The Goals of U.S. Agricultural Policy: A Mechanism Design Approach

Author(s): Brent Hueth

Source: *American Journal of Agricultural Economics*, Feb., 2000, Vol. 82, No. 1 (Feb., 2000), pp. 14-24

Published by: Oxford University Press on behalf of the Agricultural & Applied Economics Association

Stable URL: https://www.jstor.org/stable/1244475

The Goals of U.S. Agricultural Policy: A Mechanism Design Approach

Brent Hueth

This article examines motivations underlying the government's choice of alternative policy mechanisms for subsidizing agriculture. Optimal policies are analyzed for three government objectives: one where the government wishes to ensure a minimum level of net income for all farmers, a second where the government's only concern is to transfer income from consumers and taxpayers to the farm sector, and a final "augmented" income-transfer objective. The analysis offers an explanation for agricultural policy mechanisms that involve overproduction by high-cost producers, relative to a free-market equilibrium. Such a distortion might arise from the existence of nonmarket values for the production of relatively high-cost farmers in the government's objective.

Key words: agricultural policy, farm structure, mechanism design.

Issues of farm structure, particularly relating to farm size and ownership, have been part of the debate surrounding U.S. agricultural policy for more than fifty years, and yet many agricultural economists argue that such issues are only the rhetoric surrounding a more direct policy objective: To transfer income from consumers and taxpayers to the agricultural sector. As one example, Gardner (p. 347) writes: "In short, the set of farm policies we observe, in the United States and the industrial countries generally, whatever the stated goals may be, appear to be observationally equivalent to policies intended to support the incomes of farmers as an interest group."

This conclusion is partly reached by observing that agricultural policies are generally not tied to specific characteristics of farms. For example, in relation to the oft-mentioned goal of preserving the family farm, one might ask the question: If the goal of agricultural policy is to support or promote family farms, why are payments not made contingent on farm ownership structure?

But then one might also ask why, if the goal of U.S. agricultural policy is really just to "support the incomes of farmers as an interest group," has the U.S. government always, at least until very recently, favored income-transfer policies that entail deadweight loss? By using policies other than lump-sum transfers, the government wastes resources that could otherwise be transferred to agricultural producers. Just argues that lump-sum transfers are simply not possible, and that the government views itself as constrained to policies which have proven implementable in the past. That is, although many of the policies we observe are inefficient as income-transfer mechanisms, this is only because practical considerations limit the use of more efficient policies. An alternative explanation that is explored in this article is that existing policy mechanisms are not constraints in policy formation, but rather the result of a particular policy objective. We ask what ends are served by particular policy instruments, instead of evaluating each instrument based on some normative criteria.

We do this by taking a mechanism-design approach in examining the structure of optimal policies under three alternative governmental objectives. The analysis extends the work of Chambers (1988, 1992) to objectives other than weighted utilitarian. One important consequence of this extension is an explanation for the farm policy that provides production subsidies with total payment caps. This mechanism can be viewed as a stylized version of U.S. target-price policy that, until very recently, was the primary policy tool

---

Brent Hueth is assistant professor in the Department of Economics at Iowa State University.

The author thanks Robert Chambers for his many careful readings of this article at earlier stages of its development. The helpful comments of Bruce Gardner, Richard Just, and two anonymous referees are gratefully acknowledged, as is financial support from Resources for the Future.

Amer. J. Agr. Econ. 82 (February 2000): 14–24

used in major program crops, and which has included a total payment cap since the early 1970s (Knutson). The results in this article suggest that such a mechanism is consistent with the government attaching a social benefit to the production of high-cost farmers beyond market benefits. For example, the government might wish to adopt a policy that not only transfers income to agriculture, but also alters its structure by insuring that there are a greater number of relatively high-cost producers, each producing more than they would in the absence of intervention. One interpretation in this case is that the government perceives "family farmers" to be relatively high-cost, and wishes to "preserve the family farm" by subsidizing its production. However, it can't subsidize only high-cost producers because other types of producers might attempt to mimic high-cost behavior. A payment cap awarded to all farm types producing above some minimum level helps to alleviate this perverse incentive.

The theoretical analysis in this article borrows from the literature on mechanism design (e.g., Fudenberg and Tirole, chap. 7). An important advantage of this approach is that one is able to allow for heterogeneity across farmers, in contrast to more traditional models of agricultural policy where all farmers are treated equally. Recent contributions in the agricultural economics literature using a similar approach include Lewis, Ware, and Feenstra; Smith; and Bourgeon, Jayet, and Picard. In the model that follows, the government designs a "farm policy" that specifies the payment or transfer that each farmer receives, and his associated production. Transfers come from consumers in the form of market revenues, and from taxpayers. The model is consistent with other models of agricultural policy in treating consumers and taxpayers as a single group (e.g., Gardner; Alston and Hurd), and there is only a single commodity. Finally, optimal policy is analyzed under three alternative assumptions about the motivations underlying the government's desire to intervene in agricultural markets.

The Model

Producers are represented by a single parameter, θ, representing their farm type. For output q, variable production costs are given by the continuously differentiable function $C(q,\theta)$ with $C(0,\theta) = 0$, $C_1(q,\theta) > 0$ and $C_{11}(q,\theta) > 0$.[1] Thus, there are no fixed costs, and variable production costs are assumed to be strictly increasing and strictly convex in q. Furthermore, farmers with larger θ are assumed to be less efficient in the sense of having strictly higher total and marginal production costs: $C_2(q,\theta) > 0$ and $C_{12}(q,\theta) > 0$ for all θ.[2]

The distribution of farm types is weighted with mass N, and is assumed to be continuous on the interval $\Theta = [\underline{\theta}, \bar{\theta}]$ with distribution function $G(\theta)$ known to the government, and associated density $g(\theta)$ strictly positive on Θ. A farmer's type is assumed to be private information. While the government knows the distribution of farm types $G(\theta)$ it does not know the type of a given farmer. For example, the government might have reasonably good information on the distribution of production costs for some crop and county combination, and yet not know the exact costs of an individual farmer. Alternatively, θ might represent an observable characteristic (e.g., farm size) that, perhaps for political reasons, cannot be the explicit basis of policy.

