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A MULTILEVEL ANALYSIS OF AGRICULTURAL CREDIT DISTRIBUTION IN EAST JAVA, INDONESIA

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Scope and Purpose—The Indonesian government has been providing agricultural loans at a subsidized rate to help farmers enhance their production methods. Small, low-income farms form the majority of all farms, and they have access only to high-interest, non-institutional credits. Medium and large farms, on the other hand, have been the main recipients of subsidized government credits. The government funds are more scarce than before making it more difficult to improve the agricultural sector's performance by increasing the amount of government credits. However, redistribution of the credits between the farm groups may serve the purpose. This article investigates such an improved redistribution and its welfare implications. The results indicate that not only aggregate agricultural output, but also rural income distribution can be improved by increasing the availability of subsidized credit to small farmers.

East Java supplies the bulk of the agricultural production in Indonesia. With the exception of sugarcane, crop production in East Java is not directly controlled by the government. However, government credit allocation influences farm decisions which in turn affect the government's growth objective. This hierarchical decision making situation is modeled as a linear/quadratic bilevel program. Although the size of the model was moderate, the solution algorithms available to the authors failed to solve the resulting problem. Therefore, a heuristic approach, which is a combination of quadratic programming and cutting plane methods, is used to generate an improved redistribution scheme.

Abstract—This article investigates improved allocation of subsidized credits among farm groups in East Java, Indonesia. The empirical results of a bilevel programming model show that not only aggregate agricultural output, but also rural income distribution can be improved by increasing the availability of subsidized credit to small farmers.

INTRODUCTION

Over the past decade, the Indonesian economy has experienced rapid growth, due in part to the agricultural sector which expanded at an average annual rate of 4.6%. A substantial portion of the country's agricultural output was produced in East Java. In 1981–1985, the region contributed 20% of rice, 43% of corn, 47% of soybeans, 28% of cassava and 63% of sugarcane produced in Indonesia. This development was stimulated by the Indonesian government which provided a large budget for rural development programs, including substantial credit subsidies. Agricultural loans have been provided to participating farmers at an interest rate of 12%, far below the prevailing market rate of about 25%. Due to declining government revenues and tight budgets, agricultural

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development funds are now more scarce, thus making efforts to boost agricultural production by increasing the volume of cheap credit more difficult than before. However, reallocating agricultural credit among farm groups and improving small farms' access to subsidized credit may have a significant impact on bringing the rural poor into the mainstream of agricultural development. Small, low-income farmers usually have access only to high-interest, non-institutinal credit, while medium and large farmers have been the main recipients of the subsidized institutional credit. National surveys show that 35–55% of small farmers cultivating less than 0.5 ha (73% of all respondents) still need access to institutional credit programs to fund their farm activities [1]. These farms operate about 34% of the total agricultural land, yet they receive only 20% of institutional credits.

In addition to the farm size consideration, another important issue is the distribution of limited funds between different production systems, namely irrigated, rainfed and dryland agriculture. Each of these systems is characterized by the technology used (input–output relations) and resource availabilities. A particular credit distribution affects the resource limits, interfarm resource exchanges, and the production plans of farm groups operating on each land category. Because of this interdependence, determining the optimal credit allocation and its impact on farm activities becomes a complex decision problem.

It is widely recognized that cheap credit programs often become a transfer program to the non-poor rather than helping the poor in most developing countries [2]. Indonesia is no exception. Thus, whether the reallocation of institutional credit between farms groups can also enhance rural income distribution is another important issue.

Public policy objectives which target agricultural development can take several forms. Output enhancement, food self-sufficiency, and improvement of rural well being are among the most frequently stated objectives in Indonesia. In the present analysis, the first objective, namely to increase overall agricultural output, is considered. To fulfill this objective, the government uses a variety of policy instruments, including subsidized credit and its distribution. The goal of this study is to determine the optimal allocation of government credit among farm groups, and to examine the effects of this optimum on the distribution of agricultural production and rural income. A mathematical programming model is used for this purpose.

