A General Theory of Pharmaceutical Innovation Incentives*

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Abstract

This paper develops a unified theory of pharmaceutical innovation incentives. Patents, research subsidies, prizes, advance market commitments, and priority review vouchers can generate equivalent research incentives while differing in how rewards are linked to post-innovation utilization. When utilization is itself a welfare margin, research-incentive equivalence therefore need not imply welfare equivalence. Product-decoupled rewards can increase the return to innovation without directly changing the marginal incentive for utilization. The framework identifies when financing constraints, market size, commitment, and product linkage make institutional form consequential for innovation policy.

Keywords: Pharmaceutical innovation; research and development; innovation incentives; patents; advance market commitments; priority review vouchers

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1 Introduction

Pharmaceutical innovation creates social value that often exceeds the private returns available to the innovator. The resulting underinvestment problem has long motivated research on intellectual property and innovation incentives (Arrow, 1962; Nordhaus, 1969; Scotchmer, 2004). It is particularly consequential in pharmaceuticals, where market size may poorly reflect social value and vaccines generate public-health externalities (Kremer, 2002; Acemoglu and Linn, 2004). Society may also value the development of new antibiotics while simultaneously limiting their use to slow antimicrobial resistance (Outterson et al., 2016).

A variety of institutions attempt to close this private–social return wedge. Patents reward innovation through product-market exclusivity, research subsidies support investment before success, prizes reward successful innovation directly, advance market commitments create future demand, and priority review vouchers provide transferable regulatory value (Wright, 1983; Kremer and Glennerster, 2004; Ridley et al., 2006; Kremer et al., 2022). Despite their different institutional forms, these policies ultimately operate by changing the private return to research.

This paper develops a unified framework for comparing these mechanisms. Innovation incentives are decomposed into three margins: research support independent of final success, rewards contingent on successful innovation, and institutions governing the private product-market value of success. Policies that generate the same marginal private return to research induce the same research expenditure under otherwise identical conditions. This research-incentive equivalence provides a benchmark for identifying when institutional form does and does not matter.

The central result is that research-incentive equivalence need not imply welfare equivalence when post-innovation utilization is itself a welfare margin. Product-linked mechanisms obtain their incentive value through sales, prices, procurement, or other use of the innovation, and therefore can affect both research and utilization. Product-decoupled rewards increase the return to successful research without directly changing the marginal incentive for utilization. Linkage consequently becomes an independent dimension of policy design when the social value of developing a product differs from the social value of expanding its use.

This distinction is particularly relevant to pharmaceuticals. Vaccination can generate positive externalities from greater utilization, so linkage between purchases and innovation rewards may reinforce the social objective. Antibiotics provide the opposite case: society may want more innovation but less utilization because current use contributes to antimicrobial resistance. High product prices can similarly strengthen research incentives while restricting access. The framework therefore separates the incentive to create a therapy from the incentive governing its subsequent use and characterizes when tying the two together is beneficial or costly.

The paper builds on the literature comparing patents, prizes, and research contracts as mechanisms for rewarding invention (Wright, 1983; Shavell and van Ypersele, 2001; Scotchmer, 2004) and relates to contracting under externalities (Segal, 1999). The externality here differs from the multilateral contracting problem studied by Segal: research creates social value not fully captured by the developer, while utilization may create an additional external effect. The contribution is to show that when the instrument used to correct the innovation wedge also affects this second margin, the source and linkage of compensation matter even when alternative policies induce the same research expenditure.

The framework also connects several strands of pharmaceutical innovation research, in which innovation financing and incentives interact with commercialization and downstream pharmaceutical markets (Garthwaite, 2025). Expected market size shapes innovation incentives (Acemoglu and Linn, 2004); advance market commitments can create demand where ordinary markets provide insufficient incentives (Kremer, 2002; Kremer and Glennerster, 2004; Kremer et al., 2022); priority review vouchers provide rewards outside the qualifying product market (Ridley et al., 2006); and antibiotic policy has motivated proposals to delink innovation rewards from sales volume (Outterson et al., 2016). The framework places these institutions within a common model and identifies product linkage as a distinct design margin rather than merely another source of reward.

The remaining results show how other institutional differences break research-incentive equivalence. Ex ante support can relax financing constraints that ex post rewards cannot; stronger appropriability becomes ineffective when the target market is too small; advance commitments can construct future demand; and mixed push–pull systems arise when financing and incentive constraints coexist. Together, the results distinguish the amount of innovation incentive from the institutional channel through which it is supplied.

2 Pharmaceutical Innovation

Pharmaceutical innovation encompasses new drugs, vaccines, biologics, and other therapeutic technologies. Although these products differ in their scientific and regulatory characteristics, they share a common economic structure. Research requires a costly investment before its outcome is known, successful innovation generates both private and social value, and the innovator typically captures only part of the value created. This section develops a minimal model of that structure. Policy institutions are introduced only

after the underlying innovation problem has been established.

2.1 Research and Development

Consider a pharmaceutical developer that chooses research and development expenditure $x \geq 0$. The project succeeds with probability $p(x)$, where

$$p(0) = 0, \qquad p'(x) > 0, \qquad p''(x) < 0.$$

Research expenditure has cost $c(x)$, where

$$c(0) = 0, \qquad c'(x) > 0, \qquad c''(x) > 0.$$

The assumptions capture diminishing technological returns to research and increasing marginal costs of expanding a research program. The variable x may represent laboratory research, clinical development, regulatory preparation, production-related development, or a composite of these activities.

If the project succeeds, it generates a private value $\pi \geq 0$ for the developer. This value is the expected present value of the income that the firm can obtain from the innovation under the prevailing institutional environment. It may depend on the number of potential users, their willingness and ability to pay, insurance reimbursement, production costs, competition, and the extent to which the innovator can appropriate product-market returns. At this stage, however, π is taken as given.

The developer chooses research expenditure to solve

$$\max_{x \geq 0} \{p(x)\pi - c(x)\}.$$

Let $x^P(\pi)$ denote the resulting private research choice. When the solution is interior, it satisfies

$$p'\left(x^P\right)\pi = c'\left(x^P\right). \tag{1}$$

The left-hand side is the marginal private return to research, while the right-hand side is its marginal cost. A larger private value raises research expenditure because it increases the return to improving the probability of success.

2.2 Social Value

Let $v \geq 0$ denote the expected social value created by a successful innovation. Social value includes the innovator's profit but may also include consumer surplus, health gains not reflected in market payments, reduced transmission of infectious disease, lower burdens on caregivers and health systems, and knowledge that facilitates subsequent innovation. The relevant social objective is therefore

$$\max_{x \geq 0} \{p(x)v - c(x)\}.$$

Let $x^S(v)$ denote the socially efficient level of research. When the solution is interior,

$$p'\left(x^S\right)v = c'\left(x^S\right). \tag{2}$$

The central friction is that the developer need not capture the full social value of the innovation. We therefore maintain

$$v \geq \pi. \tag{3}$$

This inequality may be strict even when intellectual property rights are perfectly enforced. Patent protection allows the innovator to capture part of the product's market value, but it does not generally transfer all consumer surplus, public-health externalities, or knowledge spillovers to the firm. The

wedge may be especially large when a disease primarily affects populations with limited purchasing power, when governments or large purchasers are expected to bargain down prices after development costs have been sunk, or when socially valuable use is deliberately restricted, as with antibiotics whose consumption accelerates resistance.

Proposition 1 (Research Underinvestment)**.** *Suppose that $v \geq \pi$. Then*

$$x^S(v) \geq x^P(\pi).$$

If $v > \pi$ and the socially efficient research choice is positive, the inequality is strict whenever the private and social optima are uniquely determined.

