Ideas and Innovations: Which should be subsidized?[1]

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Abstract

The Bayh-Dole Act allows universities to commercialize their research. University laboratories therefore have two sources of funds: direct grants from the government and funds from commercialization. In addition to giving direct subsidies to university laboratories, the government also subsidizes the commercial sector, for example, through tax credits. Subsidies to commerce contribute indirectly to the university's research budget, because they increase the profit from commercialization. This paper investigates the optimal mix of direct and indirect subsidies to the university, in a context where the role of university research is to turn up "ideas" for commercial investments, and the role of commerce is to turn the ideas into innovations. It also asks whether there is an argument for protecting "ideas" as well as commercializations, as is authorized by the Bayh-Dole Act.

JEL Classifications: O34, K00, L00

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1 Introduction

Public subsidies to R&D go both to private firms and to noncommercial laboratories, such as those in universities. About half of public subsidies in the U.S. go to commercial firms. These subsidies take many forms, from tax credits to competitively given grants, administered in a way that is similar to the university grant process.[1]

With the Bayh-Dole Act of 1980, university research became less dependent on grants, and more dependent on commercialization. In order for the university to profit from commercializations, the knowledge they create must be protectable. That is what the Bayh-Dole Act authorized. This raises two questions: First, what is the best way to subsidize research? Given that the university can profit indirectly from subsidies given to commerce, how should government subsidies be divided between subsidies to commerce and direct subsidies to universities? Second, is the premise of the Bayh-Dole Act welfare-improving? That is, should the knowledge turned up in universities be protectable?

The premise of this paper is that there are two distinct research activities: the activity of turning up ideas and the activity of turning the ideas into innovations. These are assumed to take place in two sectors, loosely called universities and firms. Universities (and other public laboratories) are mainly charged with producing "knowledge," interpreted here as a flow of ideas or investment opportunities. Firms commercialize the ideas. I thus follow O'Donoghue, Scotchmer and Thisse (1998), Scotchmer (1999), Erkal and Scotchmer (2007, 2009) in distinguishing between ideas for investment and the investments or innovations themselves. However, in the earlier papers, the idea generation process was taken as primitive. Here, similarly to Banal-Estañol and Macho-Stadler (2010), I conceive of idea generation as costly. This has the defect of obscuring what is primitive (apparently the meta-idea to invest in the idea-generation process), but maps rather closely to the institutions through which knowledge is created.

An important distinction at the heart of this investigation – and at the heart of any discussion of the Bayh-Dole Act – is whether the ideas produced in universities are pro-

[1] See Chapter 8 of my 2004 book, *Innovation and Incentives.*

tectable. Here, I distinguish between protectable ideas and protectable innovations. The "idea" is an investment opportunity, such as an idea for how to create a new product or an improvement to an old product, or to make a cost reduction in producing an old product. The idea becomes an innovation if a firm invests in implementing it. I assume that the implementation is patentable, but the idea might not be. I study this as a policy choice.

If the idea is protectable, then it can be auctioned exclusively to a commercializing firm, and the university will collect the profit. If the idea is not protectable, the university cannot auction the exclusive use of it. Because university researchers publish, the idea will enter the public domain, and there may be a patent race to commercialize it. The patent race will dissipate profit. Even though the commercial winner of the patent race will have a protected product, the firms in the patent race make zero profit in expectation, and the university gets nothing. Thus, if the Bayh-Dole Act serves the purpose of creating funds for university research, it is because the ideas it turns up are protectable. If ideas are not protectable, the university must depend entirely on direct subsidies for its research budget. If ideas are protectable, the university earns money by commercializing ideas under the Bayh-Dole Act.

The subsidy policies considered below have two parts: an investment tax credit for the commercial sector, and direct subsidies to universities. The objective is to study the optimal mix of these two subsidies in the two cases that ideas are protectable or not protectable.

This paper is built on the premise that all the profit earned by the university through commercialization, as well as the direct subsidies, are spent in research. More particularly, I assume that the university wants to maximize its research spending to the extent allowed by its budget. This seems like a natural assumption, and one that is descriptive. Universities probably want to maximize fame and visibility. Research serves that purpose.

However, since the university's objective is not social welfare, this raises a question about optimality. Is it possible that commercialization is so lucrative that the university spends too much, rather than too little, on generating ideas? The university wants to maximize research spending, whereas a social planner would want to maximize social welfare. When do these objectives conflict, given that the government controls much of the purse?

Section 2 presents a model of idea generation and commercialization. Section 3 characterizes the optimal subsidy policy when ideas are protectable. The main conclusions are that

- Direct subsidies to universities "prime the pump" in the sense that a subsidy increases university spending by more than the subsidy.
- Because universities maximize research rather than profit, they may overspend on research. Direct subsidies are only optimal if commercialization is not very profitable.
- If direct subsidies are not optimal and not provided, then tax credits for commercialization should be smaller than when direct subsidies are provided.

Section 4 recognizes that when ideas are protectable, idea generation could alternatively be provided by a profit-maximizing firm. Would that be better? Here I conclude

- A profit-maximizing firm will spend less on idea generation than is optimal, regardless of subsidies, and less than the research-maximizing university.
- Direct subsidies to a profit-maximizing firm crowd out its own private spending, whereas direct subsidies "prime the pump" in research-maximizing universities.