We also make the following simplifying assumptions:

(A1) $\dfrac{\partial}{\partial\theta}\dfrac{G(\theta)}{g(\theta)} \geq 0$

(A2) $C_{112}(q, \theta) \geq 0$

(A3) $C_{122}(q, \theta) \geq 0$.

The first of these is a variation on the monotone hazard-rate property and is satisfied by a number of common distributions. The remaining conditions hold, for example, with a cost function where θ enters multiplicatively. These assumptions simplify our analysis in two ways: First, in two of the cases analyzed below, assumption (A2) is a sufficient condition for an optimum, and second, assumptions (A1)–(A3) rule out pooling (where a nondegenerate interval of farm types produce the same amount) that arises solely from the structure of $G(\theta)$ or $C(q, \theta)$. Because part of the analysis examines pooling that derives from the government's objective, these assumptions help isolate cause and effect.

In each of the governmental policy objectives analyzed below, farmers receive the market revenues from their production, pq,

[1] Subscripts on functions will always indicate partial derivatives with respect to the argument indicated.

[2] The model could be generalized to include a fixed cost, independent of (or increasing in) θ, without changing any of the qualitative properties of the analysis.

where $p > 0$ represents the market price, plus a transfer, t, from the government.[3] To avoid imposing any artificial structure on the government's policy mechanism, we suppose the government uses a revelation mechanism: Each farmer is asked to report their type, say $\hat{\theta}$, in exchange for a pair of functions $q(\hat{\theta})$ and $t(\hat{\theta})$, and these functions are chosen to induce truthful revelation of θ. The allocation of a type-θ farmer is then given by $\langle q(\theta), t(\theta)\rangle$. Because the functions $q(.)$ and $t(.)$ are allowed to depend in an arbitrary way on each farmers' report of θ, this particular mechanism can mimic the outcome of any arbitrary mechanism the government might use.

This insight is a consequence of the revelation principle and is useful in this analysis because it allows us to focus attention on the government's policy objective, and on the outcomes $\langle q(\theta), t(\theta)\rangle$, without considering the choice of a specific policy instrument.[4] For a given policy objective, once we choose an optimal allocation from the set of allocations that can be implemented via a truthful revelation mechanism, we can then consider the design of a specific instrument to achieve the desired outcome. Thus, our analysis endogenizes the government's choice of policy instrument, and we can ask the question: "For a given policy objective, what policy instrument (other than a truthful revelation mechanism) would be optimal?"

In a revelation mechanism, farmers report their type truthfully if and only if the following incentive compatibility condition is satisfied:

$$(1) \quad t(\theta) + pq(\theta) - C[q(\theta), \theta] \geq t(\tilde{\theta}) + pq(\tilde{\theta}) - C[q(\tilde{\theta}), \theta] \quad \forall\, \theta, \tilde{\theta} \in \Theta \times \Theta.$$

That is, farmers report truthfully if a truthful report at least weakly dominates any other report. A standard result from the mechanism-design literature is

LEMMA 1. *(Guesnerie and Laffont) An incentive-compatible production profile $q(\theta)$ is nonincreasing, and for all θ where $q(\theta)$ and $t(\theta)$ are differentiable, necessary and sufficient conditions for* (1) *are*

$$(2) \quad \left.\frac{dt(\hat{\theta})}{d\hat{\theta}}\right|_{\hat{\theta}=\theta} + p\left.\frac{dq(\hat{\theta})}{d\hat{\theta}}\right|_{\hat{\theta}=\theta} - C_1[q(\theta), \theta]\left.\frac{dq(\hat{\theta})}{d\hat{\theta}}\right|_{\hat{\theta}=\theta} = 0,$$

$$(3) \quad \frac{dq(\theta)}{d\theta} \leq 0.$$

Defining $\Phi(\theta,\hat{\theta}) \equiv t(\hat{\theta}) + pq(\hat{\theta}) - C[q(\hat{\theta}), \theta]$, equation (2) is the first-order condition for maximization of $\Phi(\theta,\hat{\theta})$ with respect to $\hat{\theta}$, where truthful reporting is optimal. The weak monotonicity condition (3) is a necessary consequence of the second-order condition for a maximum. Intuitively, equation (2) recognizes that, given the revelation mechanism $\langle q(\theta), t(\theta)\rangle$, producers will report the θ that maximizes their return. Thus, equation (2) ensures that the mechanism is consistent with truthful reporting. An incentive-compatible production profile must be monotonic because the marginal cost of increasing q is smaller for producers with smaller θ. Hence, if a type-θ farmer receives $\langle q(\theta), t(\theta)\rangle$ and q is slightly increased, we can find a new $t(\theta)$ such that for $d\theta > 0$, a producer with type θ-$d\theta$ at least weakly prefers this new allocation, while the original farmer does not.

Having defined the set of incentive-compatible allocations, we now consider the choice of an optimal allocation under three alternative governmental objectives. As a point of reference, we define the free-market outcome, $q^m(\theta)$, as the quantity that maximizes producer profit, taking price as given: $q^m(\theta) \equiv \arg\max_q[pq - C(q, \theta)]$.

Income-Support Objective

To begin, assume that the government's agricultural policy objective is to ensure, at least cost, a minimum level of net income for all farm types, including types who may be asked not to produce under the government's program. This objective is consistent with the view that the purpose of agricultural policy is to ensure a level of net income considered "reasonable" relative to earnings in other sectors of the economy. For example, one intended purpose of the Agricultural Adjustment Act of 1933, the nation's first comprehensive supply management program, was to establish "parity prices" for farmers that gen-

[3] The model is initially set in any economy with perfectly elastic demand, although this assumption is relaxed later in the article.

