultural research organization.

Between 1975 and 1989, ICA did not release new varieties for the region. The share of the improved varieties fell to 40%. Three varieties disappeared from the region and twelve new ones were introduced. In 1989 farmers planted close to

Table 2

Prices and scarcity confronting bean producers in Huila and Nariño, Colombia (US$ of 1985) [1]

Item	1975	1989	% Change
Prices ($)			
Day labor (1 day) [2]	2.14	2.40	+12
Land rent (1 ha/year) [2]	70.82	116.73	+65
Nominal interest rates for agricultural loans [4]	21%	36%	n.a.
Average inflation rates, 1974–1976 and 1988–1990 [5]	22.4%	28.8%	n.a.
Machinery cost for plowing 1 ha of land [2]	57.06	51.62	−10
Animal + equipment cost for plowing 1 ha of land [2]	10.35	8.30	−20
Fertilizer (kg) [3,6]	0.48	0.24	−50
Dithane (kg) [3]	3.00	3.07	+3
Malathion (l) [3]	4.70	4.12	−12
Beans (kg) [2]	0.62	0.69	+11
Maize (kg) [2]	0.21	0.20	−6
Scarcity			
Farmers agreeing:			
Labor is scarce [2]	40%	54%	+35
Credit is scarce [2]	21%	9%	−57

[1] US$1.00 = 172.20 Colombian pesos in December 1985.

Sources:

[2] CIAT Bean production surveys, 1975 and 1989.

[3] CVC, various years.

[4] Fondo Financiero Agropecuario, Bogotá.

[5] DANE (Departamento Administrativo Nacional de Estadística), Bogotá.

[6] Average of urea, KCl, 10-30-10, 10-20-20 and triple super phosphate.

Table 3
Average bean production costs, Huila and Nariño, Colombia in US$ (1985) per ha

Cost item	1975			1989		
	Average costs [1]	% Production costs	% Farmers	Average costs [1]	% Production costs	% Farmers
Oxen land preparation [2]	2.17	0.5	21	3.10	0.7	38
Mechanized land preparation [2]	12.56	3.1	22	10.86	2.3	21
Inputs						
– Herbicides	0	0	0	1.13	0.2	7
– Seed	49.37	12.0	100	56.81	12.1	100
– Fertilizers	2.32	0.6	10	39.55	8.5	77
– Insecticides	1.48	0.4	15	3.90	0.8	57
– Fungicides	0.85	0.2	3	3.80	0.8	57
– Other inputs [3]	19.63	4.8	100	32.35	6.9	100
Labor	252.17	61.3	100	199.58	42.7	100
Credit	n.a.		47	n.a.		34
Land [4]	70.82	17.2	100	116.73	25.0	100
Total	411.38	100.0		467.83	100.0	

n.a., not available.
[1] Averages are calculated for the total sample, not only for users of certain practice/input.
[2] Only concerns machinery, oxen, equipment and energy. Does not include labor.
[3] Bags.
[4] Land rent value imputed for owners.
Source: CIAT Bean production surveys, 1975 and 1989.

2.5 varieties each, a 30% increase over 1975. The proportion of the red-mottled varieties in the seed stock stayed the same.

Table 4
Varietal and seed management in 1975 and 1989, Huila and Nariño, Colombia

Management item	1975	1989
Varietal management		
Total number of varieties identified	16	25
Number of red-mottled varieties	6	9
Number of varieties per farm	1.82	2.44
% Seed of red mottled varieties	63	66
% seed of improved varieties [1]	51	40
Varietal disappearances 75–89	3	
New varieties	12	
Seed management		
Seed selection (%)	72	87
Seed treatment (%)	0	57
Seed establishment rate (% of seed planted)	59	82
Seed density at planting (1000 seeds per ha)	262	272

[1] All improved varieties were released before 1975.
Source: Bean production surveys, 1975–1989.

Contrary to the hypothesis that modernization leads to genetic erosion, farmers increased their gene pool. Similar trends have been observed in Peru (Ruiz de Londoño and Janssen, 1990). The farmers' search for new varieties was not supported by the agricultural research system. New improved varieties did not become available.