The methodology used in this study is discussed in the next section. The specific mathematical model and the solution procedure are then described in detail in subsequent sections. Empirical results of the model are presented in the remainder of the paper.

METHODOLOGY

Although agricultural production in East Java is strongly influenced by public policies, it is not directly controlled by the government. Individual producers respond to policy signals sent by the government and make their own production plans freely by allocating their resources to maximize net farm revenues. In turn, their individual responses collectively determine the level of the policy objective which may or may not meet the public goals. This is a typical multilevel decision-making process involving independent but interactive decision units acting in a hierarchical order. The traditional approach used for analyzing this type of policy issue is to specify a discrete set of policy options and compare the outcomes (lower level responses) for a specified range of policy parameters. However, the number of options can be numerous if a wide range of policy parameter values are to be used. Multilevel programming is a more direct approach to determining the optimal allocation.

Multilevel programming problem involves nested optimization problems, called "lower-level problems", in the constraints. The feasible solutions must satisfy not only the constraints of both upper- and lower-level problems, but also must optimize the lower-level decision problems. In this particular case study, the government and farmers constitute the upper- and lower-level decision makers, respectively, in a two-level (or bilevel) problem which can be described mathematically as follows:

$$\max \quad G(\mathbf{p}, \mathbf{d}) \tag{1.1}$$

$$\begin{array}{ll} & \mathbf{p} \in \mathscr{P} \\ \text{s.t.} & \mathbf{d} \mid \mathbf{p} \text{ solves:} \\ \max & F(\mathbf{d}) \qquad (1.2) \\ & \mathbf{d} \in \mathscr{R} \\ \text{s.t.} & \\ & \mathbf{Ap} + \mathbf{Bd} \leqslant \mathbf{b}, \qquad (1.3) \end{array}$$

where G and F are the objective functions for the upper-level (government) and lower-level (farmers) decision problems; **p** and **d** are vectors of policy (credit allocation), and demand and supply variables controlled by the government and farmers, respectively; $\mathscr{P}$ and $\mathscr{R}$ are the respective decision sets; **A** and **B** are matrices, and **b** is the r.h.s. vector describing the joint constraint set. In conventional optimization problems, only conditions (1.1) and (1.3) are involved. In the above bilevel programming, maximization of the lower-level objective, condition (1.2), is explicitly considered as a behavioral constraint. Thus, the policy variables are determined in view of the responses derived from the lower-level decision problem.

Mathematical programming problems with an optimization problem in the constraint was first introduced by Bracken and McGill [3]. The concept of multilevel optimization was formally defined by Candler and Townsley [4], who also introduced the first solution algorithm for the special case of linear bilevel programming. Several solution algorithms have appeared in the literature for this type of problem [4–12]. A review of the literature is presented by Wen and Hsu [13], and by Ben-Ayed [14].

Conceptually, all problems in development planning, where a planner and subordinate units operate interactively in a hierarchical order, fall into the category of multilevel programming. Despite its potential usefulness and applicability, this methodology has not been used in real policy analysis situations as often as other mathematical programming techniques. Yet, a wide variety of applications have appeared in the literature. Cassidy *et al.* [15] studied the efficient allocation of federal funds among different levels of government. Bracken and McGill [16] present a military application to determine an optimal weapon mix, while DeSilva [17], and Falk and McCormick [18] present examples in industrial economics. Kolstad [19] analyzed the optimum tax policy in an environmental regulation problem. Anandalingam and Aprey [20] applied this methodology to a water conflict problem. Bey-Ayed *et al.* [21] formulated the problem of optimal highway network design as a bilevel program. Candler *et al.* [22] pointed out the potential usefulness of the multilevel programming approach in agricultural policy analysis. Several attempts have been made to study special bilevel decision processes in agricultural economics [23–26]. However, an empirical application of the pure multilevel programming approach to agricultural policy analysis has not been presented in the literature. This study presents such an application.

