Research funding and price negotiation for new drugs

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ABSTRACT. We study a three-side negotiation model where a health authority, a lab producing basic research and a lab producing applied research agree on the investments in basic and applied research and on the final price of a drug. When the three agents are independent, we show that the interest of the health authority and that of the applied research lab are fully aligned. Then we study how integration with the basic research lab affects the sharing of surplus among the three agents. Results depend on relative bargaining powers and on the gain in bargaining power after integration. If the latter is not too high, the agent outside of the integration is the only one to benefit from integration between the other two agents. Specifically, consumers’ surplus increases and negotiated price for the new drug falls if basic and applied research labs merge together.

KEYWORDS. Pharmaceutical innovation, drug prices, negotiation, basic research, applied research.

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1. INTRODUCTION

Pharmaceutical innovations result from the successful achievement of basic and applied research. Applied research labs generally make use of the fundamentals from basic research to develop tradable innovations. Cohen et al. (2002) document that public research importantly affects industrial R&D across much of the manufacturing sector and that university research largely generates new ideas for industrial R&D projects. Applied research mostly lies in the hands of private companies that lead to tradable innovations, while basic research is traditionally financed by the government and was mainly developed in the public sector. Aghion et al. (2008) provide a powerful argument to justify public early-stage research and private applied research. They show that, by serving as a pre-commitment mechanism that allows scientists to freely pursue their own interests,

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academia can be indispensable for early-stage research. At the same time, the private sector’s ability to direct scientists towards higher-payoff activities makes it more attractive for later-stage research.¹

Nowadays, private forms of basic research are emerging so that basic research is not confined to public universities and institutes any more. In the United States, for example, where basic research was mainly funded by federal government and mainly performed within universities and research institutes, the government funding steadily diminished in the 2010s and private funding became increasingly important (see Broad, 2014). Independent spin-offs, start-ups, joint ventures appeared and independent basic research labs are now sometimes integrated in the research department of big private corporations (see Billette de Villemeur and Versaevel, 2017, among others).

The changing organization of basic research is concomitant with the public debate about the fast rising prices of innovative drugs. On the one hand, the patent system provides innovators with market power and with the corresponding earning of a monopoly rent. On the other hand, the existence of either public or compulsory health insurance justifies the public concern for rising prices that generate an ever-higher burden on the public budget. Indeed, insurance subsidies decrease the price elasticity of the patients’ demand. The monopoly producer anticipates this effect and, absent regulation and price negotiation, accordingly sets prices that are increasing in the generosity of insurance (Jelovac, 2015). Hence, insurance reimbursement of pharmaceuticals increases innovators’ rents above the traditional monopoly rents associated with patents.

Drugs’ excessive pricing has recently been recognized as a main issue in OECD countries and the document titled “Excessive Prices in Pharmaceutical Markets” has been delivered in 2018 (OECD 2018).² As it is increasingly acknowledged, drug price negotiation can curb such prices downwards. This is why the US administration has recently adopted the Medicare Prescription Drug Price Negotiation Act of 2017, which requires Medicare and Medicaid to negotiate drug prices with pharmaceutical companies. This new law satisfies the recommendation by Tefferi, Ayalev et al. (2015), among others, to negotiate drug prices to curb the fast-increasing prices of innovative cancer drugs. In France, where drug prices are negotiated and patients are protected against catastrophic out-of-pocket expenses, prices of all innovative drugs are high and increasing. As a consequence, the Cour des Comptes (2017) has recommended to provide the Comité Économique des Produits de Santé with increased financial and legal resources to raise its negotiation power.³

We offer a contribution to this debate with a very simple model focusing on the negotiation process which leads to basic research funding and price setting for new drugs

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¹Gonzalez et al. (2016) show that pharmaceutical firms’ incentives for conducting R&D activities for breakthrough drugs are inferior to those socially optimal and that firms invest too much in incremental innovations. But the authors disregard the role played by basic research in obtaining the innovation.

²Antitrust authorities discussed a large number of cases concerning the excessive pricing of pharmaceutical products starting from the 1970s. In Germany, the most representative case was the Valium case. In 2001 in UK, the Office of Fair Trade pursued a case relating to the excessive pricing of morphine products. A more recent case is the one of an anti-epileptic drug called Epatunin. In 2016 in the US, following the sudden price increase of EpiPens manufactured by Mylan, the Federal Trade Commission started an investigation for possible antitrust violations. In 2016 the Italian Competition Authority found that Aspen had charged an excessive price for a portfolio blood cancer drugs after their price was raised by 300%-1,500%.

