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# Private or Public? A Taxonomy of Optimal Ownership and Management Regimes.<sup>α</sup>

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## Abstract

We develop a theory of public versus private ownership based on value diversion by managers. Government is assumed to face stronger institutional constraints than has been assumed in previous literature. The model which emerges from these assumptions is flexible and has wide application. We provide a mapping between the qualitative characteristics of an asset, its main use - including public goods characteristics, and spillovers to other assets values - and the optimal ownership and management regime. The model is applied to single and multiple related assets. We address questions such as; when is it optimal

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to have one of a pair of related assets public and the other private; when is joint management desirable; and when should a public asset be managed by the owner of a related private asset? We show that while private ownership can be judged optimal in some cases solely on the basis of qualitative information, the optimality of any other ownership and management regimes relies on quantitative analysis. Our results reveal the situations in which policy makers will have difficulty in determining the optimal regime.

## 1 Introduction

"... the Government proposals are a massive betrayal of our National Interest against which the activities of [cold war spies] Burgess, Maclean, Philby and Blunt are very minor matters."<sup>1</sup>

Fierce passions are aroused by debate over public versus private ownership. Supporters of privatization argue that private ownership improves efficiency while opponents claim that public ownership better serves the wider social interest. To reconcile these contrasting views a key underlying question must be answered. What basic characteristics distinguish public and private firms? Our answer differs significantly from existing approaches adopted by the literature.

The model we develop uses an incomplete contracting framework to systematically explore the relationship between ownership, incentives and the public goods characteristics of managerial activities. Public managers face relatively flat commercial incentives compared with private managers. Flat incentives can be socially desirable when commercially productive activities generate large social harms relative to profit, but are undesirable when these activities are either benign or create external social benefits.

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<sup>1</sup>The Right Honourable Mr. Tony Benn, in the British parliamentary debate over the sale of the British National Oil Corporation, Parliamentary Debates, Sixth Series, Volume 2, House of Commons, Official Report Session 1981-82, page 500.

Our model also addresses several fundamental shortcomings of the existing literature on private versus public asset ownership. For example in several influential existing papers, the government is assumed to maximize welfare ex ante, but does not maximize social welfare ex post.<sup>2</sup> If it did, then there would be no difference in these models between public and private ownership. From this perspective, these models do not constitute purely normative theories of public versus private ownership. In contrast, ownership matters in our framework even if it is assumed the government maximizes social welfare.<sup>3</sup> Our model is also applicable to ownership and management of multiple assets. We consider mixed or separate public and private ownership, and joint or separate management – regimes that have widespread practical applicability. To the best of our knowledge, these possibilities have not been explored in previous literature.

The starting point of our analysis is the literature on incomplete contracts, beginning with Grossman and Hart (1986) and Hart and Moore (1990). These papers were the first to present a formal model that explains which agents should have ownership of an asset, when private firms should merge and when they should stay separate. More recently, Hart, Shleifer and Vishny (1997) and Bolton and Xu (1997b) have extended the reasoning of these early pieces to the choice between public and private ownership. The literature on outside ownership, for example Rajan and Zingales (1998), and Dell'ozza and Lockwood (1998), can also be applied to the choice between public and private ownership, if one interprets the outside owner in their setting as government.

A crucial assumption in each of these models is ex post observability and bargaining. The parties with an interest in the firm observe and bargain over production variables that are chosen after one or both of the parties has

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<sup>2</sup>See for example Hart, Shleifer and Vishny (1997), Rajan and Zingales (1998) (as applied to public ownership).

<sup>3</sup>Although the focus of our model is normative, it also allows the possibility of alternative government objectives.

makes some specific investment. However, while the early ownership literature assumed that both parties were private individuals, the new literature on privatization extends the power of observability to government. For example, in Hart, Shleifer and Vishny (1998), the government and the manager bargain over cost and quality after the manager chooses his specific investments. The government can observe cost and quality ex post. A similar informational assumption is made by Schmidt (1996). In that paper, when the government is owner, it is able to observe the true performance of the firm as represented by a cost parameter.

One significant difference between our theory and the papers mentioned above, is the assumed ability of government to observe production variables, and to subsequently bargain with managers. In practice, public managers are subjected to specific and intrusive constraints on their activities. These constraints go well beyond the normal restrictions placed on private firms. For example, the Federal Aviation Administration "did not control its budget and was forced to overcome burdensome procurement regulations for every major purchase" (Aman, 1996 p35).<sup>4</sup> It might be argued that these restrictions are intended to delineate the residual rights of public managers as a precursor to bargaining with government. However, we believe that an alternative explanation is more realistic. The observed restrictions are intended

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<sup>4</sup>Examination of the legislation governing public firms provides plentiful evidence of restrictions. For example, managers of the government owned British Steel Corporation needed the consent of the Secretary of State to undertake substantial changes in activities (Statutes in Force, Official Revised Edition, Iron and Steel Act 1982, Chapter 25, Part I, 2-(2), 4-(2) and (3), 5-(1) and (3)). Managers of the government owned Trans-Australian Airlines were unable to acquire rights or property, sell rights or property, or enter into a contract for construction, without prior approval of the minister, if the amount involved exceeded \$250,000 (Australian National Airlines Act 1945, Division 1, section 22). Similar controls were also placed on the ability to lease or purchase land. Managers of Intrak, the TVA and when publicly owned, British Telecom, as well as numerous smaller state owned firms face restrictions on their ability to dispose of or purchase assets (eg Part 1, section 6 of the British Telecommunications Act 1981). As an extreme example, managers of Telecom Australia, at one stage, were required to ask for ministerial approval for standard business activities such as the routine purchase of cable.

to prevent public managers from diverting funds to themselves or to their pet projects. This explanation is at odds with the literature described above, and forms the basis of our model.

We assume that the typical government is significantly less specialized in production than the typical private owner. Such a lack of specialization means that government cannot observe production variables, and so cannot bargain with their managers over the levels of these variables. Instead, the government can set up public accountability mechanisms that operate in a coarse fashion and result in rigid rules that reduce the extent to which public managers are able to divert value to themselves. In our framework, public ownership is defined as a ban on potential value diverting activities, and private ownership is the allowance of such activities. We assume that, as a result, public managers are not able to seize the value generated by core activities, whereas private owners can. This approach is a departure from the incomplete contracts literature where ownership differs according to the allocation of residual rights to choose production variables. The residual rights that are important for the definition of ownership in our model are rights over the choice of financial variables. This assumption is similar to that adopted by Hart and Moore (1998). In their paper, a debt holder is able to divert funds from a creditor. In this paper, a private owner can seize asset value. The government can only prevent this by placing a blanket prohibition on all actions (including financial actions) that might allow asset value diversion.

While this is a stark assumption, it allows us to develop a model which is very flexible. We explain in section 2 how our model can capture some of the key features of Hart, Shleifer and Vishny (1997) and Schmidt (1998). The basic model (section 2) has one asset and one manager. We provide a mapping between the commercial characteristics of the core activity associated with the asset, the external effects generated by the activity, and optimal ownership. The simplest case involves an activity that improves asset value,

and confers external benefits. Private ownership is optimal for such a combination of characteristics, because a public manager has no profit motive to increase the activity. If instead the activity generates an external harm, either public or private ownership can be optimal. The decision to privatize depends on whether the external harm generated outweighs the increased private value.

The model is extended in section 3 to allow for two assets and two potential managers.<sup>5</sup> This leads to a considerably richer set of results compared with the one asset - one manager model. Having two assets introduces the possibility of spillovers between asset values and allows us to examine issues of joint and separate ownership that have not been formally explored by other authors. For example, we address the following questions. When privatizing related assets, should they be sold as a single entity or sold as separate firms? If it is desirable to separate assets, when does it make sense for one to be publicly owned and the other private?

A general pattern emerges from our framework. While the case for private ownership can sometimes be made on the basis of qualitative characteristics (that is, the sign of the external, commercial and spillover effects) public ownership requires quantitative analysis. From a policy maker's perspective, this means that the case for public ownership is more difficult to establish. Moreover, the set of potentially optimal regimes expands whenever private and social effects move in different directions. For example, we show that when the core activities improve asset value and generate spillovers, but cause external harm, any ownership or management regime can be optimal. Some attempt at measurement is required to determine the best regime.

A central objective of this paper is to provide policy makers with an organizing framework and a method to determine optimal ownership and

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<sup>5</sup>The ownership and regulation of multiple assets is important in practice. For example, the break-up of the Bell group in the US (see Brennan 1987), gas privatization in the UK (see Armstrong, Cowan and Vickers 1995 and Vickers and Yarrow 1988) and rail and telecommunications reform in Japan (see Takeuchi, Imahashi and Yamauchi 1997).



management. To aid this process, the paper includes applications that we feel are relevant. Among other things, the model is able to explain why in some cases disposal of toxic waste might best be dealt with by a public agency, why some kinds of innovative activity are best kept in the private sector, and why basic research effort might be higher in public firms. We discuss applications to emergency service provision, retail product innovation, airport ownership, management of public resources by nearby private businesses, strategic blockading of entry by competitive rivals, water supply and distribution, and joint ventures.

## 2 The single asset case

At date 0, the government  $G$  decides whether an asset should be publicly or privately owned.<sup>6</sup> We assume that  $G$  is unspecialized, and cannot perform the management activity. Therefore, under either regime, a specialized manager  $M$  is hired to control the asset after the regime is announced.

The manager's task is to choose the level of a 'core' activity  $e \in \mathbb{R}_+$  associated with the asset. The activity  $e$  can be interpreted as either an investment or an action that affects firm value  $a : \mathbb{R}_+ \rightarrow \mathbb{R}$ . The value  $a$  is interpreted as the change in asset value due to  $e$ . The activity  $e$  is commercially productive if it increases asset value, precisely, if  $a' > 0$  for all  $e$ , and  $\lim_{e \rightarrow 0} a'(e) = 1$ . It is commercially unproductive if it decreases asset value, i.e.  $a' < 0$  for all  $e$ .

We allow  $a$  to be either increasing or decreasing in  $e$  in order to allow wide practical application. There are abundant examples for both cases. A profitable commercial activity that is an activity where revenue exceeds costs, provides an example for the case where  $a$  is increasing in  $e$ . For example, research and development could be embodied in higher asset value. If higher  $e$  leads to a fall in  $a$ ,  $e$  can be interpreted as an action that wears down the

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<sup>6</sup>The asset can be interpreted as a group of essential assets that make up a firm. At present we assume that the asset is indivisible. Multiple assets are considered in section 3.

...firm's capital (or any other unprofitable activity). For example, suppose the firm in question is a provider of emergency services, for which the collection of revenues is difficult. Assets consist of emergency service equipment such as vehicles, medical and rescue supplies. Greater emergency service activity leads to a reduction in the value of these assets because they depreciate with use.

