PB-225 651

INCOME DISTRIBUTION, EFFICIENCY AND THE EXPERIENCE OF COLOMBIAN FARM MECHANIZATION

Wayne R. Thirsk

Rice University

Prepared for:

Agency for International Development

1972

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. CO-3Ø1.441-T447	2.

4. Title and Subtitle	5. Report Date
"Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization"	Fall 1972
	6.
7. Author(s) Wayne R. Thirsk	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Rice University Department of Economics Houston, Texas 77001	10. Project/Task/Work Unit No. 931-19-995-534
	11. Contract/Grant No. AID/csd-3302
12. Sponsoring Organization Name and Address Department of State Agency for International Development Washington, D.C. 20523	13. Type of Report & Period Covered Staff Paper.
	14.

15. Supplementary Notes
This s

16. Abstracts
This study describes and evaluates adjustment in the structural composition of the economy that would be expected to result from subsidizing large farm capital in Colombia. Changes in income distribution arise from shifts in the prices received by owners of land, labor and capital, and from shifts in the prices each group of factor owners pays for its consumption goods. Changes in the level of national income depend on whether resources are transferred to higher or lower productivity uses. The following major effects are observed from the simulations: (1) a reduction in total labor demand because (a) mechanized agriculture is highly capital intensive (b) this effect outweighs the increase in labor demand due to land conversion from cattle to crops; (2) an increase in the share of income going to capital owners (or capitalists and labor) largely at the expense of labor and small farmers, although landowners also lose on balance; (3) a lower level of national income because mechanization has been privately but not socially profitable. (4) sensitivity of the overall results to the labor absorption capacity of the nonagricultural sector.

17b. Identifiers/Open-Ended Terms

Reproduced by
NATIONAL TECHNICAL INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17c. COSATI Field/Group 33Ø

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 58
	20. Security Class (This Page) UNCLASSIFIED	22. Price $5.00/1.45

PROGRAM OF DEVELOPMENT STUDIES
121 Sewall Hall
WILLIAM MARSH RICE UNIVERSITY
Houston, Texas 77001

Paper No. 33

INCOME DISTRIBUTION, EFFICIENCY AND THE EXPERIENCE OF COLOMBIAN FARM MECHANIZATION

by

Wayne R. Thirsk

Fall, 1972

The author is Assistant Professor of Economics at Rice University. This paper reports research related to AID contract no. csd-3302, on Distribution of Gains, Wealth and Income from Development. Program Discussion Papers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Discussion Papers should be cleared with the author to protect the tentative character of these papers.

Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization

1. Introduction

It is well known proposition in the theory of economic policy that the effects of introducing a distortion in an economy are uncertain if prior distortions exist elsewhere in the economy. This study illustrates the value of a general equilibrium framework as an empirical tool in the analysis of second-best situations. The process of farm mechanization in Colombia is used to provide this illustration.[1]

The impact on income distribution and resource allocation of farm mechanization in Colombia is complicated by the presence of significant disequilibrium in the factor markets for land, labor and capital. Colombian agriculture is comprised essentially of a large farm sector producing crops or cattle and a small farm crop sector. In these two crop production sectors there is no reason to anticipate that factor proportions would vary by a wide margin between large and small farms. But in fact, in crop production smaller farms are much more labor-intensive than larger farms. This variance in factor proportions occasions a marked difference in the marginal returns to labor and a consequent static misallocation of labor resources.

A number of institutional constraints on factor use seems responsible for this result. Impediments to land mobility tend to block the transfer of land from larger to smaller farms by sale or rental. On the demand side of the land market, there is little or no credit available for land purchase. On the supply side, rental is often precluded by landowners' fear of squatting and the current

---

[1]This paper is a condensation of chapters VI and VII of my unpublished Ph.D. thesis entitled The Economics of Farm Mechanization in Colombia, Yale University, 1972. I wish to express my appreciation to R.A. Berry and R. Evanson for their comments on early versions of these chapters.

agrarian reform laws which view rented land as proof of inadequate use and thus more liable to expropriation than unrented land. In the labor market a largely unexplained rigidity in rural wage scales seems to hinder the transfer of labor from smaller to larger farms. Another factor is an apparent nonprofit-maximizing preference by large landowners for engaging in extensive cattle grazing rather than growing crops more lucratively and using larger amounts of labor.[2] As a result of this distortion, too much land is allocated to cattle raising. The combined effect of all these distortions is to produce a nonoptimal allocation of land which has as its counterpart the underutilization of labor in the small farm sector.

Into such a factor market setting significant growth in mechanization took place rapidly on large farms in the late 1940s and early 1950s. This growth was encouraged by a capital market distortion which produced a lower cost of capital for large mechanizing farmers than for nonagricultural users of capital. Low interest loans from foreign lenders to purchase farm machinery were converted by Colombian authorities into low interest domestic credit for large farm machinery buyers.

Given the preceding initial conditions, it is plausible that the impact of mechanization on the Colombian economy has been favorable. Mechanization might be good, if not optimal, second best policy if the relevant policy choice were between accepting the status quo ante of unmechanized cattle raising or fostering the expansion of mechanized crop growing on large farms. The

[2]This statement is not equivalent to one which says, ceteris paribus, large landowners are willing to settle for less income than they could obtain. The point is that the realized rate of return to capital is lower in many instances in cattle than it would be in a number of labor intensive crops. From the large landowner's viewpoint he might be maximizing his income if he were to lose more income from his urban occupation than he could gain from devoting more time to his farm and if he views renting or reliance on a farm administrator as a high risk venture.

benefits of mechanization would consist of improved resource allocation as land on large farms was shifted from cattle to crops and as labor was shifted from smaller to larger farms. Since the demand for labor could be expected to increase under these circumstances, possibly some of the poorest groups in Colombia would be better off under a policy of stimulating farm mechanization. These gains could be large if the initial misallocation of land and labor were severe and if special measures like land redistribution were not considered feasible alternatives to overcoming the imperfections in the land and labor markets.

While this argument for Colombian mechanization is reasonable, it is not necessarily valid. It has the advantage of exposing the essentially empirical nature of the farm mechanization issue and the partial equilibrium framework in which the question has been discussed. For example, if the cost of the subsidy to large farm capital were calculated, it might outweigh the benefits of improved resource allocation within agriculture. This particular result could occur if most nonagricultural sectors were much more labor-intensive than mechanized crop growing. The approach of this study is to recognize the importance of sectoral interdependence and the fact that capital resources devoted to farm mechanization deprives other sectors of the use of those resources.

2. The Models

Two closely related models are developed for largely pragmatic reasons. Both owe their inspiration to an important piece of work by A. Harberger.[3]

[3] A.C. Harberger, "The Incidence of the Corporate Income Tax," Journal of Political Economy, June 1962, pp. 215-240. Other important extensions and modifications of the Harberger analysis include: C.E. McLure, "The Inter-Regional Incidence of General Regional Taxes, Public Finance 24(3), 1969, pp. 457-483; _____, "The Theory of Tax Incidence with Imperfect Factor Mobility," mimeo, 1968; P. Mieszkowski, "On the Theory of Tax Incidence," Journal of Political Economy, June 1967, pp. 250-262.

Their difference lies in an explicit recognition of the cattle sector in the second and larger model. In the first and simpler model the cattle sector is suppressed, an omission which facilitates algebraic analysis. There are three sectors (nonagricultural, large farm and small farm) and three homogeneous factors (capital, mechanizable land and labor). Labor is an input common to all three sectors and the capital is shared between the nonagricultural sector and the large farm sector. Mechanizable land is the input unique to the large farm sector. The second and more complete model, which requires computer simulation for analysis, divides the large farm sector into crops and cattle, and adds a fourth factor (nonmechanizable land) which is only suitable for employment in the cattle sector. The cattle sector shares mechanizable land with large farm crops and provides an additional cource of labor employment. Capital, as defined in this study, is not used in the cattle sector. Table 1 conveniently summarizes these basic assumptions.

TABLE 1: Resource Employment Assumptions

Factors:	Capital	Mechanizable Land	Nonmechanizable Land	Labor
Sectors:				
Small Model and Large Model				
(1) Nonagriculture	X			X
(2) Large farm crops	X	X		X
(3) Small farm crops		Fixed Land Base		X
Large Model only				
(4) Cattle		X	X	X

This taxonomy corresponds roughly to the sectoral outline observed in Colombia and to the pattern of factor market distortions among different

sectors. In a more complete analysis, intrasectoral dualism in nonagriculture might be explicitly considered. Here it would clutter an already complicated model. However, ad hoc allowance for the heterogeneous nature of nonagriculture is made in the choice of this sector's factor substitution elasticity in section "4" (Parameter Values).

Nomenclature

Capital letters represent either final outputs, factors of production, or prices. A subscript on a factor denotes the amount of that factor used in a particular sector. Price subscripts refer to sectors for commodity prices and to factors for factor prices. Double subscripts are used in some cases where factor prices are specific to both factor and sector.

Equations are expressed in terms of first derivatives or first-order approximations. For example, a constant returns production function which in implicit form would be written as $X = F(L_x, K_x)$ is transformed into $dX = f_\ell dL_x + f_k dK_x$ where the marginal products f_ℓ, f_k are measured at the original equilibrium.

The definition of and notation for the variables used in the analysis is: F = level of crop output supplied or demanded. F_ℓ, F_s are the same homogeneous output or are perfect substitutes in consumption so there is only one output price for crops.

Y = level of nonagricultural output supplied or demanded. Y is viewed as a composite commodity.

C = level of cattle output supplied or demanded.

L = level of labor input. According to their subscript, L_f, L_s, L_y, L_c are employment levels in large and small scale agriculture, the nonagricultural and cattle sectors respectively.

K = capital employment. K_y and K_f are the amounts of capital used in the nonagricultural and large farm sectors respectively.

A - mechanizable land used in the large farm (A_f) and cattle (A_c) sectors.

M = nonmechanizable land (hilly or uneven ground) used exclusively in the cattle sector.

PK = the rate of return on, or the price of, capital.

PL = the money wage received by labor. PL_f signifies the money wage paid to labor in large farm agriculture, for example.

PA_f = the rental price of mechanizable land in large farm agriculture.

PM = the rental price of a unit of nonmechanizable land in the cattle sector, assumed to be constant.

P_f
P_y = output prices for commodities F, Y and C respectively.
P_c

Δi_f = the income share of factor i in sector F.

σ_{ij} = the partial elasticity of substitution between factors i and j. $\sum_k \Delta_k \sigma_{jk} = 0$, $\sigma_{ij} = \sigma_{ji}$, are theoretical restrictions on the values for this parameter.

E_{fy} = income-compensated price elasticity of final demand between products F and Y. It is the pure substitution effect in Hicks' terminology.

g_p = constant despecialization elasticity measuring the percentage change in relative product prices.

gL_s = constant labor intensity elasticity denoting the percentage response of small farm marketed surplus to a given percentage change in the land-man ratio of small farms.

Z = heterogeneous output bundle produced in small scale agriculture

but not tradable for other kinds of output.

S = per unit subsidy on the cost of using capital in large scale agriculture. S is the result of government policy which lowers the capital cost of large farm agriculture relative to the cost of capital in non-agriculture.

Units for all of these variables are chosen so that initial prices can be set equal to unity. When this is done, $\frac{dP_f}{P_f}$ for example, becomes simply dP_f and all price changes can be interpreted as percentage price changes.

A few other points of clarification deserve mention. Capital is a composite bundle of fixed durable inputs. The farm machinery component of this bundle comprises imported capital goods. Other forms of capital goods, such as structures, are produced from a mixture of imports and domestic resources. If the relative prices of imported and domestic capital goods are constant, it is possible to define an aggregate of these capital goods. By holding the foreign prices of capital goods, the exchange rate and the domestic prices of capital goods constant, there is no ambiguity in defining the share of capital in each capital-using sector as the product of the price of capital and the value of capital goods in that sector. A domestic capital goods industry is subsumed as part of the nonagricultural sector.