³The Cour des Comptes is a French administrative court charged with conducting financial and legislative audits of most public institutions; the Comité Économique des Produits de Santé is the French public authority in charge of drug price negotiations.
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in regulated health insurance markets. We want to reply to the following questions; how should basic research be funded? Is integration with the basic research lab desirable from the perspective of the health authority?

In the model, the health authority, the lab producing basic research and the lab producing applied research interact and agree on the investments in basic and applied research and on the final price of the drug. In our interpretation, basic research represents an intermediate input necessary to finalize a new drug so that it is produced upstream. Applied research is instead produced downstream by a pharmaceutical firm that commercializes the innovation and negotiates with the health authority the price of the drug. The collectivity attaches some social value to the innovation that enters the payoff of the health authority. The monopoly power of the unique pharmaceutical firm (i.e., the downstream lab) is justified by some guaranteed protection (patent) of the innovation. Our setting describes a stylized regulated market for a new drug: the health authority can actually influence the price of a new drug because it partially or totally pays this price to the pharmaceutical firm when providing public health insurance coverage to its citizens.

We first analyze the funding of basic research when all agents are independent and public and private payments are simultaneously negotiated. We then investigate in turn private and public integration of basic research. The former implies a merger between the basic and the applied research labs. The latter illustrates instead the case of basic research within the public sector. Importantly, in order to focus on how the total surplus is shared among the agents agreeing on the financing of basic research and on the final price of the drug, we build a model where investments in basic and applied research are efficient and the total surplus is always at its maximum level.

We find that the interest of the health authority and of the downstream lab are fully aligned: both agents are better off when basic research is funded by the one with the highest bargaining power. As an intuition, the health authority and the downstream lab negotiate the price together in the last stage of the game and, at that point, they share the surplus that is not appropriated by the upstream lab. To increase such surplus, both agents find it convenient that the one of them characterized by the largest negotiation power negotiates with the upstream lab.

Moving to integration (or equivalently, to merger) and considering the likely situation in which the bargaining power does not display very important ‘increasing returns to merger’, we show that integration with the lab producing basic research impairs the merging agents and benefits the agent remaining independent. Specifically, we observe that the health authority benefits from the merger of the two labs and, in the same way, the downstream lab benefits from the integration of the health authority and the upstream lab. The intuition is that the independent agent shares the total surplus with only one other negotiator rather than two, and thus obtains a higher share of the total surplus. The remaining surplus accrues to the integrated body, the components of which would have earned more in total if they were independent. However, in case of very important ‘increasing returns to merger’, the previous results are reversed and the merging agents are better off.

As mentioned before, together with the monopoly rent stemming from patent protection, the pharmaceutical firm receives extra rents generated by the fact that the health authority reimburses the price of the drug to consumers. This is why we take the perspective of the health authority and deliver the following policy implications. When the bargaining power of the health authority (alone) is relatively high, the latter should fund
basic research but should not integrate with the lab producing it. When instead the bargaining power of the health authority is relatively low, it should leave the funding of basic research to the downstream lab. In both cases, the health authority would benefit from the integration of the labs producing basic and applied research provided their bargaining power does not display very important ‘increasing returns to merger’. The merger of the two labs assures a higher share of the surplus to the health authority and a lower negotiated price paid by the health authority to the downstream lab.

The remaining of the note is organized as follows. The next section describes our theoretical setting. Section 3 shows the general case where drug price, private and public grants for basic research are negotiated. Section 4 introduces the possibility of integrating basic research into either the public sector or the private pharmaceutical firm. Section 5 concludes.

2. The Model

Consider three agents: a health authority, $H$; a laboratory $B$ producing basic research $b$; and a lab $A$ producing applied research $a$. In our interpretation, basic research $b$ represents an intermediate input necessary to finalize a new drug (see also Aghion et al. 2008). Thus, lab $B$ produces upstream whereas lab $A$ produces downstream. This implies that the decision about the amount $b$ invested in basic research is always made before the decision about the amount $a$ invested in applied research. In addition, lab $A$ commercializes the new drug. Hence, it negotiates with the health authority $H$ the final price of the drug $P$, which the health authority pays to the lab. Given that lab $A$ sells the new drug in the market, we will refer to it as ‘lab A’ or ‘firm A’ interchangeably.