[4] The revelation principle states that if an allocation $[q(\theta), t(\theta)]$ for all θ can be implemented through some mechanism, then it can also be implemented through a truthful revelation mechanism.

erated returns comparable to those in some base period (Cochran).[5]

We denote the desired level of income-support for farmers by $\overline{\pi}$. The total cost of the program to the government is $N\int_{\Theta} t(\theta)dG(\theta)$, which we assume strictly positive. Taking $\overline{\pi}$ as given, the government's problem is stated as

$$\min_{q(\theta),t(\theta)} N\int_{\Theta} t(\theta)\,dG(\theta) \quad \text{s.t.}$$
$$\Pi(\theta) \equiv t(\theta) + pq(\theta) - C[q(\theta), \theta] \geq \overline{\pi} \quad \forall\, \theta, \text{ and (2) and (3)} \quad \forall\, \theta.$$

This problem can be solved using methods familiar from the literature on hidden-information agency problems (e.g., Fudenberg and Tirole, Guesnerie and Laffont). The definition of $\Pi(\theta)$ above, together with condition (2), yields $\Pi'(\theta) = -C_2(q(\theta),\theta)$. Integrating this term over the interval $[\underline{\theta}, \overline{\theta}]$, and using our definition for $\Pi(\theta)$, we can then derive the following expression for $t(\theta)$:

$$(4) \quad t(\theta) = \Pi(\overline{\theta}) + \int_{\theta}^{\overline{\theta}} C_2[q(c), c]\,dc - pq(\theta) + C[q(\theta), \theta].$$

Substituting this expression for $t(\theta)$ into the government's objective, integrating by parts, defining $\nu(\theta) \equiv G(\theta)/g(\theta)$, and choosing $q(\theta)$ as a pointwise optimum yields the following condition for an interior solution:

$$(5) \quad p - C_1[q(\theta), \theta] = C_{12}[q(\theta), \theta]\nu(\theta).$$

If for some θ, say θ_*,

$$p - C_1(0, \theta_*) - C_{12}(0, \theta_*)\nu(\theta_*) < 0,$$

then $q(\theta) = 0$ for all $\theta > \theta_*$. Using assumptions (A1)–(A3), one can easily verify that equation (5) is both necessary and sufficient for an optimum, and that the solution satisfies equation (3).

Expression (5) implies that the transfer is increasing in θ. This can be verified by totally differentiating the expression in equation (4):

$$(6) \quad \frac{dt(\theta)}{d\theta} = \frac{dq(\theta)}{d\theta}\{C_1[q(\theta), \theta] - p\} \geq 0.$$

Thus, as one would expect, higher-cost producers receive greater support from the government. Furthermore, if for some $\theta > \underline{\theta}$

$$pq(\theta) - C[q(\theta), \theta] > \overline{\pi} + \int_{\theta}^{\overline{\theta}} C_2[q(a), a]da,$$

then relatively low-cost producers are taxed. The right-hand side of this expression represents the minimum total surplus that a type-θ producer must earn if $[q(\theta), t(\theta)]$ is to be incentive compatible. Thus, in this case, any surplus above this amount which is earned from the sale of $q(\theta)$ is taxed away and redistributed to higher-cost farm types.

If the intent of agricultural policy is to ensure a minimum level of net income for all agricultural producers at least cost to taxpayers, then from equation (5) production will generally be less than would occur in the free market. Furthermore, relatively low-cost producers may be taxed to help finance support of higher-cost producers. It is also possible that some producers may be asked not to produce, yet still receive positive payment. Although it might seem odd to pay producers not to produce, the analysis in this section indicates that one rationale for such a policy would be a concern that everyone in the industry earn some minimum level of net income. When relatively high-cost farmers produce nothing, low-cost producers can be taxed (or paid less) because the cost of mimicking high-cost behavior becomes costly (in the form of lost market revenues). Such a tax can be used to support the incomes of less efficient farmers who are not producing. In the context of past U.S. dairy policy that paid willing farmers to slaughter their herds, Chambers (1988) succinctly summarizes the rationale for such a policy by noting that "sometimes it is cheaper to kill cows than let them produce surplus milk."

Income-Transfer Objective

Next, assume the government's agricultural policy objective is to transfer income to the farm sector. The total money available for transfer is assumed exogenous, and is denoted by $\overline{B}$. The assumption implicit in a fixed budget is that it is determined independently of the objectives of agricultural policy. Thus, we might view $\overline{B}$ as the expected (or existing) budget at the time specific policies are designed.[6] Stated formally, the government

[5] In the present model, income support is equivalent to price support since the government knows that costs are given by $C(q, \theta)$ for $\theta \in [\underline{\theta}, \overline{\theta}]$.

[6] It is easy to think of situations in which the budget available for agricultural programs might depend on the structure of an entire farm-policy package. For example, agricultural interests might be able to obtain greater overall support by incorporating resource conservation policies into a "farm bill." It is less clear how the specific provisions of policy for a single commodity might influence the budget available for implementing such a policy.

maximizes total net income in the farm sector subject to the budget constraint and incentive compatibility[7]:

$$\max_{q(\theta),t(\theta)} N \int_{\Theta} \{t(\theta) + pq(\theta) - C[q(\theta), \theta]\} \, dG(\theta) \quad \text{s.t.}$$
$$N \int_{\Theta} t(\theta) \, dG(\theta) \leq \overline{B}, \text{ and}$$
$$\text{equations (2) and (3)} \quad \forall \, \theta.$$

An obvious solution to this problem is to let each farm type produce for the market, and then to provide equal lump-sum transfers to all farm types in an amount that just exhausts the budget. This solution is summarized in the following proposition.

PROPOSITION 1. *A solution to the government's income-transfer problem is given by* $q^m(\theta)$ *and* $\overline{B}/N$ *for all* θ. (See the appendix for proof of proposition 1.)

Another way of stating proposition 1 is to say that the solution to this problem is first best, or is the same that would occur in the absence of asymmetric information. Because the market mechanism is Pareto efficient, no other mechanism can generate greater total surplus. Furthermore, the government is unconcerned with the distribution of resources within the farm sector, so that one incentive-compatible way to distribute the budget is to offer each farmer the same lump-sum payment.