The personal cost to the manager of exertion is denoted  $\psi : \mathbb{R}_+ \rightarrow \mathbb{R}$ . While  $\psi$  will often be thought of as the disutility that  $M$  suffers from  $e$ , we allow  $\psi < 0$  in some cases, and interpret this as the manager either enjoying the activity or increasing her human capital through on-the-job training. In the emergency services example,  $\psi < 0$  corresponds to  $M$  obtaining transferrable skills from being a rescue service manager.

Following Hart, Shleifer and Vishny (1997), we assume that  $e$ ,  $\psi$  and  $a$  are non-verifiable, so that these variables cannot be included in a contract. We assume that both  $\psi$  and  $a$  are  $C^2$  and strictly concave with  $a(0) = 0$  and  $\psi(0) = 0$ . We define  $m \equiv \arg \max_e \psi(e)$ . In addition to these assumptions, we impose two consistency requirements. The first is that  $G$  always prefers the project to go ahead, than to leave the firm dormant.<sup>7</sup> The second is that if  $M$  received  $a$  directly, she would always be willing to choose an interior level of  $e$ .<sup>8</sup>

## 2.1 Value Division

Existing models comparing private and public ownership, such as Hart, Shleifer and Vishny (1997), Bolton and Xu (1997a) (1997b) and Rajan and

<sup>7</sup>This could be satisfied by assuming  $a(e) - \bar{A}(e) > 0$ , i.e. there are sufficient benefits through  $\bar{A}$  to ensure the project goes ahead.

<sup>8</sup>Several assumptions are required for this to hold. First, we assume that the manager cannot perform  $e$  without using the asset. If  $m > 0$ ,  $a'(0) < 0$  and the manager faces a return  $a - \bar{A}$ , she must incur cost  $a < 0$  in order to realize the gain  $a - \bar{A} > 0$ . Second, we assume that the gain is positive. A sufficient condition for this is  $a'(0) - \bar{A}'(0) > 0$ .

Zingales (1998), have a number of critical common features.<sup>9</sup> Each of these papers assumes that the key residual rights to be allocated are production variables.<sup>10</sup> The government is able to observe and bargain with  $M$  over these variables ex post.

Our analysis is based on two significantly different assumptions. First, we assume that  $G$  is sufficiently unspecialized so that it is unable to observe ex post variables. The government is made up of politicians who in general have little or no specialist knowledge concerning the firms over which they have influence. As a consequence,  $G$  and  $M$  are unable to bargain ex post. Second, rather than simply rights to make production decisions, the residual rights underlying our model are broader and include the rights to choose financial or commercial activities. The two key sets of actions that make up residual rights in our model are (1) potential value diverting activities (the leading examples being procurement and asset disposal) and (2) actions that involve the right to incur debt in the name of the government.

The following example shows how our assumptions lead to a difference between public and private ownership. Suppose a business decides to sell a substantial item of equipment. Under public ownership the process of sale follows strict guidelines.  $M$  must seek approval before the sale is authorized. The process may be subject to review and  $M$  may have little or no role in the choice of the successful purchaser. These restrictions guarantee that  $M$  cannot abuse the sale process to divert funds, say by selling the asset to a company in which  $M$  holds some interest. In contrast, under private ownership,  $M$  is free to conduct the sale in any legal manner. Thus,  $M$  is

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<sup>9</sup> Rajan and Zingales (1998) does not directly address the issue of private versus public ownership, but mentions this issue as an application of their results. Bolton and Xu (1997b) do not have a formal government in their model but note that 'student ownership' captures some elements of public ownership.

<sup>10</sup> Hart et al consider the allocation of the residual right to implement cost and quality innovations. Rajan and Zingales model the residual right to pursue an outside option if negotiations break down. Bolton and Xu assume that the important residual rights are the rights of employees to leave the job and work in a competing firm.

able to directly receive the funds from the sale say through selling the asset to a company in which  $M$  has an interest. In the absence of tight guidelines, the private manager is thus able to guarantee a purely private gain from the asset sale.

We generalize the idea of value diversion described in this example as follows. The government is unable to observe specific financial actions. However,  $G$  knows whether or not some action has been taken and, if so, the general class of the action. To be precise,  $G$  can tell by an action's general description whether it is (1) a potential value diverting or (2) a debt management activity, but  $G$  cannot identify the specific action, or evaluate whether it is appropriate in the circumstances. For example,  $G$  can tell if debt has been incurred in its name, since it is liable for the debt. However, it cannot judge whether the reasons for the expenditure were sound. Similarly,  $G$  may be aware of the transfer of an asset (as in the example above), but be unable to assess the probability of such a transfer.

As  $G$  can only observe the class membership of an action (i.e. (1) or (2)), it can only either ban or allow such classes. We define public ownership as a ban on potential value diverting actions. In contrast, private ownership is defined as the allowance of potentially value diverting activities, but a ban on the right to incur debt in the name of the government. Therefore, public ownership means that  $M$  receives a fraction  $z = 0$  of  $a(e)$ . Private ownership means that  $M$  can capture a fraction  $z = 1$  of  $a(e)$  when  $e$  is commercially productive, and obliges the manager to pay the fraction  $z = 1$  of  $a(e)$  when  $e$  is commercially unproductive.<sup>11</sup>

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<sup>11</sup>More formally, suppose the manager has two sets of actions,  $X$  and  $Y$  and there is a set of states of nature  $\Omega$ . The set of actions  $X$  are potential value diverting activities. In particular, let  $\phi(x; \hat{A})$  be the fraction of asset value the manager can seize by taking action  $x \in X$  when the state of nature is  $\hat{A} \in \Omega$ . We assume that, for all  $\hat{A} \in \Omega$  there exists an  $x \in X$  such that  $\phi(x; \hat{A}) = 1$ . The set of actions  $Y$  are activities that create a debt liability for the government. In particular, let  $\psi(y; \hat{A})$  be the fraction of debt that a manager can pass on to the government by taking action  $y \in Y$  when the state of nature is  $\hat{A} \in \Omega$ . We assume that, for all  $\hat{A} \in \Omega$  there exists a  $y \in Y$  such that  $\psi(y; \hat{A}) = 1$ .

Under the ownership definitions given above, a manager's payoff is  $z a(e) + (1-z) \psi(e) + k^z$ , where  $z = 1$  in the case of private ownership, and  $z = 0$  with public ownership. The quantity  $k^z$  is a transfer set by  $G$  to keep the manager's payoff equal to her outside opportunity of zero. Under either ownership regime, firm profits are defined as  $\pi = a(e) - \psi(e)$ . Note that in defining both firm profits and the manager's payoff, we have implicitly assumed that private ownership occurs in an owner-managed or closely held firm.<sup>12</sup>

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The government cannot observe the state of nature  $\tilde{A}$  or the particular actions  $x$  and  $y$  chosen by the manager. This reflects the unspecialized nature of government. The government, however, can observe whether or not some action in the set  $Y$  or  $X$  is undertaken. So the government can either broadly allow or ban the manager from taking actions in these sets. There are clearly four possibilities. We define private ownership as the situation where the government allows the manager to take actions in set  $X$  but bans actions in set  $Y$ . A private owner can seize (all) asset value but is not able to pass financial liabilities on to the government. Rather, a private owner is liable for all debts that they incur. Public ownership involves the government banning activities in the set  $X$ . The government may or may not also ban activities in set  $Y$ . In other words, a public manager may be able to take actions that incur financial liabilities for the government or may require special ministerial approval before any such action is undertaken. The treatment of set  $Y$  represents two slightly different forms of public ownership. This difference, while interesting in its own right, does not affect our results so we will not distinguish between 'tight' public ownership ( $Y$  banned) and 'loose' public ownership ( $Y$  allowed) in our formal model. Finally, the government could allow a manager to take actions in both sets  $X$  and  $Y$ . But this would allow the manager to use the government as a 'money pump' by raising debt in the government's name and seizing the value of the debt through the assets they control. We assume that the government's objective is such that this is never optimal government policy.

In practice the government will often have access to additional imperfect measures of actions in the sets  $X$  and  $Y$ . This means that the government has additional instruments of control over managerial actions. Such instruments can be thought of as regulatory controls, for example profit based regulation. To focus on ownership issues (and following most of the current literature) we do not analyze the possibility of regulation in this paper. King and Pitchford (1998b) explores the issue of ownership and regulation in a less general framework.

<sup>12</sup>Except for the paper by LaPorta and Tjebk (1991), the papers on privatization that we have referenced assume that there are no agency problems in the case of private ownership. This is a reasonable approximation in many cases of small and medium sized enterprises, such as hospitals, local police force, toxic waste disposal companies and local public utilities, judicial services, and some large companies where there is concentrated ownership. A relaxation of this assumption adds considerable complexity to the current model (which is instead focussed on providing a taxonomy of cases aimed at policy) and is beyond the

So far, the model does not contain any elements that would call for  $G$  to choose public over private ownership. However, the kinds of business that are seriously considered for public ownership typically have externalities associated with them. We assume that as well as generating the value  $a_i$ , the activity  $e$  creates an external benefit  $b_i$  that cannot be captured directly through trade with the group of people who receive this benefit. The benefit  $b_i$  is assumed to be non-verifiable unless otherwise stated.<sup>13</sup> We say a positive externality exists whenever  $b_i > 0$  for all  $e_i$ , and a negative externality exists if  $b_i < 0$  for all  $e_i$ . An example of a negative externality is any kind of pollution. Increased community safety from increased emergency service activity is an example of a positive externality.

We do not limit the interpretation of  $b_i$  to the impact on a group of consumers of the activity. The function  $b_i$  captures any benefit external to the firm that the planner cares about. From a positive political economy perspective, it could be interpreted as any effect of the manager's action on reelection chances. We assume that  $G$ 's objective is to maximize utilitarian social welfare  $W = b + \pi = b + a_j \psi$ .<sup>14</sup>

One of our goals is to find a mapping between the properties of the asset and the optimal ownership regime. In other words, we want to find the

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scope of the paper. Such an extension is an interesting topic for future research in this field.

<sup>13</sup>In many situations of practical relevance, external social benefits are likely to be difficult to quantify. This is almost true by definition, since the magnitude captures the welfare cost or benefit of events outside markets. Nevertheless, we examine the consequences of verifiable benefits in section ???. Under this assumption, in the single asset/single manager case, ownership is irrelevant. Perhaps surprisingly, when there are two assets, ownership matters.

<sup>14</sup>This represents a utilitarian government that weighs the dollar value of external harm and firm profits equally. We could make a variety of alternative assumptions about  $G$ 's objective function. For example, the function  $W = b$  represents a planner who may be captured by the constituency that faces the external benefit. If  $W = \lambda b$ , then  $G$  could be considered revenue maximizing since  $G$  is unconcerned about external benefits that cannot be monetized and captures all profits under either ownership regime through the transfer  $k^2$ . With  $W = b + (1 - \lambda)\pi$ , the planner is concerned about the constituency that faces the external benefit, but has an empire building preference for public ownership.

optimal value of  $z$  given the nature of the externality (positive or negative) and the commercial effect (productive or unproductive).

