

# Social Insurance and the Design of Innovation Incentives\*

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March 17, 2004

## Abstract

We consider the insurance aspects of research policy. Patents or rewards have an advantage over research subsidies when a new invention replaces an existing good at lower cost. Research subsidies have an advantage when inventions spawn an entirely new product.

*JEL Classification:* D0, D6, O3

*Keywords:* research policy, technological change, patents, research contracts

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\*This work was conducted in RAND Health's global health research program in the Center for Domestic and International Health Security as the result of a private donor's generous gift.

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# 1 Introduction

Governments and societies have two primary means of encouraging innovations: patents or prizes awarded to inventors in the event of discovery, and subsidies for research and development. Put differently, it is possible to make “contingent” payments to successful inventors, or “uncontingent” payments to a researcher still working on an invention.

Economists have long emphasized that the choice among research contracts, cash prizes and patents depends on the degree of agency problems, uncertainty about the social value of potential inventions and the deadweight loss from monopoly pricing (cf, Wright, 1983; Kremer, 2000; Shavell and Ypersele, 1999). However, prior research has so far overlooked an important feature of research policy—its function as social insurance, or as a transfer of wealth between the invention state and the no-invention state. The impact of these transfers depends on the relationship between invention and the marginal utility of wealth.

Some inventions are primarily designed to replace old products—a process known as “creative destruction” (cf, Schumpeter, 1947; Lichtenberg and Philipson, 2002; Gans and Stern, 2000). Such inventions lower the price of existing goods. For example, engineering a tastier but no more expensive apple would make “quality-adjusted apples” cheaper. Since the consumer is poorer in the no-invention state than in the invention state, transferring resources from the invention to the no-invention state improves welfare. This is a beneficial side effect of patents or cash rewards that compensate

inventors only in the event of a discovery; this can make rewards optimal even in the absence of any agency costs.

Conversely, some inventions may raise the marginal utility of wealth. Inventions of this type can be called “product-spawning,” in the sense that they establish brand new products that may enhance the marginal utility of existing products, but do not supplant older, more expensive versions of the same thing. For example, the introduction of spices to the Old World did not so much make existing foodstuffs cheaper as establish a brand new product that enhanced their value. These product-spawning inventions call for transfers of resources to the invention state. Society can effect these transfers by employing uncontingent research subsidies, payable to inventors before a discovery and regardless of whether research efforts are successful. Even with extreme agency costs, research contracts can be beneficial.

## 2 Invention as a Wealth Effect

Our first polar case of invention is a “product-spawning” invention. Suppose the consumer buys  $n$  units of the new good (if available) and  $c$  units of an existing composite consumption good, where  $c$  and  $n$  are complements in the utility function such that  $U_{cn} > 0$ .  $M$  is the consumer’s income, and the relative price of the new product is  $q$ . Prior to the invention, the marginal utility of income is:  $V_M^0(M) \equiv U_c(M, 0)$ . After the invention, this becomes  $V_M^I(M) \equiv U_c(M - qn, n)$ . Complementarity and diminishing returns to consumption guarantee that  $V_M^I > V_M^0$ : invention raises the marginal utility

of wealth.

Now consider “creative destruction.” The price reduction makes the consumer richer and lowers the marginal utility of wealth. Suppose that  $c$  and  $n$  are perfect substitutes, but that  $n$  is cheaper:  $c$  costs  $q_0$  units (of, say, labor), while  $n$  costs  $q_I < q_0$  units. Before the invention, utility is  $u(\frac{M}{q_0})$ , where  $u(\cdot)$  denotes the utility obtained from the underlying service provided by both  $c$  and  $n$ . After the invention, the consumer receives  $\max\{u(\frac{M}{q_0}), u(\frac{M}{q_I})\} = u(\frac{M}{q_I})$ . Since  $u'(\frac{M}{q_I}) < u'(\frac{M}{q_0})$ , the marginal utility of wealth falls with the price reduction.

### 3 Rewards for Creative Destruction

Since creative destruction lowers the marginal utility of wealth, rewards or contingent payments involve a transfer from the low marginal utility invention state to the higher marginal utility no-invention state. As a result, rewards are optimal for such inventions even if there are no agency costs.

Society contracts with  $N$  research firms,<sup>1</sup> sets a contingent payment made to a successful inventor  $P_I$ , and an uncontingent payment totaling  $P_U$ . Without agency costs, society can contract upon the investment level of each firm  $I_i$ . If more than one firm discovers the new invention, the contingent payment of  $P_I$  is shared among them. The uncontingent payment  $P_U$  is always shared by all  $N$  firms. If all firms are identical, society specifies identical values  $I_i = I$  for each firm.

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<sup>1</sup>For simplicity,  $N$  is exogenous, but it is straightforward to endogenize it.