Proof. For every $x \geq 0$, the marginal social return to research is $p'(x)v$, while the marginal private return is $p'(x)\pi$. Since $p'(x) > 0$ and $v \geq \pi$, the social objective has weakly greater increasing differences in x and the value generated by success. The maximizer of $p(x)v - c(x)$ is therefore weakly greater than the maximizer of $p(x)\pi - c(x)$. If $v > \pi$, the marginal social return is strictly greater at every x, yielding a strictly larger optimum whenever the relevant solution is positive and unique. □

Proposition 1 states the basic pharmaceutical innovation problem without committing to any particular policy instrument. Insufficient research is not defined by low research expenditure in itself. It arises because the private return governing the firm's decision is smaller than the social return governing efficient investment.

2.3 The Innovation Incentive Gap

Define the pharmaceutical innovation incentive gap as

$$\Delta \equiv v - \pi \geq 0. \tag{4}$$

At any research level x, the corresponding marginal incentive gap is

$$p'(x)\Delta. \tag{5}$$

The distinction between Δ and $p'(x)\Delta$ is useful. The first measures the value from successful innovation that is not captured privately. The second measures how that missing value distorts the marginal research decision. A large social value does not by itself imply a large research response to policy if additional expenditure has little effect on the probability of success. Conversely, even a moderate value wedge may generate substantial underinvestment when research is highly productive at the margin.

The gap can arise from several conceptually distinct sources. The potential market may be small; the population may have limited ability to pay; the innovator may be unable to appropriate the value of the product; purchasers may be unable to commit before investment occurs; or important benefits may lie outside the product market altogether. These sources need not call for the same institutional response. A policy may lower the private cost of research, increase the return obtained from the target product, guarantee that a market will exist if innovation succeeds, or create a reward whose value is realized outside that product market.

Accordingly, the purpose of an innovation incentive is not necessarily to eliminate the entire difference between social and private value. It is to alter the developer's optimization problem so that privately chosen research more closely approaches the socially efficient level. The next section defines a general incentive system through which otherwise different institutions can perform that function.

The benchmark deliberately suppresses the allocation of the product after successful innovation. Under that simplification, any policy that generates

the same marginal return to research is potentially equivalent from the developer's perspective. This observation provides a useful benchmark but also identifies what the benchmark cannot explain. Pharmaceutical institutions frequently affect not only whether a therapy is developed but also its price, availability, and utilization after development. The distinction becomes important below because the social objective need not assign the same value to greater innovation and greater utilization.

3 A General Incentive System

The preceding section describes pharmaceutical innovation as a wedge between the private and social value of successful research. This section introduces a general incentive system without presupposing any particular policy instrument. The basic idea is that a policy can support research before success is known, reward the developer if the project succeeds, or alter the private value that can be realized from the resulting product. Patents, advance market commitments, priority review vouchers, prizes, and research subsidies differ in institutional form, but each changes one or more of these components of the developer's problem.

3.1 The Incentive Problem

Let $y \in \{0, 1\}$ denote the research outcome, with $y = 1$ representing successful innovation and

$$\Pr(y = 1 \mid x) = p(x).$$

An incentive system may provide a payoff $T_0(x)$ when the project fails and a payoff $T_1(x, \theta)$ when it succeeds. The variable θ describes the institutional environment governing the private realization of value, including market size, intellectual property protection, procurement arrangements, reimbursement

rules, and regulatory treatment. The developer's expected payoff is

$$p(x)\big[\pi(\theta) + T_1(x,\theta)\big] + \big[1 - p(x)\big]T_0(x) - c(x). \tag{6}$$

Define

$$A(x) \equiv T_0(x) \tag{7}$$

and

$$R(x,\theta) \equiv T_1(x,\theta) - T_0(x). \tag{8}$$

The term $A(x)$ is support received independently of ultimate success, while $R(x,\theta)$ is the additional payoff contingent on successful innovation. Substitution into equation (6) gives the developer's problem as

$$\max_{x \geq 0} \left\{ A(x) + p(x)\big[\pi(\theta) + R(x,\theta)\big] - c(x) \right\}. \tag{9}$$

Theorem 1 (Incentive Representation)**.** *Any pharmaceutical innovation policy whose payoff consequences for a developer depend on research expenditure, a binary research outcome, and the institutional environment can be represented by a research-support function $A(x)$, a success-contingent reward $R(x,\theta)$, and a private-value function $\pi(\theta)$, as in equation* (9)*.*

Proof. Let $T_0(x)$ and $T_1(x,\theta)$ denote the policy payoffs following failure and success, respectively. Setting $A(x) = T_0(x)$ and $R(x,\theta) = T_1(x,\theta) - T_0(x)$, expected policy benefits equal

$$\big[1 - p(x)\big]T_0(x) + p(x)T_1(x,\theta) = A(x) + p(x)R(x,\theta).$$

Adding the private product value $p(x)\pi(\theta)$ and subtracting research cost $c(x)$ yields equation (9). □

Theorem 1 is a representation result rather than a welfare result. It establishes a common contracting language for innovation policies, but by itself it

does not imply that institutions generating the same private research incentive are socially equivalent. That distinction becomes central once the policy also affects actions taken after successful innovation.

This common representation makes institutional comparison possible. Policies that appear legally unrelated may generate the same marginal research incentive, while policies with similar expected monetary values may produce different choices because they differ in timing or contingency. The decomposition also does not imply that each institution affects only one margin. A policy may combine research support, a contingent reward, and changes in the product market.

3.2 Research Incentives

When the solution to equation (9) is interior, the developer's research choice x^I satisfies

$$A'\left(x^I\right) + p'\left(x^I\right)\left[\pi(\theta) + R\left(x^I, \theta\right)\right] + p\left(x^I\right) R_x\left(x^I, \theta\right) = c'\left(x^I\right). \tag{10}$$

The first term captures support tied directly to research expenditure. The second captures the effect of increasing the probability of receiving the private product value and the success-contingent reward. The third captures any reward that varies with research expenditure even after success is held fixed.

Many familiar policies have a simpler form in which the success reward is independent of x. If $R(x, \theta) = R(\theta)$, the first-order condition becomes

$$A'\left(x^I\right) + p'\left(x^I\right)\left[\pi(\theta) + R(\theta)\right] = c'\left(x^I\right). \tag{11}$$

Research support affects the effective marginal cost of investment, whereas success-contingent rewards and value-realization policies affect the return to increasing the probability of success.

Proposition 2 (Research-Incentive Equivalence)**.** *Consider two incentive systems* $\mathcal{I} = (A, R, \theta)$ *and* $\widetilde{\mathcal{I}} = (\widetilde{A}, \widetilde{R}, \widetilde{\theta})$*, and suppose that success-contingent rewards do not depend directly on research expenditure. If*

$$A'(x) + p'(x)\big[\pi(\theta) + R\big] = \widetilde{A}'(x) + p'(x)\big[\pi(\widetilde{\theta}) + \widetilde{R}\big] \tag{12}$$

for every x*, then the two systems induce the same research choice whenever the developer's objective is strictly concave.*

Proof. Under either system, an interior research choice equates marginal private benefit to marginal research cost. Equation (12) implies that the marginal private benefit is identical under the two systems at every x. Since the cost function is also identical and the objective is strictly concave, the unique maximizer is the same. □

Proposition 2 establishes a deliberately narrow equivalence result. A grant, prize, patent extension, purchase commitment, or transferable reward can be calibrated to induce the same research expenditure, but this does not make the policies institutionally or socially equivalent. They may differ in fiscal cost, information rents, risk allocation, access, and incidence. Most importantly for pharmaceutical markets, they may differ in whether the innovation reward depends on subsequent utilization of the target product. The next subsection shows that this linkage creates a substantive boundary to research-incentive equivalence.