THE MODEL

The policy objective is to maximize the total value of agricultural output at constant prices. This leads to the linear objective function given by equation (2.1), where p_j is the constant base-year price, and Q_j is the total supply (also demand) of the jth commodity. The restriction placed on the credit allocation decision is that the total allocation not exceed the amount of credit distributed during the base year, denoted by K_0. Thus, the government's problem is:

$$\max \quad \textstyle\sum_j p_j Q_j \qquad (2.1)$$

s.t.

$$\textstyle\sum_f K_f \leqslant K_0, \qquad (2.2)$$

$$K_f \geqslant 0, \qquad (2.3)$$

where K_f is the credit allocation to farm group f.

Since East Java is a major supplier to the agricultural sector in Indonesia, aggregate output levels directly affect market prices. Therefore, the lower-level problem is specified as a market equilibrium problem where production and demand levels are determined endogenously in view of the policy variables set by the government. The problem is formulated using the surplus maximization methdology whereby the sum of producers' and consumers' surplus is maximized subject to the production possibility and product balance constraints. With the exception of sugarcane, the price of which is determined by the government, linear separable demand functions are specified for all products, and the production possibility sets of representative farm groups are specified by linear relations. A simplified compact algebraic description of the market equilibrium problem (lower-level problem) is given below.

$$\max \quad \textstyle\sum_j Q_j(e_j - 0.5h_jQ_j) - \sum_{f,l} c_{fl}X_{fl} \tag{3.1}$$

s.t.

$$\textstyle\sum_l a_{ifl}X_{fl} \leqslant b_{if}, \quad \text{for all } i, f, \tag{3.2}$$

$$\textstyle\sum_l d_{fl}X_{fl} \leqslant K_f + o_f, \quad \text{for all } f, \tag{3.3}$$

$$Q_j - \textstyle\sum_{f,l} X_{fl} \leqslant 0, \quad \text{for all } j, \tag{3.4}$$

$$Q_j,\ X_{fl} = 0, \quad \text{for all } f, j, l, \tag{3.5}$$

where f is the farm index; e_j, h_j are demand function parameters; c_{fl} is cost of purchased inputs per unit of X_{fl}; a_{ifl} is requirement of ith production factor per unit of X_{fl}; b_{if} is availability of ith input; $d_{f,l}$ is cash requirement per unit of X_{fl}; o_f is cash owned by farm f for purchasing inputs; y_{jfl} is yield of jth output per unit of X_{fl}; and X_{fl} is level of lth production activity by farm f.

The objective function measures consumers' plus producers' surplus defined as the sum of areas under demand functions upto equilibrium quantities minus total cost of production.† Equation (3.2) states that the total use of each input cannot exceed its availability. Equation (3.3) establishes the balance between cash expenses for purchased inputs and the cash availability for each farm group. Equation (3.4) is a balance equation stating that the total demand of each commodity cannot exceed the total amount supplied by all farms.

The only policy variables in the model are the credit amounts allocated among farm groups, K_f, while all other variables are behavioral variables. Note that the policy objective function, equation (2.1), does not include K_f. However, equation (3.3) includes K_f as external variables (determined by the government rather than the farm groups). This directly affects farm level decisions which in turn establishes the link between the policy objective and the policy variables.

Equations (2.1)–(2.3) and (3.1)–(3.5) lead to a linear/quadratic bilevel programming problem.

SOLUTION PROCEDURE

The lower-level problem, described by equations (3.1)–(3.5), is replaced by the Kuhn–Tucker conditions leading to the following model which is equivalent to the original bilevel programming model:

$$\max \quad \textstyle\sum_j p_jQ_j \tag{4.1}$$

s.t.

$$\textstyle\sum_f K_f \leqslant K_0, \tag{4.2}$$

$$-c_{fl} - \textstyle\sum_i a_{ifl}\alpha_{if} - d_{fl}\beta_f + \sum_j y_{jfl}\gamma_j + r_{fl} = 0, \quad \text{for all } f, l, \tag{4.3}$$

$$e_j - h_jQ_j - \gamma_j + s_j = 0, \quad \text{for all } j, \tag{4.4}$$

$$\textstyle\sum_l a_{ifl}X_{fl} + u_{if} = b_{if}, \quad \text{for all } i, f, \tag{4.5}$$

$$\textstyle\sum_l d_{fl}X_{fl} + v_f = K_f + o_f, \quad \text{for all } f, \tag{4.6}$$

