

PATENT BUYOUTS AND CONSUMER EXTERNALITIES

I. INTRODUCTION

Innovations, ranging from those in pharmacology and vaccinology to those in the energy sector, are typically rewarded by patents and market power. Consumption externalities (positive/negative) are also important in these sectors. For both reasons, governmental patent buyouts are considered by many policymakers. With large positive consumption externalities, for example, the government prefers to produce more than what even a competitive market would produce. Thus, "*Greece has suggested EU member states jointly buy patent rights for vaccines against COVID-19,*" with the additional justification: "*purchasing such patent rights would give global pharmaceutical companies incentives for further research and development.*"¹ Also in the US, it has been argued that: "*Governments can offer strong incentives to drugmakers while ensuring affordability by committing to patent buyouts for effective treatments.*"²

The quality-ladder growth model below first confirms that the *static* gain of governmental patent buyouts is indeed larger when the externality, " b ", is large: see the green curve in Fig. 1.

Nevertheless: The *dynamic* cost of the buyout, in terms of distorted R&D, outweighs the static gain *precisely* when the externality is large (in absolute value): see the red curve. With positive externalities, buyouts reduce future R&D. With large negative externalities, buyouts can increase R&D to suboptimally large levels.

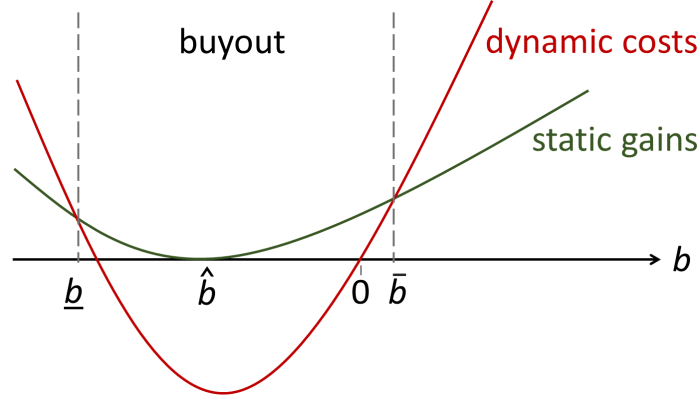


Fig. 1: *Static gains are larger than dynamic costs iff $b \in (\underline{b}, \bar{b})$.*

This result, and Section III, assumes that the planner cannot commit to future prices. Section IV considers commitment and derives the markup, and the R&D subsidy, that implements the first best.

II. ASSUMPTIONS

Preferences and externalities. There is a continuum of identical individuals of mass 1. Individual i consumes y_i units and, because of a consumption externality measured by $b \in \mathbb{R}$, i may also benefit from the average consumption of other individuals (denoted y_{-i}):

$$u_i = \ln(y_i^a y_{-i}^b) - p y_i = a \ln y_i + b \ln y_{-i} - p y_i.$$

It is reasonable that $b > 0$ when we consider vaccines, pharmaceutical products, or green technology. For polluting goods, as when we consider innovations in shale oil, $b < 0$. It would be straightforward (but not really necessary) to allow for a continuum of heterogeneous goods. If the good were durable, the results would be strengthened: see Remark 2.

Every i takes the price, p , as given, so i 's f.o.c. implies $y_i = y = a/p$ and $u_i = u = \ln(a/p)^{a+b} - a$.

Technology and market structure. If firm j produces y_j units, its production cost is $c y_j / A_j$. There is a single patent holder, called the leader, with technology $A_j = \gamma^k$, where $\gamma > 1$ and $k \geq 1$.

¹ <https://www.reuters.com/article/us-health-coronavirus-greece-pm-idUSKBN21O1LJ>

² <https://www.nytimes.com/2020/04/08/opinion/coronavirus-drug-company-profits.html?searchResultPosition=9>

The leader competes (Bertrand) with the old leader with technology γ^{k-1} . The leader's competitor is willing to sell each unit of y at price c/γ^{k-1} . With limit pricing, the leader sells at this price, produces $y_M = a\gamma^{k-1}/c$ at marginal cost c/γ^k and obtains profit:

$$\pi_M = \left(\frac{c}{\gamma^{k-1}} - \frac{c}{\gamma^k} \right) y_M = \left(1 - \frac{1}{\gamma} \right) a.$$

Remark 1—Quality-ladder model: This cost-reducing technology model is equivalent to the (Aghion-Howitt '92) quality-ladder model because the leader produces $\ln(\gamma^k/c)$ units of utility per dollar.

