Designing a private industry
Government auctions with endogenous market structure

James D. Dana, Jr.
Department of Economics, Dartmouth College, Hanover, NH 03755, USA

Kathryn E. Spier*
Department of Economics, Harvard University, Cambridge, MA 02138, USA

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This paper considers government mechanisms for auctioning production rights in which both the winners and the market structure, duopoly (dual-sourcing), monopoly (sole-sourcing), or government-owned production, are a function of the bids. In designing the optimal mechanism, the government considers the tradeoffs among consumer surplus, producer surplus, and revenue. Under incomplete information, duopoly is implemented less frequently, and government production more frequently, than under complete information. When bidders are symmetric, the optimal mechanism can be implemented as a modified second-price auction. Applications to privatization, deregulation, and defense procurement are discussed.

1. Introduction

Market structure is an integral and important consideration in the design of public policy programs such as the privatization and deregulation of industry, the distribution of government franchises, and the liberalization of trade. However, from a planner’s perspective, the choice of an optimal market structure is complicated by the fact that the government may have incomplete information about the value that a firm places on a production right. Furthermore, that value may depend on the number of other firms awarded these rights. This paper demonstrates that the optimal government mechanism for auctioning production rights is one in which the market

*Correspondence to: Kathryn E. Spier, Department of Economics, Littauer Center, Harvard University, Cambridge, MA 02138, USA.

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structure is endogenous, that is, the number of participants awarded production rights may depend on their bids.

A central characteristic of our model is that a firm's private information influences both its own valuation of the production rights and the socially optimal market structure. The planner cannot know the optimal market structure ex ante, although she can condition the market-structure decision on information acquired through the auction. However, even in the best mechanism, the market-structure decision will not be optimal when the government has incomplete information. In particular, the dual-source outcome occurs less frequently and government production occurs more frequently under incomplete information than under complete information. Increasing the likelihood of the monopoly outcome has a positive effect on firms' incentives to reveal their private information, while increasing the likelihood of government production, like a minimum bid in a standard auction, discourages low cost firms from attempting to emulate high cost firms. Furthermore, we show that the optimal mechanism can be implemented by a modified second-price auction.

This paper is one of the first to consider optimal mechanisms with an endogenous market structure. Anton and Yao (1989, 1992) analyze splitaward auctions featuring an endogenous market structure, but do not consider optimal auctions. Riordan and McGuire (1991) examine the optimal mechanism with an endogenous market structure for a particular example in which firms produce differentiated products. The mechanism design techniques used here are similar to those used in the standard auction design problem considered by Myerson (1981) and Riley and Samuelson (1981) and to the multi-unit auction design problem considered by Maskin and Riley (1989). But since the market structure is endogenous to the auction, our problem is distinct from these earlier models. Our work also can be interpreted as a multi-unit auction with endogenous valuations: the bidders' valuations of production rights depend on the distribution of production rights to other firms. In this sense, our model is related to that of Krishna (1990) who considers sequential auctions with endogenous valuations under complete information.

In the next section we outline and solve the mechanism-design problem faced by the social planner when firms have private information. In section 3 we present two special cases. The first is an example in which the two firms privately observe their fixed costs of production and are Cournot competitors in the dual-source market structure. The second case is similar to the first, except that it is the firms' marginal costs that are privately observed. In section 4 we show that when bidders are symmetric the optimal mechanism can be implemented using a modified second-price auction. Section 5 discusses applications of our theoretical results including privatization and government franchising. A conclusion follows.
2. The model

We assume that the social planner's objective is to maximize social welfare given by

\[ W = E \left[ \sum \pi_i + S + (\lambda - 1) \sum t_i \right], \]

where \( t_i \) denotes the transfer payment from bidder \( i \) to the government, \( S \) denotes the consumer surplus, \( \pi_i - t_i \) denotes the net profit of firm \( i \), and \( \lambda \) is the shadow cost of public funds. We make the important assumption that \( \lambda > 1 \). This corresponds to the assumption that the government values revenue more than it values consumer and producer surplus. If the role of the government is to raise revenue in order to make public expenditures, then some revenue will undoubtedly be generated through distortionary taxes. At the optimum, \( \lambda \) represents the marginal welfare cost of raising an additional dollar of revenue from alternative sources, or, equivalently, the marginal welfare gain from having an additional dollar to spend on public goods.

We assume that there are only two bidders (although this assumption can easily be relaxed without affecting our results). Each bidder privately observes a parameter of its own cost function, denoted \( \theta_i, i = 1, 2 \). \( \theta_1 \) and \( \theta_2 \) are independently distributed on \([\theta, \bar{\theta}]\) with continuously differentiable probability density functions \( f_1(\theta_1) \) and \( f_2(\theta_2) \), respectively. Let \( \pi_{m,i}(\theta_1, \theta_2) \) denote firm \( i \)'s profit if it is awarded a sole production right (monopoly/single-source) and \( \pi_{a,i}(\theta_1, \theta_2) \) denote firm \( i \)'s profit if both firms are awarded production rights (duopoly/dual-source). These functions are taken as exogenous to the mechanism. \( \pi_{a,j}(\theta_1, \theta_2) \) can be thought of as the reduced-form profit function derived from the appropriately defined continuation game. We assume that \( \pi_{m,i}(\theta_1, \theta_2) \) is independent of \( \theta_{-i} \). Also, we assume that a firm earns zero profits if it is not awarded a production right. Hereafter, we will frequently use \( \Theta \) to denote \((\theta_1, \theta_2)\).