Let  $g(I)$  be the (concave) probability that a firm investing  $I$  discovers the product, with Inada condition  $\lim_{I \rightarrow 0} g'(I) = \infty$ . Denote by  $I^*$  the investment level of a firm's competitors. Each firm knows the probability of at least one firm discovering the invention is  $1 - (1 - g(I^*))^N$ , and that the total expected reward paid by society is  $P_I(1 - (1 - g(I^*))^N)$ . Since all firms are identical, each firm also perceives its unconditionally expected reward as  $\frac{P_I(1 - (1 - g(I^*))^N)}{N}$ . Finally, the expected reward paid to each firm, conditional on success, is given by Bayes' Rule as  $\frac{P_I(1 - (1 - g(I^*))^N)}{Ng(I^*)}$ . Note that the conditional expected reward depends only on  $I^*$  rather than  $I$ : it cannot depend on the firm's own investments, because it is *conditional* on successful research. In light of these arguments, the firm's expected profits are given by:<sup>2</sup>

$$\frac{P_U}{N} - I + \frac{g(I)}{g(I^*)} P_I \frac{1 - (1 - g(I^*))^N}{N} \quad (1)$$

In equilibrium, expected profits will be nonnegative and investment by each firm will not exceed the expected value of its payout. The optimal research contract is the solution to:<sup>3</sup>

$$\begin{aligned} \max_{I \geq 0, P_I \geq 0, P_U \geq 0} & (1 - (1 - g(I))^N)(V^I(M - P_I - P_U) - V^0(M - P_U)) + V^0(M - P_U) \\ \text{s.t. } & I \leq \frac{P_U}{N} + P_I \frac{1 - (1 - g(I))^N}{N}, i = 1, \dots, N \end{aligned} \quad (2)$$

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<sup>2</sup>A more lengthy and formal argument can be made for this expression by directly computing the expected reward for each firm.

<sup>3</sup>Our framework and results are consistent with a case where consumers own research firms. Suppose that each risk-averse consumer holds a diversified portfolio of inventors, where returns exactly equal expected profits. Since shareholders earn zero income, this problem is identical to ours.

Since rewards transfer resources from a low marginal utility state to a high marginal utility state, they are always an optimal means of encouraging research, even though there are no agency costs. This is apparent in the first order conditions:

$$[I] : \quad g'(I)(V^I - V^0) + \lambda g'(I)P_I \leq \frac{\lambda}{(1-g(I))^{N-1}} \quad (3)$$

$$[P_U] : \quad (1 - (1 - g(I))^N)(V_M^0 - V_M^I) - V_M^0 + \lambda \leq 0 \quad (4)$$

$$[P_I] : \quad \lambda \leq V_M^I \quad (5)$$

Suppose that no reward is offered, so that  $P_I = 0$ . This implies that  $V_c^I > \lambda$ .

If the latter is true, it follows that

$$(1 - (1 - g(I))^N)(V_M^0 - V_M^I) - V_M^0 + \lambda < -(1 - g(I))^N(V_M^0 - V_M^I) < 0 \quad (6)$$

The latter inequality obtains because consumption is equal to  $M - P_U$  in both states of the world, and  $V_M^0 > V_M^I$  for equal levels of consumption. The inequality in 6 implies that the first order condition for  $P_U$  cannot hold at equality, and thus that  $P_U=0$ . Since there are no contingent or uncontingent payments, there cannot be any research effort  $I$  either. This contradicts the Inada condition.

The above result has two important corollaries that are straightforward to prove. First, the optimal reward can never exceed the amount that provides “perfect insurance” against failure, and society will never choose to over-insure itself. Second, even with no agency costs, it is possible that only

contingent rewards are offered in equilibrium. In fact, research contracts are optimal only if society is perfectly insured against failure.

## 4 Research Contracts for Product-Spawning Inventions

Since product-spawning inventions raise the marginal utility of wealth, research contracts transfer resources away from the low marginal utility state. They can have value even with extreme agency costs. To illustrate, suppose that firms are completely free to set  $I$ —given the offers of  $P_I$  and  $P_U$ , and the number of competitors  $N$ —to maximize expected profits. Its first order condition implicitly defines its investment function:<sup>4</sup>

$$g'(I(P_I, N))P_I = \frac{Ng(I^*)}{1 - (1 - g(I^*))^N} \quad (7)$$

Given the investment function, the optimal contract must also guarantee nonnegative expected profits. When society cannot contract upon the firm's investment effort, the efficient research contract solves the problem:

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<sup>4</sup>This function is well-defined, because a given increase in investment raises  $Ng(I)$  more than society's probability of discovery.



reward offered when  $P_U = 0$ . Research contracts will be offered if

$$V_M^I(M - P_I^*) - V_M^0(M) > \frac{N}{1 - g(I)} \frac{g'(I)I_P(V^I(M - P_I^*) - V^0(M))}{\frac{\partial \pi}{\partial P_I}} \quad (12)$$

at this reward level. Second, with extreme agency costs, research contracts are never optimal for product-replacing inventions that lower the marginal utility of wealth. In these cases, the marginal benefit of research contracts (the left-hand side) is strictly negative, while the marginal cost (the right-hand side) is strictly positive.

## 5 Conclusion

Governments and societies often face the question of whether to subsidize research or reward successful inventions. Our analysis suggests that they ought to consider the novelty of a potential invention in deciding upon a course of action. Inventions that are designed primarily to effect creative destruction by replacing existing products are less likely to benefit from research subsidies, and more likely to benefit from rewards that are paid only in the event of success. On the other hand, truly new products that are designed to enhance, rather than replace, existing products may call for research subsidies, even if agency costs are present and significant.

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