Seed density at planting went up 4%. Seed selection before planting increased somewhat, but from a high initial value. Also, row planting increased, from 65% to 93%. Maize seed density fell from 21 000 to 19 500 plants per ha.

In 1975, none of the farmers treated seed with protective chemicals, whereas in 1989 this practice was common for over half of the sample. The seed treatments increased considerably the rate of seed establishment. In 1975 the average seed establishment was 59%. In 1989, among the farmers that did not treat seed it was 66% and among the others it was 91%, for an average of 82%. Seed treatment is an example of innovative technical change. It was unknown in the region in 1975 but had diffused widely in 1989. Its costs are below US$1.20/ha and its absence in 1975 was not caused by its costs.

As a result of the changes in plant density, the improved selection and planting methods and the introduction of the chemical seed treatment, the established plant density rose from 155 000 to 223 000 plants. Of the total increase of 68 000 plants, 8200 plants were due to increased planting density, 19 000 were due to improved selection and planting methods and 40 800 plants were due to chemical treatment.

6. Profitability and productivity in 1975 and 1989

Productivity and profitability comparisons depend on the yields obtained in the years of analysis. There is a risk in comparing yield levels across years, since they can be affected by climatic conditions. In 1975, estimated losses due to climate were small, while in 1989 farmers indicated that yields were below what they expected. The climate favors 1975, the year with the lower yields.

Bean yields in 1989 were substantially higher than in 1975, whereas maize yields increased only slightly [1] (Table 5). Yields caused gross income per ha to increase by 30%, and higher bean prices caused an additional increase of 8%. As reported in Table 3, total production costs increased by 14%. Nevertheless, costs increased less than benefits and net income per ha increased by 112%. Returns to land almost doubled and returns to labor went up 80%. For family farms, where the cost of land is often not considered, returns to labor would have surpassed US$7 per day.

At the same moment the structure of production costs changed strongly. In accordance with the observed price trends, labor was replaced by inputs, such as fertilizer, and by oxen land preparation. To understand productivity changes independent from price changes, total factor productivity (TFP) was calculated. To calculate TFP, non-factor costs were subtracted from the gross income per ha, and the resulting figure was divided by total factor costs (Griliches, 1988). In 1975 prices, TFP was 1.42 in 1975 and 2.13 in 1989, for an increase of 50%. In 1989 prices, TFP was 1.19 and 1.87 in 1989, for an increase of 57%. The average increase of TFP was 54%. At changing prices between 1975 and 1989, TFP increased from 1.42 to 1.87, by only 32%. Growth in TFP was thus partly absorbed by price changes. Higher bean prices and lower fertilizer prices could not fully compensate for higher land rent and increased day wages.

Table 5
Yield and profitability parameters of bean production systems, Huila and Nariño, Colombia

Parameter	1975	1989	% Change
Yields (kg/ha)			
Beans	575	820	42.6
Maize	900	940	4.4
Gross income (Col. $/ha) [1]	545.44	752.26	37.9
Costs			
Inputs	88.39	151.52	71.4
Labor	252.17	199.58	79.1
Land	70.82	116.73	64.8
Net income per ha	134.07	284.44	112.1
Return per ha [2]	204.88	401.17	95.8
Return per labor day [3]	3.27	5.70	74.2
Return per labor day [4]	3.87	7.07	82.5

[1] US$1.00 = 172.20 Colombian pesos in December 1985.
[2] Assuming zero cost for land.
[3] Assuming zero cost for labor.
[4] Assuming zero cost for labor and land.

7. Input and management sensitivity of bean production

What part of the productivity improvement was due to technical change, increased allocative efficiency or increased technical efficiency? The 1989 data were used to estimate the effect of changing production practices on yields. We assumed that input use and sanitary control were directed at beans (the dominating crop in the

[1] Yield statistics by the Ministry of Agriculture show a 20% bean yield increase in Huila and stagnant yields in Nariño. These data are not very reliable, as recognized by most agricultural economists and by the Ministry itself. We trust the surveys provided more reliable data.