Proposition 3 (Research Response)**.** *Suppose that the developer's objective is strictly concave in* x*. Relative to the benchmark in Section 2, the privately chosen research level is weakly higher if the incentive system weakly increases the marginal private return to research at every* x*. In particular, this condition is satisfied if*

$$A'(x) \geq 0, \qquad R(x, \theta) \geq 0, \qquad R_x(x, \theta) \geq 0,$$

and

$$\pi(\theta) \geq \pi$$

for all relevant x*.*

Proof. Under the stated conditions, the marginal payoff from research under the incentive system is weakly greater at every x than the benchmark marginal payoff $p'(x)\pi - c'(x)$. Strict concavity implies a unique optimum, so the research choice cannot be lower than the benchmark choice. □

Proposition 3 does not imply that all increases in private research are socially desirable. A policy may reward projects whose private eligibility does not correspond closely to social value, subsidize research that would have occurred without intervention, or finance rewards through distortions elsewhere in the economy. The representation identifies how a policy affects research incentives; evaluating the policy additionally requires accounting for information, financing, access, fiscal cost, and the source from which the reward derives its value.

3.3 Innovation and Utilization

The preceding analysis treats successful innovation as generating a scalar private value. This is sufficient for studying research incentives but suppresses a second decision that is particularly important in pharmaceuticals: how intensively the resulting product is used. Let $q \geq 0$ denote utilization conditional on successful innovation. Let $\pi(q)$ denote the developer's product-market payoff and let $b(q)$ denote the social value generated by utilization, net of production costs but before any utilization externality. Finally, let $e(q)$ denote an external social effect of utilization. The social value conditional on success is

$$v(q) = b(q) + e(q). \tag{13}$$

The function $e(q)$ may be positive, as when vaccination reduces disease transmission, or negative, as when greater antibiotic use accelerates antimicrobial resistance.

Suppose first that innovation is rewarded through a product-linked payment $L(q)$, whose value increases with utilization. Conditional on successful innovation, the developer chooses

$$q^L \in \arg\max_{q \geq 0} \{\pi(q) + L(q)\}. \tag{14}$$

Anticipating this choice, the developer selects research expenditure according to

$$\max_{x \geq 0} \left\{ A(x) + p(x) \left[\pi(q^L) + L(q^L) + R \right] - c(x) \right\}. \tag{15}$$

A product-linked reward therefore enters the innovation and utilization margins simultaneously.

By contrast, let $D \geq 0$ denote a product-decoupled reward paid upon successful innovation and independent of utilization. Conditional utilization solves

$$q^D \in \arg\max_{q \geq 0} \pi(q), \tag{16}$$

while research solves

$$\max_{x \geq 0} \left\{ A(x) + p(x) \left[\pi(q^D) + D \right] - c(x) \right\}. \tag{17}$$

The decoupled reward changes the return to successful innovation without directly changing the marginal private return to utilization.

Proposition 4 (Linkage)**.** *Suppose that the developer's conditional product-market payoff is strictly concave in q. A change in a product-decoupled reward D does not change the privately chosen utilization level q^D. By contrast, let a product-linked reward be $L(q; \lambda)$. If the developer's conditional payoff remains*

strictly concave and $L_{q\lambda}(q;\lambda) \neq 0$ *at an interior optimum, then a marginal change in* λ *changes the privately chosen utilization level.*

Proof. Under a product-decoupled reward, D enters the developer's payoff as an additive constant conditional on success. The utilization choice therefore maximizes $\pi(q)$ independently of D. Under a product-linked reward, an interior utilization choice satisfies

$$\pi'(q^L) + L_q(q^L;\lambda) = 0.$$

Implicit differentiation gives

$$\frac{dq^L}{d\lambda} = -\frac{L_{q\lambda}(q^L;\lambda)}{\pi''(q^L) + L_{qq}(q^L;\lambda)}.$$

Strict concavity makes the denominator negative. Hence $dq^L/d\lambda \neq 0$ whenever $L_{q\lambda}(q^L;\lambda) \neq 0$. □

Proposition 4 identifies the first substantive difference between incentive-equivalent institutions. A reward need not affect utilization merely because it increases the expected payoff from successful innovation. What matters is whether the value of the reward is obtained by increasing use of the target product. Product decoupling therefore creates an independent innovation incentive that does not mechanically alter the utilization margin.

Theorem 2 (Innovation–Utilization Separation)**.** *Suppose that the socially desired utilization level* q^S *is implemented by a policy instrument that can be chosen independently of the innovation reward, and suppose that there is no additional research support,* $A(x) = 0$*. Let the resulting private product value be* $\pi(q^S)$*. If the socially efficient research level* x^S *is interior, the product-decoupled success reward*

$$D^S = v(q^S) - \pi(q^S) \tag{18}$$

implements x^S without altering the incentive condition governing utilization. By contrast, a product-linked reward $L(q)$ enters the utilization condition through $L'(q)$. It can therefore preserve q^S while implementing x^S only if its marginal effect on utilization is consistent with the condition required to implement q^S.

Proof. At the socially desired utilization level, the social research problem is

$$\max_{x \geq 0} \left\{ p(x) v(q^S) - c(x) \right\}.$$

Under the decoupled reward in equation (18), the developer instead solves

$$\max_{x \geq 0} \left\{ p(x) \left[\pi(q^S) + D^S \right] - c(x) \right\} = \max_{x \geq 0} \left\{ p(x) v(q^S) - c(x) \right\}.$$

The private and social research problems therefore coincide. Because D^S is independent of q, it does not enter the condition governing utilization. A product-linked reward $L(q)$, in contrast, enters the utilization condition through $L'(q)$. It therefore preserves q^S only when its marginal effect is consistent with the condition required to implement that utilization level. □

Theorem 2 gives product decoupling an economic role that is distinct from simply increasing the size of the reward. Conditional on the policymaker having an independent instrument for the utilization margin, a decoupled reward can close the private–social research wedge without disturbing the utilization condition. A linked reward instead uses the same margin to influence innovation and utilization, so correcting the research incentive may create or magnify a downstream distortion.

This distinction is particularly important when the desired directions of the two margins differ. For antibiotics, society may want more innovation but less utilization because current use contributes to antimicrobial resistance. A sales-linked reward moves the private return to innovation and

the private return to utilization in the same direction. A product-decoupled reward can instead increase the return to developing the antibiotic while leaving stewardship policy free to restrict its subsequent use. For vaccines, by contrast, utilization may itself generate positive externalities, so a product-linked purchase subsidy can simultaneously strengthen innovation incentives and increase socially valuable use. The sign and magnitude of the utilization externality therefore help determine whether linkage is a benefit or a cost.

3.4 Timing and Linkage

The preceding results identify two dimensions of institutional design that are not summarized by the expected monetary value of an incentive. The first is timing. Research support is generally provided before the final outcome is known, whereas a success-contingent reward is paid only after a specified result has been achieved. Earlier support transfers technological risk from the developer to the funder and may relax financing constraints. Later rewards preserve stronger selection and performance incentives because payment depends on producing a successful innovation.

The second dimension is linkage. As Proposition 4 and Theorem 2 show, product linkage determines whether increasing the innovation reward also changes the incentive governing post-innovation utilization. Changes in patent protection, reimbursement, and purchase subsidies generally derive value from the target product market and can therefore affect both innovation and utilization. Cash prizes and transferable regulatory privileges can instead provide value independently of the quantity of the qualifying product used.

Timing and linkage solve different contracting problems. Timing determines when technological risk is transferred and whether the developer must finance research before success. Linkage determines whether the reward for

successful innovation is bundled with the economic incentives governing the resulting product. Two policies can therefore generate the same expected research return while differing on both dimensions.