†The quadratic expression inside the first summation is the definite integral of the demand function $p_j = e_j - h_jq_j$ evaluated from zero to the endogenous quantity Q_j. The optimum solution of the quadratic program is the desired market equilibrium generated endogenously. In this solution, each firm's output is consistent with the assumed competitive behavior when endogenous market prices, the shadow prices of equation (3.4), are plugged into the firm LP models (which are not explicitly considered here). In turn, individual firm responses are consistent with aggregate equilibrium quantities. This artifice was first discovered by Samuelson [39] and later fully developed by Takayama and Judge [27]. McCarl and Spreen [29] provide a rigorous discussion of this methodology.

$$Q_j - \sum_{f,l} y_{jfl} X_{fl} + w_j = 0, \qquad \text{for all } j, \tag{4.7}$$

$$Q_j - \sum_{f,l} X_{fl} r_{fl} + \sum_j Q_j s_j + \sum_{i,f} u_{if} \alpha_{if} + \sum_f v_f \beta_f + \sum_j w_j \gamma_j = 0, \tag{4.8}$$

$$K_f, Q_j, X_{fl}, r_{fl}, s_j, u_{if}, v_f, w_j, \alpha_{if}, \beta_f, \gamma_j \geqslant 0, \qquad \text{for all } i, f, j, l, \tag{4.9}$$

where u_{if}, v_f, w_j are slack variables, and α_{if}, β_f, γ_j are Kuhn–Tucker multipliers associated with equations (3.2), (3.3) and (3.4), respectively; and r_{fl}, s_j are slack variables associated with the first order derivatives of the Lagrangian of the lower-level problem with respect to X_{fl} and Q_j, respectively.

Equation (4.8) is a compact expression of complementary slackness conditions and implies that each and every product term included in the summations is zero. This constraint makes bilevel programming problems hard to solve because of the improper convexity involved. Fortuny-Amat and McCarl [6] linearize the non-linear constraints formed by the latter product forms by using a zero–one variable for each constraint and replace them by linear equations involving binary variables. This transforms the bilevel programming problem into a mixed integer programming problem. GAMS [30] in combination with ZOOM [31] failed to solve the resulting integer programming problem.† A special bilevel programming code developed by Bard and Moore [8] has been reported as the best performing algorithm among its contenders. However, the problem could not be solved by the latter algorithm either. The algorithm terminated without finding the global solution even though a very large number of branch and bound nodes was specified. These were the only alternatives available to the authors at the time this study was conducted. Therefore, a heuristic approach is used to generate the desired "optimum" solution.

The approach used here was originally proposed by Bard [32]. Instead of linearizing the complementary slackness constraints, equation (4.8) is moved to the upper-level objective, condition (4.1), as a penalty function after multiplying each product term by a suitably large penalty parameter, M. This yields the following objective function:

$$\max \quad \sum_j p_j Q_j - M\left[\sum_{f,l} X_{fl} r_{fl} + \sum_j Q_j s_j + \sum_{i,f} u_{if} \alpha_{if} + \sum_f v_f \beta_f + \sum_j w_j \gamma_j\right]. \tag{4.1A}$$

The bilevel program defined by equations (4.1)–(4.9) is equivalent to the problem defined by equations (4.1A), and (4.2)–(4.8). If M is sufficiently large, the penalty term will be forced to vanish, thereby the complementary slackness conditions will be satisfied, the lower-level problem will be optimized and a feasible solution (in the bilevel sense) will be obtained. This solution, however, may or may not be the global optimum solution of the original bilevel programming problem. Because of the non-concave character of the objective function (4.1A), local solutions may exist. However, at any such solution, the value of function (4.1A) is determined by the linear term only (since the penalty term is zero) which is the upper-level objective function that we desire to maximize. This fact is used to improve the upper level objective function value by adding the following linear constraint to the equations described by equations (4.2)–(4.8),