**Assumption 1.** The profit functions, \( \pi_{m,i}(\Theta) \) and \( \pi_{a,i}(\Theta) \), are twice continuously differentiable, and their derivatives satisfy \( \pi_{m,i}^j < 0 \), \( \pi_{a,i}^j < 0 \), \( \pi_{a,i}^{0,i} \geq 0 \), \( \pi_{a,j}^{0,j} + \pi_{a,j}^{0,j} \leq 0 \), and \( \pi_{a,i}^{j} \leq \pi_{a,i}^{j} \), where a subscript \( j \) denotes the partial derivative with respect to \( \theta_j \).

We assume that consumer surplus depends on the market structure and the firms' private information, and is denoted by \( S_{m,i}(\Theta) \) when firm \( i \) is a monopolist, and by \( S_{a}(\Theta) \) when both firms produce. \( S_{m,i}(\Theta) \) is assumed to be independent of \( \theta_{-i} \).

\(^1\)If \( \lambda = 1 \), then the government can implement the first-best market structure using distortionless transfers even under incomplete information.
Assumption 2. \( S^m_i(\Theta) \) and \( S^d(\Theta) \) are twice continuously differentiable, and satisfy \( S^m_i \leq 0 \), \( S^d \leq 0 \), \( S^d_1 \leq 0 \), and \( S^m_i \leq S^d_i \).

If \( \theta_i \) is defined to be the firm's marginal cost or the firm's fixed cost and consumer surplus is derived from demand functions satisfying standard assumptions, then Assumptions 1 and 2 are satisfied for a variety of duopoly models, including Cournot competition, Bertrand competition, and price competition with differentiated products.

We also assume that the government has the option to produce itself and has its own cost (or profit) parameter, \( \theta_g \), which is assumed to be common knowledge.\(^2\) Let \( S^g(\theta_g) \) denote the consumer surplus and \( \pi^g(\theta_g) \) denote the "profit" when the government produces.

2.1. Complete information

We suppose that the government can choose any market structure and transfer payments but is not able to regulate output. When the planner can observe \( \theta_1 \) and \( \theta_2 \) directly, she can extract all of the firms' profits through the transfer payments. Hence, \( t^i = \pi^m_i(\Theta) \) when firm \( i \) is awarded a monopoly (or sole-source) production right, and \( t^i = \pi^d_i(\Theta) \) when dual-source production rights are awarded. Proposition 1 describes the optimal market structure under complete information, where the social welfare for each market structure is defined as follows:

- **Sole-source (firm \( i \)):** \[ W^i(\Theta) = S^m_i(\Theta) + \lambda \pi^m_i(\Theta); \]
- **Dual-source:** \[ W^d(\Theta) = S^d(\Theta) + \lambda [\pi^d_1(\Theta) + \pi^d_2(\Theta)]; \]
- **Government production:** \[ W^g(\Theta) = S^g(\theta_g) + \lambda \pi^g(\theta_g). \]

**Proposition 1.** The optimal (complete information) market structure is given by \( i \in \{1, 2, d, g\} \) if and only if \( W^i(\Theta) = \max \{W^1, W^2, W^d, W^g\} \).

Under Assumptions 1 and 2, the derivatives of the welfare functions satisfy \( W^1_1 < 0, W^2_1 < 0, W^d_1 < 0, W^g_1 < 0 \). Furthermore, \( W^1_1 < W^d_1 < 0 \), which implies that an increase in \( \theta_1 \) influences the optimal market structure by making monopoly relatively less attractive.

2.2. Incomplete information

We now consider the case where firms have private information about

\(^2\)The assumption that \( \theta_g \) is common knowledge could be relaxed, yielding a informed-principal problem.
their costs of production. By employing the Revelation Principle [see, for example, Myerson (1981)] we can restrict attention to truth-telling equilibria of direct-revelation mechanisms. Hence, the government's mechanism, \(\{t, p\}\), specifies transfers, \(t'(\hat{\theta}_1, \hat{\theta}_2)\), \(i = 1, 2\), and the probability of implementing each market structure, \(p(\hat{\theta}_1, \hat{\theta}_2)\), \(i = 1, 2, d, g\), where \(\hat{\theta}_1\) and \(\hat{\theta}_2\) are the announcements made by the firms, and \(p = (p^1, p^2, p^d, p^g) \in \Delta^4\). Each firm has prior beliefs about the other firm's cost parameter given by \(f(\theta)\). Firm 1's expected profit (and, by analogy, firm 2's profit) as a function of its reported cost and the true costs of both firms is given by

\[
\Pi^1(\hat{\theta}_1 | \Theta) = E_{\theta_2}[p^1(\hat{\theta}_1, \theta_2)\pi^m.1(\Theta) + p^d(\hat{\theta}_1, \theta_2)\pi^{d.1}(\Theta) - t'(\hat{\theta}_1, \theta_2)]. \tag{2}
\]

The planner's optimization is given by

\[
\max_{(t, p)} E_{\theta}[\lambda(\hat{\theta}_1 - 1)(t^1(\Theta) + t^2(\Theta)) + p^1(\Theta)[\pi^m.1(\Theta) + S^{m.1}(\Theta)]
+ p^d(\Theta)[\pi^{d.1}(\Theta) + S^{d.1}(\Theta)] + p^g(\Theta)[\pi^g(\theta_g) + S^g(\theta_g)]] \tag{P}
\]

s.t. \((p^1, p^2, p^d, p^g) \in \Delta^4;\)

\[
\Pi^1(\theta_i | \theta_j) \geq \Pi^1(\hat{\theta}_i | \theta_j), \quad \forall \theta_i, \hat{\theta}_i \in [\theta, \bar{\theta}], \quad i = 1, 2; \tag{IC}
\]

\[
\Pi^1(\theta_i | \theta_j) \geq 0, \quad \forall \theta_i, \theta_j \in [\theta, \bar{\theta}], \quad i = 1, 2, \tag{IR}
\]

where (IC) and (IR) are the incentive-compatibility and interim individual-rationality constraints, respectively. The following technical assumption simplifies the analysis [see Myerson (1981)].