## 2.2 Results

The mapping between asset characteristics and optimal ownership is derived by solving the manager's problem, and then selecting the value of  $z$  that maximizes  $W$ . Given the government's ownership choice,  $M$  chooses  $e = e^z$  to maximize her payoff:

$$e^z = \arg \max_e [z \Phi(e) - \psi(e)]. \quad (1)$$

An immediate result from (1) is that the public manager always chooses  $e = e^0 = m$ , the value that minimizes  $\psi(e)$ . When the activity is commercially productive, then  $e^1 > e^0$ , and when it is commercially unproductive,  $e^1 < e^0$ .

Subject to  $M$ 's choice  $e^z$ ,  $G$  chooses  $z$  to maximize

$$W(e^z) = b(e^z) + a(e^z) - \psi(e^z). \quad (2)$$

To establish the optimal regime, let  $\pi^z = \pi(e^z)$  and note that profits are always higher under private ownership, i.e.  $\pi^1 > \pi^0$ . Thus  $G$ 's decision to privatize depends whether the increase in firm profits  $\pi^1 - \pi^0$  exceeds the loss in external benefits  $b^0 - b^1$ .

A taxonomy of the possible cases is presented in Table 1. When the activity is commercially productive and has a positive externality (cell (III)), private ownership is optimal. In this case,  $e^1 > e^0$ . The marginal commercial gain from the activity is positive, so a private manager chooses a higher level of the activity. Since the externality is positive, external benefits are also higher under private ownership. For commercially unproductive activities that generate negative externalities (cell (IV)), private ownership is also optimal. A private manager has a commercial incentive to cut back the activity

so that  $e^1 < e^0$ . Since  $e$  also generates an external harm, private ownership is unambiguously preferred.

Retail product innovation is a leading example of a commercially productive activity that generates positive externalities. An innovation that is privately profitable can provide spillover benefits to other businesses. A public sector firm faces no commercial incentive to innovate. The lack of product innovation in the former Soviet Union and other centrally planned economies is illustrative of this case. For commercially unproductive activities that generate negative externalities, one example might be personal bias. Suppose a manager has preferences that are biased against a particular group of people on grounds of race, religion or personality.<sup>15</sup> A public manager faces no commercial incentive to refrain from discriminatory behavior, whereas a private manager may find it a money losing strategy. Private ownership will therefore be preferred.

Cells (III) and (IV) present situations where qualitative information on the nature of the asset is sufficient to determine the optimality of private ownership. The remaining cells in Table 1 involve ambiguous cases where relative magnitudes must be compared. Consider cells (I) and (II) where a commercially productive activity generates a negative externality. Since  $e^1 > e^0$ , private ownership creates a larger external harm than public ownership. Clearly, benefit functions  $b(\phi)$  exist where the increment in harm is larger than the gain in profits, and there are others where this increment is smaller. The former could be called relatively strong negative externalities, and the latter, relatively weak negative externalities.<sup>16</sup> An example in this

<sup>15</sup> It may be difficult for the government to prevent such discrimination. Rules favoring minorities when candidates are of equal ability are difficult to enforce when the public manager judges candidate ability. Also, discrimination may operate over many dimensions and rules cannot prevent discrimination if the government does not know exactly which groups the manager is biased against.

<sup>16</sup> For example, suppose  $b(\phi) = -B(\phi)$ , for  $B^0 > 0$ ,  $B(0) = 0$ . There exist negative  $\phi$  such that  $-(B^0 + B^1) > \frac{1}{2} \phi^1 + \frac{1}{2} \phi^0$ , and also there exists negative  $\phi$  such that the reverse is true.



category is disposal of toxic waste, where effort is time spent thinking about cheaper methods of containment or dumping. Suppose the effects of poor waste disposal will not be felt until far in the future, so it is not possible to hold a manager personally liable.<sup>17</sup> A public manager is unconcerned about the costs of disposal. However, a private owner will have an incentive to cut corners and keep costs low. With waste of slight toxicity, savings from cheaper disposal could outweigh expected environmental costs, shifting the balance in favor of private ownership. However, if the waste is extremely toxic, public ownership will be preferred. Australia is currently considering privatization of the disposal of a store of Halon gases – gases which are supposed to destroy the ozone layer. A private manager may face a strong commercial incentive simply to let the gas into the atmosphere, rather than undertake costly chemical disposal.

Cells (V) and (VI) represent optimal ownership when there is a commercially unproductive activity that generates a positive externality. Since  $e^1 < e^0$ , public ownership leads to greater external benefit than private ownership. As before, this gain must be weighted against the loss in profits. When the positive externality is relatively strong, public ownership is preferred, otherwise private ownership is better. Emergency services, such as fire, ambulance and rescue are good examples of this trade-off. While a public spirited manager might prefer to attend all calls, a private ambulance or fire service faces a financial disincentive when the customer cannot provide evidence of ability to pay. The choice between ownership structures depends on whether the cost of attending false emergencies outweighs the cost of unattended emergencies. Ambulance services are private in many parts of

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<sup>17</sup>The doctrine of successor liability, where subsequent owners of the assets are held liable for future environmental costs associated with the asset, will alleviate the problem in some, but not all circumstances. A successor is only held liable if the contamination is detected, and this may occur well after the firm has ceased operations. Parties may also use bankruptcy to become judgement proof and avoid facing the full costs of the contamination. Pitchford (1995) demonstrates that the potential for judgement proofness ensures that an irreducible external social cost remains.

the United States, and public in the United Kingdom and Australia<sup>18</sup>

> From our analysis, with a single asset, qualitative information is sufficient to establish the dominance of private ownership in two cases. In contrast, quantitative information is always needed to establish the dominance of public ownership. Since estimation of external benefits for normative purposes is typically difficult, our model suggests that the case for public ownership will generally be more difficult to establish. Nevertheless, the 'privatization index',  $p = \frac{b^1 - b^0}{\pi^1 - \pi^0} + 1$ , might be a useful cost-benefit ratio to estimate when optimal ownership is ambiguous.  $p > 0$  indicates private ownership is optimal and  $p < 0$  means public ownership is optimal. The index is also useful as a summary of qualitative factors that favor privatization. When  $p > 1$ , external benefits and profits are higher under privatization. For other values of  $p$ , the magnitudes of private and external benefits need to be measured and compared.<sup>19</sup>

### 2.3 Comparisons with Current Literature

To the best of our knowledge, Schmidt (1991; 1996) was the first paper to distinguish between public and private ownership in an incomplete contracts model where the government has social welfare as its objective.<sup>20</sup> The manager of the firm in his model is assumed to make a non-contractible private

<sup>18</sup> The disincentive created by ownership in this example is similar in spirit to Rajan and Zingales (1998). In their model, ownership may reduce (socially desirable) investment by undermining an agent's ex post bargaining position. In our model, private ownership may reduce socially desirable activities when they directly generate private costs. We are grateful to Luigi Zingales for pointing out this analogy.

<sup>19</sup> Different objective functions for  $G$  alter the results somewhat. When  $G$  is captured by the constituency facing the external benefit ( $W = b$ ), optimal ownership is straightforward to predict. Cells (I), (II), (V) and (VI) have public ownership as optimal. Private ownership is optimal in cells (III) and (IV). With  $W = b + (1 - z)w$ , assuming  $w^0 > 0$ , public ownership is preferred in cells (I), (II), (V) and (VI), and may be preferred in (III) and (IV) if  $w^0$  outweighs the loss  $b - b^0$ .

<sup>20</sup> There are also a number of papers that analyze privatization in a positive political economy framework. For example, Boyco, Shleifer and Vishny (1996). See also Lopez-de Silanes, Shleifer and Vishny (1997).

investment  $e$  at date 0 that increases the probability that costs will be low when production takes place at date 1. Under public ownership, the government can observe costs at date 1, and chooses a production plan that is ex-post efficient. This, however, reduces the manager's incentive to invest at date 0. Under private ownership, the government induces more efficient investment ex-ante, but at the cost of distortionary ex-post regulation. Thus, Schmidt explains why public firms can suffer from X-inefficiency, where private firms suffer from distortionary regulation. The optimal regime is found by comparing these effects.

In contrast to Schmidt, the government in our model is never sufficiently specialized to observe and negotiate over ex-post production variables. If his assumption of an informed government under public ownership is replaced with our assumption, the distinction between public and private ownership disappears. Our analysis is not the only perspective on this issue; Schmidt makes the important basic point that having too much information can hurt government. However, our model is relatively parsimonious. It can be used to explain similar outcomes to Schmidt's model when  $G$  has no informational advantage under public ownership. Suppose the activity is commercially productive. Under public ownership,  $M$  chooses too low a level of effort because she is lacking a commercial incentive. This could be interpreted as X-inefficiency. Under private ownership, effort is higher due to the commercial incentive, but may be inefficiently high if production generates a negative externality. This can be interpreted as an inability to properly regulate to account for the external effect.

Hart, Shleifer and Vishny (1998) emphasize the fact that different incentives to implement cost and quality innovations have been central to the privatization debate in the informal literature. They develop an incomplete contracts model, with ex-post renegotiation between the government and the public or private manager. One of their key results is that relative to public ownership, private ownership gives stronger (and socially excessive) incen-

tives to lower costs at the expense of quality. But overall, quality under private ownership can be higher or lower than under public ownership.

Although Hart, et al's analysis involves two distinct activities, similar results can be derived in the one asset version of our model. Suppose the manager can engage in an activity that is commercially productive but generates a negative externality. For example, the activity reduces production costs but also reduces product quality. If the private manager cannot be made to bear the full social costs of the quality reduction then the activity will generate a negative externality.<sup>21</sup> From our results above, a private owner will choose a higher level of this activity than a public manager. Optimal ownership depends on the relative size of both the cost reduction and the deterioration in quality (cells I and II in the diagram). If there is relatively little reduction in quality but a substantial cost saving from the activity then private ownership will be desirable. Conversely, where cost savings are outweighed by the negative effects of quality deterioration, public ownership will be preferred.

Our model can also be used to explain how private ownership can yield higher levels of quality and lower net costs. Consider an activity that is commercially productive and generates a positive externality. For example, the manager may be able to raise product quality. If the manager can only imperfectly capture the benefits of any quality improvement through increased revenues, then raising quality will generate both increased asset value and external social benefits.<sup>22</sup> A private manager will choose a higher level of the activity than a public manager. Private ownership raises quality and asset value, and is unambiguously desirable.

Our framework can capture the favor of the cost versus quality trade-off in Hart, et al, and also avoids a potential difficulty of their model. Hart, et al assume that the government's utility function at the time of ex-post

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<sup>21</sup> Such an activity is equivalent to the investment  $e$  in Hart, et al.