This is the solution referred to in the introduction. If the government's only concern is to transfer income to the agricultural sector, then lump-sum transfers (decoupled payments) represent an efficient transfer mechanism. Although it is difficult to draw comparisons between a highly stylized model of program design like the one presented here and actual policy, the income support component of the Federal Agriculture Improvement and Reform Act of 1996 is structured very much like a lump-sum transfer. Under this act, roughly $35 billion was promised (over a period of seven years) to producers of wheat, feed grains, upland cotton, and rice. However, lump-sum payments are distributed according to historical levels of production and acreage planted (for details see Nelson and Schertz, p. 6), reflecting sensitivity to political issues like the distribution of program benefits within the agricultural sector. Nevertheless, the government's policy mechanism under this new program appears to be more consistent with a strict income-transfer objective than mechanisms used in previous years.

Augmented Income-Transfer Objective

Now suppose that the government also derives "nonmarket" benefits from the production of relatively high-cost farms represented by

$$V(q, \theta) = \begin{cases} v(q) & \text{for } \theta \geq \hat{\theta} \\ 0 & \text{for } \theta < \hat{\theta} \end{cases}$$

where $v(q) \geq 0$ is assumed continuously differentiable, strictly increasing, and concave. It is important to recognize that $V(q, \theta)$ does not depend at all on the income of the farm population (or on the income of a fraction of this population), but rather on the *production* of relatively inefficient farm operations.

One rationale for this type of function is that it represents, in reduced-form, the desire of the general populace to preserve relatively inefficient or small farms. Political rhetoric associated with U.S. agricultural policy often appeals for preservation of the "family farm" (e.g., Browne). Presumably, this appeal is based on the notion that a larger number of relatively small family-style farms are more conducive to the sustainability and well-being of rural communities than a small number of relatively large "corporate" farms. If family-run farms produce at higher cost than industrial or corporate farms, then $V(q, \theta)$ might represent a reduced-form version of this notion. Under this interpretation, $v(q)$ would represent the social benefit of the family farm's production, beyond its market benefits. In this section, we suppose that the government wishes to transfer income to the farm sector, in addition to valuing the output of high-cost producers in the form of $v(q)$.

Under the income-transfer objective, the government's and farmers' objectives were perfectly aligned. In such a setting, it would never be optimal for some farm type to earn negative returns. Here, however, the government values production differently than farmers, and an allocation that generates negative farm returns may simultaneously generate

[7] There is no need to include a constraint ensuring the participation of each farm type, because the government's objective is literally to maximize farm sector returns (for a given budget). Thus, any need for a "participation" constraint is obviated by the fact that the program will offer farmers at least what they can get in the free market.

positive social returns.[8] To be consistent with actual policy, we suppose that farmer participation is voluntary, and hence rule out the possibility of negative farm returns:

$$(7)\quad t(\theta)+pq(\theta)-C[q(\theta),\theta]\geq 0 \quad \forall\,\theta.$$

Augmenting the government's income-transfer problem with $V(q, \theta)$ and equation (7), the government now solves

$$\max_{q(\theta),t(\theta)} N\int_{\Theta}\{V(q,\theta)+t(\theta)+pq(\theta) - C[q(\theta),\theta]\}\,dG(\theta) \quad \text{s.t.}$$
$$N\int_{\Theta} t(\theta)\,dG(\theta)\leq \overline{B}, \text{ and}$$
$$\text{equations (2), (3), and (7)} \quad \forall\,\theta.$$

The first thing to note about this problem is that the government's budget constraint must bind. If this were not true, the government could distribute the surplus evenly across all farm types without affecting any of the other constraints, and thereby increase the value of its objective. Using arguments identical to those used in analysis of the government's income-support objective, we can then replace equation (7) with $\Pi(\overline{\theta}) \geq 0$, and eliminate equation (2) and $t(\theta)$ with expression (4).

Substituting the expression from (4) for $t(\theta)$ into the binding budget constraint (and integrating by parts) yields

$$(8)\quad \Pi(\overline{\theta})=\overline{B}/N-\int_{\Theta}\{C_2[q(\theta),\theta]\nu(\theta) - pq(\theta)+C[q(\theta),\theta]\}\,dG(\theta).$$

Thus, returns of the highest-cost type are given by $1/N$ times the budget surplus available after subtracting the minimum total budget necessary to implement $q(\theta)$.

Replacing $t(\theta)$ and equation (2) with expression (4), and using the preceding expressing for $\Pi(\theta)$, we can rewrite the above problem as

$$\max_{q(\theta)} \overline{B}+N\int_{\Theta}\{V[q(\theta),\theta]+pq(\theta) - C[q(\theta),\theta]\}\,dG(\theta) \quad \text{s.t.}$$
$$\overline{B}/N-\int_{\Theta}\{C_2[q(\theta),\theta]\nu(\theta)-pq(\theta) + C[q(\theta),\theta]\}\,dG(\theta)\geq 0$$
$$\frac{dq(\theta)}{d\theta}\leq 0 \quad \forall\,\theta.$$

Letting $y(\theta) = dq(\theta)/d\theta$ be a piecewise continuous control variable, and $q(\theta)$ be a piecewise differentiable state variable, this is an optimal-control problem with an isoperimetric constraint and a nonpositivity restriction on the control. The following proposition summarizes the conditions for an interior solution in terms of $q(\theta)$.[9]

PROPOSITION 2. *Suppose $q(\theta) > 0$ for all θ in the solution to the government's augmented income-transfer problem. Then the following system of equations, which determine θ^1, θ^2, $q(\theta)$, and $\overline{q}$, represents a solution to the government's augmented income transfer problem:*

$$(9)\quad \frac{\nu'[q(\theta)]}{1+\lambda}+p-C_1[q(\theta),\theta] - \frac{\lambda}{1+\lambda}C_{12}[q(\theta),\theta]\nu(\theta)=0$$

$$(10)\quad p-C_1[q(\theta),\theta] - \frac{\lambda}{1+\lambda}C_{12}[q(\theta),\theta]\nu(\theta)=0$$

$$(11)\quad \int_{\theta^1(\overline{q})}^{\theta^2(\overline{q})}\{V_1(\overline{q},\theta)+(1+\lambda)[p-C_1(\overline{q},\theta)] - \lambda C_{12}(\overline{q},\theta)\nu(\theta)\}\,dG(\theta)=0.$$

(See the appendix for proof of proposition 2.)