**Assumption 3.** The mechanism, \(\{t, p\}\), is piecewise continuously differentiable.

We define 'virtual welfare' to be the complete information welfare function, \(W^i\), less the cost of inducing firms to reveal their private information:

\[
\tilde{W}^i(\Theta) = S^{m.1}(\Theta) + \lambda\pi^{m.1}(\Theta) + (\lambda - 1)\pi^{m.1}(\Theta) \frac{F(\theta_i)}{f(\theta_i)}. \tag{3}
\]
\[ \hat{W}^q(\Theta) = S^q(\Theta) + \lambda[\pi^{a-1}(\Theta) + \pi^{a-2}(\Theta)] + (\lambda - 1) \left[ \lambda_1^{a-1}(\Theta) \frac{F^1(\theta_1)}{f^1(\theta_1)} + \lambda_2^{a-2}(\Theta) \frac{F^2(\theta_2)}{f^2(\theta_2)} \right] \]

\[ \hat{W}^q(\Theta) = S^q(\theta_2) + \lambda \pi^q(\theta_2). \]

The following assumption guarantees that the 'virtual welfare' functions satisfy \( \hat{W}_1^1 < 0, \hat{W}_2^1 < 0, \hat{W}_1^2 < 0, \hat{W}_2^2 < 0, \hat{W}_1^4 < \hat{W}_2^4 \), and \( \hat{W}_2^4 < \hat{W}_2^4 \).

**Assumption 4.** The profit and distribution functions satisfy \( dA^{m,i}/d\theta_i < dA^{4,i}/d\theta_i < 0 \), \( i = 1, 2 \), where

\[ A^{m,i}(\Theta) = \pi^{m,i}(\Theta) + \pi^{m,i}(\Theta) \frac{F^i(\theta_i)}{f^i(\theta_i)} \]

and

\[ A^4(\Theta) = \pi^{a-1}(\Theta) + \pi^{a-2}(\Theta) \frac{F^4(\theta_4)}{f^4(\theta_4)}. \]

Assumption 4 is similar to assumptions on the cost function made in McAfee and McMillan (1987) and Lewis and Sappington (1989). It is likely to hold whenever \( F^i(\theta_i)/f^i(\theta_i) \) is increasing in \( \theta_i \) (the monotone-hazard-rate condition), and may hold even when the monotone-hazard-rate condition is violated.

The following proposition defines the optimal mechanism under incomplete information.

**Proposition 2.** Under Assumptions 1 through 4, the government's optimal mechanism is characterized by \( p'(\Theta) = 1 \) if and only if \( \hat{W}^q(\Theta) = \max \{ \hat{W}_1^1, \hat{W}_2^1, \hat{W}_1^4, \hat{W}_2^4 \} \). The expected transfer payments are given by

\[ E_{\theta_1} t^1(\Theta) = E_{\theta_1}[p^1(\Theta)\pi^{m-1}(\Theta) + p^1(\Theta)\pi^{a-1}(\Theta)] \]

\[ - \int_{\theta_1} E_{\theta_2}[p^1(\theta_1, \theta_2)\pi^{m-1}(\theta_1, \theta_2) + p^1(\theta_1, \theta_2)\pi^{a-1}(\theta_1, \theta_2)] d\theta_2. \]

\[ E_{\theta_2} t^2(\Theta) = E_{\theta_2}[p^2(\Theta)\pi^{m-1}(\Theta) + p^2(\Theta)\pi^{a-1}(\Theta)] \]

\[ - \int_{\theta_2} E_{\theta_1}[p^2(\theta_1, \theta_2)\pi^{m-1}(\theta_1, \theta_2) + p^2(\theta_1, \theta_2)\pi^{a-1}(\theta_1, \theta_2)] d\theta_1. \]
Proof. See the appendix.

Proposition 2 implies that the social planner chooses the market structure that maximizes virtual welfare. In Proposition 3, we compare the complete-information mechanism (Proposition 1) with the second-best incomplete-information mechanism (Proposition 2).

Definition. $\Omega^1$ and $\Omega^4$ are subsets of $[\underline{\theta}, \bar{\theta}] \times [\underline{\theta}, \bar{\theta}]$ such that $\Theta \in \Omega^1$ if and only if $W(\Theta)$ maximizes $\{W^1, W^2, W^4, W^8\}$ and $\Theta \in \Omega^4$ if and only if $\tilde{W}(\Theta)$ maximizes $\{\tilde{W}^1, \tilde{W}^2, \tilde{W}^4, \tilde{W}^8\}$, for $i = 1, 2, d, g$.

Proposition 3. As compared with the most efficient (complete-information) outcome, the optimal mechanism under incomplete information features (i) a greater likelihood of government production (i.e. $\tilde{\Omega}^g \supseteq \Omega^g$), and (ii) a smaller likelihood of duopoly (i.e. $\tilde{\Omega}^d \subseteq \Omega^d$).