Although primary interest is in imported farm machinery, it was found desirable for several reasons to broaden the capital measure. First, it is readily apparent that all forms of capital in large farm agriculture receive a subsidy through the capital market imperfection. Second, viewing all large farm capital as eligible for subsidy facilitates the ease with which national accounts data can be used. By assuming constancy in the relative prices of different capital goods, substitution within the capital aggregate

is ruled out and imported farm machinery becomes a fixed percentage of the total capital of large farms. Thus other forms of capital can be viewed as strictly complementary with imported farm machinery.

Fixing the relative prices of capital goods also fixes the quantity of real capital which, in our long run models, can be costlessly transferred to either of the two capital-using sectors. As explained later, the government impóses a subsidy on the price of capital in large scale agriculture and assures that the supply of capital is adequate to meet the demand at this new price. The price of capita, in nonagriculture adjusts to clear the capital market in that sector when this capital diversion occurs. In spite of a fragmentation of the capital market caused by the subsidy to a particular sector there is no excess demand for capital.

This description of the capital market assumes that changes in the returns to capital--and to savers if interest rates are flexible--do not induce changes in consumption and saving which will influence exports and the availability of capital goods. For example, if all imports were capital goods and all exports were consumer goods, an increase in savings in response to higher capital prices might increase exports and imports as long as the price elasticity of foreign demand were greater than one. If higher returns to capital generated an increase in the capital stock by this means, farm mechanization would have more favorable long run effects on the economy than otherwise.

Large farm production

If all large scale farmers have access to a common, constant returns three-factor production function of the form $F_\ell = F_\ell(L_f, K_f, A_f)$, the derived demands of this group for labor, capital and land can be expressed as:

$$\frac{dL_f}{L_f} = \Delta K_f \sigma_{\ell k} dPK + \Delta L_f \sigma_{\ell\ell} dPL + \Delta A_f \sigma_{a\ell} dPA + \frac{dF_\ell}{F_\ell} \tag{1}$$

$$\frac{dK_f}{K_f} = \Delta K_f \sigma_{kk} dPK + \Delta L_f \sigma_{\ell k} dPL + \Delta A_f \sigma_{ak} dPA + \frac{dF_\ell}{F_\ell} \tag{2}$$

$$\frac{dA_f}{A_f} = \Delta K_f \sigma_{ka} dPK + \Delta L_f \sigma_{\ell a} dPL + \Delta A_f \sigma_{aa} dPA + \frac{dF_\ell}{F_\ell} \tag{3}$$

In each equation the first three terms represent the factor substitution effects of factor price changes while the last term captures the expansion of scale effect on factor demand of a changed level of total costs resulting from factor price changes.[4] The size of the expansion effect depends on the price elasticity of demand for the product in each case.[5]

Small farm sector

This sector is a repository of surplus labor. Due to failures in the land and labor markets for institutional reasons and in the capital market because of policy choice, this sector offers a perfectly elastic supply of labor to other sectors at the constant real wage received by landless rural workers and labor in the nonagricultural sector. Also, because of latent

[4]Factor substitution is confined to the production of value-added so intermediate input relations are assumed to be linear.

[5]The role of final demand is easily seen if we let E be the price elasticity of demand and write the final demand function as

$$\frac{dF_\ell}{F_\ell} = E\frac{dP_f}{P_f}, \quad E < 0, \text{ and note that in equilibrium}$$

$$\frac{dP_f}{P_f} = \Delta K_f dPK + \Delta L_f dPL + \Delta A_f dPA.$$

Substituting these equations into the equation for the demand for labor gives $dL_f/L_f = \Delta K_f dPK(\sigma_{\ell k}-E) + \Delta L_f dPL(\sigma_{\ell\ell}-E) + \Delta A_f dPA(\sigma_{a\ell}-E)$. Thus, the own-price elasticity of demand for any factor will always be negative and the cross-price demand elasticity will be negative if $\sigma_{ij} < E$ and positive if $\sigma_{ij} > E$.

family ties or noblesse oblige, this sector behaves as if it had a perfectly elastic demand for labor at this constant real wage. This implies that labor which cannot obtain employment elsewhere in the economy will be absorbed into employment here. Thus no overt unemployment exists in either model although it would not be difficult to allow it in terms of the gap between the supply price of labor in this sector and the ruling real wage.[6] Perhaps because transfer payments or savings are inadequate to finance search activity for alternative employment, it is assumed that any migration out of this sector takes place only in response to job opportunities elsewhere.[7]

The production and consumption behavior of small farmers can be summarized by a marketed surplus schedule F_s which depends on only two variables, the land-labor ratio and the relative prices of agricultural and nonagricultural goods. It is assumed that an adverse change in the terms of trade will lead to a retreat from market activities and that an increase in the amount of labor, ceteris paribus, will also cause a decline in the marketed surplus.[8] These assumptions imply a function of the form

$$\frac{dF_s}{F_s} = g_p(dP_f - dP_y) + gL_s\frac{dL_s}{L_s} \qquad (4)$$

---

[6] Cf. J. Harris, M. Todaro, "Migration, Unemployment and Development: A Two-Sector Analysis," American Economic Review, March 1970, pp. 126-142.

[7] Surveys of urban unemployment in Colombia indicate a low exposure to unemployment among migrants.
Cf. R. Nelson, P. Schultz, R. Slighton, Structural Change in a Developing Economy, Princeton, N.J.: Princeton University Press, 1971, pp. 151-152.

[8] An increase in the ratio P_y/P_f would be expected to raise the consumption and reduce the production of F on small farms. If Z and Y are substitutes in consumption while F and Z are complements, a rising man-land ratio will likely lead to greater self sufficiency. Cf. Thirsk, Appendix IV, op. cit.

where gL_s, the labor intensity elasticity, and g_p, the terms of trade elasticity, are assumed to be constant over the observed range of variation in labor supply and relative prices. The presumptive signs of these elasticities are respectively $gL_s < 0$ and $g_p > 0$. These coefficients are not strictly independent of each other as, for example, a reduction in marketed surplus caused by an increase in L_s will ultimately affect relative prices. This interaction is assumed to be unimportant. It is also implicitly assumed that labor's marginal product in this sector is never zero due to Z-goods alternative, although it is less than the constant real wage and labor would hire out to other sectors if alternative employment was available.

Total supply of crops

Given the supply relationships in each agricultural sector, a total supply relationship for the entire sector can be determined. In equilibrium the sum of supply from each sector, when combined with the demand for food output, must yield a price which clears the market and defines the market share of each sector. Thus,

$$\frac{dF}{F} = \theta_{\ell} \frac{dF_{\ell}}{F_{\ell}} + \theta_s \frac{dF_s}{F_s} \tag{5}$$

where θ_{ℓ} and θ_s are the original market shares of the large and small farm sectors respectively.

The relative price elasticity of F_s will determine both the vulnerability of the small farm sector to a price squeeze initiated by an expansion of the large farm sector, and the effective demand curve confronting the larger subsector. The more price inelastic F_s is, the more small scale agriculture will be harmed by such an expansion since inelasticity indicates there are few alternatives by which this sector can escape the price-induced decline in income.

On the other hand, the more price elastic the supply from small farmers the more elastic the demand curve confronting large farmers since withdrawal from the market by small farmers leaves more room for the large ones. An increase in the amount of labor in small scale agriculture would also tend to increase the market share of large scale agriculture and augment the incentive to mechanize from the side of product demand.

The labor market

$$\bar{L} = L_f + L_Y + L_s \tag{6a}$$

$$\bar{L} = L_f + L_Y + L_c + L_s \tag{6b}$$

Equations (6a) and (6b) describe the overall constraint on labor allocation in the case of the small and large models respectively. In the labor market the *ex ante* supply of labor exceeds the demand for labor at a fixed real wage. At the exogenous real wage any difference between the labor supplied by landless labor and labor demanded in large scale agriculture is met by variations in the supply of labor from small scale agriculture. This queuing characteristic of the labor market is in harmony with current "cold storage" notions about the peasant sector as a reservoir of labor to be drained or filled as demand conditions elsewhere dictate. Under these circumstances, increasing labor productivity in the rest of the economy is fully compatible with a constant labor price.[9]

The constant real wage is defined in terms of the price of agricultural goods and results from the preponderance of food items in household budgets

[9]Surplus labor can be reconciled with an active rural labor market by appeal to Lewis-type sharing of land rents, legal minimum wages or employers' desire to provide a living wage to landless workers.

at low *per capita* income levels.[10] The assumption of constancy implies that nominal wages in all sectors of the commercial economy outside small scale agriculture move proportionately with crop prices. Thus PL_f/P_f is equal to a constant or

$$dPL_f = dP_f \tag{7}$$

and $dPL_Y = dP_f$ if real wages in sectors Y and F are to be equal. It was a helpful simplification to take the price of labor, and hence the real wage, as the numeraire for the system in determining relative price effects:

$$dPL_f = dPL_Y = dPL_c = dP_f = 0 \tag{8}$$

The labor market has two other characteristics. Initial conditions are assumed such that, even under the most favorable demand circumstances, the supply of surplus labor is never exhausted. Also, land tenure conditions exert no influence on the outcome because tenancy on land in large agriculture is assumed equivalent to the use of hired labor in that sector. This is not unreasonable since with flexible land rental contracts, a maximizing landowner would have to receive the same return on his land, whether he hired labor to work it or leased it to tenants.[11]

The land market

Besides a difference in land returns between large and small scale agriculture, land used within large scale agriculture is also subject to a distortion. It is traceable to the failure to choose the profit-maximizing output mix between crops and cattle, so that the return to land use is lower

---

[10] Between 1951 and 1968 it appears real rural wages grew at less than .5 percent per year and this rate is upward biased due to the increasing importance of higher paid tractor drivers and large farm workers in the DANE wage survey. Ft. 22, p. 38, discusses further the budgetary importance of food.

[11] For a more complete explanation, see S. Cheung, "Private Property Rights and Sharecropping," Journal of Political Economy, November/December 1968, pp. 1107-1122.

in the cattle sector. This private distortion is recognized in the land rental equation:

$$PA_c = \lambda PA_f, \ \lambda < 1 \tag{9}$$

where λ is the constant distortion parameter. In the smaller model which suppresses the demand for, and supply of, cattle, there is assumed to be an exogenous supply of land to large scale agriculture given by the equation

$$\frac{dA_f}{A_f} = \frac{\alpha dPA}{PA}$$

where α is the supply price elasticity of land. Though cattle are ignored in this model, the size of α will, in fact, depend on whether outputs C and F are strong substitutes in consumption and on the nature of the factor substitutes for land in the cattle sector. For example, α will be larger if, as production of F expands and the price of F falls, the price of C also falls and if there are good substitutes for mechanizable land in cattle production whose relative price does not rise. In the larger model (10) is replaced by (11) $P_M = \bar{P}_M$ (supply of nonmechanizable land is perfectly elastic) and (12) $\bar{A} = A_f + A_c$.

The capital market

The main feature of the capital market is its segmentation caused by sectoral differences in the supply price of capital. Government control and regulation of financial markets lowers the supply price of capital to large scale agriculture relative to the price in nonagriculture. The government also insures that the amount of capital supplied at this lower price matches the quantity demanded. Capital rents in nonagriculture are assumed to adjust to this diversion of capital through a higher scarcity value. With a fixed capital stock, the capital subsidy to large scale agriculture is equivalent to a tax on the use of capital in nonagriculture. Although the cost

and return to capital differs between sectors, within each sector competition produces the same rate of return on capital. Competitive arbitrage between sectors is blocked through restrictions on the mobility of funds. Investors are unable to borrow in the low cost portion of the capital market and invest in the higher return segment. Neither can savers shift easily from a low to a high return compartment of the capital market. These restrictions assure the absence of excess demand for agricultural credit.

The capital price relationship in this institutional setting states that the rate of return to capital in sector F is lower than that in sector Y by the amount of a fixed subsidy S per unit of capital.

$$dPK_Y = dS + dPK_f \tag{13}$$

where dS measures the size of the capital subsidy. S is the single policy instrument in both models.

