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Agricultural settlement with joint production services

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ABSTRACT

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A theory of settlement planning focussing on village-level production services is presented, and settlement plans are compared. The analysis draws on the modern theory of local public goods. Conditions for optimal level of services and optimum settlement size are derived, together with rules of finance of collective operations. The value of the right to settle is calculated for the cases considered.

INTRODUCTION

Economic development in rural areas sometimes requires settlement or resettlement. Examples are opening of new land, developing of irrigation schemes, or moving farmers when dams flood arable land. Settlements are centers of economic activity; they are often villages, but scattered homesteads also exist. Whatever the spatial structure of the settlements, and whether they are planned or develop spontaneously, their size, distribution, structure and functioning are affected by economic forces. In the past, a major consideration was geographic distribution, and settlements were planned to minimize distance to the cultivated plots. Today, distance is no longer an over-riding consideration: more important are the services provided. We concentrate on production services. To exploit scale economies, the services are often supplied publicly. But these economies may be exhausted, and the average cost curves of the services are generally U-shaped. This is the rationale for the existence of separate local communities – villages in our case.

The historic example of village-level public services is the management of grazing 'commons'. Among the recently described examples relevant to our discussion are the FELDA land-settlement program in Malaysia, the Lilongwe land-development program in Malawi (Kirsch et al., 1980), and the specialized agricultural cooperatives in Egypt (Rochin and Grossman, 1987).

The example we are more familiar with is the 'moshav' in Israel (Zusman, 1988), a cooperative village, typically with 60 to 120 farms. The first moshav was established in 1920, but the majority were settled in the 1950s. They offer their members a variety of production services, such as provision of farm inputs, financial intermediation, bookkeeping, water distribution, drainage, machinery and implements, produce collection and trucking, extension, and village-wide pest control. Moshavim are cooperatives, but our analysis is not limited to cooperatives; we deal with joint public supply of production services in agriculture, whatever the organizational structure of the group of farmers using these services.

In a typical settlement project, a region is divided into villages whose land is further subdivided into farms. The planner's problem is to solve simultaneously for the number of villages and farms in a village (that is, land area per farm), level of services, and mode of cost allocation. We lay the basis for the analysis of these problems by considering first a single village with a given amount of land. The village is planned once when the objective function is to maximize income per farm, and once when it is the maximization of total income in the village. We turn to regional planning after the village-level analysis. The paper continues with a discussion of land taxation and an analysis of comparative statics.

We draw on the analysis of the modern theory of local public goods (Arnott and Stiglitz, 1979; Berglas, 1982, 1984; Rubinfeld, 1987; Mieszkowski and Zodrow, 1989). When attempting to maximize settlers' income, our approach resembles in some aspects the theory of the labor-managed firm (Oi and Clayton, 1968; Vanek, 1970) in which, in most cases, the objective is the maximization of income per laborer. There is a closely related literature on the theory of agricultural cooperatives (LeVay, 1983) since, even if settlements are not organized as such, often they are, like cooperatives, associations of a voluntary nature operating collective ventures.

STRUCTURAL ASSUMPTIONS

The participation of settlers in the project, in the analysis below, is in the form of labor input in production. When this variable is continuous, the farmer in the model can work part-time, hire labor, or even be an absentee

settler. In most real-world cases these alternatives are not actually open to settlers and are not included in the menus of activities planners have in mind. To avoid these possibilities, we assume in the analysis that settlers devote *all their time* to the farms; part-time farming and hired labor are not permitted.

A settlement project is not viable unless farmers recover the costs of labor and capital. Urban wage is therefore included as a cost in the analysis. Capital is not treated explicitly, though the settler's income (termed in the paper settler's rent) can be seen as covering the cost of this factor – if settlers bring their own equity to the project.

Settlers joining a new project either buy their land or, as in many development projects, rent it from the development authority or from another agency of the national government. Sometimes they may get it free. As shown below, the magnitude of the land rent, and whether it is actually collected, affects the value of the farm and settlement plans and services.