Proof. If $W^g$ maximizes $\{W^1, W^2, W^4, W^8\}$, then $\tilde{W}^g$ maximizes $\{\tilde{W}^1, \tilde{W}^2, \tilde{W}^4, \tilde{W}^8\}$, since $\tilde{W}^g = W^g$, $\tilde{W}^1 \leq W^1$, $\tilde{W}^2 \leq W^2$, and $\tilde{W}^4 \leq W^4$. Therefore $\tilde{\Omega}^g \supseteq \Omega^g$. Similarly, if $\tilde{W}^d$ maximizes $\{\tilde{W}^1, \tilde{W}^2, \tilde{W}^4, \tilde{W}^8\}$, then $W^d$ maximizes $\{W^1, W^2, W^4, W^8\}$, which implies that $\tilde{\Omega}^d \subseteq \Omega^d$. \qed

The government can extract more of the surplus when the two bidders are vying for monopoly production rights than it can when the firms are vying for duopoly rights. Also, government production occurs more frequently under incomplete information because, like a minimum bid in a conventional auction, the government can raise the amount that participants are willing to bid by increasing the cutoff between government production and monopoly production.

3. Special cases

Case I: Fixed costs

This section examines a particular example in which firms have private information about their fixed costs of production, $\theta_i$, but have a common marginal cost, $c$. So each firm's cost function is $C(q, \theta_i) = \theta_i + cq$. The government can choose between awarding an unregulated monopoly (sole-source), awarding an imperfectly competitive duopoly (dual-source), and retaining the production rights. We assume a homogeneous good and Cournot competition. Demand is assumed linear, and, without loss of generality, we assume that the inverse demand is given by $p(q) = 1 - q$. The government's costs of production are given by $C(q, \theta_q) = \theta_q + cq$ and government output is given by $q^* = \arg\max_q \lambda(p(q)q - C(q, \theta_q)) + S(q)$. We assume
that the government's optimal output, $q^*$, is greater than the total output under duopoly.

Table 1 gives the complete-information social-welfare and the incomplete-information virtual-welfare functions for each market structure. It is easily established that Assumptions 1 and 2 hold for this case. Moreover, if $\frac{F'(\theta_1)}{f'(\theta_4)}$ is increasing in $\theta_3$, then Assumption 4 also holds.

The optimal mechanisms are depicted in fig. 1. With complete information, the monopoly regions are separated by the 45° line, because the government prefers to award a monopoly production right to the most efficient firm, and the duopoly region is rectangular because the benefit of dual-sourcing (the increase in consumer surplus) is independent of fixed costs. As established in Proposition 3, the second-best mechanism under incomplete information exhibits a greater likelihood of government production and a smaller likelihood of duopoly production. Also, under incomplete information the regions are not symmetric except in the special case in which $f^1 = f^2$.

Case 2: Marginal costs

Suppose now that firms have private information about their marginal costs of production, denoted $\theta_i$, and have a common fixed cost, $V$, so that each firm's cost function is $C(q, \theta_i) = V + \theta_i q$. Also, assume for simplicity that $\theta_1$ and $\theta_2$ are known to both firms in the continuation game (note that this assumption was irrelevant to the firms' payoffs in case 1). In all other respects this case is the same as case 1. We make two regularity assumptions which guarantee that firms will want to produce: (i) $\theta_i < (1 + \theta_{-i})/2$, and (ii) the monopoly profit is positive for all levels of marginal cost.

The social-welfare and virtual-welfare functions are given in table 2. The table reveals that Assumptions 1 and 2 hold for this case as well. In addition,
we assume that the distributions and the profit functions also satisfy Assumption 4. The decision rules are depicted in fig. 2. Again, the incomplete-information regions are not necessarily symmetric because we allow for the possibility that $f^1 \neq f^2$.

4. Optimality of modified second-price auctions

When the bidders and the profit functions are symmetric, i.e. $f^1(\theta) = f^2(\theta)$, then the optimal mechanism can be easily implemented as a 'modified' second-price auction. In a standard second-price auction, the good is

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3The monotone-hazard-rate condition is neither necessary nor sufficient for Assumption 4 to hold in this case.

4The asymmetric case is more complicated. For example, with asymmetric bidders the optimal mechanism does not necessarily award the monopoly production right to the most efficient firm.
Table 2
Case 2: Marginal costs. Welfare and virtual-welfare functions.

<table>
<thead>
<tr>
<th>Complete information</th>
<th>Incomplete information</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W^*(\theta) = \frac{(1-\theta_1)^2}{8} + \lambda \left(\frac{(1-\theta_2)^2}{4} - \nu\right)$</td>
<td>$\bar{W}^<em>(\theta) = W^</em>(\theta) - (\lambda - 1) \frac{4(1-\theta_1)}{2} \frac{F'(\theta_1)}{f'(\theta_1)}$</td>
</tr>
<tr>
<td>$W^\eta(\theta) = \frac{(1-\theta_1 - \theta_2)^2}{18}$</td>
<td>$\bar{W}^\eta(\theta) = W^\eta(\theta)$</td>
</tr>
<tr>
<td>$+ \lambda \left(\frac{(1-2\theta_1 + \theta_2)^2}{9} + \frac{(1+\theta_1 - 2\theta_2)^2}{9} - 2\nu\right)$</td>
<td>$-(\lambda - 1) \frac{4(1-2\theta_1 + \theta_2)}{9} \frac{F'(\theta_1)}{f'(\theta_1)} + \frac{4(1-2\theta_1 + \theta_2)}{9} \frac{F'(\theta_2)}{f'(\theta_2)}$</td>
</tr>
<tr>
<td>$W^\eta(\theta) = \lambda \left(\frac{(1-\theta_1)^2}{2(\lambda - 1)}\right)^\lambda$</td>
<td>$\bar{W}^\eta(\theta) = W^\eta(\theta)$</td>
</tr>
<tr>
<td>$+ \lambda \left((\lambda - 1)\lambda \left(\frac{(1-\theta_1)^2}{2(\lambda - 1)}\right) - \nu\right)$</td>
<td>$\bar{W}^\eta(\theta) = W^\eta(\theta)$</td>
</tr>
</tbody>
</table>

awarded to the highest bidder at a price equal to the second highest bid, and it is a dominant strategy for each bidder to bid his or her true valuation. In the modified second-price auction presented here the same principle applies, but the auction mechanism departs in two ways from the traditional second-price auction. This result is described in Proposition 4, where $v^\#$ is defined by $\bar{W}^1(v^\#(\cdot, \cdot)) = W^\eta(\xi^\#(\cdot, \cdot))$ and $v^\alpha(\theta_1)$ is defined by $\bar{W}^2(\cdot, v^\alpha(\theta_1)) = W^\eta(\xi^\#(\cdot, \theta_1))$.