The nonagricultural sector

A simple production structure is assumed. The nonagricultural sector employs only labor and capital in a constant returns production function. By Walras' law the supply and demand equations for Y are redundant. Only the factor demand relationship is required for this sector.

$$\frac{dK_Y}{K_Y} - \frac{dL_Y}{L_Y} = \sigma^Y(dPK-dPL) \tag{14}$$

where σ^Y is the elasticity of factor substitution between capital and labor. Since the definition of nonagriculture comprises eight different one-digit industries, the aggregate elasticity is a weighted average of the individual industry elasticities: that is, $\sigma^Y = \sum_j^8 w_j \sigma_j$ where w_j is the proportion of nonagricultural output arising in industry j.[12]

[12]Consistent aggregation requires that relative output prices be independent of a given factor price change in all of the nonagricultural sectors. This can occur only if each industry in the aggregate has the same

The relationship of product to factor prices

Because sector Y employs only two factors, it is simplest to illustrate its price equation.[13]

$$dP_Y = \Delta L_Y dPL + \Delta K_Y dPK \tag{15}$$

which says that product prices are homogeneous of degree one in factor prices. Analogous price equations are used for every other good except that the price changes for cattle and for crops reflect, respectively, the influence of the land market distortion and the capital subsidy.

$$dP_f = \Delta K_f(dPK-dS) + \Delta A_f\ dPA + \Delta L_f dPL \tag{16}$$

$$dP_c = \lambda\Delta A_c dPA_f + \Delta M dPM + \Delta L_c dPL \tag{17}$$

Commodity demand conditions

Since factor price changes are ultimately reflected in product price changes, the division of output among different sectors will depend on the final demand sensitivity of consumers to changes in relative product prices. Thus, for example, the expansion effects subsequent to farm mechanization, which proponents of mechanization are fond of citing, will be

---

initial capital-labor ratio or relative factor shares. An aggregate elasticity is then a weighted average of the industry elasticities with weights given by the fraction of capital (or labor) employed in the industry. With constant returns to scale, these weights are identical to the output weights above. Because these aggregation conditions are not met in the data, measured aggregate elasticities include some inter-commodity substitution or compositional changes and are biased up from the underlying technical substitution elasticities.

[13] Differentiate the identity which says total revenue of sector Y equals the sum of factor payments to labor and capital. From $P_Y.Y = PL.L_Y + PK.K_Y$ comes $dP_Y.Y + P_Y dY = dPL.L_Y + dPK.K_Y + PK.dK_Y + PLdL_Y$ or $dP_Y + \frac{dY}{Y} = \Delta L_Y(dPL + \frac{dL_Y}{L_Y}) + \Delta K\ (dPK_Y + \frac{dK_Y}{K_Y})$.

Assuming marginal cost pricing by each firm, it is easy to show

$$\frac{dY}{Y} = \Delta L_Y.\frac{dL}{L_Y} + \Delta K_Y.\frac{dK}{K_Y}$$

Subtracting this equation from the first produces equation (15).

large only if the price elasticity of final demand for farm output is fairly large. For simplicity only relative product prices were allowed to influence relative commodity demand. In the two good situation of the small model the demand equation for F is

$$\frac{dF}{F} = E_{fY}(dP_Y - dP_f) \tag{18}$$

where E_{fY} is the income-compensated price elasticity of demand between agricultural and nonagricultural goods. The demand equations also satisfy the constraint $V_Y\frac{dY}{Y} + V_f\frac{dF}{F} = 0$, where V_Y, V_f are the proportions of total expenditure on Y and F respectively. Since $V_Y + V_f = 1$, relative product price changes lead to a pattern of demand changes whose weighted sum is zero. A result of this constraint is that the demand equations for F and Y cannot be specified independently of each other. Knowledge of $\frac{dF}{F}$, given V_Y and V_f, is sufficient to determine the percentage change in the demand for Y.

A similar expression holds in the larger model which contains three final demands for cattle and crop output and nonagricultural goods.

$$\frac{dF}{F} = E_{fY}(dP_Y - dP_f) + E_{fc}(dP_c - dP_f);\ E_{fY}, E_{fc} > 0, \tag{19}$$

where E_{fc}, E_{fY} are the compensated price elasticities between F and Y and F and C respectively.

$$dC/C = E_{cf}(dP_f - dP_c) + E_{cY}(dP_Y - dP_c) \tag{20}$$

is the change in demand for cattle. The overall constraint appears as

$$V_f\frac{dF}{F} + V_Y\frac{dY}{Y} + V_c\frac{dC}{C} = 0$$

so that knowledge of two demand changes permits the third to be estimated residually.

Two properties of the demand equations may not be immediately obvious. One concerns the question of income effects. These equations require that everyone have the same marginal propensity to consume each good--identical

homothetic preference patterns is a sufficient condition--although average propensities to consume may differ from one person to another. If average propensities to consume were everywhere the same, redistribution on the side of the uses of income would be impossible. By assuming identical marginal propensities, income effects have been neutralized so that any redistribution of income among final consumers will not affect the pattern of demand. It could also be argued that the effect on relative prices from a redistribution of real income in the case where marginal propensities differ is a second-order effect which can safely be ignored.

A second feature of these equations is that they are an aggregate net of small farm demand which is independently specified elsewhere. The marketed surplus of the small farm subsector carries as its counterpart a demand for nonagricultural goods. A separate demand equation for small scale agriculture is desirable in order to bring out the adjustment of this sector to mechanization.

The cattle sector

In production this sector is assumed to employ three inputs: mechanizable land and labor, in a constant returns production process

$$C = C(A_c, M, L_c)$$

Output C is a net or value-added concept which recognizes that the stock of cattle is an intermediate input in this process. Output adjustments are captured in the three factor demand equations:

$$\frac{dA_c}{A_c} = \Delta A_c \sigma_{aa} dPA_f + \Delta M \sigma_{am} dPM + \Delta L_c \sigma_{a\ell} dPL + \frac{dC}{C} \tag{21}$$

$$\frac{dL_c}{L_c} = \Delta A_c \sigma_{a\ell} dPA_f + \Delta M \sigma_{\ell m} dPM + \Delta L_c \sigma_{\ell\ell} dPL + \frac{dC}{C} \tag{22}$$

$$\frac{dM}{M} = \Delta A_c \sigma_{am} dPA_f + \Delta\sigma_{mm} dPM + \Delta L_c \sigma_{\ell m} dPL + dC/C \tag{23}$$

As in the case of crops, a separate supply function for cattle would not be independent of the three factor demand equations.

What happens to the price and output of cattle as mechanization proceeds is straightforward. As the price of crops falls, the demand for cattle decreases by an amount dependent on the ease of substitution in demand between crops and cattle. The extent to which crop and cattle prices move together is one factor determining changes in the relative profitability of crops and cattle. If the price of land rises, the supply curve in this sector shifts upwards by an amount which depends on the price changes of substitute factors and the size of the partial elasticities of substitution. Thus, the output of cattle would be expected to fall if demand declined while the relative price of cattle would rise if production costs increased.

Note that crops are not an input into the production process, so that a declining crop price creates no inducement to substitute feed for land.[14]

3. Solutions

The smaller model contains 14 independent equations, (1)-(6a), (7), (8), (10), (13)-(16), and (18) to solve for A_f, L_f, L_Y, L_s, K_Y, K_f, PA, PL, PK, P_f, P_Y, F, F_ℓ and F_s.

The larger model substitutes (6b) for (6a), (12), (19) for (18) and adds (9), (11), (17), (20) and (21)-(23) to determine 7 more variables, A_c, L_c, C, M, PM, P_c and PA_c or 21 variables in all.

In matrix form the small model can be reduced to:

---

[14] Cf. D. Hedley, "An Economic Analysis of Corn Production in the Cauca Valley," Michigan State University, 1969, unpublished Ph.D. dissertation.

$$\begin{bmatrix} \frac{dK_f}{K_f}/dS \\ \frac{dL_f}{L_f}/dS \\ \frac{dPK}{dS} \\ \frac{dL_s}{L_s}/dS \end{bmatrix} \begin{bmatrix} 1 & 0 & U & \frac{\theta_s}{\theta_\ell} \cdot gL_s \\ 0 & 1 & W & \frac{\theta_s}{\theta_\ell} \cdot gL_s \\ -\frac{K_f}{K_y} & \frac{L_f}{L_y} & \sigma^y & \frac{L_s}{L_y} \\ 0 & 0 & R & -\frac{\theta_s}{\theta_\ell} \cdot \Delta A_f gL_s \end{bmatrix}^{-1} \begin{bmatrix} V \\ X \\ 0 \\ T \end{bmatrix}$$

where the letters on the right-hand side indicate the following expressions:

$$R = \Delta K_f \left\{ \Delta A_f (\sigma_{ka} - \sigma_{aa}) + \alpha \right\} - \frac{\Delta A_f}{\theta_\ell} (E - g_p \theta_s) \Delta K_Y$$

$$T = \Delta K_f \left\{ \Delta A_f (\sigma_{ka} - \sigma_{aa}) + \alpha \right\}$$

$$U = \Delta K_f (\sigma_{ka} - \sigma_{kk}) + \frac{\Delta K_Y}{\theta_\ell} (E - g_p \theta_s)$$

$$V = \Delta K_f (\sigma_{ka} - \sigma_{kk})$$

$$W = \Delta K_f (\sigma_{a\ell} - \sigma_{\ell k}) + \frac{\Delta K_Y}{\theta_\ell} (E - g\,\theta)$$

$$X = \Delta K_f (\sigma_{a\ell} - \sigma_{\ell k})$$

Solutions for the larger are similarly obtained. The compact matrix representation of this system is:

$$\begin{bmatrix} \frac{dA_f}{A_f}/dS \\ \frac{dK_f}{K_f}/dS \\ \frac{dL_f}{L_f}/dS \\ \frac{dPK}{dS} \\ \frac{dL_c}{L_c}/dS \\ \frac{dL_s}{L_s}/dS \\ \frac{dM}{M}/dS \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & G & 0 & \frac{\theta_s}{\theta_\ell} gL_s & 0 \\ 0 & 1 & 0 & I & 0 & \frac{\theta_s}{\theta_\ell} gL_s & 0 \\ 0 & 0 & 1 & K & 0 & \frac{\theta_s}{\theta_\ell} gL_s & 0 \\ 0 & -\frac{K_f}{L_y} & \frac{L_f}{L_y} & \sigma^y & \frac{L_c}{L_y} & \frac{L_s}{L_y} & 0 \\ -\frac{A_f}{A_c} & 0 & 0 & R & 0 & 0 & 0 \\ 0 & 0 & 0 & U & 1 & 0 & 0 \\ 0 & 0 & 0 & W & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} H \\ J \\ P \\ 0 \\ T \\ V \\ X \end{bmatrix}$$

where the letters on the right-hand side denote the following:

$$G = \Delta K_f(\sigma_{aa} - \sigma_{ka}) - \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s) + \frac{\lambda\Delta A_c}{\theta_\ell \Delta A_f}(\Delta K_f E_{fc})$$

$$H = G + \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s)$$

$$I = \Delta K_f(\sigma_{ka} - \sigma_{kk}) - \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s) + \frac{\lambda\Delta A_c}{\theta_\ell \Delta A_f}(\Delta K_f E_{fc})$$

$$J = I + \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s)$$

$$K = \Delta K_f(\sigma_{a\ell} - \sigma_{\ell k}) - \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s) + \frac{\lambda\Delta A_c}{\theta_\ell \Delta A_f}(\Delta K_f E_{fc})$$

$$P = K + \frac{\Delta K_y}{\theta_\ell}(E_{fy} + g_p\theta_s)$$

$$R = -\Delta K_y E_{cy} + \frac{\Delta K_f}{\Delta A_f}\{\Delta A_c \sigma_{aa} - \lambda\Delta A_c(E_{cf} + E_{cy})\}$$

$$T = R + \Delta K_y E_{cy}$$

$$U = \Delta K_y E_{cy} + \frac{\Delta K_f}{\Delta A_f}\{\Delta A_c \sigma_{a\ell} - \lambda\Delta A_c(E_{cf} + E_{cy})\}$$

$$V = U + \Delta K_y E_{cy}$$

$$W = -\Delta K_y E_{cy} + \frac{\Delta K_f}{\Delta A_f}\{\Delta A_c \sigma_{am} - \lambda\Delta A_c(E_{cf} + E_{cy})\}$$

$$X = W + \Delta K_y E_{cy}$$

Since it can be solved by hand the small model is capable of generating some insight into the determinants of the impact of farm mechanization. For example, the change in the amount of surplus labor per unit of capital subsidy which is easily obtainable from the smaller model. This response is given by:

$$\frac{dL_s}{L_s}/dS = \left(\frac{K_f}{K_y} - \frac{L_f}{L_y}\right)(-E + g_p\theta_s)\frac{\Delta K_y}{\theta_\ell}\Delta K_f\left(\Delta A_f\left\{\sigma_{ka} - \sigma_{aa}\right\} + \alpha\right)$$

$$+ \Delta K_f \frac{\Delta A}{\theta_\ell}\Delta K_y (E - g_p\theta_s)\left(\frac{L_f}{L_y}\left\{\sigma_{a\ell} - \sigma_{\ell k}\right\} - \frac{K_f}{K_y}\left\{\sigma_{ka} - \sigma_{kk}\right\}\right)$$

$$+ -\sigma^y \left(\Delta K_f\left\{\Delta A_f(\sigma_{ka} - \sigma_{aa}) + \alpha\right\}\right) / D$$

where the denominator D is positive in the usual range of parameter values.[15]

The numerator contains three complicated terms. Since the sign of the change in the amount of surplus labor, provoked by a capital subsidy of a given size, depends only on the numerator, the three terms in the numerator can be associated with three different effects of farm mechanization on the demand for labor.