Finally, Section 5 studies the case that ideas are not protectable, and shows that

- Social welfare is higher if ideas are protectable under the Bayh-Dole Act than if not.

Section 6 concludes with a discussion of basic and applied research, how they have been studied in some of the economics literature, and how this model might relate to those concepts.

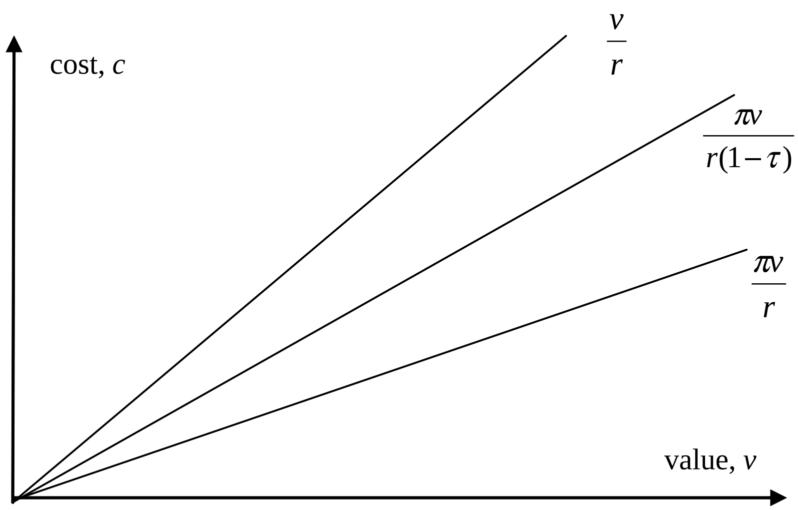

Figure 1: A tax credit τ increases the pool of ideas that are commercialized.

2 A model

There are two types of research: university research that produces a stream of ideas for commercial investments, and the commercial investments themselves. Universities and firms have different objectives. The objective of universities is to maximize their research output (the number of ideas generated). The objective of firms is to maximize profit.

Following Scotchmer (1999), ideas are drawn from a distribution F, with density f, where $f(v,c)$ is the density of ideas with per-period social value v and development cost c. Figure 1 shows a space of "ideas" (v,c), with cost on the vertical axis and per-period social value v on the horizontal axis. The value v is the per-period social value if the good is supplied competitively, with total discounted value v/r. We suppose that a proprietary supplier could collect a fraction $\pi < 1$ of this value, that is, $\pi v/r$.

In figure 1, if tax credits are not provided, only the ideas (v,c) under the line $\pi v/r$ will be developed. Suppose, however, the government gives a tax credit, so that the developer only bears a fraction of the cost.

The main purpose of the tax credit is to overcome a problem of appropriability, to increase the probability that an idea will be commercialized. As we will see, the tax credit has an additional effect as well. It increases the profit on inframarginal ideas that would be commercialized even without the tax credit, and feeds back into university research.

With a tax credit $\tau \in [0,1)$, an idea (v,c) is profitable when

$$\begin{aligned} \frac{\pi v}{r} - (1-\tau)\, c &\geq 0 \\ \frac{\pi v}{r\,(1-\tau)} - c &\geq 0 \end{aligned} \tag{1}$$

This raises the threshold line in figure 1, and adds ideas to the development pool.

If the tax credit satisfies $(1-\tau) = \pi$, then all ideas with cost below the v/r threshold will be developed. However, such a high subsidy is usually not optimal. Aside from the deadweight loss that reduces social value, critics of government spending usually suppose that subsidies lead to waste. For example, the tax credit may be used for expenditures that are not related to an R&D project. Accordingly, I shall assume that for every project that is subsidized at rate τ, there is a waste $K(\tau)$, where K is convex, increasing, and $K(0) = K'(0) = 0$. I assume that the waste is not a pure transfer, but rather that at least part of it is social waste due to inefficient actions.

Write $P(\tau)$ for the probability that an idea is commercialized and $\Pi(\tau)$ for the average profitability of ideas, taking account of the fact that an idea might not be commercialized. Write $\epsilon(\tau)$ for the average social value of an idea. Then

probability of commercialization	$P(\tau) \equiv \int_{\left\{(v,c):c\leq\frac{\pi v}{r(1-\tau)}\right\}} dF(c,v)$
expected profit of ideas	$\Pi(\tau) \equiv \int_{\left\{(v,c):c\leq\frac{\pi v}{r(1-\tau)}\right\}} \left[\frac{\pi v}{r} - (1-\tau)\,c\right] dF(c,v)$
expected social value of ideas	$\epsilon(\tau) \equiv \int_{\left\{(v,c):c\leq\frac{\pi v}{r(1-\tau)}\right\}} \left[\frac{v}{r}(1-d) - c - K(\tau)\right] dF(c,v)$

where $d \in (0,1)$ is the fraction of social value that is deadweight loss.

The functions P and Π are increasing. A higher tax credit increases the probability of commercialization by reducing the private cost, and increases the commercializers' private profit on inframarginal ideas. The expected profitability of an idea is positive because the inframarginal ideas (below the line marked $\frac{\pi v}{r(1-\tau)}$ in figure 1) are profitable.