The basic research lab $B$ can negotiate some compensation, $X_H$, with the health authority. Lab $B$ can also negotiate some compensation $X_A$ from firm $A$, which is equivalent to outsourcing of basic research.

We assume that $a$ and $b$ represent research activities as well as their costs. The value of innovation to the health authority depends on the investments in both basic and applied research and we denote it $V(a,b)$. We reasonably assume that the variable cost of producing the pharmaceutical innovation is null and the demand for it is part of its social value. The monopoly power of lab $B$ is justified by the fact that the lab is able to provide the basic knowledge $b$ which is complementary to $a$ in the production function $V(a,b)$. The monopoly power of firm $A$ is justified by some guaranteed protection (patent) of the innovation.

The objectives of the health authority, labs $A$ and $B$ are as follows:

\[ W = V(a,b) - X_H - P; \] (2.1)
\[ \Pi_B = X_H + X_A - b; \] (2.2)
\[ \Pi_A = P - X_A - a; \] (2.3)

where $X_H, X_A \geq 0$ and at least one of the two payments is positive, meaning that basic research must be financed. Notice that the health authority maximizes consumers’ surplus net of the public contribution to basic research and of the price paid to firm $A$. From (2.1)-(2.3), total surplus is $TS = V(a,b) - a - b$. The efficient investment in basic and applied research maximizes total surplus by equating marginal cost and marginal benefit: $V_a(a,b) = V_b(a,b) = 1$. 

We define $\beta_H$, $\beta_B$ and $\beta_A$ the negotiation power of the three agents. In any bargaining stage, the relative negotiation powers of any two bargaining agents must sum at one. We normalize outside options to zero.\footnote{Outside options may correspond to a monopoly situation in which the drug is protected by a patent but sold without price negotiation. Given that the latter always accrues the firm’s and the health authority’s surplus, we can assume that outside options are zero without loss of generality.}

The timing of the game is as follows. The research lab $B$ first chooses her investment in basic research $b$. Then, lab $B$ simultaneously negotiates a transfer $X_H$ with the public health authority $H$ and a transfer $X_A$ with the downstream lab $A$ to finance basic research. In a third step, the downstream lab $A$ decides to invest $a$ in applied research. Last, $H$ and $A$ negotiate the final price, $P$.

Investments $b$ and $a$ are chosen anticipating the negotiation, occurring in the subsequent period, which defines payments $X_H$ and $X_A$ for basic research and price $P$ for the final drug. As we will show, this implies that agents choose the efficient investments in basic and applied research and the total surplus is always at its maximum level. Hence, we are able to focus on how the total surplus is shared among the agents.

3. HOW SHOULD BASIC RESEARCH BE FUNDED?

Solving the game backwards, we start by deriving the final negotiated price, which is the solution to the following Nash Bargaining Program between the health authority and the downstream lab:

$$\max_P \beta_H \ln(V(a,b) - X_H - P) + \beta_A \ln(P - X_A - a).$$

The Nash Bargaining Solution provides the following negotiated final price:

$$P = \frac{\beta_H(a + X_A) + \beta_A(V(a,b) - X_H)}{\beta_H + \beta_A}. \quad (3.1)$$

The negotiated price positively depends on $a + X_A$, i.e. on the total contribution to innovation provided by the downstream lab, both in terms of applied research and funding to basic research. Conversely, the negotiated price negatively depends on the contribution to basic research, $X_H$, provided by the health authority. This means that the price of the new drugs is reduced according to public funding of basic research. If the pharmaceutical firm, owner of a patent for the final innovation, was free to set the preferred price, it would set a price close to the social value of the innovation net of the public investment in research, so as to fully extract the surplus from pharmaceutical consumption. If instead, the health authority was the unique price decision maker, it would set a price that compensates the pharmaceutical firm for its research investment but leave to the firm only limited profits. The negotiated price lies between the before mentioned two extreme values, at a level that depends on the respective negotiation powers of both negotiating parties.