R&D. Time is discrete. At the end of each period, exactly one firm that is *not* the current leader faces a chance to innovate. The equilibrium R&D level, $z \in [0, 1]$, measures the probability that the innovator succeeds and obtains the next leading technology, γ^{k+1} .

With probability $1 - z$, the R&D effort fails and the current leader continues to be the unique leader next period. This assumption (which contrasts with the alternative assumption that the fringe can costlessly imitate the previous-best technology) implies that the equilibrium level of z can be interior even if the R&D cost is linear. Thus, let the investment cost be κz . (The logic follows from eq. (2), below. A convex investment cost would strengthen the results: see Remark 3.)

Patent buyouts. The benevolent planner maximizes $E \sum_{t=0}^{\infty} \beta^t (u + \pi - \kappa z)$, where $\beta \in (0, 1)$ is the common discount factor. The "static" benefit from a patent buyout (i.e., abstracting from the effect on z) is that the quantity can change from the equilibrium quantity without buyouts, $y_M = a\gamma^{k-1}/c$, to the socially optimal level, $y_B = (a + b)\gamma^k/c$.

Following the buyout in one period, the next leader, with technology γ^{k+1} , will have to compete with a planner that is willing to sell at price $a/y_B = ac/(a + b)\gamma^k$.

It does not matter to the innovator that its innovation is sold to the planner: To buy a patent, the planner must pay the leader the present-discounted sum of profits which the leader could earn by keeping the patent. (Commitments to markups are considered in Section IV.)

III. RESULT

The static gain (fixing z) from a buyout is simply that the planner can implement $y \neq y_M$.³ If $b = 0$, the buyout is socially valuable since the leader is otherwise producing too little because it has market power. If $b > 0$, the leader is, in addition, producing too little because it does not profit from the consumption externality. So, the larger is $b > 0$, the larger is the static gain.

If $b < \hat{b} \equiv -(1 - 1/\gamma)a$, which is negative, the static gain is that the planner can limit the damaging production relative to y_M . The smaller is $b < \hat{b} < 0$, the larger is the gain from such a limit. The static gain is zero when $b = \hat{b}$ (then, $y_B = y_M$) but strictly positive when $b \neq \hat{b}$.

To determine whether buyouts raise welfare, the static gain must be compared to the dynamic cost when R&D is distorted.

Proposition 1.

- (i) The static gain from buyouts is positive, U-shaped in b , and minimized at $\hat{b} \equiv -(1 - 1/\gamma)a < 0$.
- (ii) Nevertheless: There exists $\underline{b} < 0 < \bar{b}$ s.t. buyouts reduce welfare if $b \notin (\underline{b}, \bar{b})$, i.e., iff:

$$\gamma \ln \left(\frac{a+b}{a} \gamma \right) < \gamma - 1 + \frac{b}{\kappa} \frac{\beta}{1-\beta} \ln \gamma. \quad (1)$$

Part (ii) disproves the intuition that large externalities justify buyouts. The dynamic cost of distorted R&D levels is even greater than the static gain – precisely when the externality is large. Before presenting the proof, let's consider the intuition.

A larger $b > 0$ reduces the price that the planner is willing to sell at, and the lower price will reduce the profit (π_B) the next leader can expect (see Fig. 2). Hence, equilibrium R&D decreases in b after a

³Formally,

$$\left[\ln(y_B^{a+b}) - cy_B/\gamma^k \right] - \left[\ln(y_M^{a+b}) - cy_M/\gamma^k \right] = (a+b) \ln \left(\frac{a+b}{a} \gamma \right) - \left(1 - \frac{1}{\gamma} \right) a - b.$$