<sup>22</sup> This is equivalent to the investment  $i$  in Hart, et al.

bargaining is given by the welfare of society excluding the utility of the manager. This can be justified in terms of a voting model where the manager has insignificant power to elect the government. However, if a purely normative approach is taken,  $G$ 's utility at the time of ex post bargaining will be identified with ex post social welfare. As Hart, et al. note,<sup>23</sup> if the government seeks to maximize total ex post social welfare, the first best can be achieved. In this case, their model does not yield a theory that is able to distinguish between public and private ownership.

This problem is not unique to their analysis. If the government (a) has the ability to observe and negotiate over ex post variables, and (b) has a purely normative objective of maximizing social welfare both ex post and ex ante, then the first best can be achieved. The reason is that  $G$  will be willing to transfer resources to any agent so that agent faces the marginal social incentive to invest. The outside ownership analyses of Rajan and Zingales (1998), and Dell'era and Lockwood (1998) if reinterpreted and applied to the issue of private versus public ownership, suffer from the same problem. In contrast, our model is based on a more informationally constrained government. The first best is not achieved even if  $G$  includes  $M$ 's utility in its welfare function, because informational constraints due to specialization do not allow ex post renegotiation.

One could argue that in our framework, the government could mimic a public regime by transferring ownership to an unspecialized private party. Such a party would be the recipient of asset value, and would only be responsible for making sure that the manager does not undertake potentially value diverting actions. This argument is flawed for two reasons. The government is different from other unspecialized private owners since it is able to commit to remain unspecialized (being too busy with politics), and is accountable to voters. However, a currently unspecialized private owner has an incentive to specialize or collude with the manager to enable her to capture

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<sup>23</sup>Hart, Shleifer and Vishny (1997) page 9, footnote 6

a higher net return. There is little point in the government selling to an unspecialized outside owner since government will then have to incur costs in monitoring this parties actions. The second problem with the argument that our theory is not unique to government ownership, is that ownership could confer other residual rights that are socially beneficial. An unspecialized private owner will not select the socially optimal level of ex post production variables, whereas a social welfare maximizing government will.

### 3 The two asset case

Extending the model to two assets, with two potential managers, introduces the possibility of interactions between activities, and more complex ownership and management regimes. The single asset case analyzed above provides basic results for the choice between public and private ownership. The favor of these results is maintained when considering multiple assets. Specifically, private ownership is optimal if the personal desires of the manager are aligned with external effects. Public ownership is only preferred if private incentives and external effects are sufficiently misaligned. However, in addition, the two asset case allows us to analyze when assets should be jointly or separately owned and managed under either private or public ownership.

For example, when considering a railway system, should the tracks and rolling stock be private or public? If private, should they be jointly owned or separated? If one is private and one is public, should the owner of the private asset also manage the public asset? The same questions arise when privatizing gas, electricity or water utilities. Should distribution and transmission assets be jointly or separately owned and managed? Similar issues emerge with basic and applied research infrastructure within a university. These questions are important for public policy<sup>24</sup>, but to the best of our knowledge have not been previously considered in the literature on private versus public

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<sup>24</sup>ibid footnote 3

asset ownership.

We denote the managers by  $A$  and  $B$ , and index the assets by  $j \in \{1, 2\}$ . Other than their 'name', the managers are identical. At date 0,  $G$  decides whether each individual asset will be publicly or privately owned and which of  $M \in \{A, B\}$  will manage it.  $G$  may choose either a single manager for both assets or different managers for each asset.<sup>25</sup>

The notation for ownership and management regimes is as follows. The dummy variable  $z_j$  represents the ownership regime for asset  $j$ , where  $z_j = 0$  if asset  $j$  is publicly owned and  $z_j = 1$  if asset  $j$  is private. The dummy variable  $\phi_{jM}$  represents the management regime for asset  $j$ . If  $\phi_{jM} = 1$  then  $M$  manages asset  $j$  while  $\phi_{jM} = 0$  if  $M$  does not manage  $j$ . We assume that there is only one manager for each asset, so that  $\phi_{jA}\phi_{jB} = 0$  for  $j = 1, 2$ . Since the managers are identical, with any joint management we assume that  $A$  is selected as the manager, and with any separate management,  $A$  manages asset 1 and  $B$  manages asset 2. There are six relevant ownership and management regimes that  $G$  must choose between at date 0:

Unified public ownership:  $z_1 = z_2 = 0$  and  $\phi_{1A} = \phi_{2A} = 1$ ;

Independently managed public ownership:  $z_1 = z_2 = 0$  and  $\phi_{1A} = \phi_{2B} = 1$ ;

Unified mixed ownership:  $z_1 \neq z_2$  and  $\phi_{1A} = \phi_{2A} = 1$ ;

Independently managed mixed ownership:  $z_1 \neq z_2$  and  $\phi_{1A} = \phi_{2B} = 1$ ;

Unified private ownership:  $z_1 = z_2 = 1$  and  $\phi_{1A} = \phi_{2A} = 1$ ; and

Independently managed private ownership:  $z_1 = z_2 = 1$  and  $\phi_{1A} = \phi_{2B} = 1$ .

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<sup>25</sup>As before,  $G$  always prefers to hire a manager for an asset rather than leave any asset dormant and manager  $M$ 's remuneration is set to keep her payoff equal to the outside opportunity of zero.

At date 1, managers choose their activity levels. The manager of asset  $j$  has the residual right to choose an effort  $e_j \in \mathbb{R}_+$ . This effort affects the value of asset  $j$  through the asset value function  $a_j(e_j) + \alpha_j(e_k)$  where  $a_j$  inherits the properties of the single asset case, and  $\alpha_j : \mathbb{R}_+ \rightarrow \mathbb{R}$  is a spillover effect from the effort associated with the other asset. We assume  $\alpha_j(\cdot)$  is concave and  $C^2$ .

The definitions of commercially productive and commercially unproductive are inherited from the single asset case. To account for spillover effects, we say that an activity  $e_k$  is conflicting if  $\alpha'_j < 0$  for all  $e_k$ . In this case, the activity  $e_k$  has a depressing effect on asset  $j$ 's value. A commercially productive activity  $e_k$  is weakly conflicting if  $\alpha'_j(e_k) + a'_k(e_k) > 0$  for all  $e_k$ . This definition captures the idea that the depressing effect of the spillover does not outweigh the positive direct effect of the effort on its own asset value. An activity  $e_k$  is contributory if  $\alpha'_j > 0$ , and a commercially productive activity is weakly contributory if  $\alpha'_j(e_k) < a'_k(e_k)$  for all  $e_k$ . In this case, the positive spillover is weaker than the direct effect of the activity on its own asset value. With analogous reasoning a commercially unproductive activity is weakly contributory if  $\alpha'_j(e_k) + a'_k(e_k) < 0$  for all  $e_k$ , and is weakly conflicting if  $\alpha'_j(e_k) > a'_k(e_k)$  for all  $e_k$ . Definitions of strongly conflicting and contributory have opposite inequalities in all cases, indicating that the spillover effect exceeds the direct effect. Note that the definitions are all global.<sup>26</sup>

Activities also generate externalities through the external benefit function  $b(e_1, e_2) = \beta_1 B(e_1) + \beta_2 B(e_2)$  where  $B : \mathbb{R}_+ \rightarrow \mathbb{R}_+$  is  $C^2$  and strictly increasing with  $B(0) = 0$ . The externalities have a relatively simple functional form that allows us unambiguously to change their relative magnitude. Activity  $e_j$  generates a negative externality if  $\beta_j < 0$  and a positive externality if  $\beta_j > 0$ . The relative strength of an externality is measured by the size of the

<sup>26</sup>Analogous local definitions have the same inequalities, but evaluated at particular levels of  $e_k$ .



coefficient  $\beta_j$ .

Activity  $e_j$  creates disutility  $\psi(e_j)$  for the manager of asset  $j$  where  $\psi(\cdot)$  has the same properties as for the single asset case. If  $A$  manages both assets, then total disutility is  $\psi(e_1) + \psi(e_2)$ .<sup>27</sup> If at date 0  $G$  chooses to retain two separate managers then date 1 activities are selected simultaneously by each manager and constitute a Nash equilibrium.<sup>28</sup>

### 3.1 Solving the model

To solve for the optimal regime, we first find the solutions to the manager's problem(s), and then substitute the corresponding efforts into  $G$ 's objective function to find the highest value. Manager  $M$ 's problem at date 1 is

$$\max_{\langle \phi_{1M} e_1, \phi_{2M} e_2 \rangle} \phi_{1M} f_{z_1}(a_1(e_1) + \alpha_1(e_2)) + \psi(e_1) + \phi_{2M} f_{z_2}(a_2(e_2) + \alpha_2(e_1)) + \psi(e_2) \quad (3)$$

for  $M = A, B$ . For notational convenience, we denote the solutions to (3) as  $e_j^{r, z_j, z_k}$ ,  $j \in k$ , where  $r$  is the management regime, either unified ( $r = u$ ) or independent ( $r = i$ ) and  $z_j, z_k$  are the ownership regimes for  $j$  and  $k$  respectively.

The first order conditions from the managers' problems are

$$\phi_{jM} z_j a'_j(e_j) + \phi_{jM} z_k \alpha'_j(e_j) = \phi_{jM} \psi'(e_j) \quad (4)$$

for  $j, k = 1, 2$ ,  $j \in k$ ,  $M = A, B$  and  $\phi_{jA} \phi_{jB} = 0$ .

The solutions to (3) given by (4) can be significantly simplified by noting that regimes with the same values of  $\phi_{jM} z_j$  and  $\phi_{jM} z_k$  result in the same level of activity  $e_j$ . This is summarized in the following lemma<sup>29</sup>

<sup>27</sup> Additive separability of effort cost eliminates any technical bias towards separate or joint management

<sup>28</sup> As will become apparent below, we have ruled out strategic effects between activities, by assuming that asset value and effort cost are additively separable. Thus the equilibria are in dominant strategies. We discuss the general model with strategic effects in section 3.4

<sup>29</sup> The notation  $\phi_j$  in (i) refers to the direct effect of a manager's activity on the relevant asset's value, that is, the effect through  $a_j$ .

**Lemma 1** If  $M$  is the manager of asset  $j$ , then the choice of  $e_j^{r z_j z_k}$  satisfies  
 (i)  $e_j^{i10} = e_j^{i11} = e_j^{u10} = d_j$  where  $a'_j(d_j) = \psi'(d_j)$ , and (ii)  $e_j^{i01} = e_j^{i00} = e_j^{u00} = m = \arg \min \psi(e)$

**Proof:** As  $M$  is the manager of asset  $j$  we have  $\phi_{jM} = 1$ . For each of (i10), (i11) and (u10) we have  $\phi_{jM} z_j = 1$  and  $\phi_{jM} z_k = 0$  and for (i01), (i00) and (u00) we have  $\phi_{jM} z_j = 0$  and  $\phi_{jM} z_k = 0$ . Direct substitution into (4) yields the result  $\square$

We adopt the convention of labelling ownership regimes by  $(r, z_1, z_2)$ , but in applying lemma 1, we abuse this notation slightly. For example, suppose that we wish to find the efforts chosen by each manager under the regime  $(r, z_1, z_2) = (i10)$ . Since  $A$  is the manager of asset 1 by convention, she selects  $e_1 = e_1^{i10} = d_1$ . By symmetry, however, we imagine that  $B$  is the manager of asset  $j$  in the above lemma, and note that  $B$  chooses  $e_2 = e_j^{i01} = m$ .