At $\hat{\theta}$ there is a discrete change in the government's objective—one that produces a desire to expand production beyond the level that is optimal for a slightly lower-cost producer. But this type of production profile cannot be achieved for incentive reasons. The best the government can do is choose a profile that is constant over an interval that connects the production levels of relatively low cost ($\theta \leq \theta^1$) and high-cost ($\theta > \theta^2$) producers. The expression in equation (11) determines the level of production $\overline{q}$ at which the profile is constant, and when evaluated at $\overline{q}$, expressions (9) and (10) determine the interval over which this occurs.

Two possible solutions (one for $\lambda > 0$ and another for $\lambda = 0$) to equations (9)–(11) are depicted graphically in figure 1, together with the free-market outcome denoted by $q^m(\theta)$. In each solution, relatively high-cost farmers overproduce (relative to the free market),

---

[8] I thank Jean-Marc Bourgeon for pointing this out, and acknowledge helpful discussions with both Jean-Marc Bourgeon and Rodney Smith regarding formal aspects of the analysis in this section.

[9] From lemma 1, if some farm type θ^c produces strictly positive output, then so do all types $\theta < \theta^c$. Thus, by focusing only on an interior solution we presume that $\nu'(q)$ is sufficiently large to warrant strictly positive output by the highest-cost farmer.

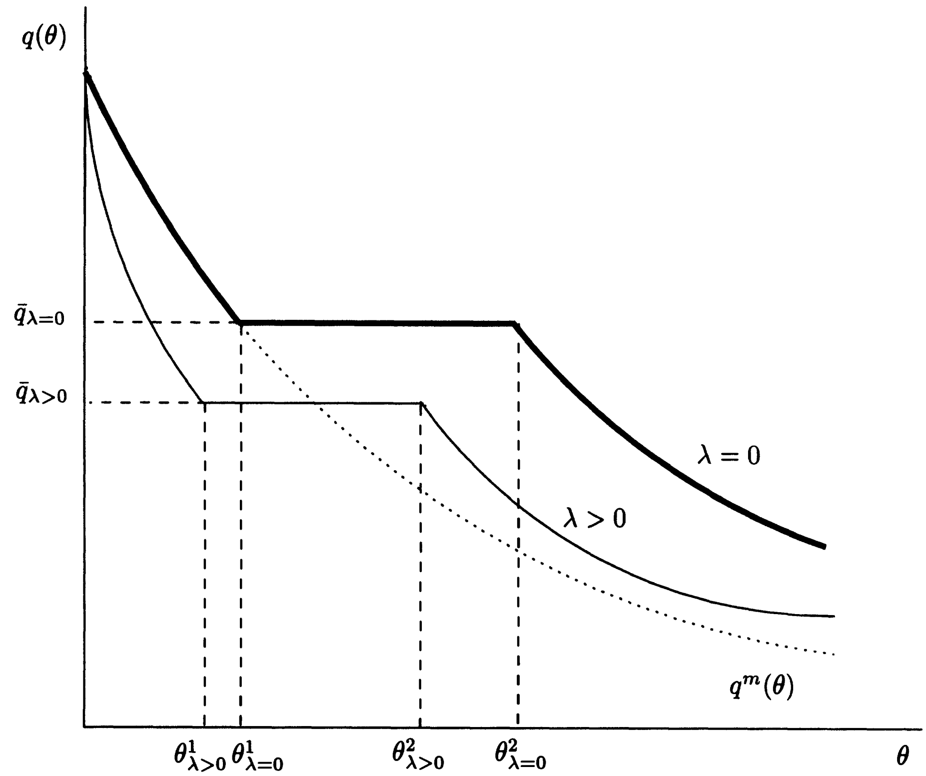

Figure 1. Free market and augmented income-transfer production profiles

whereas relatively low-cost farmers underproduce ($\lambda > 0$) or produce efficiently ($\lambda = 0$). From equation (10), relatively low-cost producers never produce in excess of their free-market level. High-cost producers may produce above or below the free-market level, depending on the structure of $v(q)$. If marginal off-farm benefits are sufficiently steep, it's possible that some high-cost farmers may actually produce below the free-market level, even though there is a nonmarket benefit from their production. This would allow the government to provide greater incentives to intermediate farm types (where nonmarket benefits are particularly high) to produce higher output.

The portion of $q(\theta)$ that is constant ($q(\theta) = \bar{q}$) has an interesting counterpart in terms of the optimal payment $t(\theta)$. Using expression (6), producers whose type lies in the interval $[\theta^1, \theta^2]$ receive a lump sum payment since for these producers $dq(\theta)/d\theta = 0$. Conditions (9) and (10) from proposition 2, together with the expression for $dt(\theta)/d\theta$ from equation (6), indicates that relatively low-cost producers receive a payment that increases with θ, while payment to relatively high-cost producers may increase or decrease with θ, depending on the relative magnitudes of $v'[q(\theta)]/(1 + \lambda)$ and $\lambda/(1 + \lambda)C_{12}[q(\theta), \theta]$. When the magnitude of $v'(\cdot)$ is sufficiently large, high-cost producers receive a payment that decreases in θ. This outcome is presented graphically in figure 2 for $\lambda > 0$.

When $\lambda = 0$ the payment schedule takes on a particularly simple structure. Here, all farm types with θ less than θ^1 receive a constant payment. Although the budget constraint in this case is not binding (or is just binding), a first-best outcome is still not achieved. The payment needed to induce production above free-market levels creates an incentive for low-cost producers to mimic high-cost behavior. This incentive is alleviated by asking only farm types $\theta \geq \theta^2$ to produce above free-market levels, and by offering relatively low-cost producers a lump-sum payment for production above (or equal to) $q(\theta^2)$.