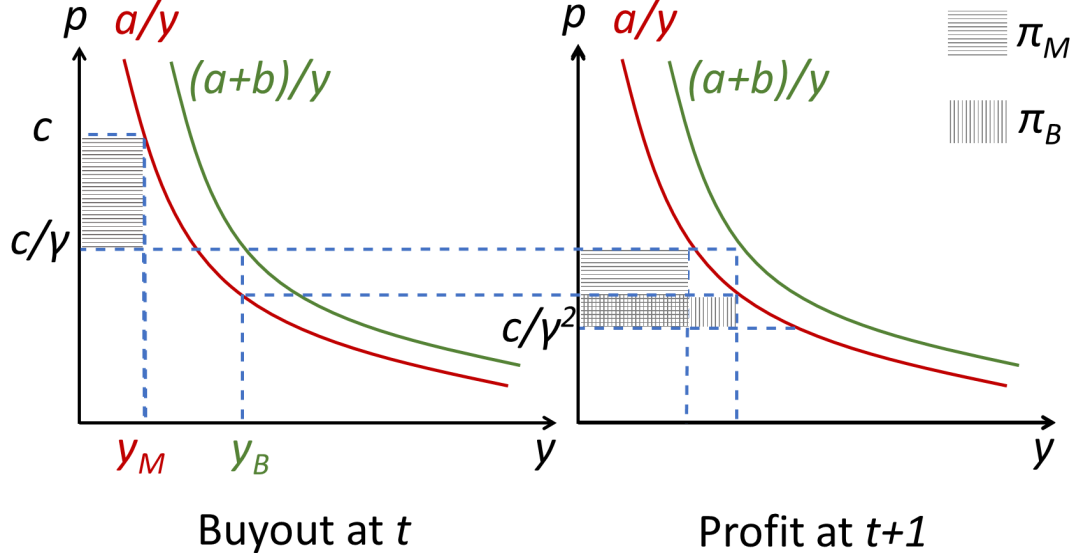


Fig. 2: If $b > 0$, a buyout reduces the profit of becoming the next technology leader.

buyout. This dynamic cost increases in the externality faster than does the static gain (this follows, in the proof, because the utility function, $\ln(\cdot)$, is concave). Thus, there exists a threshold, $\bar{b} > 0$, so that a buyout policy reduces welfare when $b > \bar{b}$.

If $b < 0$, the planner limits production. A negative externality implies that, when there is a new innovation, the planner competes less aggressively than would a non-leading firm. In this case, a buyout raises the profit (π_B) of becoming the next leader. Anticipating the larger profit, R&D is also larger. So, when $b < 0$, buyouts generate static gains as well as more R&D. The smaller is b , the larger is the corporate value of R&D when the planner buys patents, but the smaller is the *social* value of R&D. Thus, there exists $\tilde{b} < 0$, so that when $b < \tilde{b}$, there is too much R&D under buyouts. Further, there exists $\underline{b} < \tilde{b}$ so that when $b < \underline{b}$, this dynamic cost (i.e., that there is too much R&D under buyouts) outweighs the static gain.

Inequality (1) always fails if $b \approx 0$: In this case, there are static gains from buyouts, and no cost.

Numerical example: For $a = 1$ and $\kappa = 1/3$, the table shows how β and γ influence $(\underline{b}, \bar{b})$.

$(\underline{b}, \bar{b})$	$\beta = 0.87$	$\beta = 0.90$	$\beta = 0.95$
$\gamma = 1.10$	$(-0.03, 0.38)$	$(-0.28, 0.03)$	$(-0.89, 0.003)$
$\gamma = 1.15$	$(-0.05, 0.53)$	$(-0.24, 0.07)$	$(-0.87, 0.007)$
$\gamma = 1.20$	$(-0.06, 0.68)$	$(-0.22, 0.13)$	$(-0.85, 0.013)$

Other comparative statics are also interesting: If a increases, β increases, or κ decreases, both $\underline{b}$ and $\bar{b}$ fall. After such a change, buyouts become less (more) likely to be beneficial when consumption externalities are positive (negative). Intuitively, all these changes raise the social value of R&D, and thus underinvestment (when $b > 0$) becomes more harmful, while overinvestment (when $b < 0$) becomes less problematic. The effect of γ is ambiguous, as the table shows.