I assume that the university's research program turns up ideas for commercial investment at a Poisson rate $\theta(x)$, where x is the flow rate of spending on generating ideas. Because ideas are generated at the rate $\theta(x)$ per period, and each idea yields expected social value $\epsilon(\tau)$, the flow of social value created is $\theta(x)\epsilon(\tau)dt$ and the flow of costs is xdt. Thus, social welfare can be written as the following function of (x,τ):

$$\text{social welfare} \qquad W(x,\tau) \equiv \frac{1}{r}\left[\epsilon(\tau)\theta(x) - x\right] \tag{2}$$

Let (x^*,τ^*) be the maximizers of (2). Thus, τ^* is the maximizer of $\epsilon(\tau)$, and (x^*,τ^*) satisfies

$$\epsilon(\tau^*)\theta'(x^*) - 1 = 0 \tag{3}$$

The optimum cannot be achieved directly because spending is not directly under the control of the social planner. The planner's tool to encourage efficient spending is a *subsidy policy,* namely, a pair (s,τ), where s is a direct subsidy to the university or other institution that invests in generating ideas, and τ is a tax credit to the commercial sector.

3 Optimal subsidies (s,τ) when ideas are protectable

I assume that universities invest in ideas, and that universities want to maximize research, but cannot run a budgetary deficit. All their funds come either from government grants or from commercialization. (In section 4, I compare with the case that the objective is to maximize profit instead of research.)

Let b represent the university's contribution to the flow of research expenditures. These funds are generated internally by commercializing the ideas turned up in the university's research program. Adding the direct subsidy, total research spending is $s+b$.

The spending $s+b$ generates a hit rate $\theta(b+s)$ of ideas, and each idea returns an expected profit $\Pi(\tau)$. The university's net expected revenue at each point in time is $[\Pi(\tau)\theta(b+s) - b]dt$. With discounting, the university's budgetary surplus is (4).

$$S(b,s,\tau) \equiv \frac{1}{r}\left[\Pi(\tau)\theta(b+s) - b\right] \tag{4}$$

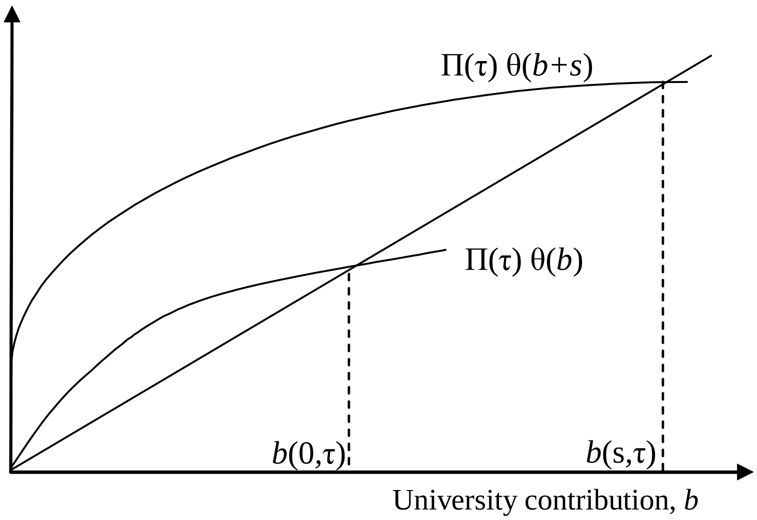

Figure 2: Direct subsidies prime the pump for university spending

Write $\hat{b}(s,\tau)$ for the university's maximum feasible expenditure, namely, the maximum value of b that satisfies $S(b,s,\tau)=0$, in particular,

$$\theta\left(\hat{b}(s,\tau)+s\right)\Pi(\tau)-\hat{b}(s,\tau)=0 \tag{5}$$

The following assumption implies that (5) has a unique solution except when $s=0$, and then $\hat{b}(0,\tau)$ is the positive solution rather than $b=0$.

Assumption 1: θ is a concave, increasing function such that $\theta(0)=0$ and

$$\lim_{x\to 0}\theta'(x)=\infty$$
$$\lim_{x\to\infty}\frac{\theta(x)}{x}=0$$

Assumption 1 ensures that some portion of the function $\Pi(\tau)\theta(b+s)$ lies above the diagonal in figure 2, for every $(s,\tau)\geq 0$. It also ensures that eventually $\Pi(\tau)\theta(b+s)$ crosses the diagonal. (It is a stronger assumption than needed.)

Now consider the optimal subsidies (s,τ). The optimal tax credit is described in Proposition 1.

Proposition 1 [Positive subsidy to commercialization] *The tax credit* τ^* *that maximizes the social value of ideas,* $\epsilon(\tau)$*, satisfies* $\tau^* \in (0, (1-\pi))$.