BASIC LAYOUT

For simplicity, the analysis is limited to a village with two public services [the ensuing principles are the same for a multi-service settlement (Berglas, 1984)]. The village operates a well supplying water to the farms (household consumption of water is negligible) and it provides a pure public good: inner roads, joint pest-control program, weather forecasting, extension service, price information, or others. There are n farms in the village, all of identical size.

The farm-level production function is 'well behaved' (linear homogeneous, twice differentiable, etc.):

$$q = F(y, A/n, L, Q) \quad (1)$$

where q is farm output; y water, supplied from the village well; A/n land, A total area cultivated by the village and n the number of farms; L labor, constrained – according to our earlier assumptions – to full employment $L = L_0$, and with urban wage as the alternative cost w ; and Q public service provided by the village.

The cost function of the village services is:

$$\begin{aligned} C &= C(ny, Q) \\ &= c_1(ny) + c_2(Q) \end{aligned} \quad (2)$$

In (2), ny is the total amount of water pumped at the village well. Marginal cost is assumed to increase both in $c_1(\)$ and in $c_2(\)$. This assumption is introduced here for simplicity, it is not necessary. For an internal solution,

marginal costs may be decreasing so long as they are not decreasing faster than marginal products (see equations 5a–5c below). If, however, marginal costs are decreasing everywhere faster than marginal products (second-order conditions are not met) the agricultural sector will not be divided into villages and all the services will be provided at the national level.

A basic conclusion of the theory of local public goods is that the marketable and chargeable services (water in our case) and the non-chargeable public goods ought to be financed jointly. The separate formulation in the second line of (2) is introduced to demonstrate that joint financing is not due to jointness in production or costs.

The village is a non-profit entity. Farmers are charged for water (α dollars per unit) and, in addition, taxed to complete local finance according to the linear cost-allocation rule:

$$[c_1(ny) + c_2(Q)]/n = \alpha y + t \quad (3)$$

The lump sum tax, t , covers the gap between per-farm cost of services and user charges. The tax t is *local*; we consider below land taxation by the national government.

Income per farm

We start with Objective F , maximizing income, net product, per farm. The maximization is done at two levels. On the farm, profits are maximized by equating marginal product of water to unit price, α . At the village level, the planner's problem is to set the *policy variables* α , t , Q , and n consistently with the objective while taking into account farmers' behavior.

To calculate these values, start with the Lagrangian:

$$H = PF(y, A/n, L, Q) - wL - [c_1(ny) + c_2(Q)]/n + \theta(L_0 - L) \quad (4)$$

where P is the price of the product and θ is a Lagrangian multiplier. Equation (4) is maximized with respect to the village policy variable. For a given number of farmers, the first-order conditions are (a total derivative is marked by an apostrophe, a partial by a subscript):

$$PF_y = c'_1(ny) \quad (5a)$$

$$nPF_Q = c'_2(Q) \quad (5b)$$

$$PF_L = w + \theta \quad (5c)$$

Equations (5a)–(5c) are the *factor allocation rules*. On the farm $PF_y = \alpha$, hence by (5a) the village sets $\alpha = c'_1(ny)$ and optimal water utilization will be with marginal cost pricing. Equation (5b) characterizes Q as a public

good, and equation (5c) specifies the value of the shadow price of the labor constraint.

Maximizing (4) with respect to n , we set:

$$\partial H / \partial n = [-PF_{A/n}(A/n) + C/n - c'_1(ny)y] / n = 0 \tag{6}$$

Equation (6) summarizes the effect a new entrant has on income of an insider – a farmer already in the project. The negative elements in (6) stand for the reduction in farm income due to the sharing of land and water with the newcomer, and the positive element – for the sharing of village cost. Equilibrium is attained when marginal costs and benefits are matched. Rewriting (6) and combining with (3), the lump-sum tax is:

$$t = PF_{A/n}(A/n) \tag{7}$$

With optimum number of settlers, the settlement exactly covers its cost collecting user charges for water and a lump-sum tax equal to the marginal product of land.