**Proposition 4.** When bidders are symmetric, the optimal mechanism can be implemented as a second-price auction with two modifications:

1. The auction specifies a minimum bid $b^\# = \pi^{m-1}(v^\#, \cdot) = \pi^{m-2}(\cdot, v^\#)$ such that if both bids are below this minimum the government retains control, and

2. The auction specifies a duopoly cutoff function for firm 1, $\pi^{m-1}(\nu^\alpha((\pi^{m-2})^{-1}(b_1), \cdot))$, and a duopoly cutoff function for firm 2, $\pi^{m-2}(\cdot, v^\alpha((\pi^{m-1})^{-1}(b_1)))$, such that if both bids exceed the cutoffs then a duopoly is awarded.

If both bids exceed the minimum bid and at least one does not exceed the duopoly cutoff, then a monopoly (sole-source) production right is awarded to the highest bidder at the price (transfer) bid by the second highest bidder.

It is clear that the modified second-price auction given in Proposition 4 implements the same decision rules as the optimal mechanism, and it can be
verified that it implements the same expected transfer payments as those given in Proposition 2. It can also be verified that the price paid by bidder \( i \) is always independent of \( \theta_i \), hence bidder \( i \) will bid its monopoly valuation.\(^5\)

This indirect mechanism is easily illustrated for the case in which firms have private information about their fixed costs of production (case 1). In this case, the optimal auction particularly simple because \( v^i(\theta_i) \) is constant. The government simply chooses a cutoff, \( b^d \), and a price, \( t^d \), associated with the cutoff, and a minimum bid, \( b^s \). If both firms bid above \( b^s \), then they both pay \( t^s \), and a duopoly is awarded. If at least one bid is below \( b^d \), and one is above \( b^s \), then a monopoly is awarded to the highest bidder at the second highest price or \( b^s \), whichever is greater. These transfer payments and

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\(^5\)Using Proposition 4, it is possible to establish that there exists an optimal mechanism that satisfies the stronger ex post individual-rationality constraints. Of course, the set of transfer functions that would implement the optimal decision rules given ex post individual-rationality constraints is smaller.
decision rules are shown in fig. 3, where $v^g$ and $v^d$ are the types corresponding to $b^g$ and $b^d$.

5. Applications

5.1. Privatization and deregulation

Much of the theoretical research on privatization has emphasized the benefits of private versus public ownership. For example, Sappington and Stiglitz (1987), Shapiro and Willig (1989), Laffont and Tirole (1990), and Pint (1991) each consider theories based on a comparison of the incentives and the allocation of rights of control under the two regimes [see Vickers and

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6Empirical research on this question, and in particular on the relative efficiency of privately versus publicly-owned enterprises, has been largely mixed [see Millward (1982) for a survey of the relevant literature]; however, the evidence from recent privatization programs suggests that privatized firms are able to lower costs and increase efficiency. Still, some have argued that the observed benefits of privatization are primarily attributable to increased competition (i.e. deregulation) and not to changes in ownership [see Millward (1982) and Yarrow (1986)].
Yarrow (1988) for a more general survey]. Instead, we examine government mechanisms for privatization, and in particular mechanisms that exploit the trade-off between revenue and market structure-objectives in the presence of asymmetric information.

We have found ample evidence that scholars and governments are aware of the importance of this trade-off. In Britain, the privatization of electric power resulted in 12 regionally divided distribution companies, a single national transmission company (cooperatively owned by the distribution companies), and three large generation companies (one of which controls all of the nuclear power plants and remains state-owned). Although the vertical disintegration of generation, transmission, and distribution is certainly the most dramatic change in the organization of the industry, increased competition in the wholesale generation of electric power was one of the main objectives of privatization [Vickers and Yarrow (1991)].

Competition is also being emphasized as a policy objective in plans for the privatization of British Rail. Moreover, this may be a good example of an industry for which both the assets' value and the optimal market structure are unknown; hence, it represents a potential opportunity to employ an auction mechanism with an endogenous market structure. Several market structures have been considered for British Rail. The first proposal would privatize British Rail as a single, national firm. The second proposal would divide the market regionally, as was recently done in the privatization of Japan National Railways (this is also the historical market structure in Britain prior to nationalization). The third proposal would divide British Rail along basic lines of business (i.e. freight, passenger, etc.). The fourth and most complicated proposal would vertically divide railroads, creating a nationally-owned track authority which would own and manage the permanent track and a competitive market for 'operating services'. Franchises for the right to provide operating services would be awarded in competitive auctions, and in some cases franchises for the same routes would be awarded to more than one firm. Of course, it is precisely these cases which are likely

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7Governments also give up revenue when they pursue other objectives such as more stringent regulations, wider share ownership, and increased competition through the relaxation of entry barriers.

8The decision to create only two private generation firms was made when the government still planned to privatize nuclear power. Estrin et al. (1990) have argued that not enough competition was introduced into this industry, and the post-privatization price evidence appears to support this position (The Economist, 12 October 1991, p. 62).