The total surplus from this transaction is shared between the health authority and the downstream research lab according to their respective negotiation power:

$$W = \frac{\beta_H}{\beta_H + \beta_A}(V(a,b) - X_A - X_H - a);$$
\[ \Pi_A = \frac{\beta_A}{\beta_H + \beta_A} (V(a, b) - X_A - X_H - a). \]

The total surplus so far still depends on the payments \( X_A \) and \( X_H \), decided two step backwards. In the meanwhile, firm \( A \) decides its investment in applied research \( a \) so as to maximize its profit and the resulting investment equates marginal cost and marginal benefits: \( V_a(a, b) = 1 \).

In the preceding step, the two labs negotiate their transfer \( X_A \) according to the following Nash Bargaining Program:

\[
\max_{X_A} \beta_A \ln \frac{\beta_A}{\beta_H + \beta_A} (V(a, b) - X_A - X_H - a) + \beta_B \ln(X_A + X_H - b).
\]

The resulting best-reply private transfer is:

\[
X_A = \frac{\beta_A}{\beta_B + \beta_A} b + \frac{\beta_B}{\beta_B + \beta_A} (V(a, b) - a) - X_H. \tag{3.2}
\]

Simultaneously, the downstream lab and the health authority negotiate their transfer \( X_H \) according to the following Nash Bargaining Program:

\[
\max_{X_H} \beta_H \ln \frac{\beta_H}{\beta_H + \beta_A} (V(a, b) - X_A - X_H - a) + \beta_B \ln(X_A + X_H - b).
\]

The resulting best-reply private transfer is:

\[
X_H = \frac{\beta_H}{\beta_B + \beta_H} b + \frac{\beta_B}{\beta_B + \beta_H} (V(a, b) - a) - X_A. \tag{3.3}
\]

Solving the system of equations given by (3.2) and (3.3) for the transfers \( X_A \) and \( X_H \), we have either \( X_A = 0 \) or \( X_H = 0 \). Specifically:

**Lemma 1** (The financing of basic research). (i) If the health authority has a larger bargaining power than the downstream lab \( (\beta_H > \beta_A) \), then \( X_A = 0 \), i.e., basic research is exclusively financed by the health authority. (ii) If the health authority has a lower bargaining power than the downstream lab \( (\beta_A > \beta_H) \), then \( X_H = 0 \), i.e., basic research is exclusively financed by the downstream lab. (iii) If bargaining powers are the same \( (\beta_H = \beta_A) \), then both agents may contribute to the financing of basic research and any combination of payments such that (3.2) and (3.3) hold is optimal.

Given quasilinear payoff functions, unless bargaining powers are the same, we obtain a corner solution: only the agent with the larger bargaining power finances basic research. Intuitively, this depends on the fact that the health authority and the downstream lab negotiate price \( P \) together in the last stage of the game and, at that point, they share the surplus that is not appropriated by the upstream lab. To increase such surplus, both \( H \) and \( A \) find it convenient that the one of them characterized by the larger market power negotiates with the upstream lab. In the case of symmetry between \( H \) and \( A \) \( (\beta_H = \beta_A = \beta) \), instead, optimal contributions are such that:

\[
X_H + X_A = \frac{\beta}{\beta_B + \beta} b + \frac{\beta_B}{\beta_B + \beta} (V(a, b) - a).
\]

We are now going to study situations (i) and (ii) of Lemma 1 in turn.
3.1. Basic research financed by the public sector

Here the basic research lab receives a payment from the public health authority only. Given that $\beta_H > \beta_A$ and $X_A = 0$, the agents’ payoff functions simplify to:

$$W = V(a, b) - X_H - P;$$
$$\Pi_B = X_H - b;$$
$$\Pi_A = P - a.$$

Now the payoff functions of the two labs are isomorphic. However the distinction between basic and applied research labs is still captured by the timing: the decision about the amount $b$ invested in basic research is always made before the decision about the amount $a$ invested in applied research. In addition, recall that firm $A$ commercializes the new drug and negotiates with the health authority the final price of the drug $P$.

Substituting $X_A = 0$ into (3.1) and (3.3) and solving for drug price $P$ and public payment $X_H$, we obtain the following solution holding when $\beta_H > \beta_A$:

$$P^{(1)} = a + \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a, b) - a - b). \quad (3.4)$$

$$X_H^{(1)} = \frac{\beta_H}{\beta_B + \beta_H} b + \frac{\beta_B}{\beta_B + \beta_H}(V(a, b) - a). \quad (3.5)$$

Superscript (1) refers to the solution to the present case where basic research is funded by the health authority only.