Theorem 1 therefore provides a common language rather than a claim that institutional form is irrelevant. Pharmaceutical innovation policies can be represented through the same incentive components, but their timing, contingency, linkage, financing, and informational requirements remain distinct. The next section places the principal existing institutions within this general system.

4 Institutional Forms

The general incentive system developed in Section 3 encompasses the principal institutions used to encourage pharmaceutical innovation. These institutions differ in legal form and administrative design, but each operates through research support $A(x)$, a success-contingent reward R, the private value of the resulting product $\pi(\theta)$, or some combination of these margins. This section maps the major institutional forms into that representation.

4.1 Patents and Exclusivity

Patent protection increases the value that an innovator can appropriate from a successful product. Let T denote the effective period of exclusivity and write private product value as

$$\pi = \pi(T), \qquad \pi'(T) > 0.$$

The firm's problem is

$$\max_{x \geq 0} \left\{ p(x)\pi(T) - c(x) \right\}.$$

A patent therefore operates through the value-realization margin. It does not finance unsuccessful research and provides no reward unless an innovation reaches the market. Patent-term extensions, data exclusivity, and additional periods of market exclusivity have the same basic structure: they increase the duration or strength of the innovator's claim on product-market returns.

The effectiveness of exclusivity depends on the underlying market. A stronger patent can increase the fraction of market value captured by the innovator, but it cannot create substantial revenue where potential users are few or unable to pay. Moreover, because the reward is financed through product sales, stronger exclusivity may increase prices and reduce access after innovation has occurred. Patent policy therefore links dynamic research incentives to the static allocation of the resulting product.

4.2 Research Grants and Subsidies

Research grants, tax credits, and cost-sharing arrangements operate primarily through research support. Let $s(x)$ denote public support received as a function of research expenditure. The firm's problem becomes

$$\max_{x \geq 0} \{s(x) + p(x)\pi - c(x)\}.$$

Equivalently, the policy reduces effective research cost from $c(x)$ to $c(x) - s(x)$. Because support may be received before the final outcome is known, it transfers part of the technological risk from the developer to the funder and may enable firms to undertake projects that could not be financed solely against uncertain future returns.

This advantage is accompanied by weaker selection. A funder must decide which projects or inputs to support before observing final success, and developers may possess better information about technical prospects and private

costs. Research support may therefore finance unsuccessful projects or subsidize research that would have occurred without intervention. Its relative value is greatest when financing constraints are important or when useful intermediate research activity can be observed and verified.

4.3 Innovation Prizes

An innovation prize provides a payment $B(q)$ when a successful product satisfying specified characteristics q is developed. The firm's problem is

$$\max_{x \geq 0} \left\{ p(x) \left[\pi + B(q) \right] - c(x) \right\}.$$

The prize operates through the success-reward margin. Unlike a patent, its value need not depend on charging a high product price or realizing substantial sales in the target market. The policymaker can therefore separate the reward for innovation from the subsequent pricing and distribution of the product.

The design problem is to specify the rewarded outcome. A prize based only on regulatory approval may induce products that satisfy formal requirements but generate limited additional social value. A reward indexed to clinical quality, health impact, or accessibility can improve targeting, but these dimensions may be difficult to measure or contract upon. Prizes substitute a problem of public valuation and verification for the market test embedded in product-linked rewards.

4.4 Advance Market Commitments

An advance market commitment promises before investment that a qualifying product will receive a specified price subsidy, purchase volume, or aggregate market value after development. Let P and Q denote the promised

price and quantity terms. The private product value becomes

$$\pi = \pi(P, Q),$$

and the firm solves

$$\max_{x \geq 0} \{p(x)\pi(P, Q) - c(x)\}.$$

An AMC therefore operates primarily through the value-realization margin. It does not merely grant the innovator greater control over an existing market; it commits purchasers or donors to create a sufficiently valuable market if an acceptable product is developed.

The commitment is made ex ante, but payment remains contingent on successful production and purchase. This combination permits an AMC to retain the selection properties of a pull mechanism while addressing the risk that purchasers will reduce prices after research and capacity costs have been sunk. In low-income markets, the mechanism can also supplement limited purchasing power while requiring that the reward be earned through delivery of a product that users or purchasing authorities are willing to adopt.

An AMC remains product-linked. Its value must be realized through purchases of the target innovation, and its design must specify eligibility, product quality, price, quantity, and the treatment of competing suppliers. Its effectiveness therefore depends not only on the size of the promised market but also on the credibility and structure of the commitment.

4.5 Priority Review Vouchers

A priority review voucher rewards the developer of a qualifying product with a transferable right to accelerated regulatory review for another product. Let V denote the market value of the voucher. The developer's problem

becomes

$$\max_{x \geq 0} \left\{ p(x)\left[\pi + V\right] - c(x) \right\}.$$

The voucher operates through the success-reward margin. Its value does not arise from sales of the qualifying product, but from the ability to accelerate the approval and commercial launch of another potentially valuable product.

The PRV is therefore product-decoupled and cross-market. Innovation for a disease with little commercial demand is rewarded by creating a regulatory asset whose value is realized in a different pharmaceutical market. Transferability allows a developer without a suitable product in its own pipeline to sell the voucher to another firm. The reward is consequently financed neither by direct public expenditure nor by higher prices for the qualifying product, but by the value of earlier market access elsewhere.

The supply of vouchers affects their value. If many vouchers are available relative to the number of products for which accelerated review is valuable, their market price and incentive effect decline. Moreover, the social cost of expedited review may include administrative congestion or delayed review of other products. The value received by the innovator is therefore not itself a measure of the mechanism's net social benefit.

4.6 A Common Representation

The institutional forms can be summarized by their principal incentive margin, timing, and linkage:

Table 1: Institutional Forms of Pharmaceutical Innovation Incentives

Institution	Principal Margin	Payment Timing	Product Linkage	Direct Utilization Effect
Patent or exclusivity	$\pi(\theta)$	Ex post	Linked	Yes
Research grant or subsidy	$A(x)$	Ex ante or interim	Not required	No
Innovation prize	R	Ex post	Decoupled	No
Advance market commitment	$\pi(\theta)$	Promised ex ante, paid ex post	Linked	Generally yes
Priority review voucher	R	Ex post	Decoupled	No for qualifying product

The final column refers to the direct incentive operating through the qualifying product. A policy classified as having no direct utilization effect may still affect utilization indirectly through entry, pricing, complementary regulation, or general-equilibrium responses. The classification concerns whether the reward itself is earned through greater use or market value of the target product.

The classification is not exclusive. A single policy may affect several margins, and actual pharmaceutical innovation systems routinely combine institutional forms. A subsidized project may retain patent protection, an AMC may supplement ordinary product revenue, and a qualifying drug may receive both exclusivity and a priority review voucher. The general representation is useful precisely because it separates the economic channels contained within such institutional packages.

The institutions also differ in the source from which their rewards derive value. Patents are financed through product-market rents paid by users or insurers. Grants and prizes rely on public or philanthropic funds. AMCs rely on committed purchases by governments, donors, or other purchasers. PRVs create value through scarce regulatory priority in another market. Consequently, two institutions that provide the same expected private return may differ substantially in their fiscal costs, access effects, informational requirements, and incidence. The next section examines how market size shapes both the underlying innovation problem and the effectiveness of these alternative incentive forms.

5 Market Size and the Direction of Innovation

The preceding sections treat the private value of a successful innovation as given. In pharmaceutical markets, however, private value depends critically on the size and composition of demand. A larger market raises the return to successful research and thereby affects not only the aggregate level of research expenditure but also the diseases and technologies toward which research is directed. This section incorporates market size into the general incentive system and distinguishes markets generated by underlying demand from markets created by policy.