system) and we did not estimate the effect on maize yields. The following equation was estimated with OLS:

$$\begin{aligned} \text{YIELD} = {} & \underset{(4.98)}{401.2} + \underset{(7.70)}{0.00153} * \text{BEANPLANTS} \\ & - \underset{(-5.94)}{0.0145} * \text{MAIZPLANTS} + \underset{(7.36)}{310.8} * \text{ROTATION} \\ & + \underset{(2.47)}{0.01709} * \text{SANCON} + \underset{(4.70)}{0.01075} * \text{FERTAP} \\ & + \underset{(0.16)}{6.2} * \text{NARIÑO} \qquad R^2 = 0.79 \quad F = 100.9 \end{aligned}$$

where YIELD is bean yield in kg/ha; BEANPLANTS is established bean plants per ha; MAIZPLANTS is established maize plants per ha; ROTATION is a dummy variable: 1 if plot was not planted with beans in the previous crop cycle; SANCON is cost of sanitary field control (Col. pesos/ha); FERTAP is cost of fertilizer applications (Col. pesos/ha); NARIÑO is a dummy variable: 1 if plot located in Nariño; and t-values are shown in parentheses.

Bean yields depend positively on bean plant density, rotation practices, fertilizer use and chemical control, and negatively on maize plant density. Yield levels in Nariño and Huila were very comparable. Since soil quality and climatic differences were not included in the estimation because of measurement problems, we consider the R^2 to be very satisfactory. More sophisticated forms of the production function with quadratic components for plant density, cost of sanitary control and cost of fertilizer application, and with interactions between fertilization and rotation or bean plant density, did not improve the quality of the estimation.

The production function allows us to dissect the yield increase in the three components of allocative efficiency, technical efficiency and technical change. Regarding allocative efficiency, four changes can be distinguished: increased bean seed density at planting, reduced maize plant density, increased costs for sanitary control, and for fertilizer use. The bean plant density increase of 8200 plants contributed 12.5 kg/ha. The maize density reduction of 1500 plants allowed bean yields to grow by 21.5 kg/ha. US$5.60 was spent additionally on sanitary control and led to a yield increase of 16.5 kg/ha. Cost of fertilizer application increased by US$37/ha, leading to a yield

Table 6
Effect of productivity changes on profitability, Huila and Nariño, Colombia

Productivity component	Prices of 1975	% Contribution to increased profitability	Prices of 1989	% Contribution to increased profitability
Allocative efficiency				
Gross income increase	83.11		91.03	
Input costs increase	84.98		45.17	
Labor costs increase	6.39		7.17	
Subtotal allocative efficiency	−8.25	−10	38.69	29
Technical efficiency				
Income increase because of rotation	32.93		36.63	
Income increase because of better seed establishment	18.08		20.11	
Subtotal technical efficiency	51.02	65	56.74	42
Technical change (seed treatment)				
Gross income increase	38.77		43.12	
Input costs increase	0.56		0.58	
Labor costs increase	2.14		2.40	
Subtotal technical change	36.07	46	40.14	30
Total profitability increase	78.84	100	135.57	100

increase of 69.8 kg/ha. The total effect of allocative efficiency on bean yields was 120.3 kg/ha. We assumed that the maize yield increase of 40 kg/ha was also due to allocative efficiency (mainly the increased fertilizer use).

Regarding the technical efficiency, two changes can be distinguished: improved planting methods, and increased frequency of rotations. Improved selection and planting methods helped to increase plant establishment with 19000 plants per ha, which led to a yield increase of 29.1 kg/ha. The fact that 33% of farmers rotated in 1989 as opposed to 16% in 1975 increased average yields with 52.8 kg/ha. The total effect of the increased technical efficiency was 81.9 kg/ha.

Regarding technical change, the introduction of seed treatments increased average bean density by 40800 plants, for an effect on yields of 62.4 kg/ha.

The observed bean yield difference was 245 kg/ha instead of the estimated 264.6 kg/ha. The difference is consistent with the fact that in 1989 many farmers declared that yield levels were below their expectations.

8. Contributions to increased profitability

The profitability of the three productivity increasing components was calculated by estimating the changes in input and labor costs that they required (Table 6). At 1975 prices, the changes made for reasons of allocative efficiency would have negatively affected profitability. In 1989, output prices had increased and input prices had fallen – the total effect of the changes was positive. The effect of the increased technical efficiency would have been highly positive in both periods, because there is no obvious cost associated. However, the issue is whether farmers had sufficient land and were capable to develop a farm production plan that allowed for more rotations and improved planting methods. The innovative seed treatment would have been highly profitable in 1975, but was not known by then. The higher bean price raised profitability further in 1989.