Proof: That $\tau^* > 0$ follows from

$$
\begin{aligned}
&\epsilon'(\tau) \\
= \quad & -K'(\tau) P(\tau) + \int_0^\infty \left[\frac{v}{r}\left(1 - d - \frac{\pi}{(1-\tau)}\right) - K(\tau)\right] f\left(\frac{\pi v}{r(1-\tau)}, v\right) \frac{\pi v}{r(1-\tau)^2} dv
\end{aligned}
$$

Since $K'(0) = 0$, it follows that $\epsilon'(0) > 0$. It must hold that $\tau^* < (1-\pi)$ because otherwise some of the the integrand in the definition of $\epsilon(\cdot)$ is negative and $\epsilon'(\tau) < 0$. ■

Moving from a subsidy rate of $\tau = 0$ to a positive subsidy rate, there is a benefit from increasing the probability that an idea is commercialized, but only negligible waste. As the subsidy approaches the level $\tau = 1 - \pi$, the marginal ideas that enter the development pool provide negative social value, both because of deadweight loss and because the subsidy entails a waste K.

Now consider direct subsidies to the university, s.

Figure 2 shows the university's spending when the direct subsidy is 0 and when the direct subsidy is $s > 0$, namely $\hat{b}(0, \tau)$ and $\hat{b}(s, \tau)$. $\hat{b}(0, \tau)$ is described by the intersection of the curve $\Pi(\tau)\theta(b)$ with the diagonal, and similarly for $\hat{b}(s, \tau)$. Assumption 1 ensures that the intersection in each case is at a positive level of spending.

Figure 2 shows that an increase in s or in τ will raise the curve and cause university spending to increase. This answers the question whether subsidies crowd out university spending or increase it. Instead of crowding out, public subsidies "prime the pump." They have both a direct effect and indirect effect on idea generation. The indirect effect is that the direct subsidy leads to profitable ideas that feed more money into the university's budget, allowing the university to increase its spending on research even more.

Proposition 2 [Priming the Pump with Direct Subsidies] *An increase in the direct subsidy to the university will cause total spending on research to increase by more than the subsidy.*

$$
\frac{\partial}{\partial s}\left[\hat{b}(s, \tau) + s\right] > 1
$$

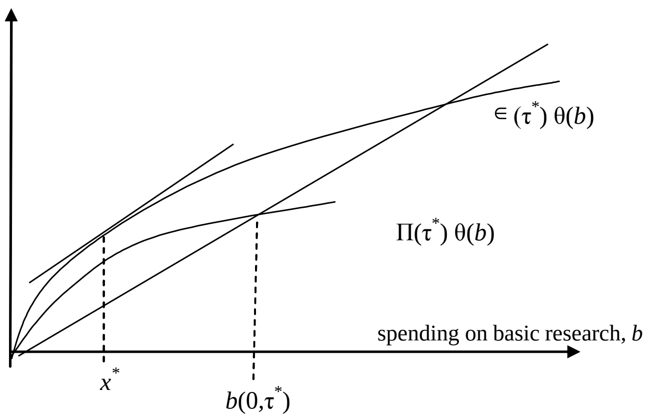

Figure 3: Universities might overspend on generating ideas

Proof: Differentiating (5) implicitly,

$$\frac{\partial}{\partial s}\hat{b}\left(s,\tau\right)=\frac{\Pi\left(\tau\right)\theta'\left(\hat{b}\left(s,\tau\right)+s\right)}{1-\Pi\left(\tau\right)\theta'\left(\hat{b}\left(s,\tau\right)+s\right)}$$

Using assumption 1, $\theta'\left(\hat{b}\left(s,\tau\right)+s\right)\Pi\left(\tau\right)$ is less than one (see figure 2). □

The government's objective is to set a subsidy policy that achieves the (x^*,τ^*) that maximizes (2). As already described, τ^* maximizes $\epsilon\left(\tau\right)$, and x^* satisfies (3).

However, it might or might not be possible to achieve the optimum (x^*,τ^*). If it is possible, the optimal subsidy policy (s,τ^*) satisfies

$$s+\hat{b}\left(s,\tau^*\right)=x^* \tag{7}$$

Figure 3 shows why it might not be possible to achieve the optimum. In figure 3, social welfare is $1/r$ times the difference between the curve $\epsilon\left(\tau\right)\theta\left(b\right)$ and the diagonal line b. The optimal level of university spending is shown as the value x^* that satisfies (3). The university's budgetary surplus is $1/r$ times the difference between $\Pi\left(\tau^*\right)\theta\left(b\right)$ and the diagonal line b. In figure 3, when the direct subsidy is $s=0$, the university spends $\hat{b}\left(0,\tau^*\right)$, shown where $\Pi\left(\tau^*\right)\theta\left(b\right)$ intersects the diagonal. In figure 3, $\hat{b}\left(0,\tau^*\right)>x^*$. Even without direct subsidies, commercialization is so profitable that the university overspends on basic research. This problem is clearly worse when commercialization is very lucrative, that is, $\Pi(\tau^*)$ is large.

The government cannot remedy the overspending by cutting back on direct subsidies, because it is not making such subsidies. Proposition 3(c) says that the sponsor can mitigate the problem by cutting back on tax credits. This reduces the profitability of turning up ideas, and reduces the resources that are fed back into the university's research budget, but the commercialization of ideas is no longer optimal.