9The privatization of British Coal may be another example with these features. Recent debate has focused on whether to privatize coal as one or two firms. Although there do not appear to be large increasing returns to scale in the traditional sense, transactions costs may represent an obstacle to competition in the coal industry since two large firms (the two recently privatized electric generating companies) are the main buyers of coal (The Economist, 19 September 1992, p. 70).

10See Lapsley and Wright (1990) and references therein.
to benefit from the auction mechanisms that we have analyzed. Because of historically low profits, many cases of competitive franchising would necessarily include government subsidies; however, our results still apply when the bids are negative.\footnote{See The Economist, 11 January 1992, p. 14, and 11 July 1992, p. 57. The most recent plan for the privatization of British Rail is a combination of regional division and competitive franchising of operating services, and is likely to proceed in a piecemeal rather than wholesale fashion.}

In Latin America and the rest of the world, privatization programs have placed some, though not as much, emphasis on competition. Mexico has divided many nationally owned companies prior to auctioning them (the national steel company was broken up into four steel companies which were sold to different buyers); however, in most cases the bidders are allowed (perhaps encouraged) to bid on each of the parts (together or separately) and the government has generally chosen market structures that maximize revenue. In Argentina the apparent emphasis on competition is greater, a position which is consistent with the free-market and free-entry deregulation policies advocated by the current government.\footnote{See World Press Review, August 1992, p. 43.}

The privatization of Empresa Nacionale de Telecomunicaciones (ENTel), which was divided geographically into two parts (ENTel North and ENTel South), is particularly interesting because it offers ex post evidence that Argentina’s government perceived a direct trade-off between revenue and market structure. In a simultaneous, sealed-bid auction for the two divisions, Telefónica de España (in a consortium with Citicorp) made the highest bid for both parts. The Argentinean government had previously stipulated that it would not award both companies to a single bidder (although the specific provisions may not have been clear ex ante), and Telefónica de España was asked to choose between the northern and southern divisions.\footnote{Telefónica de España chose ENTel South, and after protracted negotiations, ENTel North was awarded to the third highest bidder, a consortium of buyers including STET S.p.A. of Italy, France Telecom, and J.P. Morgan. The second highest bidder, Bell Atlantic and Manufacturers Hanover Corporation, failed to arrange financing necessary to meet their bid. See the New York Times, 26 June 1990, and 6 October 1990, and La Prensa, 26 June 1990.} However, despite the rhetoric about competition, it is not entirely clear what the government’s motives were for preferring this market structure. The decision was clearly a political one, and may, for example, have been an attempt to generate greater revenue or greater political support for the privatization process.

In several cases, such as the privatization of ENTel, Japan National Railways, and the proposed privatization of British Rail, governments have made ex ante decisions to divide industries into separate regional companies. Although regionally separate firms do not compete head-to-head, these privatization plans were nevertheless accompanied by rhetoric about increas-
ing competition and competitiveness. One sensible reason for this may be that a regional division of the industry can foster indirect competition: first, as in the U.S. break-up of AT&T, some benefits may arise as the regional companies begin to innovate and compete in new product areas (much of the rhetoric is about increasing investment and innovation); second, regional division may limit monopsony power, especially in labor and capital markets; and finally, regional division may facilitate explicit or implicit forms of yardstick competition when the firms are subject to ex post regulation or when they compete in the market place for private capital [see a previous version of our paper, Dana and Spier (1991)].

5.2. Defense procurement

In the United States, the split-award auction (a particular type of auction with an endogenous market structure) is sometimes used when there is uncertainty about whether one or two suppliers will produce more efficiently. This mechanism, in which each bidder submits a monopoly (sole-source) and a duopoly (dual-source) bid and the government chooses between the best sole-source bid and the sum of the two dual-source bids, has been analyzed by Anton and Yao (1989, 1992). Our work suggests that, in general, split-award auctions are not optimal and that governments can increase welfare by using more sophisticated mechanisms. However, our model is quite different from Anton and Yao's (and from other previous theoretical work on defense procurement) because we do not allow the government to contract on output (or price). Nevertheless, we believe that our model could be easily extended to include this feature, and would yield similar results.

5.3. Cable television and cellular telecommunications

Most cable television companies in the United States were originally regulated monopoly franchises, although in some areas cable began without franchises (with free entry) and in other cases two or more directly

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14 Several other papers have examined the role of ex ante competition (called second-sourcing as opposed to dual-sourcing) in designing more efficient mechanisms [see, for example, Anton and Yao (1987), Stoile (1993), and the references therein].

15 However, collusion and coordination problems may restrict the set of feasible mechanisms [see Anton and Yao (1992)].

16 A recent paper by Riordan and McGuire (1991) examines a related model in which each firm's cost is influenced by an ex post moral hazard decision and the regulator can specify both the market structure and the cost at which the firms must produce (the cost is observable). As in our paper, they show that incomplete information introduces a distortion in the optimal market structure. However, they find that when the social cost of profit is sufficiently large (and so effort distortions are more important), the market structure bias is reversed.
competing cable franchises were awarded. However, most cable television rates were deregulated by federal law in 1984.\textsuperscript{17} Today there are as many as three dozen cities in which cable companies have overlapping areas of competition and this number appears to be increasing since deregulation [see Hazlett (1986, 1990)].

Although the evidence clearly demonstrates that head-to-head competition results in statistically significantly lower rates than the national average, competition has generally been discouraged by local governments. The problem is that head-to-head competition, often referred to as overbuilding, increases costs from 7 percent to 14 percent because of redundancies in the cable network.\textsuperscript{18} Although still subject to debate, Hazlett (1990) argues that the success of competition suggests that in the absence of rate regulation, consumers would be better off if local or federal governments encouraged competitive entry.