The labor cost reduction between 1975 and 1989 (roughly 35 days/ha) is more difficult to explain. We tried to estimate the effect of labor on yields in a Cobb-Douglas production function, but its coefficient was not significant. Some of the labor cost reductions are associated with the changes that we found (e.g., mechanization and land preparation, plant establishment and weeding) but they would only explain a small part of the total reduction (between 6 and 9 days). The most feasible explanation for the moment is to consider labor cost reduction as increased technical efficiency. Farmers may have reduced inefficiencies forthcoming from the days when alternative employment was scarce, and the relative price of labor low (see Table 2).

In 1989, allocative efficiency contributed 29%, technical efficiency 42% and technical change 30% to the extra profits obtained with the higher yields. In 1975, the effect of the changes made for reasons of allocative efficiency would have been negative.

What further possibilities exist to increase profitability of bean production systems in Huila and Nariño? The previous analysis suggests that increased diffusion of seed treatment, row planting and rotations could raise yields further. If instead of one-third of farmers half of them would rotate, average yields would increase by an additional 54 kg/ha. If all farmers used seed treatments and row planting, the rate of establishment would increase from 82% to 91%, with an effect on yields of 38 kg/ha. Input use could be increased profitably, especially for chemical control. Doubling chemical control (from a low level) would raise yields with 16.5 kg.

Other possibilities, not forthcoming from the previous analysis should be explored. For 20 years no improved varieties were made available. They could be expected to contribute to yields per ha of some 200 kg (Janssen and Teixeira, 1992) and if 50% of farmers would adopt them, they could raise yields in Nariño and Huila with 100 kg/ha. Herbicide use was very low. Mechanized weeding (with so-called 'weed eaters') and threshing could further reduce labor costs. Labor cost reductions and yield increases could raise productivity considerably above the 1989 level.

9. Impact of research and extension on productivity changes

We attributed the changes in bean/maize production practices to research and extension institutions, following recently developed methodologies to measure returns to crop management research (Janssen et al., 1991; Traxler and Byerlee, 1992). For the seed treatments, some experimentation was undertaken by CIAT in the late 1970s in the Huila department, but without a follow-up by the extension service. CIAT may be associated with the innovation; however, its diffusion took place mainly on account of the farmers themselves. The extension offices of the Colombian government had been promoting row planting and minimum tillage systems and we attributed the improved planting methods to their efforts. Rotations have long been recognized as a beneficial practice, but was not subject of specific diffusion campaigns and should not be attributed to the research and extension system. Increased fertilizer and pesticide use was principally due to changing input–output price ratios. The articulation with farmers of the machinery industry and of seed/varietal improvement research was poor.

Of the 245 kg/ha average yield increase, 120 kg was due to changing allocative efficiency. Of the remaining 125 kg/ha, research and extension services can be attributed safely the improved planting methods (29.1 kg/ha) and part of the seed treatment (62.4 kg/ha in total). If we assign 50% of the effect of the seed treatment to the research and extension services, their total contribution to productivity improvements would be 60.3 kg or US$40.2/ha (Table 6).

10. Conclusions

Many changes took place in the bean/maize cropping system of southern Colombia. These changes assured that bean/maize cropping remained a viable income alternative to small farmers. The process of change had some expected facets. Employment per hectare went down, but without leading to marginalization of landless people. Chemical control increased but not to the extent of exerting ecological pressure. Fertilizer use increased to modest levels (150 kg/ha).

Modernization also had a number of unexpected sides. Input use increased, but credit use fell. Monoculture bean growing lost importance to mixed cropping. Instead of genetic erosion, the number of varieties increased. The trade-off between sustainability and economic growth did not (yet) occur. Zero tillage, rotations and increased genetic diversity favored sustainability. Modernization and sustainability went hand in hand.

Components of modernization

Allocative efficiency had a large effect on yield but less on profitability. Technical change had more effect on profitability but a smaller effect on yields. The foremost contribution to increased profitability came from the increased technical efficiency (better crop management).