Proof of Proposition 1. First, note that equilibrium z can be interior even if the R&D cost is linear, thanks to the assumption that the leader continues as a leader with prob. $1 - z$. When the innovator takes as given (future) equilibrium z , and per-period profit π , R&D is worthwhile iff:

$$\kappa \leq \frac{\beta\pi}{1 - \beta(1 - z)}. \quad (2)$$

Hence, there is a unique fixed point (where the best-response curve crosses the 45°) where the innovator is willing to invest $z \in (0, 1)$ iff:

$$z = \frac{\pi}{\kappa} - \frac{1}{\beta} + 1 \in (0, 1). \quad (3)$$

When there is no buyout, $\pi = \pi_M$, and (3) implies:

$$z_M = \frac{\pi_M}{\kappa} - \frac{1}{\beta} + 1 = \frac{(1 - 1/\gamma)a}{\kappa} - \frac{1}{\beta} + 1.$$

The R&D level after a buyout is determined by the profit the next leader can potentially obtain if it does *not* sell its new innovation to the planner, even though it must then compete with a planner that has bought the previous patent. In this case, the next leader must set the price the planner is willing to sell at, $ac/(a+b)\gamma^k$, to obtain per-period profit:

$$\pi_B = py - cy_*/\gamma^{k+1} = a - \frac{a+b}{\gamma}.$$

So, $\pi_B < \pi_M$ iff $b > 0$. In a buyout regime, (3) implies that R&D is:

$$z_B = \frac{\pi_B}{\kappa} - \frac{1}{\beta} + 1 = \frac{(1 - 1/\gamma)a - b/\gamma}{\kappa} - \frac{1}{\beta} + 1 = z_M - \frac{b}{\kappa\gamma},$$

assuming z_B and z_M are in $(0, 1)$.

Welfare: Let V_J^k be the planner's present-discounted continuation welfare when $J = B$ under buyouts, $J = M$ otherwise, and the leader has technology γ^k . Let y_J^k , with superscript k , be equilibrium y_J , given k . Without buyouts, $y_M^k = a\gamma^{k-1}/c$. Under buyouts, $y_B^k = (a+b)\gamma^k/c$. For $J \in \{B, M\}$, $\ln y_J^k = \ln y_J^0 + k \ln \gamma$ and $y_J^k/\gamma^k = y_J^0$. Therefore:

$$\begin{aligned} V_J^k &= (a+b) \ln y_J^k - cy_J^k/\gamma^k - \kappa z_J + \beta [(1 - z_J) V_J^k + z_J V_J^{k+1}] \\ &= (a+b) \ln y_J^0 + (a+b) k \ln \gamma - cy_J^0 - \kappa z_J + \beta [(1 - z_J) V_J^k + z_J V_J^{k+1}] \\ &= \frac{(a+b) \ln y_J^0 + k(a+b) \ln \gamma - cy_J^0 - \kappa z_J + \beta z_J V_J^{k+1}}{1 - \beta(1 - z_J)}. \end{aligned}$$

Here, V_J^k is a difference equation with solution $V_J^k = \varsigma_J + \vartheta_J k$. Solving for ς_J and ϑ_J , we get:

$$\begin{aligned} \vartheta_J &= \frac{(a+b) \ln \gamma + \beta z_J \vartheta_J}{1 - \beta(1 - z_J)} = \frac{(a+b) \ln \gamma}{1 - \beta}, \text{ and} \\ \varsigma_J &= \frac{(a+b) \ln y_J^0 - cy_J^0 - \kappa z_J + \beta z_J (\varsigma_J + \vartheta_J)}{1 - \beta(1 - z_J)} = \frac{(a+b) \ln y_J^0 - cy_J^0 + z_J \left[(a+b) \frac{\beta \ln \gamma}{1 - \beta} - \kappa \right]}{1 - \beta}. \end{aligned}$$

Note: R&D is socially valuable if:

$$[(a+b) \beta (\ln \gamma) / (1 - \beta) - \kappa] > 0 \Leftrightarrow b > \tilde{b} \equiv \kappa (1/\beta - 1) / \ln \gamma - a. \quad (4)$$