5.1 Market Size and Private Value

Consider a pharmaceutical product for disease i. Let $m_i \geq 0$ denote its potential market size, incorporating the number of potential users and their ability and willingness to pay. Let the private value of successful innovation be

$$\pi_i = \pi_i(m_i), \qquad \pi_i'(m_i) > 0.$$

The developer chooses research expenditure according to

$$\max_{x_i \geq 0} \left\{ p_i(x_i)\pi_i(m_i) - c_i(x_i) \right\}. \tag{19}$$

When the solution is interior, the first-order condition is

$$p_i'(x_i)\pi_i(m_i) = c_i'(x_i). \tag{20}$$

Proposition 5 (Market Size)**.** *Suppose that the objective in equation* (19) *is strictly concave. Optimal research expenditure x_i^P is weakly increasing in market size m_i, and strictly increasing whenever the optimum is interior.*

Proof. An increase in m_i raises $\pi_i(m_i)$ and therefore increases the marginal

private return $p_i'(x_i)\pi_i(m_i)$ at every research level. Strict concavity implies a unique optimum. The optimal research choice is consequently weakly increasing in market size and strictly increasing whenever the solution remains interior. □

Proposition 5 captures the demand-induced character of pharmaceutical innovation. Demographic change, disease prevalence, income, insurance coverage, and reimbursement policy can all affect research by changing the expected market for a successful product. The relevant market is prospective rather than merely current because pharmaceutical development is lengthy and firms may respond to anticipated future demand, consistent with the market-size hypothesis developed by Acemoglu and Linn (2004).

5.2 The Direction of Research

Suppose that a developer can allocate a fixed research budget X across n disease categories. Let x_i denote research directed toward disease i, with

$$\sum_{i=1}^{n} x_i \leq X.$$

The developer solves

$$\max_{\{x_i\}_{i=1}^{n}} \sum_{i=1}^{n} \left\{ p_i(x_i)\pi_i(m_i) - c_i(x_i) \right\}. \tag{21}$$

If the research-budget constraint binds, then for any two categories receiving positive research expenditure,

$$p_i'(x_i)\pi_i(m_i) - c_i'(x_i) = p_j'(x_j)\pi_j(m_j) - c_j'(x_j). \tag{22}$$

Both expressions equal the shadow value of an additional unit of the research budget.

Market size therefore affects the direction as well as the amount of innovation. Holding research technologies and costs fixed, a larger market raises the marginal return to research in that category and attracts resources away from smaller markets. A disease can consequently receive little private research even when its health burden is large if the affected population cannot generate a sufficiently valuable commercial market.

This distinction is central to pharmaceutical innovation. Social need depends on the health value of successful treatment, whereas private research responds to appropriable market value. Let v_i denote the social value of a successful innovation for disease i. The category-specific incentive gap is

$$\Delta_i = v_i - \pi_i(m_i). \tag{23}$$

A disease with high v_i but low m_i may have a particularly large incentive gap. Conversely, a large commercial market may attract substantial research even when the marginal social value of additional products is comparatively modest.

5.3 Natural and Constructed Markets

Market size need not be entirely determined by population and income. Write

$$m_i = m_i^N + m_i^G, \tag{24}$$

where m_i^N is the market generated by underlying private demand and m_i^G is the market created or financed through collective action. The first component reflects disease prevalence, population characteristics, income, insurance, and ordinary purchasing behavior. The second reflects government procurement, donor finance, reimbursement commitments, or other policies that add credible demand for a successful product.

This decomposition links market size to the general incentive system. A patent changes the fraction of a natural market that the innovator can appropriate, whereas an advance market commitment increases the market that will exist if innovation succeeds. The two policies may both raise π_i, but they do so through different mechanisms:

$$\pi_i = \pi_i \left(m_i^N + m_i^G, \theta_i \right),$$

where θ_i governs the appropriation of returns from the resulting market.

The distinction also clarifies why stronger exclusivity may be insufficient for neglected diseases. If m_i^N is very small, increasing the innovator's share of that market may generate little additional value. A purchase commitment can instead raise m_i^G directly. It converts social willingness to support innovation into a market that the developer can anticipate before research costs are incurred.

5.4 Rewards Outside the Target Market

Not every incentive operates by enlarging the target product market. A priority review voucher leaves m_i largely unchanged but adds a reward whose value is realized through another pharmaceutical product. Let V_j denote the value of accelerated review in market j. The research problem for disease i becomes

$$\max_{x_i \geq 0} \left\{ p_i(x_i) \left[\pi_i(m_i) + V_j \right] - c_i(x_i) \right\}. \tag{25}$$

The voucher therefore compensates for a small target market without attempting to enlarge that market itself.

Advance market commitments and priority review vouchers represent two distinct responses to insufficient demand. An AMC creates value within the market for the qualifying product. A PRV transfers value from another

market. The first is product-linked and requires credible future purchases; the second is product-decoupled and requires a sufficiently valuable use for the regulatory privilege. Their relative performance consequently depends on whether the target product can support a workable purchase market and whether an external reward can be created without imposing excessive costs elsewhere.

Market size is thus both a determinant of innovation and an object of institutional design. Natural demand directs research toward populations capable of sustaining profitable markets. Policy may alter that direction by enlarging the target market, changing the share of market value captured by the innovator, or providing a reward outside the target market. The next section examines how the appropriate incentive form depends on the particular constraint responsible for the innovation gap.

6 The Choice of Incentive Form

The preceding sections show that pharmaceutical innovation can be encouraged by supporting research expenditure, increasing the reward conditional on success, enlarging the target market, or creating value outside that market. These instruments may generate similar private incentives, but they are not economically equivalent. They differ in the allocation of technological risk, the information required for implementation, the source of financing, and their consequences for access after innovation occurs. This section characterizes how the source of the innovation gap shapes the appropriate incentive form.

6.1 A Policy Design Problem

Consider a policymaker that chooses an incentive system $\mathcal{I} = (A, R, \theta)$. Given this system, the developer selects x to solve

$$\max_{x \geq 0} \left\{ A(x) + p(x)\big[\pi(\theta) + R\big] - c(x) \right\}. \tag{26}$$

Let $q(\mathcal{I})$ denote utilization conditional on successful innovation. The policymaker's objective is

$$\max_{\mathcal{I}} \left\{ p\big(x(\mathcal{I})\big) v\big(q(\mathcal{I})\big) - c\big(x(\mathcal{I})\big) - K(\mathcal{I}) \right\}. \tag{27}$$

The term $K(\mathcal{I})$ includes more than direct fiscal expenditure. It may include the cost of raising public funds, distortions from monopoly pricing, information rents, administrative burdens, regulatory congestion, and losses from rewarding projects whose private eligibility does not correspond closely to social value. Direct payments to the developer are treated as transfers except to the extent that financing them creates a social cost, which is included in $K(\mathcal{I})$. This formulation separates the amount received by the developer from the social cost of generating that reward.

If post-innovation utilization were fixed and incentive instruments were costless and perfectly targeted, only the total marginal private return to research would matter. In that benchmark, any system satisfying

$$A'(x) + p'(x)\big[\pi(\theta) + R\big] = p'(x)v \tag{28}$$

at $x = x^S$ could implement the socially efficient research choice. Once q is endogenous, however, equation (28) is no longer sufficient for welfare equivalence. The policymaker must also account for how the instrument changes $q(\mathcal{I})$. Institutional form therefore matters even before fiscal and administrative implementation costs are introduced.

6.2 Research Support and Financing

A purely success-contingent reward can induce research only if the developer can finance expenditure before the outcome is known. Let $w \geq 0$ denote funds available for research. In the absence of outside finance, the developer faces

$$c(x) - A(x) \leq w. \tag{29}$$

An increase in R or $\pi(\theta)$ raises the expected return to research but does not directly relax this constraint. Research support does so by reducing the amount that must be financed before success.