According to the first term surplus labor will grow if large scale agriculture is more capital intensive than nonagriculture: that is, if $\frac{K_f}{K_Y} > \frac{L_f}{L_Y}$ or sector F uses more capital and less labor per unit of output than sector Y. This adverse factor intensity effect will be reinforced on the consumption side as the relative price of food falls and the output of large scale agriculture increases relative to the output in nonagricultural pursuits. The second term will always be positive as long as $\sigma_{a\ell}$ is less than $\sigma_{\ell k}$ and σ_{ka} is not a large negative number (capital and land are not exceptionally strong complements). As long as substituting capital for labor when the relative price of capital falls is easier than substituting labor for land when the relative price of land rises, labor surplus will grow, and will grow proportionately more the easier it is for consumers to substitute F for Y in their budgets, the larger the market share of small scale agriculture and the more

---

[15] D is equal to:

$$\frac{L_s}{L_Y}\left(\Delta K_f\left\{\Delta A_f\,(\Delta K_a-\sigma_{aa})+\alpha\right\}-\frac{\Delta A_f}{\theta_\ell}\left\{E-g_p\theta_s\right\}\Delta K_Y\right)$$
$$+\frac{\Delta A_f}{\theta_\ell}\,\theta_s g L_s\left(\sigma^y+\Delta K_f\left\{\frac{K_f}{K_Y}(\sigma_{ka}-\sigma_{kk})-\frac{L_f}{L_Y}(\sigma_{\ell a}-\sigma_{\ell k})\right\}\right)$$
$$+\left(\frac{K_f}{K_Y}-\frac{L_f}{L_Y}\right)\left(\frac{\theta_s}{\theta_\ell}\,gL_s\,\Delta K_f\left\{\Delta A_f\,(\sigma_{ka}-\sigma_{aa})+\alpha\right\}\right).$$

A large value of $\frac{L_s}{L_Y}$ relative to that of other variables is sufficient for a positive D. D is positive in all the later simulations.

readily this sector withdraws from the market when the terms of trade turn against it.

Under the most probable circumstances in Colombia the first two terms will be positive. If they are, however, they will be offset to some extent by the third term which is always zero or negative. This term captures the substitution of labor for capital in the nonagricultural sector as the output expansion in agriculture lowers the relative price of food and therefore the relative price of labor to capital and the real wage in the nonagricultural sector. Thus the net effect on employment of subsidized farm mechanization depends on the size of different parameters and cannot be determined a priori. Final demand elasticities, differences in partial elasticities of substitution and sectoral factor intensities, and the response coefficients of small scale agriculture, along with its relative size, are the most important of these parameters. Later simulations of this solution, using Colombian data to estimate the parameter sizes, suggests that farm mechanization has increased the amount of surplus labor.

Since the appearance of some parameters in both numerator and denominator, or simply in several of the terms, makes their interpretation ambiguous, Table 2 gives the results of differentiating the solution with respect to variations in different parameters.

TABLE 2: Signs of Partial Derivatives

	$\delta\sigma$	δE	$\delta\sigma_{k\ell}$	$\delta\alpha$	$\delta\sigma_{ka}$	δgL_s	$\delta(\frac{K_f}{K_Y} - \frac{L_f}{L_Y})$
$\delta(\frac{dL_s}{L_s} / dS)$....	< 0	> 0 if $\frac{K_f}{K_Y} > \frac{L_f}{L_Y}$ and/or if $\sigma_{a\ell} < \sigma_{\ell k}$	< 0	$\gtrless 0$	$\gtrless 0$	> 0 if $\frac{K_f}{K_Y} > \frac{L_f}{L_Y}$	> 0

Increases in σ^y will reduce the amount of surplus labor per unit of capital subsidy. A higher degree of capital intensity in larger scale agriculture would work in the opposite direction. A larger final demand elasticity E or a larger labor intensity elasticity gL_s would augment surplus labor if large scale agriculture were the more capital intensive sector, and if more labor per unit of output is ejected by substituting capital for labor than is hired by substituting labor for land. If factor intensities are equal in sectors Y and F, the influence of E and gL_s disappears in the first term. An increase in the partial elasticity of substitution between capital and labor $\sigma_{k\ell}$ will always lead to more surplus labor. Variations in α and σ_{ka} are ambiguous in their impact. A higher supply elasticity for land would disemploy labor if F were the more capital intensive sector and the more so the larger the final demand elasticity E. But a larger value for α would also encourage a larger expansion of F, and a lower food price and real wage in nonagriculture and more labor employment in Y. The size of this effect is smaller, the smaller is the ratio of employment in Y to employment in small scale agriculture. A higher value for σ_{ka} means that, on the one hand, capital could be substituted for land more easily as capital prices fell and if F were more capital intensive, the expansion of F would increase the amount of surplus labor. On the other hand, a larger expansion of F implies lower nominal wages and more labor employment in Y. In all of the simulations the effects of positive variations in α and σ_{ka} were also positive but quite small. All of these propositions extend to the larger model since the explicit introduction of the cattle sector in that model does not impair the generalization of these conclusions.

4. Parameter Values

In order to empirically implement the models and use them as a basis for further analysis of income distribution and resource allocation, it is necessary to quantify the parameters in each model. This requires information on 17 parameters in the small model and 28 in the large one. The values chosen for each parameter in various simulations are presented in Tables 3 and 4. The derivation of these values is discussed elsewhere.[16]

Some methodological points are considered here. There is first of all a question about the appropriate time period for measuring the parameters. Simulation comparisons are made with respect to an original equilibrium in which there is no capital subsidy. This requirement on initial conditions suggests that the estimates should refer to the period 1946-1949 before mechanization became firmly established. For many of the parameters this could not be done. Most of the estimates are based on the 1951-1964 period and on 1964 in particular. Since these estimates will reflect the previous influence of the capital subsidy, the most useful interpretation of the simulations is that they reveal the effect of removing the subsidy rather than of introducing it.

On the basis of interest rate information and empirical rate of return calculations, a likely range for the size of the subsidy dS is .35 to .5. A value of .4 is used for the simulation results. Strictly speaking, these solutions are only valid for small changes in the value of dS and .4 cannot be considered a small change. To the extent that the derivatives are not constant at all sizes of dS, another element of approximation is introduced.

The value of the elasticity of factor substitution in nonagriculture is an important determinant of the effect of subsidized mechanization. Unfortun-

[16] See Thirsk, chapter VI, op. cit.

TABLE 3: Parameter Values Used in Small Model Simulations

Simulation:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Parameter										
ΔL_y	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
ΔK_y	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
ΔL_y	.18	.18	.18	.18	.18	.18	.18	.18	.18	.18
ΔK_f	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
ΔA_f	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32
E	-1	-1	*-1.5	*-.75	-1	-1	-1.5	-.75	-1	-1
gL_s	-.2	-.2	-.2	-.2	*-.1	*-.1	*-.1	*-.1	-.2	*-.1
g_p	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
K_f/K_y	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27
L_f/L_y	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
α	.6	*1	1	1	.6	1	1	1	1	1
θ_s	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3
θ_ℓ	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
$\sigma_{k\ell}$	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	*1	1
σ_{ka}	.1	.1	.1	.1	.1	.1	.1	.1	*-.1	-1
$\sigma_{a\ell}$	.6	.6	.6	.6	.6	.6	.6	.6	*.4	.4
L_s/L_y	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5

Notes:

(a) An asterisk (*) denotes the change in assumption from one simulation to the next.

(b) Numbers (5) to (8) correspond to simulations (1) to (4) respectively in that gL_s is the only parameter change that has been made.

TABLE 4: Parameter Values Used in Large Model Simulations

Simulation:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Parameter								
ΔL_y	.50	.50	.50	.50	.50	.50	.50	.50
ΔK_y	.50	.50	.50	.50	.50	.50	.50	.50
ΔL_f	.18	.18	.18	.18	.18	.18	.18	.18
ΔK_f	.50	.50	.50	.50	.50	.50	.50	.50
ΔA_f	.32	.32	.32	.32	.32	.32	.32	.32
ΔA_c	.38	.38	.38	.38	.38	.38	.38	.38
ΔL_c	.24	.24	.24	.24	.24	.24	.24	.24
ΔM	.38	.38	.38	.38	.38	.38	.38	.38
E_{fy}	.5	*.4	.5	.4	*1	1	.5	.5
E_{fc}	.5	*.3	.5	.3	*.5	.5	.5	.5
E_{cy}	.2	*.3	.2	.3	*.5	.5	.2	.2
E_{cf}	1	*.6	1	.6	*1	1	1	1
gL_s	-.2	-.2	*-.1	*-.1	-.2	*-.1	-.2	*-.1
g_p	.1	.1	.1	.1	.1	.1	.1	.1
K_f/K_y	.27	.27	.27	.27	.27	.27	.27	.27
L_f/L_y	.07	.07	.07	.07	.07	.07	.07	.07
θ_s	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3
θ_ℓ	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
$\sigma_{k\ell}$ in sector F	1.5	1.5	1.5	1.5	1.5	1.5	*1	1
σ_{ka} in sector F	.1	.1	.1	.1	.1	.1	8-.1	-.1
$\sigma_{\ell a}$ in sector F	.6	.6	.6	.6	.6	.6	*.4	.4
λ	.8	.8	.8	.8	.8	.8	.8	.8
L_s/L_y	.5	.5	.5	.5	.5	.5	.5	.5
L_c/L_y	.18	.18	.18	.18	.18	.18	.18	.18
$\sigma_{a\ell}$ in sector C	.2	.2	.2	.2	.2	.2	.2	.2
σ_{am} in sector C	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
A_f/A_c	.3	.3	.3	.3	.3	.3	.3	.3
V_f/V_c	2	2	2	2	2	2	2	2

Notes: (a) An asterisk (*) denotes the change in assumption from one simulation to the next.

(b) Numbers (3), (4) and (6) correspond to simulations (1), (2) and (5) respectively in that only gL_s differs between the groups.

ately, there is little direct information on the size of this parameter in Colombia.[17] Studies elsewhere suggest it would be significantly less than unity. For example, Clague's best estimate of the elasticity of substitution in Peruvian manufacturing was .2.[18] This agrees with Lucas' measurement of .2 to .5 for the same elasticity in U.S. manufacturing.[19] Except for mining, it is unlikely that other components of nonagriculture would be outside this range. In utilities and personal services, the ease of factor substitution would probably be closer to zero. Therefore, each simulation for both the large and small models operates within a range of zero to .5 for this substitution parameter in order to assess the degree of sensitivity of the results to changes in assumption about its proper size.