Examining now the sign of the derivative in (6), we observe that the tax is higher than land's marginal product when n is lower than optimal, and lower than the rent otherwise. In Fig. 1, a village of n^* farms is supplied with optimum amount (for its size) of the public service, Q , and n^*y gallons of water. The cost curves of the services are drawn as functions of the village water supply. Since Q is given, $c_2(Q)$ (= constant) is the 'fixed

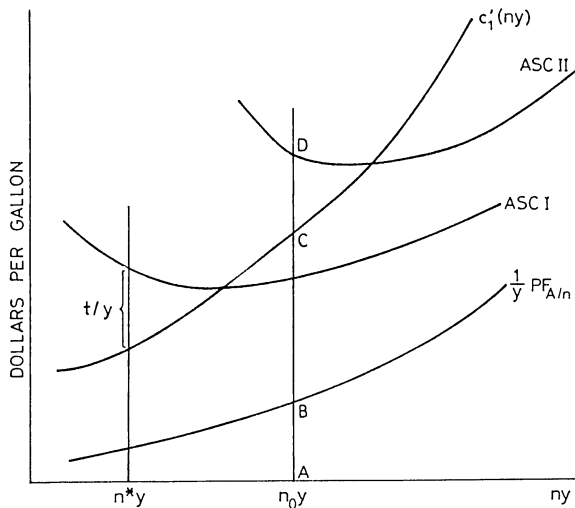


Fig. 1. Cost function of village services. Average service cost is:
 $ASC = [c_1(ny) + C_2(Q)] / ny$.

cost' element in the figure and average cost per gallon is U-shaped (ASC 1). As drawn, n^* is smaller than the optimum, and the positive lump-sum tax levied in a village of this size is higher than land's marginal product (which increases with labor and water). Optimal village size will be n_0 and, at this size, the lump-sum tax (CD) is equal to the marginal product of land (AB), both divided in the diagram by y .

The village functions as a firm with a U-shaped cost curve. But this is a zero-profit firm, the patrons of which exactly cover its cost and it does not necessarily operate at minimum AC (it will, under different circumstances, as shown below). Another difference between a regular firm and the village service sector is the shift of the average-cost curve ASC with n – with the number of 'patrons.'

Settler's rent and limited entry

We turn now to the value of joining the project. By the construction of (4), if income is positive, a settler covers the alternative cost of labor. But the project may yield for its participants further returns. We name them *settler's rent* SR and, in a viable project, $SR \geq 0$. Settler's rent is revenue minus actual and alternative costs:

$$SR = PF(\cdot) - wL - [c_1(ny) + c_2(Q)]/n \quad (8)$$

By Euler's theorem, as the production function is well behaved:

$$PF(\cdot) = P[F_y y + F_{A/n}(A/n) + F_L L + F_Q Q] \quad (9)$$

and making use of (5a)–(5c) and (8), the value of the right to join the project is:

$$SR = \theta L + PF_Q Q \quad (10)$$

By Objective F , the village is planned to maximize income on the settler's farms. So long as SR is positive, outsiders may wish to join, but since additional entrants may reduce income of the insiders, entry is limited to the number n consistent with the equality in (6). Moreover, if $\theta \neq 0$, farm income can be increased by either hiring labor at the wage rate w (for $\theta > 0$) or farming part-time and seeking off-farm work at the same wage (if $\theta < 0$). As already indicated, these possibilities are not permitted in the present model. We return to this point below.

Income in village

We assume now that the planner maximizes total income in village (Objective V). The Lagrangian is:

$$H = nPF(\cdot) - wnL - c_1(ny) - c_2(Q) + \theta n(L_0 - L) \quad (11)$$

The first three necessary conditions are identical to the factor allocation rules (5a)–(5c) and are not repeated. The conditions for optimal number of farms is now:

$$\partial H/\partial n = P F(\quad) - PF_{A/n}(A/n) - wL - c'_1(ny)y = 0 \quad (12)$$

Consistent with the current Objective V , the entrance of an additional settler is considered from the point of view of the planner. Two elements are added in (12) when compared with (6): the contribution of the marginal settler to production, and the newcomer's alternative cost of labor. These elements are taken into account by the planner but disregarded by insiders.