Proposition 6 (Financing Constraint)**.** *Suppose that the unconstrained research choice under a success-contingent reward violates equation* (29)*. Increasing the reward alone cannot implement that research choice. Research support that relaxes the financing constraint is necessary.*

Proof. A success-contingent reward changes the objective in equation (26) but not the feasible set defined by equation (29). If the desired research expenditure is infeasible, no increase in the reward can induce it. An increase in $A(x)$ reduces the developer's required initial finance and can make the desired choice feasible. □

Research support is therefore particularly valuable for early-stage projects, small developers, and technologies requiring substantial expenditure before private investors can verify their prospects. Its disadvantage is that payment need not depend on final success. When developers possess private information about research costs or technical quality, grants and subsidies may finance projects with low expected social value or provide transfers for research that would have occurred without support. The case for research support is strongest when financing constraints are severe and useful research activity can be observed with sufficient accuracy.

6.3 Success-Contingent Rewards

When developers can finance research and successful innovation can be verified, an ex post reward preserves selection incentives. Firms with better information about their own technologies choose whether to incur research costs, while the policymaker pays only when a qualifying outcome is produced. A prize or other success-contingent payment therefore avoids directly selecting research inputs or firms before technical uncertainty has been resolved.

The limitation is that the policymaker must define success. A reward based on approval alone may induce products that satisfy regulatory requirements but add little clinical value. Conditioning payment on quality, health impact, or accessibility improves alignment with social value, but only when these outcomes can be measured and incorporated into an enforceable rule. The relative advantage of a success-contingent reward thus increases with the verifiability of outcomes and decreases with the importance of dimensions that cannot be specified in advance.

6.4 Product-Market Incentives

Patents, exclusivity, reimbursement, and advance market commitments increase the return realized through the target product. These instruments preserve a market test because the developer's reward depends on adoption or purchase. Let m denote target-market demand and let $\alpha \in [0, 1]$ denote the share of market value that the innovator can appropriate. Private product value can be written as

$$\pi = \pi(\alpha, m), \qquad \pi_\alpha > 0, \qquad \pi_m > 0. \tag{30}$$

Patent protection primarily increases α, whereas an AMC primarily increases or guarantees m.

Proposition 7 (Small-Market Limitation)**.** *Suppose that $\pi(\alpha, m)$ is continuous in m and satisfies $\pi(\alpha, 0) = 0$ for every $\alpha \in [0, 1]$. As m approaches zero, increasing appropriability alone cannot generate a strictly positive product-market reward bounded away from zero.*

Proof. By continuity, $\pi(\alpha, m)$ approaches $\pi(\alpha, 0) = 0$ as m approaches zero for every feasible α. Increasing the innovator's share of a vanishing market cannot create a reward bounded away from zero. □

Proposition 7 identifies the limitation of relying exclusively on patents for diseases concentrated among populations with little purchasing power. Stronger exclusivity can increase the share of market value captured by the innovator, but it cannot by itself create a market of sufficient size. An AMC addresses a different margin by converting collective willingness to finance innovation into credible demand for the target product.

The distinction also affects access. A patent commonly raises innovation rewards by permitting prices above marginal cost. An AMC can instead promise an initial subsidy or purchase volume while requiring a lower long-run price. Both instruments are product-linked, but they distribute the cost of innovation differently and need not produce the same post-innovation allocation.

6.5 Commitment and Hold-Up

Product-market demand may exist and yet fail to induce efficient research if purchasers cannot commit to reward innovation before costs are sunk. Suppose that the developer expects product value π^E before investment but receives only $\pi^B < \pi^E$ after bargaining with purchasers. Research is then chosen according to π^B, even when purchasers would have preferred greater investment ex ante.

Proposition 8 (Commitment)**.** *Suppose that the developer's objective is strictly concave. If post-investment bargaining reduces the developer's expected product value from π^E to π^B, with $\pi^B < \pi^E$, a credible ex ante commitment to π^E weakly increases research expenditure.*

Proof. A credible commitment raises the value conditional on success from π^B to π^E. Since $p'(x) > 0$, it increases the marginal return to research at every x. Strict concavity then implies a weakly larger research choice. □

An AMC is especially suited to this environment because it commits purchasers before research or capacity investment occurs while preserving payment conditional on delivery. Its value is not simply that it increases demand, but that it makes future demand credible when later bargaining, political pressure, or monopsony power would otherwise reduce the innovator's return.

6.6 Product-Decoupled Rewards

A product-decoupled reward is useful when the social value of innovation is high but the target market is too small, access should not depend on high prices, or socially desirable use is intentionally limited. A cash prize finances the reward directly. A priority review voucher instead creates a transferable asset whose value is realized through another pharmaceutical market.

Theorem 2 clarifies why decoupling can be valuable even when a product-linked reward could generate the same research expenditure. The advantage is not that a decoupled reward necessarily provides more money, but that it creates an additional instrument. The innovation reward can be adjusted without mechanically changing the marginal return to utilization of the qualifying product.

Antibiotic development provides the clearest example. The social objective may require both greater investment in new treatments and restraint in their subsequent use. A sales-linked reward makes these objectives difficult to separate because increasing the value of innovation also increases the return to utilization. A product-decoupled reward instead raises the payoff from successful development without requiring additional antibiotic consumption. Stewardship policy can then govern utilization independently. Vaccines illustrate the opposite case: when utilization itself creates positive externalities, linkage between innovation rewards and purchases may reinforce rather than undermine the social objective.

Decoupling nevertheless shifts costs rather than eliminating them. A cash prize requires public or philanthropic finance. A PRV derives value from earlier entry in another product market and may impose costs through regulatory congestion, displaced review effort, or altered competition. The relevant comparison is therefore between the total social cost of creating the reward inside and outside the target market.

6.7 No Universally Dominant Instrument

The analysis yields a comparative institutional principle. Research support has an advantage when financing constraints bind; success-contingent rewards when outcomes are verifiable and developers possess superior information about technical prospects; stronger appropriability when a substantial product market already exists; target-market commitments when demand can be created credibly; and product-decoupled rewards when the target market cannot efficiently finance the desired incentive. These conclusions do not establish a one-to-one correspondence between market failures and institutions, because pharmaceutical projects commonly face several constraints at once.

Pharmaceutical projects commonly face several constraints simultaneously. A small target market may coexist with financing difficulties, technological uncertainty, and post-investment bargaining. The efficient response may consequently combine early research support with a later reward, or ordinary patent protection with a targeted market commitment. Institutional choice is therefore generally a problem of constructing a package rather than assigning one instrument to one market failure.

The choice of incentive form is therefore not a choice among interchangeable transfers. It is a choice over who bears technological risk, what information determines payment, where the reward obtains its value, and how innovation incentives interact with access after success. The next section examines mixed systems that combine institutional forms to address several constraints within the same research process.

7 Mixed Incentive Systems

The preceding section compares incentive forms in isolation. In practice, pharmaceutical research is rarely supported by a single institution. A developer may receive grants during early research, retain patent protection after approval, sell into a market supported by public procurement, and qualify for an additional regulatory reward. These combinations are not merely cumulative. Different instruments can address different constraints at different stages of the same research process.

7.1 Push and Pull

A mixed push–pull system combines research support with a reward conditional on successful development. Research support relaxes financing constraints and transfers part of the risk of failure to the funder, while the success-contingent component preserves incentives to select promising projects

and complete development. The relative importance of the two components may change over the research process: direct support is often most valuable when scientific uncertainty and financing needs are greatest, whereas milestone or success-contingent payments become more effective as technical performance becomes observable.