Comparison: Since $\vartheta_B = \vartheta_M$, buyouts reduce welfare, regardless of k , iff $\varsigma_B < \varsigma_M$:

$$\begin{aligned} \frac{(a+b) \ln y_B^0 - cy_B^0 + z_B \left[(a+b) \frac{\beta \ln \gamma}{1 - \beta} - \kappa \right]}{1 - \beta} &< \frac{(a+b) \ln y_M^0 - cy_M^0 + z_M \left[(a+b) \frac{\beta \ln \gamma}{1 - \beta} - \kappa \right]}{1 - \beta} \Leftrightarrow \\ [(a+b) \ln y_B^0 - cy_B^0] - [(a+b) \ln y_M^0 - cy_M^0] &< (z_M - z_B) [(a+b) \beta (\ln \gamma) / (1 - \beta) - \kappa]. \end{aligned}$$

On the l.h.s., we see the static gain of buyouts. The dynamic cost is at the r.h.s. With equilibrium y 's and z 's, the inequality becomes:

$$(a+b) \ln \left(\frac{a+b}{a} \gamma \right) - (a+b) + \frac{a}{\gamma} < \frac{b}{\kappa\gamma} \left[\frac{\beta(a+b)}{1 - \beta} \ln \gamma - \kappa \right] \Leftrightarrow (1).$$

where the implication follows when $a+b > 0$. Eq. (1) fails if $b = 0$, but because the l.h.s. is concave in b (and $\lim_{b \rightarrow \infty} \partial \ln(a+b)/\partial b = 0$), while the r.h.s. is linear in b , there exists $\underline{b} < 0$ and $\bar{b} > 0$, so that (1) holds iff $b \notin (\underline{b}, \bar{b})$. It is easily seen that when a or β increases, or κ decreases, then both $\underline{b}$ and $\bar{b}$ must fall. ■

Remark 2—Durable goods: If consumers who bought at t , don't buy at $t + 1$, the results would be strengthened: The planner's large (small) quantity when $b > 0$ ($b < 0$) will reduce (increase) the profit for the next technology leader given that the market is, to some extent, (un)saturated.

Remark 3—Convex R&D costs: If the R&D cost were a convex function, $\kappa(z)$, of z , a binding (2) would imply that equilibrium z would be concave in π . Hence, the dynamic cost of buyouts would increase as a convex function of b when b increased. This would reinforce the above mechanism that when $|b|$ becomes very large, the dynamic cost eventually outweighs the static gain of buyouts.

Remark 4—Alternating buyouts. The proof compares a buyout regime with no buyouts. When $b > 0$, and the two regimes generate similar welfare levels, both are dominated by a regime where the planner purchases *every other* patent. Intuitively: After a buyout at t , p is smaller at $t + 1$, so the static gain from a buyout at $t + 1$ is smaller. (The dynamic cost, in contrast, is unchanged.)⁴

IV. THE FIRST-BEST MARKUPS AND SUBSIDIES

There are two market failures in the model. Buyouts allow the planner to maximize static welfare, but R&D can become less efficient. If the planner can commit to buy future patents at a markup, $m(b)$, relative to its corporate value, then also R&D can be efficient (as in Kremer, 1998). Assuming (4) holds, so that $z > 0$ is socially optimal, then the necessary markup increases in b , since a larger b would otherwise reduce the corporate value of R&D under buyouts.

The first best can also be implemented if buyouts are combined with an R&D subsidy $s(b)$. In line with the intuition above, the subsidy must increase in b to motivate first-best R&D.

Proposition 2.

(i) *The first best is implemented under buyouts with markup prices that increase in b :*

$$m(b) = \frac{\kappa/\beta}{a - a/\gamma - b/\gamma}, \text{ so } m'(b) > 0,$$

or, alternatively, under buyouts combined with R&D subsidy:

$$s(b) \equiv 1 - \beta \frac{a - a/\gamma}{\kappa} + \beta \frac{b}{\kappa\gamma}, \text{ so } s'(b) > 0.$$

(ii) *The first best can also be implemented with production subsidy $S(b)$ and R&D subsidy $s_S(b)$:*

$$S(b) = \left(\frac{a+b}{a} \right) \gamma - 1 \text{ and } s_S(b) = 1 - \frac{\beta}{\kappa} (a+b) \left(\gamma - \frac{1}{\gamma} \right), \text{ so } s'_S(b) < 0 < S'(b).$$

Part (ii) confirms that the planner can also implement the first best by a combination of a production subsidy, $S(b)$, and an R&D subsidy, $s_S(b)$. In this case, the optimal R&D subsidy turns out to *decrease* in b . The effect of b is reversed because the optimal production subsidy, and thus the innovator's profit, increases in b . Hence, R&D levels increase, so the R&D subsidy can decrease in b .