The following properties can also be shown to hold (detailed derivations in Feinerman and Kislev, 1987):

(a) A shift of the settlement project from Objective F to objective V will change its plan only if under Objective F $SR \neq 0$. And then, if the settler's rent was positive, the shift will entail an increase in n . Increasing n will reduce income on the individual farms, since farm income was at its maximum under Objective F .

(b) By (13), under Objective V , the cost of over-settling exhausts the value of the public services:

$$\theta L + PF_Q Q = 0 \quad (13)$$

(c) But settler's rent is not eliminated altogether, as:

$$SR = PF_{A/n}(A/n) - t \quad (14)$$

(d) Under Objective V , $SR > 0$ (provided it was positive under Objective F). To prove the inequality, substitute $t (= C/n - c'_1(ny)y)$ into (6). Under Objective V , n is larger than under F ; hence under V , $\partial H/\partial n < 0$ and $t < PF_{A/n}(A/n)$.

THE REGION

Beside determining village size and services, the planner decides now on the number of villages in the region. A region is defined by a given amount of land, A_0 , which can be divided among M villages with n farms in each. For simplicity we disregard regional services, which are often provided in larger-scale projects; similarly, we disregard negative externalities such as that wells of several villages draw water from the same limited source. We consider several alternative planning objectives to be maximized.

Maximum income in farm

A natural objective is to maximize income per farm (Objective F) but this leads to unacceptable plans. To see it, add to the Lagrangian in (4) the

constraint $A_0 = MA$. The condition for optimal plot size is, with this constraint, $PF_{A/n} = 0$: if the production function is well behaved and marginal products are positive at any range, there will be a single village in the region and one or a few fortunate settlers will receive maximum income. If not, and marginal product vanishes at finite area per farm, village size will be determined by the condition $PF_{A/n} = 0$; still an unacceptable condition – if land is in any sense a scarce resource in the economy.

Predetermined area of farm land

Often, a regional program will allot a certain amount of land per farm. The planning problem is then to set optimal village size, and number of villages in the region (the variables n and M). We are still working under Objective F and maximizing income per farm. Substitute now a (= constant) for A/n in $F(\)$ in the Lagrangian in (4). Maximization leads again to the factor allocation rules (5a)–(5c) and to the condition for optimal village size (n):

$$C/n = c'_1(ny)y \quad (15)$$

which implies $t = 0$ – all service costs are covered by user charges. With a given plot size, determining n sets area per village and the number of villages in the region (the setting is only approximate as $A_0/(an) = M$ will most often not be an integer).

Equation (15) also implies that in a planned region, with predetermined land allotment per farm, villages operate at minimum ASC (Fig. 1). When the region expands, additional villages are added, each of identical area and number of settlers. This is in analogy to the expansion of a competitive industry, as demand rises, with entry of identical firms, each operating at minimum AC.

Settler's rent is, with the current objective and constraints:

$$SR = PF_a a + \theta L + PF_Q Q \quad (16)$$

where a is again the predetermined area of land per farm.

Parity income

A typical objective in regional planning is to set farm income on par with alternative income, say urban wage rate. Farms and villages are then planned to yield net income at the parity level for settlers fully employed on the land allotted to them by the development authority. Translating this procedure to the terminology of the present discussion, the region is

planned for maximum number of farmers (call it Objective N) provided that the alternative cost of labor, w , is *exactly* covered. The immediate implication is zero settler's rent, $SR = 0$. With this objective, farm area a becomes an endogenous variable and planning can be done by varying plot size, maintaining the first-order conditions of the previous problem, until the condition $SR = 0$ is met.

Now, by equation (16):

$$\theta L = -(PF_a a + PF_Q Q) \quad (17)$$

Combining with (5c), $PF_L < w$: farmers settled in the project region will find that they can increase their income by working part-time off their land – provided alternative employment is really available. Thus, for example, a settlement project aimed at reducing the pressure on the local labor market in a rural area may disappoint its planner when the settlers will be found competing with the non-farm laborers in the region. This eventuality can be avoided by letting the settlers reach income exceeding parity levels (at the cost of improving the lot of the settlers compared with those who have to stay with urban wages and increasing the pressure of outsiders to join the project).