$$\sum_j p_j Q_j \geqslant z_0 + \varepsilon, \tag{4.10}$$

where z_0 is the value of function (4.1) which is given by the bilevel-feasible solution previously found, and ε is a small positive scalar. Adding this constraint and solving the resulting quadratic program once again may lead to another bilevel-feasible solution. This procedure is repeated until no additional bilevel-feasible solutions can be found. This point is reached when either the penalty term does not vanish or no feasible solution can be found for the quadratic program including the cut (4.10). The last solution found by this procedure is reported as the "optimum" solution.

Bard did not report numerical experience with the above method. Some test problems were successfully solved by the authors using GAMS combined with MINOS [33]. In some problems a few improved local solutions were obtained until finding the global solution.‡ However, in some test problems GAMS/MINOS failed to converge to the known global optimum solution. Thus,

†Combinations of GAMS with other commercial IP solvers have not been successful, either.

‡For instance, the problem presented by Candler and Townsley [4] had three such bilevel feasible solutions, the last one being the global solution.

this approach is regarded as a heuristic rather than an exact solution method.† In the present study, several runs were done which resulted in different local solutions, the best of which is reported as the optimum solution. Our experience has shown that the progress is rather sensitive to both the starting solution and the penalty parameter, M.

SPECIFICATIONS OF THE MARKET EQUILIBRIUM MODEL

The model includes nine traditionally produced crops: rice, corn, soybeans, cassava, peanuts, mungbeans, sweet potato, tobacco and sugarcane. Together, these crops account for more then 90% of the crop production in East Java.

Two farm sizes, namely small and large, are considered on each of three land types, namely *irrigated sawah*,‡ *rainfed sawah* and *upland*. The first category of land includes fully or partially irrigated land, the second includes rainfed land, and the third land category is basically dry land. Each of these six farm groups is represented by a farm endowed with the aggregate resources owned by all farms in that group, and operates with the technology representing the average technology used by those farms. Fixed amounts of owned resources, including labor, land, water and operating capital, are specified for each farm group. Interfarm resource exchange, such as land renting and labor hiring, is allowed. Costs and returns due to resource exchanges are explicitly included in the resource constraints of each farm group. Three production seasons in a year are distinguished based on water availability: the rainy season, dry season and second dry season. Generally, triple cropping is possible on *irrigated sawah*, while on the other land categories double cropping (during the first two seasons) is the common practice. The model, therefore, considers crop mix activities (rotations within a year, denoted by X_{fl} above) instead of single crop production activities. Input requirements and yields are specified according to the crops included in the mix of each rotation activity, crop variety, land type, and the season in which the planting takes place.

The cash balance constraint, equation (3.3), establishes the link between the policy decisions and farm level production decisions. Farmers use either their own resources or borrow institutional credit at a subsidized rate of interest to finance their operation expenses. Institutional credit availability, by farm group and season, is determined by the government. In the analysis, the total amount of credit available for all farms is maintained at the 1987 level.

With the above specifications, the lower-level problem has 103 constraints and 253 variables. Eight of the variables, namely the demand variables (Q_j), appear in the non-linear part of the objective function, equation (3.1). Thus, together with the upper-level problem, the bilevel programming model has 104 constraints and 259 variables. Six variables, namely K_f, are controlled by the upper-level, while the remaining variables are all behavioral variables.

Data, including demand elasticities, base year (1987) production and prices, production costs and input–output relations, are collected from several government sources and previous studies [1, 34–38].

VALIDATION OF THE MODEL

The market equilibrium model is first validated for the base year. In the validation process the actual distribution of subsidized credit between farm groups is maintained.