Comparison and relevance: Is the situation with markups, or without, most relevant? This depends on the type of technology: It is possible to verify that a vaccine works for Covid-19, and the externality b is (more or less) known. For such an innovation, it might be realistic that the government can commit to a markup, or to subsidies. For other types of innovations, such as the innovation of the internet, it is instead difficult to describe in advance what and when the government would like to pay more for the innovation. If b , γ or κ is unverifiable, the planner might want to claim that the b/γ , or κ , associated with a particular innovation, is small, since, then, the markup should also be small. For these reasons, the situation with (Section IV) and without markups (Section III) are both relevant, and a comparison between them uncovers how the benefits of buyouts depend on the technology in question.

⁴Stiglitz and co-authors have suggested that “selective purchasing could both ensure that the [purchased] drugs are available at prices near their cost of production, while also putting pressure on the prices of the drugs that are not purchased, to drop.” See:

<https://www8.gsb.columbia.edu/faculty/jstiglitz/sites/jstiglitz/files/IP%20for%2021st%20Century%20-%20EN.pdf>

Bargaining power: Above, it was assumed that the planner could make a take-it-or-leave-it offer when purchasing the patent from an innovator. More generally, we may allow the innovator to obtain the fraction $\alpha \in [0, 1]$ of the bargaining surplus. The larger is α , the larger is the incentive to innovate. Since R&D levels, all things equal, fall in b under buyouts, the level of α that guarantees efficient R&D increases in b . In other words, it would be optimal to allocate more of the bargaining power to the innovator if the consumer externality, associated with the innovation, is large.

Proof of Proposition 2: Let's first prove (i).
R&D subsidies: With a subsidy on R&D, s_J , the net R&D cost is $\kappa(1 - s_J)$, so an innovator invests if:

$$\kappa(1 - s_J) \leq \frac{\beta\pi_J}{1 - \beta(1 - z_J)},$$

replacing (2). So, $z_J = 1$, which is socially optimal when $b > \tilde{b}$, iff:

$$\begin{aligned} s_J &= 1 - \beta\pi_J/\kappa \Rightarrow \\ s_B &= s(b) \equiv 1 - \beta(a - a/\gamma - b/\gamma)/\kappa \text{ and} \\ s_M &= 1 - \beta(a - a/\gamma)/\kappa = s(0). \end{aligned}$$

Markups: If every future innovation will be bought by the planner at markup $m(b)$, relative to the corporate value, then $z_B = 1$ if:

$$\kappa(1 - s_B) = m(b)\beta\pi_B \Leftrightarrow m(b) = \frac{(1 - s_B)\kappa}{\beta\pi_B} = \frac{(1 - s_B)\kappa/\beta}{a - a/\gamma - b/\gamma}.$$

(ii) Without a buyout, but with production or price subsidy S , the non-leading firms are willing to sell at price

$$c/(1 + S)\gamma^{k-1},$$

which equals the socially optimal price $ca/(a + b)\gamma^k$ if

$$S = \left(\frac{a + b}{a}\right)\gamma - 1,$$

giving the leader the profit

$$\pi_S = a(1 + S) - \frac{a + b}{\gamma} = (a + b)(\gamma - 1/\gamma).$$

With investment subsidy s_S , in addition to production subsidy S , $z = 1$ when:

$$s_S = 1 - \beta\pi_S/\kappa = 1 - \frac{\beta}{\kappa} \left[a(1 + S) - \frac{a + b}{\gamma} \right] = 1 - \frac{\beta}{\kappa} (a + b) \left(\gamma - \frac{1}{\gamma} \right),$$

which decreases in b because S increases in b . ■