Table 2 presents orderings on activity  $e_j$  as a function of the characteristics of spillovers and commercial activities. For ease of notation, the following notational conventions are used in the table. As presented in lemma 1,  $e_j = d_j$  is the optimal effort taken by a manager who owns asset  $j$  alone and reflects the direct effect of activity  $e_j$  on asset value  $a_j$ . The effort associated with a publicly owned asset  $j$  chosen by a manager who also owns the private asset  $k$  is denoted  $e_j^{u01} = s_j$ . This reflects the spillover (or indirect) effect of  $e_j$  on the value of asset  $k$  through  $\alpha_k$  alone. Finally,  $e_j^{u11} = c_j$  is the effort chosen by a manager who owns both assets and reflects the combined spillover and direct effects of  $e_j$  on  $a_j + \alpha_k$ . The orderings in table 2 follow directly from the definitions and (4). For example, a productive and weakly contributory activity leads to  $c_j > d_j > s_j > m$ . The combined effect dominates, because both direct and spillover effects are positive. The direct effect exceeds the spillover effect because the activity is weakly contributory. The manager's minimum effort cost choice  $m$  is lowest of all and is the activity choice of a manager without any incentives to increase asset value. The intuition behind the other rankings in the table is similarly straightforward.

To find the optimal regime, we need to combine the activity ranking from table 2 with the choice of  $e_1$  and  $e_2$  under each regime, then determine the regime(s) that maximize  $G$ 's payoff. Table 3 can be used for the first part of this calculation and presents the pairs of efforts chosen under each possible regime. For example, with unified mixed ownership when asset 1 is public,  $(u01)$ ,  $e_1 = s_1$  and  $e_2 = d_2$ . The private manager of the public asset will take account of the spillover effect of the activity associated with that public asset ( $e_1$ ) on her private asset, but only captures the direct benefits of the activity associated with her private asset ( $e_2$ ). The notation  $(r, z_1, z_2) \succ (e_1, e_2)$  will be used to represent entries in table 3, that is,  $\succ$  means that regime  $(r, z_1, z_2)$  induces the manager(s) to choose effort pair  $(e_1, e_2)$ .

$G$ 's objective function is  $W = b + a_1 + \alpha_1 + a_2 + \alpha_2 - \Psi$ , where  $\Psi$  is the sum of managerial effort costs.  $G$ 's problem is

$$\max_{\sigma} W(\sigma) \tag{5}$$

where  $\sigma = (\phi_{1A}, \phi_{1B}, \phi_{2A}, \phi_{2B}, z_1, z_2)$ , with  $\phi_{jA}\phi_{jB} = 0$ , and  $W$  depends on  $\sigma$  through the solutions to (3) for  $M = A, B$ . In the remainder of the paper, the symbol  $\tilde{A}$  is used to represent  $G$ 's preferences. For example  $(r01) \tilde{A} (u0z_2)$  means that the regime with asset 1 public and asset 2 private is preferred by  $G$  to any unified regime with asset 1 public.

Tables 2 and 3 can be used to rank effort levels for every conceivable regime. However, even limiting analysis to symmetric cases ( $\alpha_1 = \alpha_2$  and  $a_1 = a_2$ ), there are at least 64 possible situations we could consider. Given this multiplicity, there are several ways to make use of these tables. First, there are some cases where information on the order of efforts chosen is sufficient to indicate the optimal regime or to establish suboptimal regimes. These cases are considered in section 3.2 below. Secondly, specific functional forms provide a useful picture of the trade-offs involved as we move between each possible regime. In section 3.3 we consider specific examples.

### 3.2 When is unified ownership optimal?

Privatization with multiple assets can lead to unified or separate ownership. But which of these is optimal? In this section, we consider circumstances where unified ownership is preferred and other cases where it is not. We also consider management and present a variety of cases where unified management is optimal.

Observation 3.2 begins by asking when it is socially desirable to privatize assets together. The result of the single asset case is extended. Unified private ownership is optimal if inter-asset spillovers are aligned with both commercial and social effects.

Unified private ownership is optimal if (i) the externalities are positive and effects commercially productive and contributory, (ii) the externalities are negative and effects are commercially unproductive and conflicting (iii)  $e_1$  generates a negative externality and is unproductive and conflicting and  $e_2$  generates a positive externality and is productive and contributory.

Proof: For (i), from table 3,  $(u, 1, 1) \succ (c_1, c_2)$  and from table 2, no other ownership regime will induce greater effect. A set effect is commercially productive, has positive inter-asset spillovers and positive externalities, the socially optimal effect levels will exceed  $c_1$  and  $c_2$ . Thus, by concavity of  $G$ 's objective, unified private ownership is the best regime. The proof of (ii) and (iii) is analogous.  $\square$

To illustrate the practical relevance of observation 3.2 consider airport privatization. Airport management is an example of commercially productive and contributory activities. Good administration improves the return at a given airport, but also has a positive spillover to destination airports. For example, if a plane's departure is delayed due to poor management at the originating airport, then its arrival is also delayed, making operation of the terminating airport more difficult.<sup>30</sup> As a result, our model suggests that the

<sup>30</sup> It is difficult to write contracts to allocate liability for delays, because other factors such as weather, or delays at other airports can be blamed.

united sale of the British Airports Authority in 1987 was appropriate. The Federal Government of Australia recently privatized the airports in all major cities except Sydney. However, contrary to our model, it chose separate private ownership.<sup>31</sup>

Observation 3.2 shows that  $G$  only needs to have qualitative information about externalities and spillovers to determine that united private ownership is optimal in some cases. It will be seen below that this is the only regime that can be established as unambiguously optimal without recourse to measurement of benefits. As soon as there is some conflict between social and private incentives,  $G$  needs to know the degree of conflict to determine the optimal regime. In particular, it can be desirable to separate asset ownership.

In contrast to observation 3.2, proposition 2 below shows that united management might remain optimal even if united private ownership is not optimal. For example consider the ownership and management of research and development assets. Basic research effort,  $e_2$ , may be commercially unproductive ( $a'_2(e_2) < 0$ ), because it requires costly infrastructure and leads to large external (hence uncaptured) benefits ( $\beta_2 > 0$ ) due to an inability to patent. Basic research also generates positive spillovers to applied research ( $\alpha'_1(e_2) > 0$ ), and may be personally enjoyable to some degree or provide limited direct benefits to a manager ( $m > 0$ ). Suppose  $e_1$  is a commercially rewarding applied research activity, such as the design of a new high-tech product. Such an activity generates a spillover benefit to basic research ( $\alpha'_2(e_1) > 0$ ), and positive external benefits for consumers and for competitors who can free ride on ideas ( $\beta_1 > 0$ ).

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<sup>31</sup>Vickers and Yarrow (1988) discuss the privatization of the BAA. See 1997 and 1998 issues of Public Utility Regulators Forum, published by the Australian Competition and Consumer Commission, for details on the sale and regulation of Australian airports. In both cases, parties argued for separate private ownership to improve 'competition'. In the Australian case, this is spurious. Most flights are domestic, each major city has only one major airport and distance precludes competition by combining air and ground transport. In the UK, competition between British airports must be placed in the context of wider European airport competition.

In summary, applied research effort is commercially productive, weakly contributory, and generates a positive externality. Basic research effort is commercially unproductive, either weakly or strongly contributory, and generates a positive externality, due to non-patentability of the product. There are three alternative regimes which may be optimal in this case: unified private and either unified or independent mixed ownership with publicly owned basic research assets.<sup>32</sup>

Unified ownership internalizes the positive spillovers between basic and applied research. This is desirable as both activities also provide positive externalities. But because basic research is commercially unproductive, it might be better to encourage this activity through public ownership. Public ownership of basic research assets will encourage more basic research by insulating the manager from the costs of their activity. If public ownership is desirable should it involve unified or independent management?

If basic research is strongly contributory, independent public ownership will decrease not increase this activity compared to unified private ownership. This is because the independent public manager does not take the spillovers into account. If basic research assets are to remain public then they should be managed by the owners of related private applied research assets (i.e. unified mixed ownership with basic research assets public).

If basic research is weakly contributory, then independently managed public ownership of the basic research asset will encourage basic research relative to unified private ownership. However, basic research will not be encouraged as much as with unified management with publicly owned basic research assets. Independent public ownership will be optimal if unified management goes 'too far'. That is, unified management may encourage excessive basic research as the private firm gains the spillover benefits without facing the social costs. Independent public ownership provides an intermediate outcome.

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<sup>32</sup>This is formally shown below in proposition 2.

This example has immediate implications for the debate over government ownership and management of universities and other basic research institutions. Public ownership will tend to encourage basic research. But this does not preclude private sector involvement. In particular, strong links with firms that use basic research as an input to their own applied research and development will encourage basic research and might be preferred to the traditional British model of an independent public university.

Proposition 2 formalizes the basic/applied research example above. It also shows that the government will require quantitative information about spillovers before it can determine the optimal mix of ownership/management.

Proposition 2 (i) If  $e_1$  is commercially productive and weakly contributory, and  $e_2$  is commercially unproductive and strongly contributory, and both activities generate a positive externality, then either unified private ownership ( $u11$ ) or unified mixed ownership, with asset 2 public ( $u10$ ), is optimal. (ii) If  $e_1$  is commercially productive and weakly contributory, and  $e_2$  is commercially unproductive and weakly contributory, and both activities generate a positive externality, then either unified private ownership ( $u11$ ) or unified mixed ownership with asset 2 public ( $u10$ ), or independent mixed ownership with asset 2 public ( $i11$ ) is optimal.