This logic can be represented by a sequence of milestone payments. Let $z_k \in \{0, 1\}$ indicate whether stage k has been completed. A staged reward takes the form

$$A(x) + \sum_{k=1}^{K} R_k z_k, \tag{31}$$

where earlier payments provide finance and later payments preserve performance incentives. The system allocates technological risk between the developer and the funder over the course of research rather than assigning it entirely before or after success.

7.2 Product-Market and External Rewards

A second class of mixed systems combines product-market returns with a reward outside the target market. Let $\pi(\theta)$ denote the value realized through sales, procurement, or exclusivity, and let R denote an external reward. The developer's problem is

$$\max_{x \geq 0} \left\{ p(x) \left[\pi(\theta) + R \right] - c(x) \right\}. \tag{32}$$

The product-linked component preserves a market test because part of the developer's return depends on adoption of the innovation. The external component supplements that return when the target market cannot support an adequate incentive.

Patent protection and an advance market commitment form one such combination. The patent determines how much of product-market value the developer can appropriate, while the AMC increases or guarantees the market available after success. The instruments are complementary when neither appropriation nor market size alone is sufficient. Strong exclusivity over a very small market may generate little return, while a purchase commitment without sufficient protection may leave part of the promised value vulnerable to imitation or entry.

A subsidy and a priority review voucher provide another combination. The subsidy supports expenditure before approval, while the voucher supplies a reward only after a qualifying product is developed. This arrangement is particularly relevant for small firms that face financing constraints but whose eventual product serves a commercially weak market. The two instruments address different margins and should not be treated as substitutes merely because both increase expected private returns.

7.3 Complementarity and Substitution

Two instruments are complementary when the marginal effectiveness of one increases with the presence of the other. Let research expenditure under a system with research support a and success reward r be denoted by $x(a, r)$. The instruments are complementary when

$$\frac{\partial^2 x(a, r)}{\partial a \, \partial r} > 0.$$

For example, a larger ex post reward may have little effect when the firm cannot finance initial research, but becomes effective once an ex ante grant makes the project feasible. Conversely, early support may produce limited innovation if the developer faces little reward for completing the project.

Instruments are substitutes when they address the same constraint and one reduces the marginal value of the other. A sufficiently large prize may reduce the need to extend exclusivity, and a sufficiently large AMC may reduce the additional research induced by stronger patent protection. Substitution is particularly relevant when multiple instruments increase the same success-contingent return but impose different social costs.

7.4 Implementation with Push and Pull Incentives

A simple specification makes the role of mixed incentives explicit. Suppose that the policymaker provides research support at rate $a \geq 0$, so that $A(x) = ax$, and a fixed reward $r \geq 0$ conditional on success. The developer solves

$$\max_{x \geq 0} \{ax + p(x)(\pi + r) - c(x)\} \tag{33}$$

subject to the financing constraint

$$c(x) - ax \leq w. \tag{34}$$

Let $x^S > 0$ denote the socially efficient research level.

Theorem 3 (Mixed-Incentive Implementation)**.** *Suppose that the developer's objective is strictly concave. The research level x^S can be implemented by a pair (a, r) if*

$$a \geq \max\left\{0, \frac{c(x^S) - w}{x^S}\right\}, \tag{35}$$

$$r = \frac{c'(x^S) - a}{p'(x^S)} - \pi, \tag{36}$$

with $r \geq 0$. The minimum research-support rate consistent with feasibility is therefore

$$a^{\min} = \max\left\{0, \frac{c(x^S) - w}{x^S}\right\}, \tag{37}$$

and the residual success-contingent reward required at that support rate is

$$r^* = \frac{c'(x^S) - a^{\min}}{p'(x^S)} - \pi. \tag{38}$$

Proof. For x^S to be feasible, equation (34) requires

$$a \geq \frac{c(x^S) - w}{x^S}.$$

Since $a \geq 0$, the smallest feasible rate is given by equation (37). For x^S to be privately optimal, the first-order condition associated with equation (33) must satisfy

$$a + p'(x^S)(\pi + r) = c'(x^S).$$

Solving for r gives equation (36). Strict concavity ensures that the resulting choice is unique. □

Theorem 3 assigns distinct roles to the two instruments. Research support can first be used to make the socially desired expenditure feasible, while the success-contingent reward supplies the residual marginal incentive needed to make that expenditure privately optimal. If $a^{\min} > 0$, a pure pull system cannot implement x^S, because an ex post reward does not relax the financing constraint. At the minimum feasible support rate, a positive r^* indicates that feasibility alone does not provide the marginal incentive required for implementation. More generally, the balance between push and pull incentives depends separately on available finance, research cost, technological productivity, ordinary product-market value, and the social costs associated with each instrument.

7.5 Policy Packages

The relevant object of policy is therefore often an incentive package rather than an isolated instrument. Let

$$\mathcal{I} = (A, R, \theta)$$

denote the complete system of research support, success-contingent rewards, and value-realization rules. The same expected private return can be generated by different packages, but those packages may differ in fiscal cost, risk allocation, information requirements, access, and incidence. Optimal design requires choosing the composition of the package, not merely its total monetary value.

This perspective also changes the interpretation of existing institutions. Patents provide a general background reward rather than a complete innovation policy. Grants, AMCs, prizes, and PRVs are targeted additions that correct dimensions of the research problem that ordinary product-market returns do not resolve. Their role is therefore best understood relative to the rest of the incentive system.

Mixed systems are especially natural in pharmaceutical research because the relevant constraints change over time. Financing is often most important at early stages, technical verification becomes easier during development, market commitment becomes salient as production approaches, and access matters after approval. A well-designed incentive system can shift from research support to milestone payments and ultimately to product-linked or product-decoupled rewards as these constraints evolve.

8 Applications and Extensions

The general framework generates different comparative institutional implications across pharmaceutical technologies. The relevant distinction is not the scientific label attached to a product, but the source of the innovation incentive gap. Vaccines combine transmission externalities with capacity investment; neglected diseases combine high social value with weak purchasing power; antibiotics create a conflict between innovation and utilization; rare diseases separate numerical market size from monetizable demand; and platform technologies generate returns across products and time. This section shows how these differences alter the appropriate incentive margin.

8.1 Vaccines

Vaccines are a central case of pharmaceutical innovation because their social value commonly exceeds the value that can be recovered through ordinary product sales. Vaccination reduces disease transmission as well as protecting the recipient, so part of its benefit accrues to individuals who do not purchase the product. The corresponding social value can be written as

$$v = v^D + v^E,$$

where v^D is the direct health value to vaccinated individuals and v^E is the epidemiological externality created by reduced transmission. Because the developer generally captures only part of v^D and little of v^E, the incentive gap may remain large even in markets with substantial disease burden.

Vaccines also require investment beyond scientific discovery. Clinical development, regulatory approval, manufacturing capacity, and distribution systems must often be established before demand is fully realized. An incen-

tive system may therefore need to support both research and capacity:

$$\max_{x,k\geq 0} \left\{ A(x,k) + p(x)\left[\pi(\theta,k) + R\right] - c(x) - g(k) \right\},$$

where k denotes capacity investment. Research support may be important for technologically distant products, while a credible purchase commitment may be particularly important when the principal constraint is production capacity close to commercialization.

Vaccines illustrate the converse case. When utilization generates positive epidemiological externalities, the social objective may call for both more innovation and greater use. Product linkage can then be complementary rather than distortive: a purchase commitment or subsidy may simultaneously enlarge the expected reward from successful development and increase utilization after approval. The comparison with antibiotics shows that linkage is not intrinsically desirable or undesirable. Its value depends on whether the social marginal value of utilization moves in the same direction as the innovation incentive that the policy is intended to create.