Income (product) in region (Objective R)

Relaxing the previous assumptions of given plot size or parity income, we attempt now to maximize total income in the region (this can be the objective of a government trying to maximize the region's contribution to national product). The Lagrangian is:

$$H = MnP F() - wMnL - M c_1(ny) - M c_2(Q) + Mn \theta(L_0 - L) + \mu(A_0 - MA) \quad (18)$$

The factor allocation rules (5a)–(5c) still prevail. For optimum n :

$$PF - wL = c'_1(ny)y + PF_{A/n}(A/n) \quad (19)$$

Equation (20) is the (approximate) condition for optimum M :

$$P F() - wL = [c_1(ny) + c_2(Q)]/n + PF_{A/n}(A/n) \quad (20)$$

Combining the last two equations:

$$[c_1(ny) + c_2(Q)]/n = c'_1(ny)y \quad (21)$$

When the region is planned for maximum income, user charges cover cost of services and $t = 0$.

Settler's rent is the marginal product of the land, $PF_{A/n}(A/n)$. This is the only case among those considered in the paper in which the value of the right to settle is equal to the value of the land allotted to the settlers.

LAND TAXES COLLECTED BY THE NATIONAL GOVERNMENT

We introduce now the possibility that the development authority charges rent in the form of land tax. The revenue due to this tax is not used to finance village services, but is taken out of the region. Let the land tax be s dollars per unit of land. We examine the effect of the tax once for the plan of a village and once for the case of regional planning.

To consider village planning under Objective F , subtract sA/n from the Lagrangian in (4). The factor allocation rules (5a)–(5c) are not affected, but equation (7) is now:

$$t = (A/n)(PF_{A/n} - s) \quad (7a)$$

In particular, if the land tax is equal to the marginal product of land, the lump sum tax will vanish ($t = 0$) and all village costs will be covered by user charges (for water in our example).

How will levying a land tax affect village size, the number n , and farm income, SR ? To examine size first, consider a village with optimal n , in the absence of a land tax, with $\partial H/\partial n = 0$ in (6). Imposing land tax adds $s(A/n) > 0$ to the right-hand side of (6); the derivative $\partial H/\partial n$ is then positive, implying an increase in planned n . This means that the imposition of the tax increases village size. Intuitively, the imposition of the tax increases the cost of land services; consequently, farm-level demand for land decrease and the number of farms rises.

To check farm income when $s > 0$, we examine settler's rent. The tax sA/n has to be deducted from the right-hand side of (8). Therefore, SR in (10) is reduced by the amount $s(A/n)$: the tax imposed by the development authority or the national government reduces income of settlers in the project.

Similarly, the imposition of a land tax in a regional project with parity income as the objective reduces income and settler's rent, and modifies the expression in (17) which is now:

$$\theta L = -(PF_a a + PF_Q Q) + s(A/n) = -[a(PF_a - s) + PF_Q Q] \quad (17a)$$

Comparing (17) with (17a), one observes that levying an exogenous (to the region) tax reduces the attractiveness of off-farm work. The explanation for this effect is that when the planner aims at maintaining parity, the area a becomes an endogenous variable and the plan calls for larger plots the

higher the tax rate s . With larger plots, labor's marginal product increases, and with it the associated shadow price θ . On the other hand, with a fixed area per farm or when the objective is maximum income for the region, s is in fact a lump-sum tax; it reduces settler's rent by $s(A/n)$, but it does not affect allocation considerations [a similar point is made by Mieszkowski and Zodrow (1989) for urban property tax with strict zoning].

COMPARATIVE STATICS

In this section we turn to examine the effect of changes in planning variables. Our aim is only to exemplify the approach in order to gain a better grasp of the operation of the model. Assume that the question posed is: in a village plan under *Objective F* with village land given as A and with $s = 0$, authorities desire to change the number of settlers per settlement; how will the change affect the plan?