This type of structure is similar to a stylized version of a specific policy mechanism often used in agriculture: a production subsidy with a total payment cap. That is, assume that the government offers the following payment schedule:

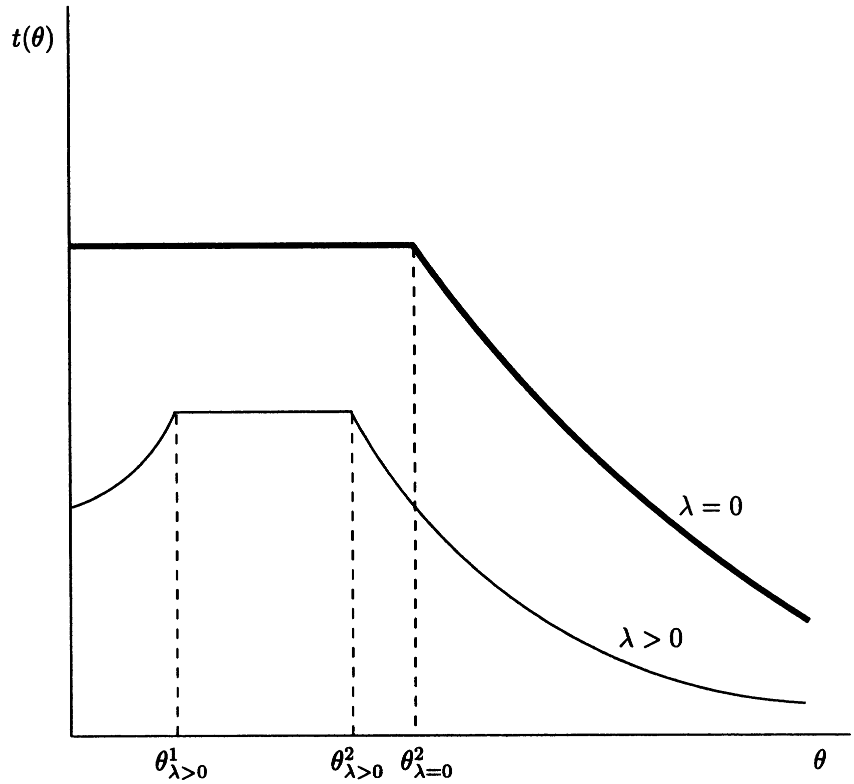

Figure 2. Augmented income-transfer payment profile

$$s(q) = \begin{cases} \alpha q & \text{for } \alpha q < \bar{s} \\ s & \text{for } \alpha q \geq \bar{s} \end{cases}$$

where α is a per-unit production subsidy, and $\bar{s}$ a total-payment cap. Then we can state the following proposition.

PROPOSITION 3. *Assume an interior solution exists for all $\theta \geq \hat{\theta}$ in equation (9) with $\lambda = 0$ and $v'(q) = \alpha$. Then a production-subsidy mechanism with a total payment limit of $\bar{s} = \alpha\bar{q}$ implements the solution to the government's augmented income-transfer problem.* (See the appendix for proof of proposition 3.)

Thus, so long as there is sufficient money in the government's budget ($\lambda = 0$), and marginal off-farm benefits are constant, a production subsidy mechanism that includes a total payment cap can implement the government's optimal allocation. Of course, neither of these conditions are likely to hold in the real world, and $s(q)$ is only a "stylized" representation of an actual target price mechanism. Nevertheless, proposition 3 suggests how a perceived social benefit from the existence of family farming operations could influence farm program provisions.

Furthermore, the relationship between actual policy and the optimal policy under the government's augmented income-transfer objective may even be more similar (although difficult to characterize analytically) when $\lambda > 0$. This is because U.S. target price mechanisms were normally coupled with acreage restrictions requiring producers to idle a fraction of their acreage. Thus, relatively low-cost farmers might actually have produced less than their free-market output in order to participate in the program (and hence receive the payment limit), while the incentive for relatively high-cost farmers to overproduce as a result of the production subsidy was somewhat mitigated by the acreage restriction. Introduction of a strictly positive λ in equations (9)–(11) achieves exactly this type of effect.

A production subsidy type mechanism coupled with a total payment limitation is therefore consistent with a government that attaches an additional social benefit to the production of relatively high-cost farmers beyond market benefits. In such a mechanism, low-cost farmers produce where price equals marginal cost, whereas high-cost farmers overproduce relative to the market equilibrium. If the government only wanted to transfer income to the farm sector, it would never have high-cost farmers overproduce because this wastes resources that could otherwise be transferred.

Imperfectly Elastic Demand

This section briefly describes the significant changes resulting when one allows for imperfectly elastic demand. Denote inverse domestic demand by $P(Q)$, where $Q \equiv N\int_{\Theta} q(\theta)dG(\theta)$. An optimal production profile under an income-support objective is characterized by

$$C_1[q(\theta), \theta] = P(Q) \cdot [1 + k(\theta)/\eta] - C_{12}[q(\theta), \theta]\nu(\theta),$$

where η is the elasticity of domestic demand, and $k(\theta)$ is the share of total output produced by a type-θ farmer.[10] Since $\eta < 0$, production is distorted down from the free-market level to an even greater degree than if price were taken as given. This occurs because restricting production produces monopoly rents for producers, thus making it less costly for the government to satisfy its income-support constraint.

Similarly, under the income-transfer objective, production is characterized by

$$C_1[q(\theta), \theta] = P(Q) \cdot [1 + k(\theta)/\eta].$$

Again, production is distorted down from the free-market level. Since the government is interested in transferring income to the agricultural sector, it transfers the entire budget plus as much as possible from consumers. This is accomplished by restricting output in exactly the same fashion as would a monopolist.