Farmers made progress by using many technological opportunities to achieve more intensive crop systems. Nevertheless, we did not find evidence for a package that was finding its way. Some farmers intensified their input use, other started to use rotations or to treat their seed. However, there were no strong interactions between the diffusion of the components (as already suggested by the results of the production function estimation procedure).

Some conclusions should be drawn on how to improve the competitiveness of the agricultural sector. First of all, technical change contributes more than allocative efficiency, which would stress the need for technology generation, also when domestic prices start to follow world market prices. Secondly, input use (fertilizer) was mainly decided by the input – output price ratio. Research on inputs may help to reduce some technical inefficiencies, but we wonder if its pay-off is worthwhile. Thirdly, increased technical efficiency should be supported by farmer education and information. Education and information should not be directed to solving specific problems in specific ways but should improve the general management capacity of farmers.

Sources of modernization

The changes observed only partly fit the theory of Hayami and Ruttan (1985). Farmers used fertilizers to enhance land use and reduced the share of labor in production costs. Other expected changes did not take place because the technologies were not supplied. Small machinery that could help to remove labor shortfalls was neither developed nor introduced. Improved varieties were not released in the 15 years between the two studies, even though the bean grain type that these farmers produced dominated the Colombian market (Luna and Janssen, 1990).

Multiplied by the 36 000 ha grown in the two departments, the impact of the 60.3 kg/ha yield or US$40.2/ha profit increase that could be attributed to research and extension would be US$1,447,200 for the year of 1989. We do not dispose of cost data for regional research and extension in bean/maize production systems, but we do not expect that they exceed US$300,000 for 1989. The 1989 Benefit/Cost ratio would then be close to 5, suggesting that the research and extension investments for improving bean/maize production systems were probably quite profitable.

At the same moment, we should be aware that the largest part of yield improvements was due to farmer efforts. Crop management research is a field where the advantage that the researcher has over the farmer is not nearly as big as in genetic improvement. Researchers may have more technical and analytical skills, but farmers tend to understand their farming system better. The suggestion for crop management research and extension would be to work in very close collaboration with farmers, not only for diffusing results, but also for defining researchable issues. To develop such contacts and to make the research and extension process more efficient, some form of farmer organization would be useful, as emphasized by Pomareda (1991).

Other conclusions

Linkage effects have received much attention in recent years (Piñeiro, 1988; Janssen and Sanint, 1991). Backward linkage effects of peasant agriculture were initially estimated to be rather small, because of limited input use. This led to the suggestion that the small farm sector of Latin America would not be a good focal point for policies that try to create economic growth, because such growth would be restricted to the small farm sector only. This study provides evidence that small farmers use inputs when price ratios permit. In accordance with the conclusions of Haggblade and Hazell (1989), this suggests that the linkage effects of the small farm sector may not be as small as previously thought. Coupled to the high multiplier effect of additional income in the small farm sector, the effects of a growing small farm sector on the rest of the economy may be substantial.

The overall impression created by changes in bean/maize cropping was rather positive and optimistic. Small farmers were able, mostly on their own, to modernize their production system. They doubled their productivity in a 15-year time period. The bean/maize growers did better than the Colombian economy on the average and were not at all bypassed by economic growth. The bean/maize production system was very resilient, and it was easy to foresee another doubling of labor productivity.

Why were these farmers successful in 'demarginalizing' themselves? First of all, they produced for the market and were fully integrated in the cash circuit, which facilitated the use of purchased inputs. Secondly, they faced a relative strong market for beans, as expressed by increasing prices and growing per-capita consumption (Luna and Janssen, 1990). Thirdly, the infrastructure improved for input availability and transportation. Fourthly, agriculture in Colombia was favorably influenced by profitable coffee growing, which allowed many farmers to invest in other activities (Garcia and Montes, 1988).

The modernization process took place with limited financial resources, with a traditional peasant crop among small farmers and in a sustainable manner. This study would suggest that even without turning to high value vegetable crops or fruits, many small farmers in Latin America can join the group of capital-efficient entrepreneurs that the continent requires for successful economic growth and development in the 1990s.

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