Now n becomes an exogenous variable, and the tool of the examination is the analysis of comparative statics. For convenience, define $z = ny$ – total amount of water pumped at the village well. The signs of the relevant second derivatives of the Lagrangian, H , in (4) are [detailed derivations are omitted here (see Feinerman and Kislev, 1987)]:

$$H_{zz} < 0 \quad H_{QQ} < 0 \quad H_{zQ} > 0 \quad H_{zn} > 0 \quad H_{Qn} \text{ indeterminate.}$$

The last two cross-derivatives, H_{zn} and H_{Qn} , demonstrate the difference between consumption-type public goods, which we do not consider here, and production services. Consumption services directly enter the utility of the household and, in general, the more households in the community, the larger the marginal contribution of the public good. Production services affect income in combination with other factors. In the expressions for H_{zn} and H_{Qn} , as n increases, land per farm decreases because land is shared with new entrants and this reduction in area subtracts from the contribution of the services. For H_{Qn} , the reduction of water per farm adds to the negative effect of area contraction and the sign of this cross-derivative cannot be determined a-priori, though in many cases $H_{Qn} > 0$ can be expected. That the sign of H_{zn} can be determined is due to $F(\cdot)$ being linearly homogeneous; with a different technology, H_{zn} could be negative or, more likely, also indeterminate.

By the analysis, the effects of a change in settlement size on the supply of the public services are:

$$\text{SIGN}(dz/dn) = \text{SIGN}(-H_{zn}H_{QQ} + H_{Qn}H_{zQ}) \quad (22)$$

$$\text{SIGN}(dQ/dn) = \text{SIGN}(-H_{zz}H_{Qn} + H_{zn}H_{Qn}) \quad (23)$$

and these signs depend on the sign of H_{Qn} in the following way:

$$\text{If } H_{Qn} \geq 0 \quad (dz/dn), (dQ/dn) > 0 \quad (24)$$

Otherwise, $\text{SIGN}(dz/dn)$, $\text{SIGN}(dQ/dn)$ are indeterminate.

Hence public services, both chargeable and the pure public good, will unquestionably increase with the number of farms only if a growth in numbers does not reduce the marginal contribution of the public good on the individual farm (recall that the analysis is done for Objective F). A similar analysis shows that, for a given n , optimal supplies of both public services z and Q will increase with the price of the product, P .

Returning to the case where n is an endogenous variable, further analysis, again not detailed here, reveals that the effect of a change in P on optimal n , z , and Q is indeterminate. Intuitively, this could perhaps be expected since in general an increase in the price of the product does not affect farm size when land supply is completely inelastic (Kislev and Peterson, 1982). Similarly, for a given n , output per farm – product supply – increases with P . This brings us to the boundary condition: a break-even P will be the price at which settlers cover alternative costs of labor and of capital – if they are required to purchase the right to settle. At a price lower than break-even, settlers will not join the project. In the same way, given P , a break-even w can be calculated, now with urban wages higher then the break-even level settlers will not join.

CONCLUDING REMARKS

The paper presents a theory of agricultural settlement and examines several cases. We find that village structure – size, services, and finance – vary with the planning objective. In particular, we show that a regional settlement project cannot realistically be planned to maximize farm income, as this objective leads to the trivial solution of allotting all the land to a single farm. Planning for parity income is possible but it encourages off-farm work away from the project. Levying land rent increases optimal number of settlers and reduces income per farm.

The model and the analysis draw on the modern theory of local public goods, but unlike the literature expounding that theory we do not focus on household utility, but rather on production. We are dealing with a simple version of the theory, in which all units are identical. Relaxing this assumption introduces the possibility of heterogenous villages supplying different services to groups of settlers: milk producers and orchard growers, for example. Alternatively, settlers may be drawn to villages ‘catering’ to their specific needs; this is the essence of the Tiebout model of local public goods. The model we presented can also be applied to the analysis

of cooperatives; an example can be cooperation in credit, where the public good is the goodwill created by joint efforts and responsibility. But these, as well as empirical applications of the theory, are left to other occasions.

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