Finally, under the augmented income-transfer objective, production is characterized by

$$C_1[q(\theta), \theta] = P(Q) \cdot [1 + k(\theta)/\eta] + \frac{V_1[q(\theta), \theta]}{(1 + \lambda)} - \frac{\lambda}{(1 + \lambda)} C_{12}[q(\theta), \theta]\nu(\theta)$$

for any interval where $q(\theta)$ is not constant. Low-cost farmers underproduce relative the free-market, and high-cost producers may overproduce or underproduce depending on the relative magnitudes of $v'(q)$ and $[1 + k(\theta)/\eta)$. Low-cost producers underproduce to generate monopoly rents, while the relation between production under the above relationship and in the free market is ambiguous for high-cost producers. This ambiguity reflects the government's desire to have high-cost farmers overproduce because their production generates social value beyond market benefits, and underproduce because doing so generates monopoly rents for the agricultural sector.

Conclusion

This article examines the motivations underlying the government's choice of particular policy mechanisms for subsidizing agriculture. The work extends the analysis in Chambers (1992) to objectives other than weighted utilitarian, and provides an explanation for observing overproduction by high-cost producers relative to a free-market equilibrium. The analysis suggests that such a distortion might arise from the existence of nonmarket values for the production of relatively high-cost farmers in the government's objective. One plausible reason for the existence of such values is that the government perceives a connection between the existence of relatively high-cost farm operations and the preservation or sustainability of rural communities. If many relatively high-cost farms are perceived to be more conducive to the survival of rural areas than a few low-cost farms, and if the government wishes to support rural communities, it would prefer that more production come from high-cost farms. In a closed economy where domestic demand is less than perfectly elastic, such a production distortion may no longer be optimal under the policy objectives considered in this article.

[Received June 1998; accepted April 1999.]

References

Alston, J., and B. Hurd. "Some Neglected Social Costs of Government Spending in Farm Programs." *Amer. J. Agr. Econ.* 72(February 1990):149–56.

[10] In each of the cases analyzed in this section, we must still verify that equation (3) is satisfied, and that the solution represents a maximum. For simplicity we assume that both conditions are always met, but note that, in each case, linear demand is sufficient.

Bourgeon, J., P. Jayet, and P. Picard. "An Incentive Approach to Land Set-Aside Policy Programs." *Eur. Econ. Rev.* 39(October 1995): 1487–509.

Browne, W. P. *Cultivating Congress: Constituents, Issues, and Interests in Agricultural Policymaking*. Lawrence KS: University of Kansas Press, 1995.

Chambers, R. "Designing Farm Programs, or When Should We Save the Cows?" Unpublished, University of Maryland, 1988.

———."On the Design of Agricultural Policy Mechanisms." *Amer. J. Agr. Econ.* 74(August 1992): 646–53.

Cochran, W.W. *The Development of American Agriculture: A Historical Analysis.* Minneapolis, MN: University of Minnesota Press, 1979.

Fudenberg, D., and J. Tirole. *Game Theory*. Cambridge, MA: MIT Press, 1992.

Gardner, B. "Efficient Redistribution Through Commodity Markets." *Amer. J. Agr. Econ.* 65(May 1983):225–34.

Guesnerie, R., and J. Laffont. "A Complete Solution to a Class of Principal-Agent Problems With An Application to the Control of a Self-Manager Firm." *J. Pub. Econ.* 25(December 1984):329–69.

Just, R. "Automatic Adjustment Rules in Commodity Programs," *U.S. Agricultural Policy: The 1985 Farm Legislation*. B. Gardner, ed., Washington DC: American Enterprise Institute, 1985.

Knutson, R. "The Goals of Agricultural Policy." Washington, DC: American Enterprise Institute, 1984.

Lewis, T., R. Ware, and R. Feenstra. "Eliminating Price Supports: A Political Economy Perspective." *J. of Public Economics* 140(November 1989):159–85.

Nelson, F., and L. Schertz. *Provisions of the Federal Agricultural Improvement and Reform Act*. Washington DC: U.S. Department of Agriculture, ERS Tech. Rep., 1996.

Smith, R. "The Conservation Reserve Program as a Least-Cost Land Retirement Mechanism." *Amer. J. Agr. Econ.* 77(February 1995):93–105.

Appendix

Proof of Proposition 1

First ignore equations (2) and (3). It is then clear that the budget constraint must bind because the government's objective is strictly increasing and separable in $t(\theta)$. Substituting the binding budget into the integrand yields the following problem:

$$\max_{q(\theta)}\left(\overline{B}+\int_{\Theta}\{pq(\theta)-C[q(\theta),\theta]\}\,dG(\theta)\right).$$

Pointwise maximization then yields $q^m(\theta)$ as the optimal production profile. One can easily verify that condition (3) is satisfied for this choice. Furthermore, because our choice for $t(\theta)$ is a constant, condition (2) reduces to $\{p - C_1[q(\theta), \theta]\}\, dq(\theta)/d\theta = 0$. Again, it is easily verified that this condition is satisfied for $q(\theta) = q^m(\theta)$.

Proof of Proposition 2

We first construct a state variable

$$z(\theta)=\int_{\underline{\theta}}^{\theta}\{pq(\tau)-C[q(\tau),\tau] - C_2[q(\tau),\tau]\nu(\tau)\}g(\tau)\,d\tau.$$

Letting initial and terminal conditions for $z(\theta)$ be given by $z(\underline{\theta}) = 0$ and $z(\overline{\theta}) \geq \overline{B}/N$, we can replace constraint (8) with the expression

$$\frac{dz(\theta)}{d\theta}=\{pq(\theta)-C[q(\theta),\theta] - C_2[q(\theta),\theta]\nu(\theta)\}g(\theta).$$

The Hamiltonian for the government's augmented income-transfer problem is then

$$\begin{aligned}H(y,q,\delta,\theta,\lambda) &= [V(q,\theta)+pq-C(q,\theta)]g(\theta) + \lambda[pq-C(q,\theta) - C_2(q,\theta)\nu(\theta)]g(\theta)+\delta y\\ &= [V(q,\theta)+(1+\lambda)(pq-C(q,\theta)) - \lambda C_2(q,\theta)\nu(\theta)]g(\theta)+\delta y\end{aligned}$$

where $\delta(\theta)$ and λ are the costate variables for $q(\theta)$ and $z(\theta)$, respectively.[11]