A zero value for the ease of nonagricultural factor substitution may seem too extreme. However, it can be rationalized as ad hoc recognition of the significance of noncompetitive wage setting in unionized portions of the modern sectors within nonagriculture.[20] If these noncompetitive practices prevent any decline in the real product wage in nonagriculture, there would be no extra absorption of labor in this sector as might otherwise occur if the real product wage fell when relative crop prices declined. This labor supply effect is equivalent to assuming a zero factor substitution elasticity in nonagriculture. Returning to the equations in the model, if the real

---

[17] For 20 manufacturing sectors in Colombia it has been estimated that the elasticity is zero in 12 of them when size of firm is held constant. An unweighted average value for the elasticity was .26. See Contribucion Al Estudio del Desemples en Colombia, DANE, Bogotá, 1971, p. 145.

[18] C. Clague, "Capital-Labor Substitution in Manufacturing in Less Developed Countries," Econometrica, Vol. 37, No. 3, July 1969, pp. 528-537.

[19] R. Lucas, "Substitution between Labor and Capital in U.S. Manufacturing," in A. Harberger (ed.), The Taxation of Income from Capital, Washington, D.C.: The Brookings Institution, 1969, pp. 223-267.

[20] Direct evidence of this splitting apart of the urban wage structure is given in Nelson et al, Structural Change in a Developing Economy,

product wage were constant, $dP_Y = dPL_Y$, and the price change equation would be amended to $dP_Y = \Delta K_Y dPK + \Delta L_Y dP_Y$ or since $\Delta K_Y + \Delta L_Y = 1$, $dP_Y = dPK$. A central equation in each model is a factor demand relationship in sector Y of the form

$$\frac{dK_Y}{K_Y} - \frac{dL_Y}{L_Y} = \sigma\ (dPK - dPL_y).$$

Then, if $dPL_Y = dP_Y = dPK$, this equation is equal to zero and monopoly wage behavior in nonagriculture can be interpreted as a low or zero factor substitution elasticity.[21] In other words, the parameter σ^y is an indicator of the ease of labor absorption in nonagriculture reflecting either technical or labor supply conditions.

The demand functions satisfy two properties. One is that changes in spending on one good are exactly offset by changes in expenditure on all other goods. This adding-up property insures changes in consumer spending exhaust consumer income and requires own-price elasticities E_{ii} be equal to the negative sum of all cross-price elasticities E_{ij}. Thus for crops

$$E_{ff} + E_{fc} + E_{fy} = 0$$

and for cattle

$$E_{cc} + E_{cf} + E_{cy} = 0.$$

The second property is symmetry in consumer substitution so that

$V_i\ E_{ij} = V_j\ E_{ji}$ where V_i, V_j are total consumer expenditure on commodities i and j. These restrictions are reflected in the chosen demand parameters.

Princeton, N.J.: Princeton University Press, 1971, Chapter V.

[21] Given $\frac{dK_Y}{K_Y} - \frac{dL_Y}{L_Y} = \Sigma\ w_j \sigma_j (dPK_j - dP_j)$, if $dPK_j = dPL_j$ for some j, σ_j for other j are weighted by numbers less than one.

5. Simulation Results

Throughout this discussion the notation SM (i), LM (i) is used to designate the i'th simulation in the small and large models respectively. Table 5 summarizes the 108 simulations that were performed and presents the range of factor allocation and price responses to a one percent change in the subsidy to large farm capital. The two models predict broadly similar effects although the range of outcomes is wider in the larger model. In each model there is a sizable expansion in the employment of land, labor and capital in large scale agriculture. Residual employment in small scale agriculture exhibits large variation indicating this variable's sensitivity to the size of the factor substitution elasticity σ^y. Employment of labor in the cattle sector changes very little in the large model in contrast to the relatively large change in the use of nonmechanizable land. The capital-labor ratio tends to increase in large farm agriculture and to decline in nonagriculture. The land-labor ratio in large farm agriculture rises by a smaller amount in the large than in the small model while the same ratio in small farm agriculture varies inversely with the change in the amount of surplus labor. In all of the simulations the prices of land, capital and nonagricultural goods increase relative to the price of labor. Since $\frac{dPK}{dS} < 1$ in every case, the after-subsidy price of capital relative to labor declines in large scale agriculture.

These results conform well to observations on the Colombian economy: rapid input growth in mechanized agriculture; slow labor absorption in the nonagricultural sector; increasing labor productivity in mechanized agriculture combined with stable or declining labor productivity in small farm agriculture; a shift of mechanizable land from cattle to crops and greater

TABLE 5: Range of Responses to a One Per Cent Subsidy on Large Farm Capital

A. Small Model (SM)

Variable:	$\frac{dK_f}{K_f}$	$\frac{dA_f}{A_f}$	$\frac{dL_f}{L_f}$	$\frac{dL_s}{L_s}$	dPA	dPK	dP_y
Range (per cent)	.3-1.3	.5-.9	.5-.8	(-.25)-.6	.6-.95	.4-.6	.2-.3

B. Large Model (LM)

Variable:	$\frac{dK_f}{K_f}$	$\frac{dA_f}{A_f}$	$\frac{dL_f}{L_f}$	$\frac{dL_c}{L_c}$	$\frac{dL_s}{L_s}$	$\frac{dM}{M}$	dPA	dPK	dP_y
Range (%)	.5-1.6	.5-1.25	.5-1.15	(-.23) to .09	(-.7) to .8	.2-.5	.2-.9	.45-.85	.21-.43

C. Preferred Results (LM (1) and LM (3); LM (2) and LM (4))

Variable:	$\frac{dK_f}{K_f}$	$\frac{dA_f}{A_f}$	$\frac{dL_f}{L_f}$	$\frac{dL_c}{L_c}$	$\frac{dL_s}{L_s}$	$\frac{dM}{M}$	dPA	dPK	dP_y
Range (%)	.78-1.07	.7-.96	.64-.93	.004 -.08	.11-.45	.2-.31	.25-.27	.82-.84	.076-.082

Source: Thirsk, Tables AT-25, AT-26, op. cit.

use of nonmechanizable land in the cattle sector; a change in the terms of trade against crops; relative stability of the price of cattle over crops; and an increase in the relative price of land.

In both models, assuming higher final demand elasticities E_{ij}, or a higher value of the labor intensity elasticity gL_s, has the predictable impact of fostering a higher rate of expansion of large scale agriculture at the expense of labor absorption from small scale agriculture. This is an important point and one that is often overlooked in partial equilibrium analysis of the employment impact of farm mechanization. Many judgments about the desirability of farm mechanization are based on a comparison of post-mechanization large farm employment levels with those of the post-mechanization large farm employment levels with those of the pre-mechanization era. If the expansion effects dominate the labor substitution effects and large farm employment expands over time, as in the models, mechanization is viewed favorably. The simulation results, however, indicate that this partial equilibrium view is inadequate for assessing whether or not subsidized farm mechanization is labor saving within the whole economy. One of the merits of a general equilibrium model is its ability to demonstrate that what may be true in the small may not be true in the large. The models reveal that increased employment of labor in large scale agriculture is quite consistent with increased amounts of surplus labor in small scale agriculture. This is true even after account is taken of the increase in labor demand due to an output switch from cattle to crops. A competitive welfare relationship between the two agricultural sectors can occur because the means of achieving higher employment in large scale agriculture may induce a still greater decline of employment in other sectors. Although labor per unit of nonagricultural output may be expected to rise by an amount depending on the value

of σ^y, this effect may not be large enough to outweigh the effect of a diminishing output level in this relatively labor-intensive sector.

Explicit recognition of the cattle sector in the larger model clearly provides for more stabilizing final demand responses than in the smaller model. The dilution and greater diffusion of final demand responses when any change in relative product prices occurs accounts for this stability. Thus, when the price of cattle relative to crops increases somewhat, there is an increase in final demand for outputs F and Y at the expense of C, and when the relative price of nonagricultural to crop goods rises outputs F and C expand over Y. Outputs C and Y then experience both an expansion and a contraction of final demand which serves to stabilize their level of production. In particular, the output level of Y is unlikely to contract as much as in the SM and so, on the whole, the positive changes in the quantity of surplus labor are normally smaller in the LM. Furthermore, any contraction of sector Y will be offset in part by the growth of the cattle sector which is another source of commercial employment in the model. For these reasons, the LM results are preferred over the SM ones, although both contain cases which in their structural outline roughly parallel the passage of events in Colombia.

Since there is a wide range of solutions for almost every variable, some judgment about representative values is required, if these results are to undergo further analysis. Because of the LM's extra complexity and closer resemblance to the actual composition of the Colombian economy, accuracy considerations restrict the menu of choice to the LM simulations. Of the 8 simulations LM (5) and LM (6) employ the most improbable parameter values on the demand side since they assume compensated own-price elasticities of 1.5

for both crops and cattle. LM (7) and LM (8) have the lowest partial substitution elasticities and are also excluded because of their close similarity to the remaining pairs: LM (1) and LM (3), LM (2) and LM (4). These pairs contain the middle and lower estimates of the final demand elasticities. LM (1) and LM (3) assume an own-price elasticity of demand for crops of 1 and for cattle of 1.2 while LM (2) and LM (4) assume these are .7 and .9 respectively.

For each pair a further choice of the appropriate size of the factor substitution elasticity in nonagriculture must be made. As mentioned before, σ^y reflects both the technical possibility of substituting labor for capital in nonagriculture and the additional constraint placed on labor absorption in some parts of this sector because of the institutional pressure towards higher real product wages. Viewed in this manner it would be surprising if the relevant value of σ^y fell outside the interval 0 to .1 or .2 at a maximum. This choice of simulations and values for σ^y is made only because it simplifies further analysis and because no evidence as yet refutes its plausibility. The range of results for this choice are listed as the preferred ones in Table 5.

6. Income Distribution Effects

In an analysis of income distribution changes some consideration must be given to the possibility that different economic groups may gain or lose in two distinct ways as relative prices change. First, as relative factor prices change, the money incomes of some groups may increase at the expense of others and, second, as relative product prices alter, real incomes of different groups may rise or fall depending on the proportions in which various commodities are consumed by each group. For any particular group changes

in the sources of income may either offset or reinforce changes in the uses of income.

A national income accounting framework is a useful stage on which to examine these two effects. In the LM, national income I may be defined by

$$P_y Y + P_f(F_\ell + F_s) + P_c C + P_z Z$$

from the side of total expenditures; and as

$$PL\ (L_f + L_c + L_y) + PK_y\ (K_y + K_y) - SK_f + PA\ (A_f + \lambda A_c)$$
$$+ PM\ M + PL_s L_s$$

from the side of income generation. A new variable is introduced here, $\hat{PL}_s$, which is defined as the average product of labor in small scale agriculture. This average product of labor is in turn equal to average consumption expressed as:

$$\frac{P_f \bar{F}_s + P_z Z + P_y Y_s}{L_s}$$

where $\bar{F}_s$ is the amount of own-consumption of agricultural output, Y_s is the amount of nonagricultural output purchased by the sale of some fraction of crop output, and Z is the amount of Z-goods production.

The change in national income dI from the side of the sources of income is, to a first-order approximation,

$$(K_y + K_f)dPK - K_f dS + (A_f + \lambda A_c)dPA + MdPM + L_s d\hat{PL}$$

Since labor is the numeraire,

$$(L_y + L_c + L_f)\ dPL = 0$$

and if another factor price change is positive, it is positive relative to the price of labor. National income is measured in terms of either the price of labor or the price of crops. If Y_i, F_i, C_i represent the total expenditure by the i'th income group on commodities Y, F and C respectively, an income

distribution balance sheet can be drawn up portraying changes in income on both sources and uses sides for each group of factor owners in the economy.