Table 1 compares the actual planting and production figures with those predicted by the model. The model results are reasonably close to the actual figures for all crops, where the absolute deviations between the predicted and actual figures range from 0.9 to 7.7%. Since rice is the most important crop produced in East Java, the validation of rice activities is especially important to

†In a recent paper, Anandalingam and White [12] propose a similar penalty function method which yields a global solution. They use a penalty function involving the duality gap which must vanish at any optimum solution of the lower level problem. The approach used here tries to eliminate the sum of infeasibilities involved in the complementary slackness constraints, while the approach by Anandalingam and White tries to eliminate the duality gap to achieve an optimum solution of the lower-level problem. They report that their code could not perform as good as Bard and Moore's branch and bound code on a series of randomly generated test problems. Furthermore, performance is reported to be poorer as the model size is increased.

‡*Sawah* is the Indonesian term for agricultural land that has been leveled and developed with irrigation banks so that it can be either irrigated or will store rain sufficient to produce a crop.

the validation of the model. The acreage and production estimates for rice deviate only about 2% from the actual values.

The results indicate that cash availability is a limiting factor for both small and large farms on all land categories. Thus, all institutional loan limits are fully utilized.

Throughout the rest of the paper, the results of the market equilibrium model (validated for the base year) will be referred to as the "base run".

IMPROVED CREDIT ALLOCATION

We now use the bilevel programming model described above to determine the optimal credit allocation. The credit allocations by farm category, which are exogenous parameters in the market equilibrium model, are now treated as endogenous variables.

The bilevel programming solution obtained by using the heuristic approach explained above is also presented in Table 1 to allow comparison with the base run results and actual statistics. According to the model results, the production levels of rice and corn drop by about 2 and 8% from the sector model results, respectively, while all other annual crops show slight increases. A significant change occurs in sugarcane production which is 22% more than the base production level.

The model results concerning institutional credit redistribution are of key importance. The results, presented in Table 2, suggest that the institutional credit share of small farms on *irrigated sawah* should be increased while the allocation of credit to large farms would be reduced drastically, by nearly 35% of their base share. The large farms on *irrigated sawah* would no longer receive credit. This would allow the small farms operating on this land category produce more rice (about 10%) than the large farm group, while in the base run the latter group was the major rice producer (producing about 50% more than the small farms). Several major changes would also occur in the cropping pattern on both *rainfed sawah* and *upland*. The large farms were the dominant sugarcane growers on both land categories (planting nearly 75% of the total sugarcane area) in the base run. Under the new distribution of subsidized credits, the small farms nearly triple their sugarcane planting on *rainfed sawah* while the large farms maintain their total sugarcane planting, but shift all of the production to *upland*. Large farms would be forced to rely more heavily on their own financial resources, and cash-short farmers would lease a significant amount of land to small farmers. According to the model results, about 205,000 ha of land, most of which (190,000 ha) is sugarcane

Table 1. Acreage and production of major crops obtained from the market equilibrium model and the bilevel model

	Actual		Market equilibrium model		Bilevel model	
	Acreage (1000 ha)	Production (1000 MT)	Acreage (1000 ha)	Production (1000 MT)	Acreage (1000 ha)	Production (1000 MT)
Rice	1698	8150	1663(−2.1)†	7994(−1.9)†	1597 (−4.0)‡	7819(−2.2)‡
Corn	1141	3034	1053(−7.7)	2801(−7.7)	943 (−10.4)	2586(−7.7)
Soybeans	449	449	463 (3.1)	463(3.1)	495 (6.9)	465(0.4)
Cassava	423	4110	408(−3.5)	3968(−3.5)	404 (−1.0)	4119(3.8)
Tobacco	459	322	465(1.3)	325(0.9)	480 (3.2)	336(3.4)
Sugarcane	165	1279	160(−3.0)	1241(−3.0)	217 (35.6)	1522(22.6)

†In this column, figures in parentheses are percentage deviations from the actual values.
‡In this column, figures in parentheses are percentage deviations from the base (market equilibrium model) values.

Table 2. Actual and optimum institutional credit allocation by farm size (billion Rupiah)†

	Small farms		Large farms	
	Base‡ allocation	Bilevel allocation	Base allocation	Bilevel allocation
Land types				
Irrigated sawah	3850	18,575	15,440	—
Rainfed sawah	1280	—	5150	6327
Upland	2770	—	11,080	14,668
Total	7900	18,575	31,670	20,995

†Rupiah is the domestic currency in Indonesia. The 1987 exchange rate was 1800 Rupiah per $U.S.
‡Base allocation is the actual allocation exogenously specified in the market equilibrium model.