8.2 Neglected Diseases

Neglected diseases illustrate the difference between social need and commercial market size. Let h_i denote the health burden associated with disease i, and let m_i denote its potential commercial market. There is no general reason for h_i and m_i to move together. A disease may impose a large health burden while affecting populations with limited ability to pay, producing

$$v_i \gg \pi_i(m_i).$$

In such cases, stronger appropriability may have limited effect because the underlying market remains small.

Targeted market commitments and product-decoupled rewards provide distinct responses. An AMC increases the market for the qualifying product by converting donor or government willingness to pay into credible future demand. A prize or PRV instead adds value without requiring the target population to finance the reward through product purchases. The relevant choice depends on whether a workable market can be constructed around delivery of the product or whether the innovation reward must be realized elsewhere.

8.3 Antibiotics

Antibiotics provide a direct application of the innovation–utilization separation developed in Section 3.3. Greater use generates current treatment benefits but can reduce future effectiveness by accelerating antimicrobial resistance. The utilization externality $e(q)$ is therefore negative at the margin once resistance costs are taken into account. At the same time, the social value of creating a new effective antibiotic may be high because it expands the set of treatments available against resistant infections. This tension has motivated proposals to delink the return to antibiotic innovation from sales volume so that research incentives need not depend on greater utilization (Outterson et al., 2016).

The two objectives can consequently move in opposite directions: society may want more research and less utilization. A reward proportional to sales couples these margins, whereas a product-decoupled reward can increase the return to successful development without requiring greater consumption. The framework therefore provides a formal rationale for delinkage in antibiotic innovation: its value lies in separating the incentive to create the product from the incentive to use it.

8.4 Rare Diseases

Rare diseases also involve small patient populations, but they need not resemble neglected diseases economically. A small number of patients may still generate a valuable market when insurance coverage is broad, willingness to pay is high, or exclusivity permits substantial prices. The relevant distinction is therefore not prevalence alone, but the relationship between social value and appropriable demand.

For rare diseases, stronger exclusivity may generate significant private value because the natural market, though numerically small, may remain highly monetizable. The principal policy problem may instead concern access and the incidence of financing. The same market size can therefore support different incentive forms depending on income, insurance, reimbursement, and the distribution of treatment costs.

8.5 Platform Technologies

Some research creates a technological platform that supports multiple future products. Let x denote platform investment and let $p_j(x)$ denote the probability of successful innovation in application j. The private return to platform research is

$$\sum_{j=1}^{J} p_j(x)\pi_j,$$

whereas the social return may additionally include knowledge spillovers to firms or applications that the original developer cannot appropriate. The resulting incentive gap is

$$\Delta(x) = \sum_{j=1}^{J} p_j(x)\big[v_j - \pi_j\big] + s(x),$$

where $s(x)$ denotes external benefits from the platform itself.

A policy tied to a single product may underreward platform research because it ignores benefits realized through later applications. Research grants, milestone contracts, portfolio commitments, or rewards linked to multiple downstream products may better reflect the value of technologies such as vaccine platforms, delivery systems, and broadly applicable biological methods.

8.6 Sequential Innovation

Pharmaceutical research is often sequential rather than isolated. A successful product may provide knowledge, data, or infrastructure that lowers the cost of later research. Let the cost of project $t+1$ depend on the outcome of project t:

$$c_{t+1} = c_{t+1}(x_{t+1}; y_t), \qquad \frac{\partial c_{t+1}}{\partial y_t} < 0.$$

The social value of current innovation then includes its effect on future research opportunities. An institution that rewards only the current product may fail to compensate the developer for these intertemporal spillovers.

Sequential innovation also complicates exclusivity. Stronger protection may increase the reward for the initial innovator while raising the cost of follow-on research by others. The optimal incentive system must therefore balance the creation of current knowledge against its subsequent use. This tradeoff extends beyond pharmaceuticals, but it is especially important where new therapies build on shared biological targets, clinical evidence, and research platforms.

These applications identify recurring correspondences between economic constraints and incentive margins. Transmission externalities increase the case for rewards not financed solely through individual purchases. Weak purchasing power increases the value of constructed markets or product-

decoupled rewards. Socially restricted utilization weakens the case for sales-based incentives. Cross-product and intertemporal spillovers increase the value of portfolio or research-support mechanisms. The applications therefore do not constitute separate theories; they show how a common incentive system changes as the source of the private–social value wedge changes.

9 Conclusion

This paper develops a unified framework for pharmaceutical innovation incentives by separating research support, success-contingent rewards, and product-market returns. Patents, grants, prizes, advance market commitments, and priority review vouchers can generate equivalent research incentives, but this equivalence does not generally extend to welfare when the mechanism used to reward innovation also affects post-innovation utilization.

The distinction between product-linked and product-decoupled rewards identifies the central boundary. A linked reward can jointly affect innovation and utilization, whereas a decoupled reward can increase the return to successful research without directly changing the marginal incentive for product use. This distinction is especially relevant in pharmaceuticals because greater utilization can generate positive externalities, as with vaccines, or social costs, as with antimicrobial resistance. The desirability of linkage therefore depends on whether the innovation and utilization margins call for incentives in the same direction.

More broadly, the private–social return wedge identifies the missing incentive but does not determine how that incentive should be supplied. Financing constraints, market size, commitment, timing, and product linkage determine whether institutionally different mechanisms remain economically equivalent. Innovation policy therefore requires choosing not only the magnitude of the

reward for socially valuable research, but also the channel through which that reward is delivered.

Declarations

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References

[1] Acemoglu, D., and J. Linn. (2004). Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry. *Quarterly Journal of Economics* 119(3): 1049–1090.

[2] Arrow, K. J. (1962). Economic Welfare and the Allocation of Resources for Invention. In R. R. Nelson (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, 609–626. Princeton, NJ: Princeton University Press.

[3] Garthwaite, C. (2025). Economic Markets and Pharmaceutical Innovation. *Journal of Economic Perspectives* 39(2): 3–26.

[4] Kremer, M. (2002). Pharmaceuticals and the Developing World. *Journal of Economic Perspectives* 16(4): 67–90.

[5] Kremer, M., and R. Glennerster. (2004). *Strong Medicine: Creating Incentives for Pharmaceutical Research on Neglected Diseases*. Princeton, NJ: Princeton University Press.

[6] Kremer, M., J. Levin, and C. M. Snyder. (2022). Designing Advance Market Commitments for New Vaccines. *Management Science* 68(7): 4786–4814.

[7] Nordhaus, W. D. (1969). *Invention, Growth, and Welfare: A Theoretical Treatment of Technological Change*. Cambridge, MA: MIT Press.

[8] Outterson, K., U. Gopinathan, C. Clift, A. D. So, C. Morel, and J.-A. Røttingen. (2016). Delinking Investment in Antibiotic Research and Development from Sales Revenues: The Challenges of Transforming a Promising Idea into Reality. *PLOS Medicine* 13(6): e1002043.

[9] Ridley, D. B., H. G. Grabowski, and J. L. Moe. (2006). Developing Drugs for Developing Countries. *Health Affairs* 25(2): 313–324.

[10] Scotchmer, S. (2004). *Innovation and Incentives*. Cambridge, MA: MIT Press.

[11] Shavell, S., and T. van Ypersele. (2001). Rewards versus Intellectual Property Rights. *Journal of Law and Economics* 44(2): 525–547.

[12] Segal, I. (1999). Contracting with Externalities. *Quarterly Journal of Economics* 114(2): 337–388.

[13] Wright, B. D. (1983). The Economics of Invention Incentives: Patents, Prizes, and Research Contracts. *American Economic Review* 73(4): 691–707.