Factor Owners	Sources	Uses
Mechanizable land	$(A_f + \lambda A_c)\ dPA$	$-\ (F_a dP_f + C_a dP_c + Y_a dP_y)$
Capital	$(K_f + K_y)\ dPK - K_f dS$	$-\ (F_k dP_f + C_k dP_c + Y_k dP_y)$
Labor	$(L_f + L_c + L_y) dPL$	$-\ (F_\ell dP_f + C_\ell dP_c + Y_\ell dP_y)$
Nonmechanizable land	$MdPM = 0$	$-\ (F_m dP_f + C_m dP_c + Y_m dP_y)$
Small farmers	$L_s d\hat{PL}_s$	$-\ (\bar{F}_s dP_f + C_s dP_c + Y_s dP_y + Y_z dP_z)$

For each group the sources entry measures the loss or gain in nominal income from ownership of that factor. The entry on the uses side captures the change in the real purchasing power of nominal expenditures due to changes in relative product prices. For example, if a group were heavily specialized in the consumption of a good whose relative price rose, that group's real income gain would be much less than any gain in nominal income it might receive.

Notice that the overall sum of the income changes in the model is zero. There is a strict zero-sum redistribution of income among different groups as a result of the subsidy to farm capital. This is most easily seen by substituting for the product price changes on the uses side, using the numeraire definition $dP_f = dPL = 0$, assuming for the moment that Z-goods prices are constant, $dP_z = 0$, and that the change on the sources side in the nominal income of small farmers is zero. The sum on the uses side becomes

$$\sum_i C_i dP_c + \Sigma\, Y_i dP_y \quad \text{or} \quad \sum_i C_i(\lambda \Delta A_c dPA) + \sum_i Y_i(\Delta K_y dPK)$$

which is equal to $\lambda A_c dPA + K_y dPK$. As shown earlier, on the sources side $A_f dPA = -K_f(dPK - dS)$ and substituting this expression into the sources side for $A_f dPA$ gives an overall sources statement of

$$-K_f(dPK - dS) + \lambda A_c dPA + (K_f + K_y)dPK - K_f dS$$

which is exactly equal to the foregoing uses statement.

If the balance sheet is to balance, it is necessary to assume no change in sources of nominal income for small farmers. The basic reason is that the foregoing approach is only a first-order approximation which is unable to account for gains or losses in real output due to improved or worsened resource allocation. These second-order effects are treated in the next section. Right now only those changes in real income for small farmers which occur on the uses side can be captured. From the balance sheet it is apparent that if dP_y and dP_c are positive, small farmers will be worse off to the extent they are not entirely self-sufficient in consumption and Y_s, C_s are greater than zero. If this sector also has to accomodate more surplus labor, it will experience a loss on the output or income side. If the real wage formerly earned by new entrants to this sector approximates the average product of labor in this sector, a sharing ethic of income distribution will diffuse any income loss in the form of a lower average product for all members. Under such circumstances the elasticity of the average product with respect to labor provides a means of measuring any income loss on the sources side. This elasticity may be expressed as $-1 + \frac{MPL}{APL}$ where MPL, APL are the marginal and average products of labor. The change in the absolute income level of the small farm sector is then equal to $dL_s(MPL - APL)$ where the marginal product measures the extra production, and the average product the additional consumption claim, of a new entrant. On the balance sheet this income change is ignored on both the income and expenditure sides.

The nature of the gain or loss to the capitalist group may not be obvious either. On the one hand, this group loses by a transfer of income to

landowners who enjoy the benefit of a subsidy. Capitalists in this sense should not be identified with the rich. Those who lose may be poor savers whose only medium for saving is the financial system which can make low interest loans to farm machinery buyers only by paying a low, perhaps even negative, real return to these savers. On the other hand, some capitalists may gain from a higher rate of return to capital in sector Y caused by the diversion of more capital to agriculture and less to nonagriculture. These capitalists may indeed be the rich, so that the income measure fails to capture redistributions of income within the capitalist group. In Colombia, land and capital owners are probably the same people so that in considering the distribution of personal incomes, changes in the amounts of nonlabor income should be grouped together.

Table 6 presents the information needed to estimate the income distribution effects implied by the simulation results. Table 7 makes allowances for the wide diversity of consumption patterns among different income groups in Colombia. The figures on uses of income reflect the assumption that recipients of non-labor income spend five percent of their income on each of crop and cattle products and the rest on nonagricultural goods. These expenditure percentages probably err on the high side, but there is little information on which to base a judgment about the degree of probable overestimation.[22]

---

[22] Two studies offer some guidance on the matter. The 1953 urban family budget study used to calculate consumption weights for cost-of-living indices indicated blue-collar families spent on average about 50 percent of their income on food. A later study, Encuesta de Presupuestos Familiares: Parte Primera, Bogotá: Universidad de Los Andes, CEDE, suggested that a proportion closer to 60 percent would be more accurate. Given that the ratio of retail to ex-farm food prices is about 1.75 to 2.00, labor's food expenditure of .36 in Table 6 is consistent with the budget studies. This proportion plus the small farm own-consumption ratio of .65 imply that recipients of nonlabor income spent 10 percent of their income on food. Marketing margins of 40-50 percent are appropriate according to the DANE study, Contribucion al Estudio del Desempleo en Colombia, Bogotá, Colombia, June 1971.

TABLE 6: Sources of Income by Type and Sector, 1964
(Millions of Current Pesos)

Sector:	Nonagriculture	Mechanized Agriculture	Cattle	Small Scale Agriculture	Total
Income Type:					
Labor	15,984	490	1,247	-----	17,721
Capital	12,075	1,355	-----	-----	13,430
Mechanizable Land	------	875	1,378	-----	2,253
Small Farm	------	-----	-----	5,298	5,298
Nonmechanizable Land	------	-----	1,907	-----	1,907
Value-added:	28,059	2,720	4,532	5,298	40,609

Notes: (a) This table is based on the National Accounts for 1964.
(b) There is no attempt to allocate small farm income between capital (land) and labor.

TABLE 7: Uses of Income by Type and Commodity, 1964
(Millions of Current Pesos)

Expenditure:	Crops	Nonagricultural Goods	Cattle	Total
Income Type:				
Labor	3,696	11,274	2,751	17,721
Capital	670	12,087	673	13,430
Mechanizable Land	112.5	2,028	112.5	2,253
Nonmechanizable Land	95.5	1,716	95.5	1,907
Small Farm	3,444	954	900	5,298
Total:	8,018	28,059	4,532	40,609

Notes: (a) The table utilizes the assumption that nonlabor income recipients have average consumption propensities of .9 for nonagricultural goods and .05 for crops and cattle. An own-consumption ratio of .65 is also assumed for small farmers.
(b) There is no attempt to allocate small farm income between capital (land) and labor.

Even though they are informed guesses, these average consumption propensities can be justified as an improvement over any procedure which, implicitly or explicitly, assumes uniform spending patterns across different income groups. The reason that labor's proportionate spending on food of .36 might appear to be too low is that food prices are measured at their ex-farm values which exclude processing and distribution margins included in the price of urban food purchases.

LM (1) with $\sigma^y = 0$ can be used to illustrate the redistributive impact of subsidized farm mechanization. The value of $\frac{dPK}{dS}$ is .826. If dS = .4, dPK, the percentage change in the rate of return to capital, is 33 percent. The percentage change in the price of nonagricultural goods, dP_Y, is $.33(\frac{12,075}{28,059})$ = 14.22 percent. (dPK - dS) is equal to .0696 so the change in the return to mechanizable land is $(\frac{1355}{875})$ .0696 = .1078 and the increase in the price of cattle is .304 (.1078) = .03277. With these relative price measures the real income gains or losses of different groups are:

Mechanizable land	\$2,253 (.1078) - 2,028 (.1422) -112.5 (.03277) = \$242.87 - 288.34 -3.69	= -\$49.16
Capital	\$13,430 (.33) - 1,355 (.4) - 12,087 (.1422) - 673 (.03277)= \$4,437 - 542 - 1,718.53 - 22.05	=\$2,154.69
Labor	0 - 11,274 (.1422) - 2,751 (.03277) = 0 - 1603.16 - 90.15	= -\$1,693.31
Nonmechanizable land	0 - 1,716 (.1422) - 95.5 (.03277) = 0 - 243.98 - 3.12	= -\$247.10
Small Farms	0 - 954 (.1422) - 900 (.03277) = 0 - 135.66 - 29.49	= -\$165.15
		0

The results of LM (2), LM (3) and LM (4) or any simulation with alternative values of σ^y of .1 or .2 would yield relative price effects that are almost identical. Therefore, balance sheet calculations for these simulations

TABLE 8: Disaggregate Wage Behavior in Nonagriculture

A. Uses of Income by Type and Commodity, 1964 (Millions of Current Pesos)

Expenditure:	Crops	Nonagricultural Goods	Cattle	Total
Income Type:				
Modern labor	1,000	5,274	1,718	7,992
Other labor	2,696	6,000	1,033	9,729
Capital	670	12,087	673	13,430
Mechanizable land	112.5	2,028	112.5	2,253
Nonmechanizable land	95.5	1,716	95.5	1,907
Small farmers	3,444	954	900	5,298
	8,018	28,059	4,532	40,609

B. Real Income Gains and Losses

Income Type		Total
Mechanizable land	$2,253 (.1078) - 2,028 (.1988) - 112.5 (.03277) = 242.87 - 403.17 - 3.68	= -163.98
Capital	$13,430 (.3304) - 1,355 (.4) - 12,087 (.1988) - 673 (.03277) = 4,437 - 542 - 2,402.98 - 22.05	= 1,469.99
Modern labor	$7,992 (.1988) - 5,274 (.1988) - 1,718 (.03277) = 1,588.8 - 1,048.5 - 56.29	= 484.01
Other labor	$0 - 6,000 (.1988) - 1,033 (.03277) = -1,192.80 - 33.85	= -1,226.65
Nonmechanizable land	$0 - 1,716 (.1988) - 112.5 (.03277) = -341.14 - 3.68	= -344.82
Small Farms	$0 - 954 (.1988) - 900 (.03277) = -189.65 - 29.49	= -219.14
		0

Notes:

(a) Assume that 1/2 of nonagricultural labor is able to preserve a constant product wage in the "modern" portions of nonagriculture. Then the labor income of modern sector employees L'_y is 1/2 ($15,984) = $7,992, and other labor income is $7,992 + 490 + 1,247 = $9,729.

(b) The weighted average relative price increase in the nonagricultural sector becomes

$$dP_y = \left(\frac{K_y}{Y}\right) dPK + \left(\frac{L'_y}{Y}\right) dPL'_y;$$

$$dP_y = dPL'_y$$

$$\text{so } dP_y = \left(\frac{K_y}{Y - L'_y}\right) dPK = dPL'_y$$

$$= \left(\frac{12,075}{20,067}\right) (.3304) = .1988$$

would generate results which differ but little from those above.

These results indicate that landowners of both kinds are on balance small real income losers. Capitalists are invariably real income gainers with 86 percent of their gains achieved at the expense of labor and small farmers who, along with owners of nonmechanizable land, sustain the largest real income losses. This income loss of small farmers is in addition to the loss they bear through having to absorb more surplus labor. When nonlabor income is considered as a whole, the conclusion is inescapable that real income is transferred toward the richest groups in the Colombian economy, or alternatively, that these groups would lose if the subsidy were removed. This important conclusion is subject to an upward bias arising from the aggregation of urban land and capital income, and from the possibility that certain segments of the nonagricultural labor force may have the institutional power to extract real income gains from a lower relative price for crops. If the real product wage of many nonagricultural employees is constant, the real income losses of labor would be smaller than those indicated while the real income gains of nonlabor factors would be less.

To assess the importance of this last qualification, Table 8 introduces a new uses-of-income distribution which assumes one half of nonagricultural labor (modern sector labor) is able to maintain a constant real product wage. One result of this behavior is a higher relative price for nonagricultural goods than before. The changes in real income distribution among the factor groups that occur with this behavioral modification are also exhibited in the table. Although landowners, other recipients of labor income and small farmers all lose more than before, the major effect of this new assumption is a redistribution of real income away from capital owners to modern sector

labor.[23] Nonetheless, 74 percent of the income gains of capital owners and modern sector labor are at the expense of other workers and small farmers.

While Table 8 lends some impression of the extent to which income distribution changes may have been overestimated, two downward biases should be noted. One is the aggregation of capital losers with capital gainers which may be inappropriate if the former are poor savers and the latter are wealthy capital stock owners. The other stems from the possibility that the losses on the uses side for nonlabor income recipients are too large if these groups' average consumption propensities for nonfood goods are less than has been assumed.