Table 3. Economic consequences of the institutional credit reallocation

	Base model†	Bilevel model
Gross production value‡	100	101.6
Income by farm§		
Small farms	100	140.6
Large farms	100	95.7
Consumers' surplus¶	100	96.2
Producers' surplus	100	117.1
Social surplus¶	100	97.9

†Base model is the market equilibrium model.
‡At observed prices of 1987.
§Calculated at endogenous prices.
¶Consumers' surplus obtained from sugar consumption is not included.

land, would be rented out by large farms (mostly on *irrigated sawah*). In the base run, leased land represented only about 150,000 ha (distributed almost uniformly between different land categories), and no sugarcane land was rented.

Table 3 illustrates the overall economic consequences. The bilevel solution indicates that, through the reallocation of subsidized credit, more than 1.6% improvement could be made in the gross production value (upper-level objective) relative to the value implied by the initial market equilibrium solution.† This somewhat conservative result is primarily due to the implicit price adjustment mechanism employed in the market equilibrium model which does not allow drastic changes in crop pattern. Namely, if production of a particular crop is to increase, the market price of that crop has to decline according to the demand function specification. This implicit price adjustment mechanism embedded into the model prevents crop specialization as it happens in the real world. This is especially true in agriculture where immediate large scale shifts seldom result from policy changes.

The credit reallocation would result in a substantial net income transfer to small farms, as much as 40% of their base incomes, while net income of large farms would decrease slightly (4.3%). At the sector level this corresponds to 17% larger producers' surplus while consumers' surplus decreases by about 3.8%. The overall effect on both consumers and producers is a net loss of 2.1%. However, it should be noted that increased sugarcane production (22%) is not taken into account when calculating the consumers' surplus because a demand function for sugar has not been incorporated in the model. Thus, the social benefits of credit reallocation is somewhat underestimated in the results, and consumers might have benefitted as well. It should also be noted that the cost of credit management, which is likely to increase to some extent, has not been included in the calculation of social welfare.

CONCLUDING REMARKS

Multilevel programming is computationally more complex and expensive than conventional mathematical programming. This approach can be a powerful analytical tool once solution difficulties are overcome. This study attempted to show the usefulness of the multilevel programming approach in public policy making.

The empirical results obtained here show that significant improvement could be made in the performance of East Java agriculture and rural welfare distribution through a reallocation of subsidized government credits. Thus, the reallocation fulfills both the growth and equity objectives. Similar analyses can be performed for other instruments controlled by the government or for alternative forms of the government objective function.

The model used in this study has some limitations. Many important factors, such as the cost of credit management, creditability of borrowers, and the influence of political power groups in policy making have not been considered.

In addition to the limitations due to the model formulation, the solution methodology employed in this study also has some limitations. As mentioned earlier, the quadratic programming approach,

†The sectoral real output (policy objective) went up from 3623 to 3654 billion Rupiah. This corresponds to about $U.S. 32 million gain (the exchange rate in 1987 was 1800 Rupiah per $U.S.).

when combined with the penalty and cutting plane methods, does not guarantee a global solution. No test has been carried out to determine the nature (i.e. global vs local optimality) of the reported solution. Yet, the solution was thought to be satisfactory for two reasons. First, it represents a meaningful market equilibrium in terms of marketed outputs and the distribution of production by farm group and land type. Second, both sectoral real production and the income distribution by farm size are improved. Thus, the reported solution presents a more preferrable alternative for policy makers who want to achieve both objectives. Whether it is the true global solution or not is less important from this standpoint.

Another limitation of the study was the model size. We kept the model small, at the expense of realism, in order to reduce computational problems. To our knowledge, the algorithms currently available have not been tested empirically on large scale models. We feel that, based on our experience, the need for robust and practical solution algorithms still continues.

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