Proposition 3 [Optimal direct subsidies] *There exists* $\bar{\Pi} < \epsilon(\tau^*)$ *such that*

(a) *If* $\Pi(\tau^*) = \bar{\Pi}$*, the optimal subsidy policy is* $(0, \tau^*)$*.*

(b) *If* $\Pi(\tau^*) < \bar{\Pi}$*, the optimal subsidy policy is* $(s, \tau^*) > 0$ *such that* $\hat{b}(s, \tau) + s = x^*$*.*

(c) *If* $\Pi(\tau^*) > \bar{\Pi}$*, the optimal subsidy policy is* $(0, \tau)$*, where* $0 < \tau < \tau^*$*.*

Proof: (a) With x^* defined by (3), define $\bar{\Pi}$ such that $x^* = \theta(x^*)\bar{\Pi}$. Then using (5), if $\Pi(\tau^*) = \bar{\Pi}$, $\hat{b}(0, \tau^*) = x^*$, so the optimal subsidy to the university is $s = 0$ and $s + \hat{b}(0, \tau^*) = \hat{b}(0, \tau^*) = x^*$.

(b) When $\Pi(\tau^*) < \bar{\Pi}$, again using (5), $\hat{b}(0, \tau^*) < x^*$, so there is a subsidy $s > 0$ such that $\hat{b}(s, \tau^*) + s = x^*$.

(c) When $\Pi(\tau^*) > \bar{\Pi}$, again using (5), $\hat{b}(0, \tau^*) > x^*$, that is, universities overspend. The following shows that reducing τ increases social welfare. Ideas become less lucrative, so less money is poured into the generation of ideas.

Write social welfare (2) as

$$\hat{W}(s, \tau) \equiv \frac{1}{r}\left[\epsilon(\tau)\theta\left(s + \hat{b}(s, \tau)\right) - \left(s + \hat{b}(s, \tau)\right)\right] \tag{8}$$

Differentiating at $(s, \tau) = (0, \tau)$

$$\begin{aligned} r\frac{\partial}{\partial \tau}\hat{W}(0, \tau) &= \\ \frac{\partial}{\partial \tau}\left[\epsilon(\tau)\theta\left(\hat{b}(0, \tau)\right) - \hat{b}(0, \tau)\right] &= \epsilon'(\tau)\theta\left(\hat{b}(0, \tau)\right) + \left[\epsilon(\tau)\theta'\left(\hat{b}(0, \tau)\right) - 1\right]\frac{\partial}{\partial \tau}\hat{b}(0, \tau) \end{aligned} \tag{9}$$

Using (5)

$$\frac{\partial}{\partial \tau}\hat{b}(0,\tau) = \frac{\theta\left(\hat{b}(0,\tau)\right)\Pi'(\tau)}{1-\theta'\left(\hat{b}(0,\tau)\right)\Pi(\tau)}$$

Because $\Pi'(\tau) > 0$ and $1-\theta'\left(\hat{b}(0,\tau)\right)\Pi(\tau) > 0$ (see figure 2), $\frac{\partial}{\partial \tau}\hat{b}(0,\tau) > 0$. Because τ^* maximizes $\epsilon(\tau)$, $\epsilon'(\tau^*) = 0$. And because $\hat{b}(0,\tau) > x^*$ and θ' is decreasing, $\epsilon(\tau)\theta'\left(\hat{b}(0,\tau)\right) - 1 < 0 = \epsilon(\tau)\theta'(x^*) - 1$. Thus, evaluated at τ^*, the derivative of social welfare (8) is negative. This implies that a social improvement can be made by reducing τ from τ^*, maintaining $s = 0$.

Further, if the optimal policy (s,τ) entails $\tau < \tau^*$, then $s = 0$. The derivative of social welfare (8) with respect to s is

$$\begin{aligned} r\frac{\partial}{\partial \tau}\hat{W}(s,\tau) &= \\ \frac{\partial}{\partial s}\left[\epsilon(\tau)\theta\left(s+\hat{b}(s,\tau)\right) - \left(s+\hat{b}(s,\tau)\right)\right] &= \left[\epsilon(\tau)\theta'\left(s+\hat{b}(s,\tau)\right)-1\right]\frac{\partial}{\partial s}\left(s+\hat{b}(s,\tau)\right) \end{aligned}$$

If $s > 0$, then at an optimum, this derivative must be zero, implying

$$\epsilon(\tau)\theta'\left(s+\hat{b}(s,\tau)\right) - 1 = 0 \tag{10}$$

In addition, at an optimum no improvement can be made by increasing τ. The derivative of social welfare with respect to τ is

$$\begin{aligned} \frac{\partial}{\partial \tau}\left[\epsilon(\tau)\theta\left(s+\hat{b}(s,\tau)\right) - \left(s+\hat{b}(s,\tau)\right)\right] &= \epsilon'(\tau)\theta\left(s+\hat{b}(s,\tau)\right) \\ &\quad + \left[\epsilon(\tau)\theta'\left(s+\hat{b}(s,\tau)\right)-1\right]\frac{\partial}{\partial \tau}\left(s+\hat{b}(s,\tau)\right) \end{aligned}$$

The second line is zero from (10), and if $\tau < \tau^*$, $\epsilon'(\tau) > 0$. Therefore an improvement can be made by increasing τ, which contradicts that (s,τ) is optimal.