Finally, it is interesting that external effects reinforce the direction of the income distribution effects. For example, higher land prices make it that much more difficult for small farmers to purchase land while the same price change increases the equity value and borrowing capacity of larger farmers and enhances their eligibility for mechanization loans.

7. Resource Allocation Effects

Although its income distribution effects may not be desirable, farm mechanization may still be beneficial in improving the allocation of resources in the economy. The problem of the efficiency losses or gains associated with

---

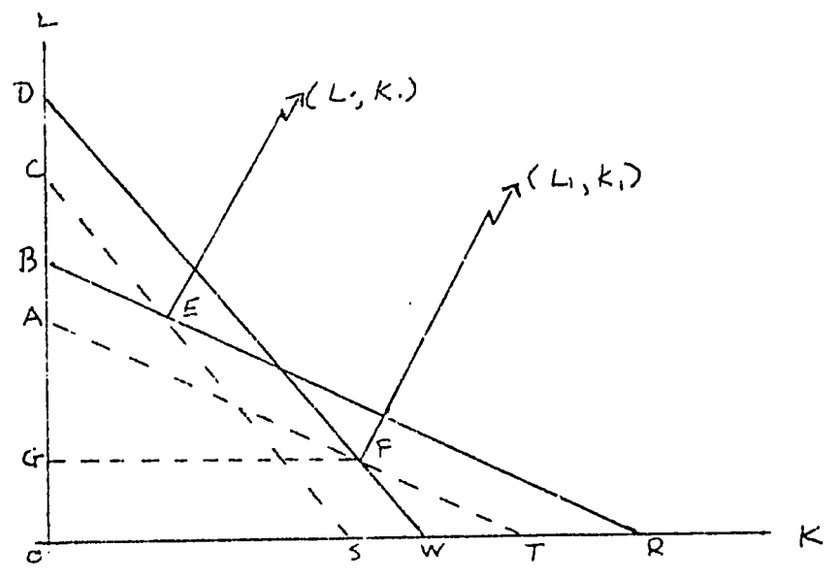
[23] The illustration in Table 8 is conceptually deficient because another factor, modern labor, and another sector, modern nonagriculture, have been admitted on an ad hoc basis without making any adjustment in the commodity demand equations. Because a higher relative price for nonagricultural goods should raise all the other final demands, the original commodity demands are misspecified in this illustration. While the direction in which the gains and losses change is probably correct, the absolute sizes of each are in doubt here.

farm mechanization can be approached from either a micro or macro point of view.

On the micro side, there is a simple criterion for discerning when the substitution of capital for labor adds to or subtracts from the real income of a country, given a divergence between the social and private costs of using capital and labor. First stated explicitly by R. Lidman, this criterion says (and logically enough) that real income will fall as a result of mechanization if the social value of the extra capital used exceeds the social value of the labor released.[24] The diagram below helps to develop and interpret this condition.

Figure 1

Changes in Real Income Associated with Mechanization



[24] R. Lidman, "The Tractor Factor: Agricultural Mechanization in Peru," Public and International Affairs, Princeton, N.J.: Princeton University, 1968, p. 13.

E and F represent two alternative input combinations for producing the same level of farm output. BR and AT are private cost lines representing the ratio of private capital to labor costs, $\frac{PK}{PL_p}$. DW and CS are social factor cost lines with slopes equal to $\frac{PK}{PL_s}$ where PL_s measures the social opportunity cost of using labor. For simplicity, it is assumed only labor has a private-social cost discrepancy. Therefore, $PL_s = \delta PL$, $\delta < 1$. If technology E were originally in use and then technology F became available, technology F would be adopted since it reduces private costs by the ratio of $\frac{OA}{OB}$. At the same time, extra social costs would be incurred--and real income in the economy would be reduced--if the ratio of $\frac{OD}{OC}$ exceeds one. It is possible to derive an explicit expression for the ratio $\frac{OD}{OC}$.[25] This ratio will be greater than

---

25/ $\frac{PK}{PL_p} = \frac{AG}{GF}$; $\frac{PK}{PL_s} = \frac{DG}{GF}$ so $\delta = \frac{PL}{PL_p} = \frac{AG}{DG}$. Then $\frac{DG}{GF} = \frac{1}{\delta}\frac{PK}{PL_p} =$

$= \frac{1}{\delta}\left(\frac{OA - OG}{GF}\right)$. Since $DG = OD - OG$, $OD = DG + OG$ or

$OD = \frac{1}{\delta}(OA - OG) + OG$, and $\frac{OD}{OG} = \frac{1}{\delta}\frac{OA}{OC} + \frac{OG}{OC}(1 - \frac{1}{\delta})$. The components of $\frac{OD}{OC}$ can be expressed in terms of costs:

$$\frac{1}{\delta}\frac{OA}{OC} = \frac{PL_p}{PL_s}\left\{\frac{\left(\frac{PL_pL_1 + K_1\,PK}{PL_p}\right)}{\left(\frac{PL_sL_o + PK\,K_o}{PL_s}\right)}\right\};\quad \frac{OG}{OC} = \frac{PL_s\,L_1}{(PL_sL_o + K_oPK)}\left(\frac{1 - PL_p}{PL_s}\right) =$$

$$= \frac{L_1(PL_s - PL_p)}{PL_sL_o + PK\,K_o}.\quad \text{Therefore } \frac{OD}{OC} = \frac{PL_pL_1 + K_1PK + L_1\,(PL_s - PL_p)}{PL_sL_o + K_oPK}$$

and this ratio will exceed unity if $PL_s(L_1 - L_o) > PK\,(K_o - K_1)$ or if $\frac{PL_s}{PK} < \frac{K_1 - K_o}{L_o - L_1}$. This last inequality states that social costs will rise if the change in the social value of the extra capital used exceeds the social value of the labor released. If there is also a discrepancy between the private and social cost of capital so that $PK_s = \phi PK_p$, $\phi > 1$, this formula generalizes to $\frac{PL_s}{PK_s} < \frac{K_1 - K_o}{L_o - L_1}$ with the same interpretation.

one if $\frac{PL_s}{PK} < \frac{K_1 - K_o}{L_o - L_1}$.

A substitution ratio of 3 to 5 man-days per tractor-hour describes the technological trade-off in Colombia. The private cost of a tractor-hour in 1964 was 25 to 30 pesos while the daily wage was about 11 pesos. If the social opportunity cost of using machinery is about 40 percent above private cost, and if the social cost of using labor is 50 to 75 percent of the market wage, the social factor cost ratio will lie in a range of about 5 to 8.[26] On this basis, past mechanization has been of dubious social profitability in Colombia, and the country would be better off, were it to tax mechanization to achieve a convergence of the social and private factor cost ratios.

Consider next the macro point of view. If farm mechanization has harmful resource allocation effects, one clue would be the observation that mechanization is associated with a larger variance of factor proportions in different sectors, on the reasonable expectation that different factors are not perfect substitutes for one another. An increased sectoral disperson of factor proportions would imply that a producer's choice of techniques based on private factor costs would be increasingly in conflict with the social opportunity costs of the factors.

Greater cleavage of sectoral factor ratios would lead to the conjecture that the economy was less efficient after the growth of mechanization than before. This statement is more likely to be correct if comparisons were being made with an original Pareto-optimal distribution of resources. A Pareto-optimal position for an economy such as Colombia's would likely involve land redistribution, by sale or rental, between large and small scale agriculture. In comparison with mechanization, this transfer would probably raise both

[26] These figures are presented and discussed in chapter III of Thirsk, op. cit.

the demand for labor and the level of output while economizing on the use of capital which, when released, would increase output and employment in other sectors. If this were the alternative position, subsidized farm mechanization could only harm the level of national income. However, when distortions are widespread in every market and comparisons are made with an initial distorted position, there is little presumption one way or the other on the allocative effects of mechanization.

The confusing influence of at least partially offsetting distortions makes some kind of quantitative analysis necessary. The approach adopted here is an application of the method suggested by A. Harberger for measuring improvements of welfare ΔW in second best situations.[27] The allocative impact of farm mechanization can be measured as $\Delta W = -\frac{1}{2} DK\Delta K_f - DL\Delta L_s + DA\Delta A_f$ where ΔW is the gain or loss in national income associated with mechanization. This measure takes account of pre-existing distortions in the land and labor markets and of the fact that prices for the same factors in different uses are not equal. ΔL_s, ΔK_f and ΔA_f represent the equilibrium changes in the allocation of labor to small scale agriculture, and of capital and land to large scale agriculture in response to a capital subsidy of given size. These changes are measured as $(dL_s/L_s)\ L_s$, $(dK_f/K_f)\ K_f$ and $(dA_f/A_f)A_f$ respectively for a given level of capital subsidy. DL, DK and DA represent the size of the distortion in the different factor markets and measure the excess of marginal social benefit over cost per unit change in factor allocation. Thus DL equals the difference between the marginal value productivity of labor in sectors F, Y and C and that in small scale agriculture; DK is a

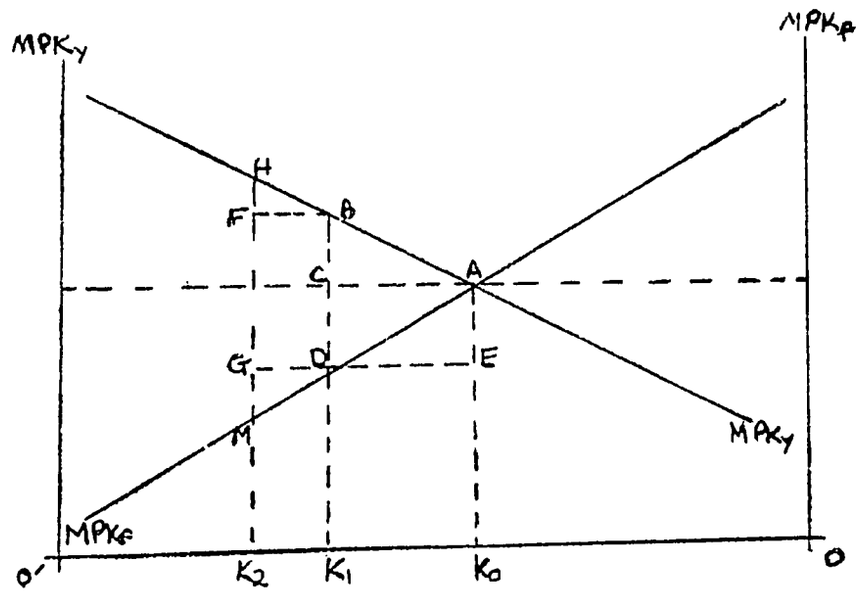
[27] A. Harberger, "The Measurement of Waste," American Economic Review, May 1964, pp. 58-76.

measure of the level of the capital subsidy S; and DA equals the difference between the marginal value productivity of land in crops and cattle in large scale agriculture. Because DL, DK and DA are positive, the first term in the expression for ΔW is always negative (a loss of income); the second is also negative if surplus labor is augmented; and the third term is positive if land is switched out of cattle and into crops.

The rationale for this welfare expression can be easily seen by referring to Figure 2 below. It portrays an initial equilibrium in the capital market at point A where the total capital stock, measured by the horizontal axis 0-0', is divided in the amounts $0'K_o$ in sector Y and $0\ K_o$ in sector F at the common rate of return K_oA. As a result of the subsidy BD to the cost of large farm capital, K_o-K_1 units of capital are shifted from sector Y to sector F and national income declines by an amount measured by the triangle ABD. The triangle ABD can be divided into two smaller triangles ABC and AED,

Figure 2

The Cost of Resource Misallocation



whose areas are equal to $\frac{1}{2}$ CB $(K_1 - K_o)$ and $\frac{1}{2}$ CD $(K_1 - K_o)$. The sum of the areas of these two triangles is $\frac{1}{2}(K_1 - K_o)$ (CB + CD) = $\frac{1}{2}$ $(K_1 - K_o)$BD which gives the first term, $\frac{1}{2}\Delta K_f S$, in the welfare measurement.