Proof: From table 2, the ranking of commercially productive and weakly contributory  $e_1$  is  $c_1 > d_1 > s_1 > m$ . The ranking for commercially unproductive and conflicting  $e_2$  is  $s_2 > m > c_2 > d_2$  for  $e_2$  weakly contributory, and  $s_2 > c_2 > m > d_2$  for  $e_2$  strongly contributory. From table 3, note that  $(u11) \succ (c_1, c_2)$  and  $(i11) \succ (d_1, d_2)$ . We have  $(u11) \succ (i11)$  because  $(u11)$  generates higher private profits and external benefits. Unified private ownership generates the maximum profits because all spillover effects are internalized. From above we have  $c_1 > d_1$ ,  $c_2 > d_2$ , which is good, because externalities are positive. Through similar reasoning we can establish  $(u11) \succ (i01)$ , and  $(u11) \succ (u01)$ . We cannot compare  $(u11)$  and  $(u10)$

without measuring the size of different effects, because  $(u10) \succ (d_1, s_2)$  and  $c_1 > d_1$  where  $c_2 < s_2$ . For (i), however we can establish that  $(u11)$  dominates all other regimes. Note that  $(i00) \succ (m, m)$  and  $(u00) \succ (m, m)$  with  $c_1 > m$  and  $c_2 > m$ . Also  $(i10) \succ (d_1, m)$  with  $c_1 > d_1$  and  $c_2 > m$ . For (ii),  $(u11)$  no longer dominates  $(i00)$  or  $(u00)$  because  $m > s_2$ . However,  $(i10)$  dominates  $(i00)$  and  $(u00)$  as it leads to the same level of  $e_2$  but more  $e_1$  (albeit still less than  $c_1$ ). However, neither  $(u11)$  nor  $(u10)$  dominate  $(i10)$  nor dominate each other as by concavity of  $W$  any of the three regimes may be optimal.  $\square$

While observation 3.2 and proposition 2 present conditions for either unified ownership or unified management, most configurations of externalities and spillovers involve a range of potentially optimal regimes. While it might be possible to rule out certain ownership and management configurations, it is necessary to consider quantitative effects to determine the optimal regime. Proposition 3 illustrates some of these cases.<sup>33</sup>

For example, consider activities that reduce cost or increase product quality. These activities can raise own profit but in the absence of perfectly discriminatory pricing lead to external benefits in the form of increased consumer surplus. The activities may also lower the profits of other firms whose products become relatively less desirable for consumers. Proposition 3 (i) shows that in such circumstances, joint public ownership of both firms is undesirable but it may be socially optimal to have either mixed or completely private ownership.

In contrast, proposition 3 (ii) considers commercially productive, conflicting activities that generate a negative externality. Quality degradation in a vertical production chain is one example.<sup>34</sup> In this situation any regime except independent private ownership may be optimal.

<sup>33</sup>King and Pitchford (1998a) presents a number of other examples.

<sup>34</sup>This is presented in more detail in section 3.3.



**Proposition 3** (i) If activities are commercially productive and weakly conflicting and both activities cause a positive externality, then unified or independently managed public ownership ( $(u00)$  or  $(i00)$ ) cannot be socially optimal, and there exists functions  $a_1, a_2$  and numbers  $\beta_1$  and  $\beta_2$  such that any other given regime  $f(r_1 z_2, (r z_1 1)g$  is optimal. (ii) If activities are commercially productive and conflicting and both activities generate a negative externality, then independent private ownership  $(i11)$  cannot be socially optimal and there exists functions  $a_1, a_2$  and numbers  $\beta_1$  and  $\beta_2$  such that any other given regime  $f(r_0 z_2), (r z_1 0)g$  is optimal.

**Proof:** For (i) note from table 3  $(r00) ! (m, m)$  and  $(i10) ! (d_1, m)$ , and by table 2,  $d_1 > m$ , which is good because  $a'_1(e_1) + a'_2(e_1) > 0$  for all  $e_1$  by the definition of weakly conflicting which means that the total direct effect outweighs the total negative spillover effect. A higher  $e_1$  also generates a larger positive externality. The example below and figure 2 show that any other regime can be optimal. For (ii), from table 3,  $(i11) ! (d_1, d_2)$ , and  $(u11) ! (c_1, c_2)$ , and from table 2,  $c_j < d_j$  for productive conflicting activities. However, the private return from  $(u11)$  exceeds the return from  $(i11)$ , because spillovers are internalized. However, lower effort under  $(u11)$  also leads to reduced external harms. Thus  $(i11)$  is dominated. The proof for optimality of any other regime comes from the example below, and the corresponding figure 2. □

### 3.3 Results from specific examples

The examples and propositions above highlight the range of potentially optimal regimes. In some cases unified asset ownership or unified management is best. In other cases, it is better to separate assets. The propositions demonstrate the need for quantitative information in order to determine the optimality of specific regimes.

This section presents two examples that illustrate these quantitative trade-offs. The first example considers weakly contributory spillovers, while the second involves weakly conflicting spillovers. Among other things, these examples are indicative of when independent private management might be optimal. In particular, they suggest that when activities are weakly conflicting but involve strong positive externalities, independent private ownership is preferred. This is because it is socially desirable to encourage these activities, but unified private ownership takes too great an account of the negative spillovers between assets. Conversely, if activities are weakly contributory, separate private ownership will only be optimal if externalities are moderately negative. If externalities are too small, then the benefits of internalizing spillovers will dominate and unified private ownership is best. If the externalities are both negative and large, some degree of public ownership will be preferred in order to reduce the relevant activities.

Consider the case where  $a_j(e_j) = e_j$ , and  $\alpha_j(e_k) = \alpha e_k$  where  $\alpha \in (0, 1)$  represents the degree of inter-firm spillover. The activities are commercially productive and weakly contributory. Suppose that effort cost is  $\psi(e_j) = \frac{1}{2}e_j^2$  and  $B(e_j) = e_j$ . Figure 1 illustrates the socially optimal ownership regimes for various levels of externalities  $\beta_1$  and  $\beta_2$ .<sup>35</sup>

The quadrant with  $\beta_1, \beta_2 > 0$  leads to unified private ownership as per proposition 3.2(i). Consider the quadrant in Figure 1 with  $\beta_1 > 0$  and  $\beta_2 < 0$ . On the dotted line beginning at  $\beta_1 = \tilde{\beta}_1$ , if  $\beta_2$  is close to zero, the benefits of encouraging  $e_1$  outweigh the costs of encouraging  $e_2$  and unified private ownership is optimal. As  $\beta_2$  falls, separate private ownership of asset 2 becomes optimal. This regime reduces the manager's incentive to undertake  $e_2$  and  $e_1$ , as spillovers are not internalized. As  $\beta_2$  decreases further, asset 2 should be publicly owned in order to further decrease  $e_2$ . However, because of the weak spillover of  $e_2$  on asset 1's value, it is worthwhile to having the owner of asset 1 also manage asset 2. That is, unified mixed ownership

<sup>35</sup>The social welfare comparisons used to generate Figure one are given in the appendix.

with asset 1 private is optimal. Effort  $e_2$  is too low if the other manager is in charge of asset 2. Finally, with  $\beta_2$  sufficiently negative, the strongest possible incentive to discourage  $e_2$  needs to be given and separate public ownership of asset 2 is optimal.

The remaining quadrant is  $\beta_1, \beta_2 < 0$ , which illustrates a situation where any regime may be optimal. Consider the dotted line in this region. At low levels of  $\beta_1$  and  $\beta_2$ , contributory spillovers outweigh the externalities and unified private ownership is optimal. Moving down the line, the externalities become more negative and outweigh the positive effect of inter-asset spillovers. Separate private ownership is preferred. As  $\beta_1$  and  $\beta_2$  continue to fall, it is desirable to have public ownership of the asset with the more severe externality.<sup>36</sup> Moving further, separate mixed ownership with 2 public is optimal, as this regime more effectively discourages  $e_2$  than unified mixed ownership. Eventually if both activities generate sufficiently strong negative externalities, public ownership of both assets is optimal.

Horizontal anti-competitive activity, such as blockading entry, exemplifies the movement along the line with  $\beta_1$  and  $\beta_2$  negative. This activity benefits other incumbents but makes consumers worse off. The choice between unified and independent private ownership depends on the severity of the effect on consumers. If the negative effects of these anti-competitive activities are sufficiently severe, then public ownership might be considered.

The trade-offs from proposition 3 can be illustrated by a slight modification to the example above. Let  $a_j(e_j) = e_j$  and  $\alpha_j(e_k) = \alpha e_k$  where  $\alpha > 0$  represents the degree of inter-firm spillover.  $\psi(\Phi) = \frac{1}{2}e_j^2$  and  $B(e_j) = e_j$ . Figure 2 illustrates the socially optimal ownership regimes for various levels of externalities  $\beta_1$  and  $\beta_2$  when  $\alpha \in (\frac{1}{2}, 1)$ .<sup>37</sup>

<sup>36</sup>This depends on the activities being weakly contributory. If the activities are strongly contributory, then it may be desirable to make the asset with the less negative externality public as this more effectively mutes incentives for the activity with the more negative externality.

<sup>37</sup>The social welfare comparisons used to generate figure two are given in the appendix.

Proposition 3 (i) is illustrated by the quadrant in Figure 2 with  $\beta_1, \beta_2 > 0$ , while proposition 3 (ii) is illustrated by the  $\beta_1, \beta_2 < 0$  quadrant. As noted above, the latter case is applicable to spillovers in vertical production. Suppose there are two assets, water supply and water distribution. Negative spillovers between asset values ( $\alpha'_j < 0$ ) are generated by reductions in water quality. While this reduces costs ( $a'_j > 0$ ), it has a negative external effect on consumers ( $\beta_1, \beta_2 < 0$ ). Because of the spillover effect between the upstream and downstream producers, separate private ownership is always socially dominated by unified private ownership. If the reduction in water quality at both production stages is sufficiently harmful, as measured by  $\beta_1$  and  $\beta_2$ , then public ownership can dominate any form of private ownership. Similar issues arise in rail privatization and the separation of track and train companies in the UK has led to considerable concern about vertical spillovers and industry performance.

### 3.4 Ownership with strategic interaction

The framework presented above assumes linear separability between direct and spillover effects on asset value. This simplifies the analysis and removes strategic effects under independent management. The framework, however, can easily be generalized to allow for strategic interaction, albeit at the cost of a substantial increase in algebraic complexity. In addition, when direct and spillover effects on asset value have non-linear interactions, the activity classification used above (commercially productive/unproductive, contributory/conflicting) will only provide a partial ordering of activities.

To generalize the model, consider the asset value functions  $a_j(e_j, e_k)$  where  $a_j : \mathbb{R}_+ \times \mathbb{R}_+ \rightarrow \mathbb{R}$ . The asset value functions include both direct effects and spillovers.<sup>38</sup> Assume that  $a_j(\cdot, \cdot)$  is  $C^2$  and concave with  $a(0, 0) = 0$ . The external benefit function is  $b(e_1, e_2)$  with  $b(0, 0) = 0$  but need not be linearly

<sup>38</sup> We have altered the notation slightly from above, where  $a_j$  represented only the direct effect. Now  $a_j$  captures spillover and direct effects.

separable. The government wishes to choose ownership and management to maximize  $a_1(\Phi\Phi) + a_2(\Phi\Phi) + b(\Phi\Phi) - \Psi$  subject to the relevant managers' activity choices. As before,  $\Psi$  is the sum of managerial effort costs.