Although our analysis would have to be modified to accommodate an incumbent firm, we believe that local governments interested in promoting competition should consider an endogenous market structure in the mechanisms which they use to award and renew franchises.\textsuperscript{19} Of course, in many markets cable television companies currently face competition from direct-broadcast television and private satellite reception, in addition to the prospect of competition from telephone companies and microwave signals, all of which may alleviate the need for direct competition between cable providers.

The cellular-telephone industry has also been developed using government franchising. Most urban areas are now served by two cellular-telephone companies because the Federal Communications Commission decided to allocate band widths for only two firms in each geographic market [see Calhoun (1988)]. An alternative, possibly superior, mechanism would have endogenized the market structure in the auction of band widths. In fact, the government did not attempt to generate any revenues from these franchises and did not vary from their policy of implementing a duopolistic market structure.

\textsuperscript{17}In April 1985, the FCC ruled that the Cable Communications Policy Act of 1984, which deregulated cable wherever 'effective competition' existed, applied to 97 percent of all US cable franchises.

\textsuperscript{18}See Hazlett (1990) on the costs of overbuilding. The 7 percent estimate is derived by Hazlett from Noam (1985) and the 14 percent estimate is from Owen and Greenhalgh (1986). Hazlett (1986) estimates that non-monopoly franchises offer rates that are $1.82 per month per subscriber lower than monopoly franchises, and Hazlett (1990) offers specific case evidence that the rate decreases are even larger in areas where there is overbuilding.

\textsuperscript{19}Our analysis would also have to be modified since local governments do not generally use cable franchising to generate revenue. However, as in the case of railroad privatization, if the government owned the cable and franchised only the right to transmit over the cable, then our model would apply directly.
6. Conclusion

This paper presents a normative analysis of government auctions of production rights. We characterize the optimal auction when social welfare might be enhanced by increased competition, and demonstrate that the optimal mechanism is one in which the market structure is endogenous. This is because, generally speaking, a firm’s private valuation of a production right is likely to be correlated with the benefits to increased competition. Incomplete information introduces a bias towards less competition relative to complete information, although in many cases the optimal mechanism will yield more competition relative to mechanisms in which the market structure decision is not endogenous.

An important area for future research is the case of correlated or common valuations. If the firms received private signals about a common cost, then the analysis would be quite different, although the government would face the same tradeoff between increased competition and increased revenue. McAfee et al. (1989) have shown that when buyers have common valuations a mechanism exists which extracts all of the buyers’ surplus. However, while their mechanism is optimal ex post, it may not be optimal from an ex ante perspective. In particular, firms may not have an incentive to participate if they cannot capture ex post rents associated with ex ante costly information gathering.

Appendix

The proof of Proposition 2 follows two lemmas.

Lemma 1. The government’s mechanism satisfies (IC) and (IIR) if and only if

(i) \( \Pi^1(\theta_1 \mid \theta_1) = \Pi^1(\bar{\theta} \mid \bar{\theta}) \)

\[ - \int_{\bar{\theta}_1} p^1(\bar{\theta}_1, \theta_2) \pi_{1 \to 1}(\bar{\theta}_1, \theta_2) + p^2(\bar{\theta}_1, \theta_2) \pi_{1 \to 2}(\bar{\theta}_1, \theta_2) \, d\bar{\theta}_1; \]

(ii) \( \Pi^2(\theta_2 \mid \theta_2) = \Pi^2(\bar{\theta} \mid \bar{\theta}) \)

\[ - \int_{\bar{\theta}_2} p^2(\bar{\theta}_1, \bar{\theta}_2) \pi_{2 \to 1}(\bar{\theta}_1, \bar{\theta}_2) + p^2(\bar{\theta}_1, \bar{\theta}_2) \pi_{2 \to 2}(\bar{\theta}_1, \bar{\theta}_2) \, d\bar{\theta}_2; \]

(iii) \( - E_{\theta_1} [p^1(\bar{\theta}_1, \theta_2) \pi_{1 \to 1}(\theta) + p^2(\bar{\theta}_1, \theta_2) \pi_{1 \to 2}(\theta)] \) is non-increasing in \( \bar{\theta}_1 \).

Crémer and McLean (1985) have shown that the seller can also extract almost all of the surplus in the correlated-values case; however, this result relies on the unrealistic assumption that the seller can impose unbounded penalties on the bidders.
(iv) \(-E_{\theta_i}[p^2(\theta_1, \theta_2)\pi_{\theta_1}^{\theta_2:2}(\Theta) + p^3(\theta_1, \theta_2)\pi_{\theta_2}^{\theta_2:2}(\Theta)]\) is non-increasing in \(\theta_2\);

(v) \(\Pi^1(\theta | \theta) \geq 0\);

(vi) \(\Pi^2(\theta | \theta) \geq 0\).

**Proof.** Using Assumption 3 it is straightforward to show that \(\Pi_i(\theta_i | \theta_1)\) and \(\Pi_i(\theta_i | \theta_2)\) are almost everywhere continuosly differentiable [see Guesnerie and Laffont (1984) for a similar proof]. It follows that incentive compatibility holds if and only if

\[
\frac{\partial \Pi^1(\theta_i | \theta_1)}{\partial \theta_i} \bigg|_{\theta_i = \theta_i} = 0
\]  

(A.1)

and

\[
\frac{\partial^2 \Pi^1(\theta_i | \theta_1)}{(\partial \theta_i)^2} \bigg|_{\theta_i = \theta_i} \leq 0.
\]  

(A.2)

Using the envelope theorem and the definition of the profit function, (6), (A.1) becomes

\[
\frac{d \Pi^1(\theta_i | \theta_1)}{d \theta_1} = \frac{\partial \Pi^1(\theta_i | \theta_1)}{\partial \theta_i} \bigg|_{\theta_i = \theta_i} = E_{\theta_2}[p^1(\theta)\pi_{\theta_1}^{\theta_1:1} + p^2(\theta)\pi_{\theta_i}^{\theta_i:1}].
\]  

(A.3)

Integration of (A.3) yields condition (i) and, by analogy, condition (ii). Conditions (v) and (vi) of the Lemma follow immediately from (IHR), (i) and (ii).