Thus, if (s,τ) is optimal and $\tau < \tau^*$, $s = 0$. □

Corollary 1 [Optimal mix of subsidies] *It is never optimal to subsidize the university directly without subsidizing the commercialization of ideas, but it might be optimal to subsidize the commercialization of ideas without giving direct subsidies to the university.*

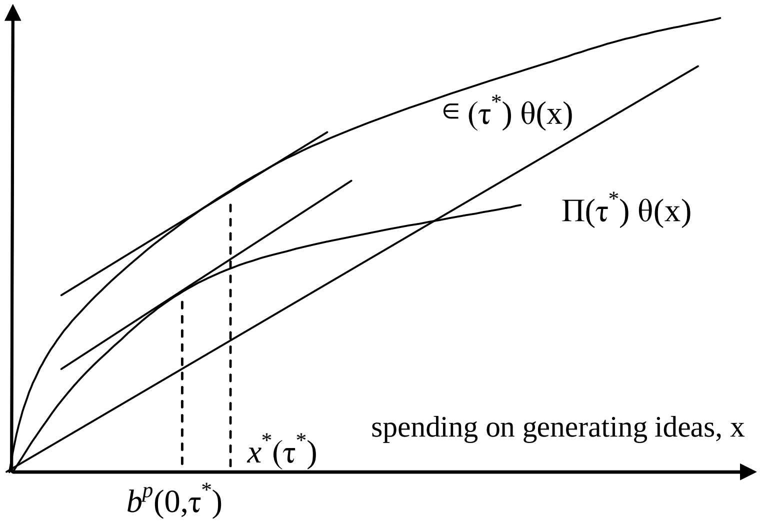

Figure 4: A profit-maximizing firm would underinvest in generating ideas

Tax subsidies to the commercial sector are the best way to create subsidies for the university's research agenda, up to τ^*. The tax credit should be τ^* unless the university is then overfunded, in which case the tax credit should be reduced. On the other hand, if τ^* underfunds the university, then direct subsidies should be provided as well.

4 Idea Generation as a Commercial Enterprise

An implication of the above analysis is that idea generation can be profitable even without direct subsidies. If so, private firms should be willing to invest in the generation of ideas as well as in commercialization. Indeed, large established firms maintain research divisions that operate like university laboratories. Their researchers are given free rein to pursue their interests, in the expectation that they will spin out commercially valuable ideas.

This section points to some defects of depending on the private market for idea generation.

In figure 4, social welfare is $1/r$ times the distance between the curve labeled $\epsilon(\tau^*)\,\theta(x)$ and the diagonal. The socially optimal level of spending is $x^*(\tau^*)$.

If the firm receives a direct subsidy s, its profit as a function of (s, τ) is given by

$$\frac{1}{r}\left[\Pi(\tau)\,\theta(s+b)-b\right]$$

Let $b^p(s,\tau)$ be the firm's most profitable level of spending, which satisfies

$$\Pi(\tau)\,\theta'\left(s+b^p(s,\tau)\right)-1=0 \tag{11}$$

In figure 4, when there is no direct subsidy to the firm $(s=0)$, private profit from the idea-generation process is $1/r$ times the distance between the curve labeled $\Pi(\tau)\,\theta(x)$ and the diagonal. If $\Pi(\tau)<\epsilon(\tau)$ as shown,[2] then $b^p(0,\tau)$, is smaller than the socially optimal level of spending, $x^*(\tau)$. This is true for every τ, not just the optimal τ^*. Thus, although the private sector will find it profitable to invest in a costly process of generating ideas, its spending will be less than optimal, provided $\Pi(\tau)<\epsilon(\tau)$.

If a direct subsidy $s>0$ is provided, it directly crowds out private spending. It is immediate from the firm's profit-maximizing condition (11) that $s+b^p(s,\tau)$ is constant, namely, $s+b^p(s,\tau)=b^p(0,\tau)$ for every $s\leq b^p(0,\tau)$. If the direct subsidy is greater than $b^p(0,\tau)$, the firm will not contribute private funds at all, and will pocket the difference between s and $b^p(0,\tau)$. The government cannot overcome the profit-maximizing firm's reluctance to spend by making larger direct subsidies

Proposition 4 [Underspending by profit-maximizing firms] *If idea generation takes place in a profit-maximizing firm, then for any* (s,τ), *the total spending on idea generation (the sum of the subsidy and the firm's contribution) will be equal to* $b^p(0,\tau)$, *which is smaller than the optimal level of spending. For* $s\in[0,b^p(0,\tau)]$, *an increase in the direct subsidy, s, crowds out private spending one-for-one, and if* $s>b^p(0,\tau^*)$, *the difference* $s-b^p(0,\tau)$ *is pocketed by the firm.*

Proposition 4 contrasts with Proposition 2, which shows that because universities maximize research rather than profit, an increase in the subsidy causes their own contribution to

[2] Proprietary profit is generally smaller than social value because it excludes consumers' surplus. In this case, it is possible that proprietary profit is larger than social value because of the social waste K of providing tax subsidies. K is a social cost, but not a private cost.

increase rather than decrease. For research-maximizing universities, direct subsidies prime the pump, whereas for profit-making firms, direct subsidies crowd out private spending.[3]

5 Optimal Subsidies (s, τ) when Ideas are not Protectable

Now suppose that ideas go into the public domain instead of being protected. There is a long standing theory, originating with Nelson (1959) and Arrow (1962) that because R&D produces knowledge, and because knowledge is a public good, it should be produced with public funds and made freely available. Although that theory was rejected by the Bayh-Dole Act, it is still persuasive. I now investigate whether social welfare would be higher in this model by embracing it. The answer turns out to be no.