As an example of the generalized model, consider a potential research joint venture. A joint venture may improve social welfare by internalizing spillovers associated with innovative activities. At the same time, these joint ventures may facilitate collusion (see Katz 1986 & Suzumura 1992). The desirability of research joint ventures and their treatment under anti-trust laws has generated considerable controversy (e.g. Jorde and Teece 1990, Shapiro and Willig 1990, Martin 1994).

Yi (1996) presents a simple model of research joint ventures, where two firms can cooperate on cost-reducing activity before engaging in Cournot competition. Cost-reducing activity increases consumer surplus but one firm's cost-reducing activity may raise or lower the other firm's profits. If spillovers (i.e. own cost reduction due to the other firm's cost-reducing activity) are sufficiently high, then each firm gains from the other's activity. However, if spillovers are small, then the reduction in profits caused by facing a more efficient product competitor outweighs the spillovers, and profits of one firm fall as the other firm's cost-reducing activity rises.

To consider these effects in our framework, let  $c_j = C - e_j - \gamma_j e_k$  be the cost of production for firm  $j$  where  $j, k = 1, 2, j \neq k$  and  $\gamma_j \in [0, 1]$ .<sup>39</sup> If the inverse market demand is  $P(Q) = A - SQ$  where  $Q = q_j + q_k$  and  $\psi(e_j) = \frac{1}{2} E e_j^2$  then under Cournot product market competition firm profits or value are  $a_j = (1/9S)[A - C + (2 - \gamma_k)e_j - (1 - 2\gamma_j)e_k]^2$ . Assume that  $E$  and  $A$  are sufficiently large so that  $a_j - \psi(e_j)$  is concave in  $e_j$  and  $a_1 + a_2 - \Psi$  is concave in  $e_1$  and  $e_2$ . If  $b(\Phi\Phi)$  equals consumer surplus then  $b = (1/18S)[2A - 2C + (1 + \gamma_k)e_j + (1 + \gamma_j)e_k]^2$ . It is easy to show that  $\partial b / \partial e_j > 0$ ,  $\partial a_j / \partial e_j > 0$ ,  $j = 1, 2$  and  $\partial a_j / \partial e_k > 0$  if  $\gamma_j > 0.5$  and  $\partial a_j / \partial e_k < 0$  if  $\gamma_j < 0.5$ . In the

<sup>39</sup> Unlike Yi (1996) the model presented here allows for asymmetric spillovers. However, as the model is illustrative, we restrict attention to simple demand and cost functions.

terminology above, both activities  $e_1$  and  $e_2$  involve positive externalities with  $e_1$  contributory if  $\gamma_2 > 0.5$  and conflicting if  $\gamma_2 < 0.5$ , and similarly for  $e_2$ .

Interpret (u11) as private ownership with a research joint venture and (i11) as private ownership without a joint venture<sup>40</sup>. If both  $\gamma_1$  and  $\gamma_2$  exceed 0.5, effort choices under a joint venture,  $c_1$  and  $c_2$ , will be strictly larger than effort choices without a joint venture ( $d_1$  and  $d_2$ ). An Isoeffort will exceed the level chosen under other ownership regimes (e.g. (u10) which can be interpreted as a joint venture between a private and a public firm). As the activities involve a positive externality, then if both  $\gamma_1$  and  $\gamma_2$  exceed 0.5 a private joint venture will be socially optimal. However, if both  $\gamma_1$  and  $\gamma_2$  are less than 0.5 then  $d_j > c_j$ ,  $m = s_j = 0$ . Depending on the effect of cost reduction on consumer surplus, a private joint venture may or may not be preferred to private ownership without a joint venture<sup>41</sup>.

This example shows how the intuition from section 3 may extend to more complex strategic interactions. It also illustrates the power of the model to allow for asset asymmetries and to highlight potential regimes, such as a joint venture between a public and a private firm, which may otherwise be overlooked.

## 4 Conclusion

In this paper we have developed a rich framework for comparing public and private ownership. The key feature underlying our model, and that differentiates it from the literature is the inability of government to observe and

<sup>40</sup>We use regime (u11) to mean a joint venture in the same sense as Yi (1996). Thus the activity choice is unified but production choices remain independent. If production choice was also unified then a unified firm would produce monopoly output and the benefit function would depend on the ownership regime. Interpreting unified ownership in this way both would unnecessarily complicate the example and make our results incomparable with Yi.

<sup>41</sup>See Yi (1996) propositions 3 and 4 for similar results.

negotiate over ex post surplus. Instead, we explore the hypothesis that government can only either ban or allow potential value diverting activities. The simple model that results from this hypothesis is applicable to a wide variety of situations involving both single and multiple assets. While our results have considerable intuitive appeal, the complexity of interactions between ownership, inter-asset spillovers and social externalities shows the need for careful formal analysis.

Our model is aimed at providing an organizing framework for policy makers. We show that the optimality of private ownership (with integrated management where relevant) may be judged purely on qualitative factors. In contrast, the optimality of all other ownership and management regimes will depend on specific quantitative information. In the case of a single asset, this makes the case for public ownership intrinsically more complex than that for private ownership. Similarly, for multiple assets, regimes involving public ownership or separate management must be based on stronger evidence than is sometimes necessary to show optimal integrated private ownership.

Our analysis makes clear the type of information that needs to be gathered to establish which regimes are preferable. Practitioners must consider how a shift in ownership interacts with managerial incentives. In some cases, it may be desirable to consider 'non-standard' combinations of ownership and management. For example, we show that it may be desirable for a public manager to own and manage related private assets.

Our model was extended to allow for a preliminary analysis of strategic interaction in 3.4. The experience of telecommunications reform in many countries suggests that strategic effects can be particularly important. Strategic issues should provide a rich research topic for future work.

A key result from our model is the need for policy makers to consider privatization on a case by case basis. While it may be easier to make the case for private ownership rather than public ownership, policy makers still face the burden of proving their case. If the government's aim is to maximize

social welfare, then a general ownership policy is unlikely to be adequate

## Appendix

Figures 1 et  $SW^{up}$  refer to social welfare under unified private ownership. Similarly,  $SW^{ip}$ ,  $SW^{imj}$ ,  $SW^{umj}$  and  $SW^g$  refer to social welfare under independently managed private ownership, independently managed mixed ownership ( $j$  private), unified mixed ownership ( $j$  private) and (either independently managed or unified) public ownership respectively. Figure 1 is derived from the following 21 relationships.

$$\begin{aligned}
 SW^{up} & \text{ ; } SW^{ip} = \alpha + \beta_1 + \beta_2 \\
 SW^{up} & \text{ ; } SW^{im1} = \alpha\beta_1 + (1 + \alpha)\beta_2 + \frac{1}{2} + \alpha(1 + \alpha) \\
 SW^{up} & \text{ ; } SW^{im2} = \alpha\beta_2 + (1 + \alpha)\beta_1 + \frac{1}{2} + \alpha(1 + \alpha) \\
 SW^{up} & \text{ ; } SW^{um1} = \alpha\beta_1 + \beta_2 + \frac{1}{2} + \frac{1}{2}\alpha^2 \\
 SW^{up} & \text{ ; } SW^{um2} = \alpha\beta_2 + \beta_1 + \frac{1}{2} + \frac{1}{2}\alpha^2 \\
 SW^{up} & \text{ ; } SW^g = \beta_1 + \beta_2 + 1 + \alpha \\
 SW^{ip} & \text{ ; } SW^{im1} = \beta_2 + \frac{1}{2} + \alpha \\
 SW^{ip} & \text{ ; } SW^{im2} = \beta_1 + \frac{1}{2} + \alpha \\
 SW^{ip} & \text{ ; } SW^{um1} = \beta_2 + \frac{1}{2}\alpha + \frac{1}{2} \\
 SW^{ip} & \text{ ; } SW^{um2} = \beta_1 + \frac{1}{2}\alpha + \frac{1}{2} \\
 SW^{ip} & \text{ ; } SW^g = \beta_1 + \beta_2 + 1 + 2\alpha \\
 SW^{im1} & \text{ ; } SW^{im2} = SW^{um1} \text{ ; } SW^{um2} = \beta_1 \text{ ; } \beta_2 \\
 SW^{im1} & \text{ ; } SW^{um1} = \beta_2 \text{ ; } 1 \text{ ; } \frac{1}{2}\alpha \\
 SW^{im1} & \text{ ; } SW^{um2} = \beta_1(1 + \alpha) \text{ ; } \beta_2 \text{ ; } \alpha \text{ ; } \frac{1}{2}\alpha^2 \\
 SW^{im1} & \text{ ; } SW^g = \beta_1 + \frac{1}{2} + \alpha \\
 SW^{im2} & \text{ ; } SW^{um1} = \beta_2(1 + \alpha) \text{ ; } \beta_1 \text{ ; } \alpha \text{ ; } \frac{1}{2}\alpha^2 \\
 SW^{im2} & \text{ ; } SW^{um2} = \beta_1 \text{ ; } 1 \text{ ; } \frac{1}{2}\alpha \\
 SW^{im2} & \text{ ; } SW^g = \beta_2 + \frac{1}{2} + \alpha \\
 SW^{um1} & \text{ ; } SW^g = \beta_1 + \alpha\beta_2 + \frac{1}{2} + 2\alpha + \frac{1}{2}\alpha^2 \\
 SW^{um2} & \text{ ; } SW^g = \beta_2 + \alpha\beta_1 + \frac{1}{2} + 2\alpha + \frac{1}{2}\alpha^2
 \end{aligned}$$



Figure 2 is derived from the following 21 relationships.

$$SW^{im1} = SW^{um1}$$

$$SW^{im2} = SW^{um2}$$

$$SW^{up} \text{ ; } SW^{ip} = \alpha \text{ ; } \beta_1 \text{ ; } \beta_2$$

$$SW^{up} \text{ ; } SW^{im1} = SW^{up} \text{ ; } SW^{um1} = \beta_2(1 \text{ ; } \alpha) \text{ ; } \alpha\beta_1 + \frac{1}{2} \text{ ; } \alpha(1 \text{ ; } \alpha)$$

$$SW^{up} \text{ ; } SW^{im2} = SW^{up} \text{ ; } SW^{um2} = \beta_1(1 \text{ ; } \alpha) \text{ ; } \alpha\beta_2 + \frac{1}{2} \text{ ; } \alpha(1 \text{ ; } \alpha)$$

$$SW^{up} \text{ ; } SW^g = (1 \text{ ; } \alpha) + \beta_1 + \beta_2$$

$$SW^{ip} \text{ ; } SW^{im1} = SW^{ip} \text{ ; } SW^{um1} = \frac{1}{2} \text{ ; } \alpha + \beta_2$$

$$SW^{ip} \text{ ; } SW^{im2} = SW^{ip} \text{ ; } SW^{um2} = \frac{1}{2} \text{ ; } \alpha + \beta_1$$

$$SW^{ip} \text{ ; } SW^g = \beta_1 + \beta_2 + 1 \text{ ; } 2\alpha$$

$$SW^{im1} \text{ ; } SW^{im2} = SW^{im1} \text{ ; } SW^{um2} = SW^{um1} \text{ ; } SW^{im2} = SW^{um1} \text{ ;}$$

$$SW^{um2} = \beta_1 \text{ ; } \beta_2$$

$$SW^{im1} \text{ ; } SW^g = SW^{um1} \text{ ; } SW^g = \frac{1}{2} \text{ ; } \alpha + \beta_1$$

$$SW^{im2} \text{ ; } SW^g = SW^{um2} \text{ ; } SW^g = \frac{1}{2} \text{ ; } \alpha + \beta_2$$