Totally differentiating (A.1) yields

\[
\frac{\partial^2 \Pi^1(\theta_i | \theta_1)}{(\partial \theta_i)^2} \bigg|_{\theta_i = \theta_i} + \frac{\partial^2 \Pi^1(\theta_i | \theta_1)}{\partial \theta_i \partial \theta_i} \bigg|_{\theta_i = \theta_i} = 0.
\]  

(A.4)

so the second-order condition is equivalent to

\[
\frac{\partial^2 \Pi^1(\theta_i | \theta_1)}{\partial \theta_i \partial \theta_i} \bigg|_{\theta_i = \theta_i} \geq 0,
\]  

(A.5)

which is conditions (iii) and (iv). Standard arguments are used to prove the converse. \(\square\)
Lemma 2. The mechanism which solves (P) is the same as the mechanism which solves the following optimization problem (P'):

\[
\max_{\mathcal{A}} \mathbb{E}_\omega \left[ p^1(\Theta) \bar{W}^1(\Theta) + p^i(\Theta) \bar{W}^i(\Theta) + p^u(\Theta) \bar{W}^u(\Theta) + p^h(\Theta) \bar{W}^h(\Theta) \right] \tag{P'}
\]

s.t. \( p \in \mathcal{A} \),

\[-\mathbb{E}_\Theta \left[ p^1(\tilde{\theta}_1, \theta_2) \pi_{n+1}^{\pi n} + p^u(\tilde{\theta}_1, \theta_2) \pi_{n+1}^{\pi u} \right] \text{ is non-increasing in } \tilde{\theta}_1,\]

\[-\mathbb{E}_\Theta \left[ p^h(\theta_1, \tilde{\theta}_2) \pi_{n+2}^{\pi h} + p^u(\theta_1, \tilde{\theta}_2) \pi_{n+2}^{\pi u} \right] \text{ is non-increasing in } \tilde{\theta}_2.\]

Proof. First, we can substitute conditions (i), (ii), (v), and (vi) from Lemma 1 into the objective function. The ex ante expected transfer payment for firm 1 is written using eq. (6) as

\[
\mathbb{E}_\omega \mathcal{A}^2(\Theta) = -\mathbb{E}_\Theta \Pi^1(\theta_1 | \theta_2) + \mathbb{E}_\Theta \left[ p^1(\Theta) \pi^{n+1}(\Theta) + p^u(\Theta) \pi^{u+1}(\Theta) \right]. \tag{A.6}
\]

From (i) of Lemma 1,

\[\frac{d\Pi^1(\theta_1 | \theta_2)}{d\theta_1} = \mathbb{E}_\Theta \left[ p^1(\Theta) \pi^{n+1}(\Theta) + p^u(\Theta) \pi^{u+1}(\Theta) \right], \tag{A.7}\]

and, since \( \Pi^1(\tilde{\theta}_1 | \tilde{\theta}_2) = 0 \), integration by parts allows us to rewrite the expected transfer as

\[
\mathbb{E}_\omega \mathcal{A}^1(\Theta) = \mathbb{E}_\Theta \left[ \left( p^1(\Theta) \pi^{n+1}(\Theta) + p^u(\Theta) \pi^{u+1}(\Theta) \right) \right]
\times \frac{F^1(\theta_1)}{f^1(\theta_1)} + p^u(\Theta) \pi^{u+1}(\Theta) + p^u(\Theta) \pi^{u+1}(\Theta). \tag{A.8}\]

Substituting this expression into the government's objective function yields (P'). \( \square \)

Proof of Proposition 2. Ignoring the second and third constraints, \( p^1(\Theta) = 1 \) if and only if \( \bar{W}^1(\Theta) = \max \{ \bar{W}^1, \bar{W}^2, \bar{W}^u, \bar{W}^h \} \) and \( p^i(\Theta) = 0 \) otherwise. The expected transfers are easily obtained (see the proof of Lemma 2). Hence it is sufficient to check that the two omitted constraints are satisfied. By Assumptions 2 and 4, \( \bar{W}^1 \) and \( \bar{W}^u \) are non-increasing in \( \theta_1 \), and \( \bar{W}^2 \) and \( \bar{W}^h \) are non-increasing in \( \theta_2 \). \( \bar{W}^u \) is independent of \( \theta_1 \) and \( \theta_2 \). \( \bar{W}^1 \) is independent of \( \theta_2 \), and \( \bar{W}^2 \) is independent of \( \theta_1 \). Therefore \( p^1(\Theta) + p^i(\Theta) \) must be non-increasing in \( \theta_1 \), and \( p^2(\Theta) + p^i(\Theta) \) must be non-increasing in \( \theta_2 \). Also
by Assumption 4, $\tilde{W}_1^i < \tilde{W}_1^j$ and $\tilde{W}_2^i < \tilde{W}_2^j$, so $p^i(\Theta)$ must be non-increasing in $\theta_1$, and $p^j(\Theta)$ must be non-increasing in $\theta_2$. Finally, since $\pi_i^{1,1} < \pi_i^{1,1}$ it follows that both of the constraints are satisfied.

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