If ideas are made freely available, the tax credit should be smaller than τ^*, in order to reduce the profitability of ideas, and to discourage patent races. Patent races are inefficient in this model because they entail duplicated costs. When ideas are protectable, patent races are avoided by auctioning exclusive licenses. When ideas are in the public domain, patent races cannot be controlled except by modifying the size of the reward. The tax subsidy is the available instrument to do this, but reducing the tax credit has the deleterious effect of eliminating some marginal ideas from the pool of commercialized ideas.

When ideas are not protectable, social welfare is given by the following, where $\Pi(\tau)$ is subtracted from social welfare because firms in a race will dissipate the entire profit. This is a waste of resources in expected amount $\Pi(\tau)$.

$$W^u(s, \tau) = \frac{1}{r}\left[\theta(s)\left(\epsilon(\tau) - \Pi(\tau)\right) - s\right]$$

With the profit subtracted from social welfare, social welfare is only the consumers' surplus provided by innovations, less the social waste of providing the tax credit.

[3] This analysis assumes that the private firm is a monopolist. The problem of competition will be left for another paper. A modeling choice that must be made to study this problem is whether, when there are two firms, the arrival rates of ideas are, for example, $\theta(x_1 + x_2)\frac{x_1}{(x_1+x_2)}$ and $\theta(x_1 + x_2)\frac{x_2}{(x_1+x_2)}$, or $\theta(x_1)$ and $\theta(x_2)$.

Let the optimizers be $(\hat{s}, \hat{\tau})$. These satisfy

$$\theta'(\hat{s})\left(\epsilon(\hat{\tau}) - \Pi(\hat{\tau})\right) - 1 = 0 \tag{12a}$$

$$\epsilon'(\hat{\tau}) - \Pi'(\hat{\tau}) = 0 \tag{12b}$$

Proposition 5 [Ideas should be protected.] *The optimal tax credit and the optimal spending on idea generation are lower when ideas are not protectable than when protectable. This leads to a lower rate of idea generation and fewer commercialized ideas. If it is optimal to make direct subsidies in both regimes, optimized social welfare is higher when ideas are protectable than when not protectable.*

Proof: Let (s^*, τ^*) be the optimal subsidies when ideas are protectable and let $(\hat{s}, \hat{\tau})$ be the optimal subsidies when ideas are not protectable. Since τ^* maximizes ϵ, the first order condition (12b) implies that $\hat{\tau} < \tau^*$. This implies that a smaller fraction of ideas are commercialized when ideas are not protectable (see figure 1). That $s^* + \hat{b}(s^*, \tau^*) > \hat{s}$ follows from comparing (3) with (12a), using concavity of θ together with $\left(\epsilon(\hat{\tau}) - \Pi(\hat{\tau})\right) < \epsilon(\tau^*)$ and $s^* + \hat{b}(s^*, \tau^*) = x^*(\tau^*)$.

Social welfare is higher when ideas are protectable because

$$W(x^*, \tau^*) = W\left(s^* + \hat{b}(s^*, \tau^*), \tau^*\right) \geq W\left(\hat{s} + \hat{b}(\hat{s}, \hat{\tau}), \hat{\tau}\right) > W^u(\hat{s}, \hat{\tau})$$

■

Proposition 5 is not an unqualified statement that society is better off with patent protection. It only says that, when commercializations are patentable, society might be better off making the ideas patentable as well. Due to patents on the commercialized products, there will be deadweight loss whether or not ideas are patentable. The important consequence of protection on the idea itself is that protection allows a proprietor to control the development process. This conclusion resonates with an idea of Kitch (1977), who argued that patents at an early stage are socially valuable because they give the rightsholder an incentive to "prospect" for uses of the protected intellectual property. Prospecting and control rights are not exactly the same. Here, there is no need for prospecting – the idea for a commercial development is turned up in the university's research.

I argue in chapter 5 of my (2004) book that private optimality in exercising control rights can diverge from social optimality if there are social benefits to patent races or other forms of competition that the initial patent holder would control. In this model, patent races are unequivocally wasteful, and there is no conflict between the privately optimal way to develop ideas and the socially optimal way to develop ideas.

6 Conclusion: Some reflections on basic and applied research

It is tempting to think of idea generation in universities as "basic" research, and to think of commercialization as "applied" research. However, there are no agreed-upon definitions of those terms. Basic research is often understood as research with no commercial value which lays a foundation for commercial products. It is a short leap to the conclusion that basic research, having no commercial value, must be subsidized, and therefore must take place in universities or public laboratories with grant support.