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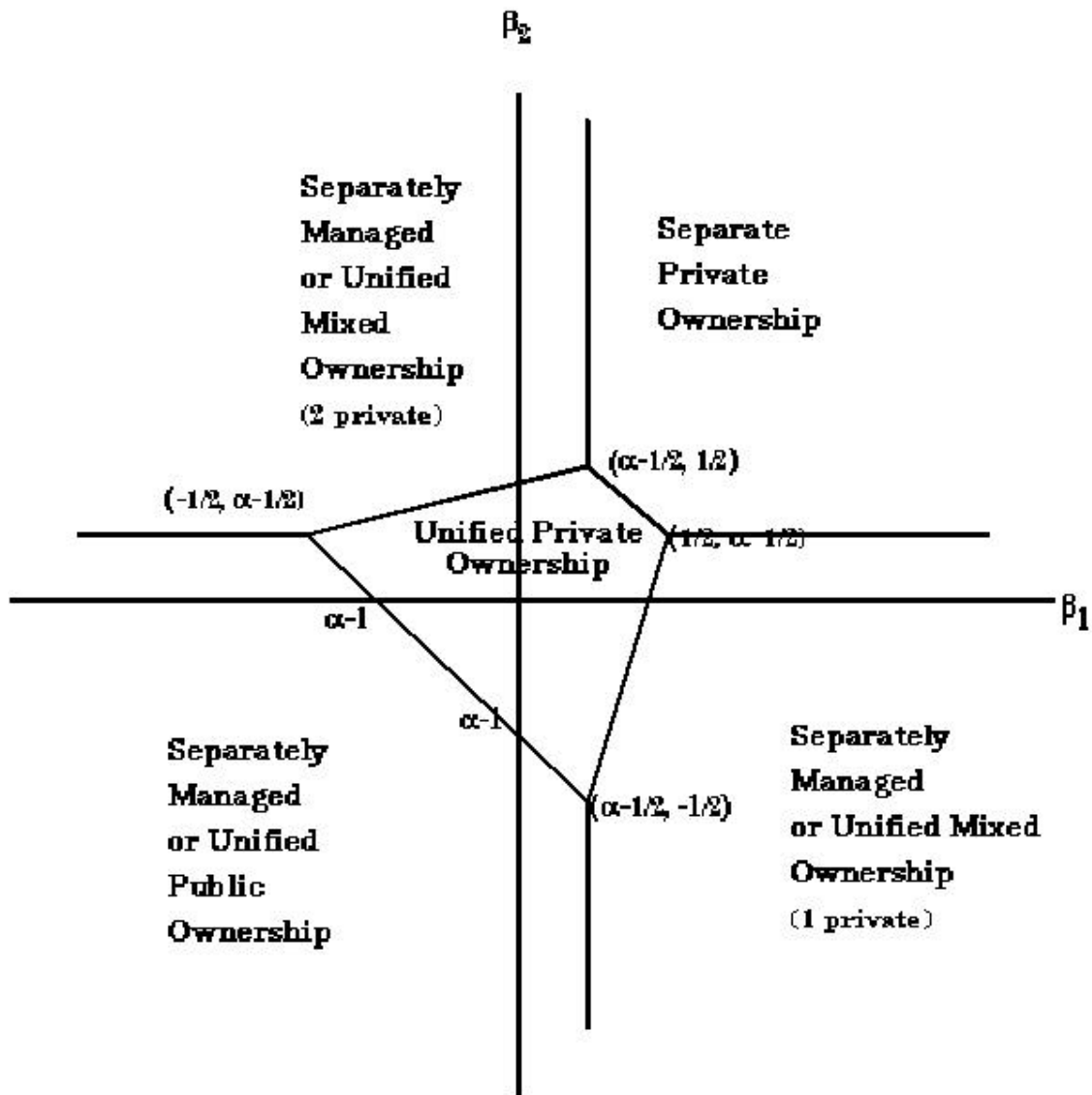


Figure 2

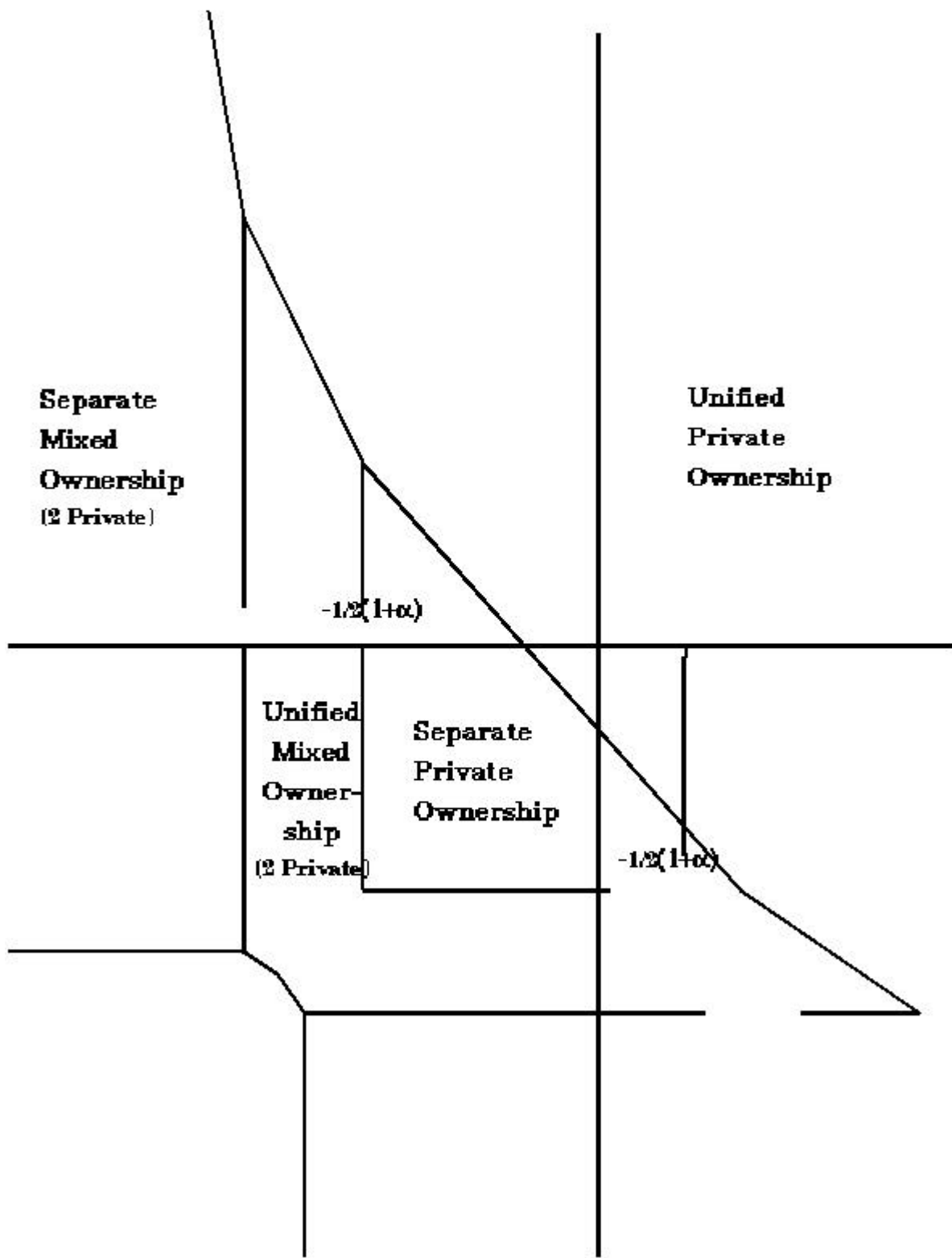


Table 1: Optimal Ownership

<b>Externality <sup>®</sup></b>	<b>Negative</b>		<b>Positive</b>	
<b>Commercially <sup>-</sup></b>	$0 > b^0 > b^1$		$0 < b^0 < b^1$	
<b>Productive</b>	<i>\$b</i> “strong”	<i>\$b</i> “weak”	<b>Private</b>	
$e^0 < e^1$	<b>Public</b>	<b>Private</b>		
$p^0 < p^1$				
<b>Unproductive</b>	<b>Private</b>		<i>\$b</i> “strong”	<i>\$b</i> “weak”
$e^0 > e^1$			<b>Public</b>	<b>Private</b>
$p^0 < p^1$				

Table 2: Ranking of Efforts Under Different Regimes

	Contributory		Conflicting	
	Weak	Strong	Weak	Strong
Productive	$c_j$	$c_j$	$d_j$	$d_j$
	$d_j$	$s_j$	$c_j$	$m$
	$s_j$	$d_j$	$m$	$c_j$
	$m$	$m$	$s_j$	$s_j$
Unproductive	$s_j$	$s_j$	$m$	$m$
	$m$	$c_j$	$s_j$	$d_j$
	$c_j$	$m$	$d_j$	$s_j$
	$d_j$	$d_j$	$c_j$	$c_j$

Tables 3: Effort Choice Under Different Regimes

Table 3A:

<b>Effort s</b>	<b>Independent Management</b>			
	<b>(i 0 0)</b>	<b>(i 1 0)</b>	<b>(i 0 1)</b>	<b>(i 1 1)</b>
<b><math>e_1</math></b>	<b>m</b>	<b>d<sub>1</sub></b>	<b>m</b>	<b>d<sub>1</sub></b>
<b><math>e_2</math></b>	<b>m</b>	<b>m</b>	<b>d<sub>2</sub></b>	<b>d<sub>2</sub></b>

Table 3B

<b>Unified Management</b>				
<b>Effort s</b>	<b>(u 0 0)</b>	<b>(u 1 0)</b>	<b>(u 0 1)</b>	<b>(u 1 1)</b>
<b><math>e_1</math></b>	<b>m</b>	<b>d<sub>1</sub></b>	<b>s<sub>1</sub></b>	<b>c<sub>1</sub></b>
<b><math>e_2</math></b>	<b>m</b>	<b>s<sub>2</sub></b>	<b>d<sub>2</sub></b>	<b>c<sub>2</sub></b>