Necessary and sufficient conditions for an optimum are given by

$$\frac{d\delta(\theta)}{d\theta}=-V_1[q(\theta),\theta]g(\theta)-(1+\lambda)[p-C_1(q(\theta),\theta)]g(\theta) - \lambda C_{12}[q(\theta),\theta]\nu(\theta)g(\theta)\quad\forall\,\theta \tag{12}$$

$$\frac{dq(\theta)}{d\theta}=y(\theta)\quad\forall\,\theta \tag{13}$$

$$\delta(\theta)\leq 0,\ y(\theta)\leq 0,\ \delta(\theta)y(\theta)=0\quad\forall\,\theta \tag{14}$$

$$\frac{dz(\theta)}{d\theta}=(pq(\theta)-C(q(\theta),\theta) - C_2(q(\theta),\theta)\nu(\theta))g(\theta)\quad\forall\,\theta \tag{15}$$

$$z(\underline{\theta})=0,\ z(\overline{\theta})\geq -\overline{B}/N \tag{16}$$

[11] When constructing a state variable to accommodate an isoperimetric constraint, it is always the case that its associated costate variable, λ in this case, is a constant.

with transversality conditions $\delta(\theta) = \delta(\bar{\theta}) = 0, \lambda \geq 0$, and $\lambda \cdot (z(\bar{\theta}) + \bar{B}/N) = 0$.[12]

Expressions (12) and (13) are the equations of motion for $\delta(\theta)$ and $q(\theta)$, respectively, and equation (14) is the first-order condition and complementary slackness condition for the control $y(\theta)$. The last two conditions just repeat the definition of our constructed state variable $z(\theta)$ and its boundary conditions. The state variable $q(\theta)$ has no initial or terminal conditions so its costate variable must be zero at both boundaries. Similarly, the transversality conditions for $z(\theta)$ are standard for a state variable with fixed initial and inequality terminal conditions.

In what follows, we construct a solution satisfying conditions (12)–(16) and the associated transversality conditions. The solution involves an interval $[\theta^1, \theta^2]$ around $\hat{\theta}$ where $q(\theta)$ is constant. To obtain such a solution, first note that in any interval where $y(\theta) < 0$ for all θ in the interval, $\delta(\theta)$ must equal zero. In such an interval, from (14), $d\delta(\theta)/d\theta = 0$ for all θ. Because equation (12) is defined in terms of $V(q, \theta)$, there are two possible outcomes; if the interval lies above $\hat{\theta}$ then we have

$$(17)\quad \frac{v'[q(\theta)]}{1+\lambda} + p - C_1[q(\theta), \theta] - \frac{\lambda}{1+\lambda} C_{12}[q(\theta), \theta]\nu(\theta) = 0.$$

Alternatively, if the interval lies below $\hat{\theta}$, then

$$(18)\quad p - C_1[q(\theta), \theta] - \frac{\lambda}{1+\lambda} C_{12}[q(\theta), \theta]\nu(\theta) = 0.$$

If $q(\theta)$ is constant on an interval $[\theta^1, \theta^2]$, then because we assume an interior solution for all θ outside this interval, $y(\theta) > 0$ for all $\theta \notin [\theta^1, \theta^2]$. By the continuity of $\delta(\theta)$, it is then true that $\delta(\theta^1) = \delta(\theta^2) = 0$. Denoting $\bar{q}$ as the value of $q(\theta)$ for $\theta \in [\theta^1, \theta^2]$, integrating equation (12) yields

$$(19)\quad \int_{\theta^1}^{\theta^2} \{V_1(\bar{q}, \theta) + (1+\lambda)[p - C_1(\bar{q}, \theta)] - \lambda C_{12}(\bar{q}, \theta)\nu(\theta)\}\, dG(\theta) = 0.$$

At $q(\theta) = \bar{q}$, equations (17)–(19) constitute three equations in three unknowns: θ^1, θ^2, and $\bar{q}$. Let $\theta^2(\bar{q})$ and $\theta^1(\bar{q})$ be the solutions to equations (17) and (18), respectively, when $q(\theta) = \bar{q}$. It is easily verified that these solutions are unique.[13] We have, therefore, constructed a solution satisfying equations (12)–(16) and the associated transversality conditions. Because these conditions are necessary and sufficient for an optimum, we do not need to consider any other potential solutions. Furthermore, equations (17)–(19) are identical to those specified in proposition 2.

Proof of Proposition 3

A producer faced with the subsidy schedule $s(q)$ chooses q to $\max_q[pq + s(q) - C(q, \theta)]$. The first-order conditions for this problem (assuming an interior solution) are

$$\alpha + p - C_1[q(\theta), \theta] = 0 \quad \text{for } q(\theta) < \frac{\bar{s}}{\alpha}$$
$$p - C_1[q(\theta), \theta] < 0 \quad \text{for } q(\theta) = \frac{\bar{s}}{\alpha}$$
$$p - C_1[q(\theta), \theta] = 0 \quad \text{for } q(\theta) > \frac{\bar{s}}{\alpha}.$$

We need to verify that these conditions determine a $q(\theta)$ that is identical to the one defined by equations (9)–(11) after substituting $\lambda = 0$ and $v'(q) = \alpha$. Upon making these substitutions, expressions (9) and (10) are identical to the above expressions for $q(\theta) \neq \bar{s}/\alpha$. Thus, we need only show that for $\lambda = 0$ and $v'(q) = \alpha$, that $\bar{q} = \bar{s}/\alpha$. But recall that we chose $\bar{s} = \alpha\bar{q}$, so that this last equality is satisfied by construction.

---

[12] $v_1(q, \theta)$ is given by $v'(q)$ for $\theta \geq \hat{\theta}$ and otherwise.

[13] Partially differentiating the expressions in equations (A.17) and (A.18) with respect to θ yields $-C_{12}(q(\theta),\theta) - \lambda/(1+\lambda)\, C_{122}(q(\theta),\theta) < 0$. Thus, at $q(\theta) = \bar{q}$, each expression evaluates to zero for only a single θ.