On closer inspection, the profit distinction between basic and applied research is shaky. When a laboratory finds a drug target (but not the drug), is that basic research? If the drug target is patentable, it has commercial value. The commercial value is not intrinsic to the technology, but rather to the legal rule. Similarly, ideas in the above model have commercial value if they are protected, but not otherwise. Whether an idea has commercial value depends on the legal rule, not on the nature of the technology.

As emphasized by Aghion, Dewatripont and Stein (2008), there is no point in getting bogged down in definitions to no purpose. Instead of trying to squeeze into the language of basic and applied research, it is better to focus on the incentives of the researchers, and how their incentives are different in the academy and in firms. Aghion, Dewatripont and Stein model universities and firms as giving different control to the researcher over her own agenda, and argue that the optimal locus of control is different for upstream and downstream research. Jenson et al (2010) focus on the symbiotic relationship between firms and academic researchers, with the firms leveraging the university and its public funding, and academics leveraging the opportunities provided by firms. Maurer and Scotchmer (2004) show how the symbiotic relationship can channel subsidies to firms while controlling opportunistic waste. Stern (2004) illuminates the value that academic researchers place on academic openness by documenting the pay cuts they accept in order to work in the academy. Banal-Español and Macho-Stadler (2010) focus on how the researcher is induced to choose between investing in idea generation and investing in commercialization, depending on the relative rewards.

The model in this paper is focussed on institutional incentives rather than on the incentives of the individual researcher. The key assumption is that the university wants to maximize research rather than profit. This leads to the conclusion that the university might spend more on research than is socially optimal, particularly when commercialization is extremely profitable. In the hands of a profit-maximizing firm, the spending on idea generation might be unfixably low.

The aspiration of the Bayh-Dole Act is to protect university-generated knowledge so that the knowledge can be licensed for profit. This aspiration conflicts with a basic economic principle, namely, that it is inefficient to exclude anyone from using a public good such as knowledge (or an idea). However, the model above gives a foundation for why the Bayh-Dole Act might make sense, despite the more traditional view. Free access to ideas leads to inefficient patent races which can be avoided through licensing. At the same time, this defense of the Bayh-Dole Act is based on another second-best arrangement, namely, that the commercialized products are themselves protected.

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$$\begin{bmatrix} \Pi\left(\tau^*\right)\theta'\left(\cdot\right)\lambda - 1 & \Pi\left(\tau^*\right)\theta'\left(\cdot\right)\lambda \\ \lambda^2\epsilon\left(\tau^*\right)\theta^{''}\left(\cdot\right) & \lambda^2\epsilon\left(\tau^*\right)\theta^{''}\left(\cdot\right) \end{bmatrix} \begin{bmatrix} d\hat{b} \\ ds \end{bmatrix} = \begin{bmatrix} -\Pi\left(\tau^*\right)\theta'\left(\cdot\right)\left(s_\lambda + \hat{b}\left(s_\lambda, b, \lambda\right)\right) \\ -\epsilon\left(\tau^*\right)\lambda\theta^{''}\left(\cdot\right)\left(s_\lambda + \hat{b}\left(s_\lambda, b, \lambda\right)\right) - \epsilon\left(\tau^*\right)\theta^{'}\left(\cdot\right) \end{bmatrix} d\lambda$$

$$\begin{bmatrix} d\hat{b} \\ ds \end{bmatrix} = \frac{1}{-\lambda^2\epsilon(\tau^*)\theta^{''}(\cdot)} \begin{bmatrix} \lambda^2\epsilon\left(\tau^*\right)\theta^{''}\left(\cdot\right) & -\Pi\left(\tau^*\right)\theta'\left(\cdot\right)\lambda \\ -\lambda^2\epsilon\left(\tau^*\right)\theta^{''}\left(\cdot\right) & \Pi\left(\tau^*\right)\theta'\left(\cdot\right)\lambda - 1 \end{bmatrix} \begin{bmatrix} -\Pi\left(\tau^*\right)\theta'\left(\cdot\right)\left(s_\lambda + \hat{b}\left(s_\lambda, b, \lambda\right)\right) \\ -\epsilon\left(\tau^*\right)\lambda\theta^{''}\left(\cdot\right)\left(s_\lambda + \hat{b}\left(s_\lambda, b, \lambda\right)\right) - \epsilon\left(\tau^*\right)\theta^{'}\left(\cdot\right. \end{bmatrix}$$

$$\begin{bmatrix} \frac{d\hat{b}}{d\lambda} \\ \frac{ds}{d\lambda} \end{bmatrix} = \begin{bmatrix} \frac{\Pi(\tau^*)\theta'^{\left(s_\lambda + \hat{b}(s_\lambda, b, \lambda)\right)2}}{-\lambda\theta^{''}\left(s_\lambda + \hat{b}(s_\lambda, b, \lambda)\right)} \\ -\frac{\Pi(\tau^*)\theta'(\cdot)^2}{-\lambda\theta^{''}(\cdot)} \\ \frac{\lambda\left(s_\lambda + \hat{b}(s_\lambda, b, \lambda)\right)\theta^{''}(\cdot) + \theta^{'}(\cdot)}{-\lambda^2\theta^{''}(\cdot)} \end{bmatrix}$$