In the case of the other two terms in the welfare expression, factor reallocations occur from an initial distorted position. As measures of changes in deadweight loss or foregone output, these terms are only first-order approximations of the output gains or losses from factor reallocation. While the capital subsidy can be assumed constant as a matter of policy, the size of the other distortions, DA and DL, will likely alter as the allocative repercussions change in size. For example, the size of the labor market distortion will likely increase if there are additions to surplus labor, and shrink if the amount of surplus labor is reduced.[28] Similarly, although a constant land distortion has been assumed for analytical purposes, it is highly probable that the marginal income gain obtained by shifting a unit of land from cattle to crops will diminish as more and more land is shifted in this direction. The significance of this approximation procedure is that any income gains from land or labor reallocation will be slightly overestimated while any income losses will be slightly underestimated.

It might appear that the costs of land misallocation between large and small scale agriculture have not been counted. Such is not the case. Since the labor market distortion is directly traceable to land misallocation, to

---

[28] Suppose the axes in Figure 2 were relabelled so the horizontal axis measured labor instead of capital. In the initial equilibrium, suppose O K_1 units of labor were in small scale agriculture and O'K_1 in higher paying commercial sectors. The wage distortion DL would be measured by BD. If the amount of surplus labor increased by K_1-K_2units, the loss in national income resulting from this reallocation is given by the area HBDM. This area is equal to $DL\Delta L + 1/2\,\Delta D\Delta L_s$ while only the area FBDG is captured in the welfare measurement ΔW. By ignoring the positive second-order term $1/2\ \Delta DL\Delta L_s$, the measure ΔW understates the true income loss. Similar analysis would apply in the case of land.

count both types of inefficiency would involve double-counting. That is, inefficiency arises from differing factor ratios so that disequilibrium in the labor market has a mirror image in a land market disequilibrium. Movement of only one factor is required to achieve the efficiency condition of less disparate factor ratios.

Attempts to obtain empirical estimates of the change in national income, based on the year 1964, were impeded by a lack of hard information on the appropriate size of the different distortions. In the capital market a unit of capital is defined as that amount which earns a peso of capital income. With the capital subsidy set at 40 percent, dS = .4, so that a unit of capital which earns a 1.4 peso amount in the nonagricultural sector will earn only one peso when transferred to mechanized agriculture. Upper and lower bounds were set at six and one peso per day for DL and at 450 and 165 pesos per hectare in the case of DA.[29]

Since 1964 has been chosen for the efficiency calculation (a choice based on data availability), the gain or loss in national income should be interpreted as the effect of removing the capital subsidy instead of the effect of introducing it, just as in the income distribution calculations. Two simulations, LM (1) with $\sigma^y = 0$ and LM (4) with $\sigma^y = .1$, were used to illustrate the efficiency calculation since they represent respectively the largest and smallest amounts of factor reallocation from the feasible set of results. In 1964 K_f, A_f and L_s were previously estimated at 1,355 million, 835,000 hectares and 1,054 thousand persons.

In the first simulation $\frac{1}{2}$ DKΔK is equal to $\frac{1}{2}$ $(.4)^2$ (1.07) (\$1,355 million) or 115.988 million. The two values for DAΔA_f are \$165 (.957) (.4) (835,000) or \$52.74027 million as a minimum, and \$450 (.957) (.4) (835,000) or \$143.8371

[29] Cf. Thirsk, Ch. VII, op. cit.

million as a maximum. Upper and lower bounds for $DL\Delta L_s$ are \$250 (.445) (.4) (1,054,000) = \$46,930 million, and \$1500 (.445) (.4) (1,054,000) = \$281.418 million respectively. Hence a minimum possible gain in national income from removing the subsidy would be \$115.988 - 143.8371 + 46.903 = \$19.0539 million and a maximum possible gain is 115.988 - 52.72027 + 281.418 = \$344.66573 million. In terms of a 1964 GNP of \$50,457.2 million, the cost of tolerating the capital subsidy or the benefit from eliminating it is between .0378 and .638 percent of GNP.

When these calculations are repeated for the factor reallocations indicated by LM (4), the picture is much the same although the magnitudes involved are smaller because of less reallocation than before. $\frac{1}{2}$ $DK\Delta K_f$ becomes $\frac{1}{2}$ $(.4)^2$ (.738) (\$1,355 million) or 79.9992 million. The range of values for $DA\Delta A_f$ becomes \$165 (.638) (.4) (835,000) and \$450 (.638) (.4) (835,000) or \$34.99485 and \$95.4405 million. Limits for $DL\Delta L_s$ are changes to \$250 (.107) (.4) (1,054,000) and \$1500 (.107) (.4) (1,054,000) or \$11.27775 and \$67.6665 million. The minimum possible gain is \$-5.16355 million and the maximum possible gain is \$112.67085 million. As percentages of 1964 GNP, the minimum gain is -.00825 percent and the maximum gain is .2233 percent. An allocative gain resulting from the imposition of the subsidy should be regarded as highly improbable because of the conservative estimate for DL and the optimistic value of DA in this particular calculation. In all the other calculations the gains ensuing from a better allocation of land are insufficient to outweigh the losses associated with a worse allocation of capital and labor. As with most calculations of this kind, the seriousness of misallocation is not large, being less than one percent of GNP in all cases.

Another feature of this welfare framework is that the term $DL\Delta L_s$ can be regarded as a rough approximation of the income losses experienced by small

farmers. A measure of this loss was expressed as ΔL_s(MPL - APL) in the previous section. Hence, if DL = MPL - APL, the measure of the cost of labor misallocation can be reinterpreted as an income loss borne by the small farm sector. As a gap of 6 pesos between the marginal and average product of small farm labor is more credible than only one peso, these losses would be somewhere between $67.67 and $281.4 million or between about 1.28 and 5.3 percent of the income generated by thi sector. There is a high probability this sector would lose more on the sources than on the uses side as a result of mechanization.

Even if mechanization had favorable effects on national income levels, it would not necessarily be a desirable policy. The desirability of mechanization should not be judged on the basis of its before-and-after effects, important as these may be. Other policies also have before-and-after effects. Although this study makes no comparison of alternative policies, it may well be that, for a given subsidy cost, a policy of encouraging the use of biochemical inputs in small scale agriculture would yield greater benefits in terms of income distribution and resource allocation than would a policy of mechanization. The basis for this opinion is simply that these inputs save land, the scarcest resource in small scale agriculture, and are complementary with the use of low cost labor in this sector. Thus the social payoff to this type of investment in small farms may be quite high, and higher than a mechanization policy. If this were true, it would make more sense to subsidize the use of these inputs than the use of farm machinery.

8. Conclusions

This study describes and evaluates the adjustment in the structural composition of the economy that would be expected to result from subsidizing

large farm capital in Colombia. Changes in income distribution arise from shifts in the prices received by owners of land, labor and capital, and from shifts in the prices each group of factor owners pays for its consumption goods. Changes in the level of national income depend on whether resources are transferred to higher or lower productivity uses. The following major effects are observed from the simulations:

(1) a reduction in total labor demand because

(a) mechanized agriculture is highly capital intensive relative to other sectors, and

(b) this effect outweighs the increase in labor demand due to land conversion from cattle to crops;

(2) an increase in the share of income going to capital owners (or capitalists and labor in modern sectors in one simulation) largely at the expense of labor and small farmers, although landowners also lose on balance;

(3) a lower level of national income because a better allocation of land is outweighed by a worse allocation of labor and capital. Mechanization has been privately but not socially profitable.

(4) sensitivity of the overall results to the labor absorption capacity of the nonagricultural sector.

If declining relative crop prices were translated into a lower real wage and large employment growth in nonagriculture, however, these negative effects would be overturned; but this is unlikely unless the factor price constraints on greater labor employment in nonagriculture are removed.

From this analysis it is concluded that the economic goals of greater equality in income distribution and higher levels of output are complementary in terms of subsidized farm mechanization. Withdrawing the subsidy to farm

mechanization would both improve the distribution of income and, as a bonus, better allocate the economy's existing resources. A tax on machinery use or a higher interest rate would remove this subsidy. Polarization of the rural economy rather than modernization is the most likely effect of a continuing subsidy.

In weighing these results it should be remembered that model building requires the suppression of a great deal of information about an economy. In the general equilibrium exercise much structural detail about the Colombian economy has been ignored. The assumption of homogeneous sectors neglects the economic diversity which exists within each sector. The nonagricultural sector, for example, is a collection of heterogeneous industries whose shifting composition and access to capital resources could conceivably alter the factor intensity and factor substitution values that have been used in the analysis. There is some evidence to suggest that the impact of farm mechanization varies with the region of the country and the changes in land utilization that accompany mechanization.[30] To some unknown degree, the conclusions are inevitably affected by aggregation bias.

This bias means there are a number of specific mechanization issues on which this study offers only minimal insight. While it is possible to express reservations about the wisdom of general mechanization, there may be particular crops, especially those on the margin of exportability, for which mechanization is desirable. Similarly, there may be some merit in mechanizing particular crop operations, though not all operations, of a given crop. The analysis also does not answer the question of how a full scale land redistribution would affect the demand for farm machinery since the initial land distribution is taken as given.

---

[30] Cf. Thirsk, Chapter V., op. cit.

PROGRAM OF DEVELOPMENT STUDIES

Discussion Papers

No. 15 "The Effect of Changes in the Distribution of Income on Labor, Foreign Investment and Growth in Brazil" (1971) Samuel A. Morley and Gordon Smith

No. 16 "Korean Rice, Taiwan Rice, and Japanese Agricultural Stagnation: An Economic Consequqnce of Colonialism--A Comment" (1971). . . Yhi-Min Ho

No. 17 "The Incidence of Taxation in West Malaysia" (1971) Charles E. McLure, Jr.

No. 18 "Vocational Improvement Centers: A Successful Nigerian Experiment" (1972). . . . . Gaston V. Rimlinger and Carolyn Stremlau

No. 19 "Government Expenditures, the Revenue Constraint and Wagner's Law: The Case of Turkey" (1972) . . . . . .Marian Krzyzaniak

No. 20 "The Long-Run Incidence of Government Spending on Education" (Rev. No. 10) (1972) . . . . . Marian Krzyzaniak and Ibrahim Eris

No. 21 "On Solow's Method of Estimating the Residual" (1972) . . . . . Yhi-Min Ho and Clive Bell

No. 22 "Models of Development Including Income Distribution" (1972) . . . . . .James W. Land and Ronald Soligo

No. 23 "Disguised Unemployment in a Subsistence Economy" (1972) . . . . . .Jose Hamilton Gondim Silva

No. 24 "A Proposal for Research on 'Distribution of Gains, Wealth and Income from Economic and Political Development'" (1972) . . . . . .James W. Land

No. 25 "Optimal Wage and Education Policies with International Migration" (1972) . . . . . R. Albert Berry and Ronald Soligo

No. 26 "Marketing and Economic Development: A Brazilian Case Study, 1930-70" (1972). . . . . Gordon W. Smith

No. 27 "Indigenisation of Industry and Progress of the Second Nigerian National Development Plan" (1972) . . . . . .Gaston V. Rimlinger

No. 28 "The Distribution of Incomes and the Short-Run Burden of Taxes in Turkey, 1968" (1972). . . . . .Marian Krzyzaniak and Süleyman Özmuçur

No. 29 "The Proper Use of Indirect Taxation in Latin America: The Practice of Economic Marksmanship" (1972) . . . . . Charles E. McLure, Jr.

No. 30 "Distributional Equity, Inflation, and Efficiency in the Brazilian Fluctuating Exchange Rate System" (1972) . . . . . Donald L. Huddle

No. 31 "A Diagrammatic Exposition of General Equilibrium Tax and Expenditure Incidence Analysis with One Immobile Factor" . . . .Charles E. McLure, Jr.

No. 32 "The Contribution of Traditional and Small Scale Culture Goods in International Trade and in Employment" . Yhi-Min Ho and Donald L. Huddle

No. 33 "Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization" (1972) . . . . . Wayne R. Thirsk

---

Note: Discussion Papers are available upon request to individual scholars and researchers and libraries of educational institutions.