The resulting total expenses for the health authority are:

$$P^{(1)} + X_H^{(1)} = V(a, b) - \frac{(\beta_H)^2}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a, b) - a - b). \quad (3.6)$$

Final payoffs are:

$$W^{(1)} = \frac{(\beta_H)^2}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a, b) - a - b); \quad (3.7)$$

$$\Pi_B^{(1)} = \frac{\beta_B}{\beta_H + \beta_B}(V(a, b) - a - b); \quad (3.8)$$

$$\Pi_A^{(1)} = \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a, b) - a - b). \quad (3.9)$$

The final payoffs illustrate how the sequence of events favors the upstream lab $B$ and impairs the final negotiators $A$ and $H$. Indeed, lab $B$ does not need to be as strong a negotiator as either lab $A$ or $H$ to have a higher payoff:

$$\Pi_B^{(1)} \geq W^{(1)} \iff \beta_B \geq \beta_H \frac{\beta_H}{\beta_H + \beta_A}; \quad (3.10)$$

and
\[ \Pi_B^{(1)} \geq \Pi_A^{(1)} \iff \beta_B \geq \beta_A \frac{\beta_H}{\beta_H + \beta_A}. \]  

(3.11)

The intuition behind such an imbalance relates to the lack of coordination between the final negotiators \( A \) and \( H \) when they negotiate the funding of basic research with the upstream lab \( B \).

Finally, in the first stage, lab \( B \) decides its investment in basic research \( b \) so as to maximize its profit and the resulting investment equates marginal cost and marginal benefits: \( V_b(a, b) = 1 \).

The comparative statics of the payoff functions show very intuitive relationships between solution and parameters. The only unexpected result relates to the role of the health authority negotiation power with regards to the payoff of firm \( A \). From (3.9),

\[ \frac{\partial \Pi_A^{(1)}}{\partial \beta_H} > 0 \iff (\beta_H)^2 < \beta_A \beta_B. \]  

(3.12)

Recalling that this case 1 occurs when \( \beta_H > \beta_A \), \( (\beta_H)^2 < \beta_A \beta_B \) implies that the following chain of inequalities holds:

\[ \beta_B > \frac{(\beta_H)^2}{\beta_A} > \beta_H > \beta_A. \]  

(3.13)

Hence, for \( \Pi_A^{(1)} \) to be increasing in \( \beta_H \), the basic research lab’s negotiation power \( \beta_B \) must be sufficiently higher than the negotiation powers of the other two agents (see comments after Lemma 2 below).

3.2. Basic research financed by the pharmaceutical firm

Here basic research is funded by the downstream firm only. Given that \( \beta_A > \beta_H \) and \( X_H = 0 \), the agents payoff functions simplify to:

\[ W = V(a, b) - P; \]
\[ \Pi_B = X_A - b; \]
\[ \Pi_A = P - X_A - a. \]

Substituting \( X_H = 0 \) into (3.1) and (3.2) and solving for drug price and funding of basic research \( X_A \), we obtain the following solution holding when \( \beta_A > \beta_H \):

\[ P^{(2)} = V(a, b) - \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_B + \beta_A)}(V(a, b) - a - b). \]  

(3.14)

\[ X_A^{(2)} = \frac{\beta_A}{\beta_B + \beta_A} b + \frac{\beta_B}{\beta_B + \beta_A}(V(a, b) - a). \]  

(3.15)

\[ X_H^{(2)} = 0. \]  

(3.16)

The superscript \( (2) \) refers to the solution to the present case where basic research is exclusively financed by the downstream lab.

The expenses for the regulator are given by the final negotiated price, \( P^{(2)} \) in (3.14).
Final payoffs are:

\[ W^{(2)} = \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_B + \beta_A)} (V(a, b) - a - b); \]  
(3.17)

\[ \Pi_B^{(2)} = \frac{\beta_B}{\beta_B + \beta_A} (V(a, b) - a - b); \]  
(3.18)

\[ \Pi_A^{(2)} = \frac{(\beta_A)^2}{(\beta_H + \beta_A)(\beta_B + \beta_A)} (V(a, b) - a - b). \]  
(3.19)

Again, the comparison between payoffs 3.17, 3.18 and 3.19 points to the advantage of the upstream firm in the negotiation.

Finally, in the first stage, lab \( B \) decides its investment in basic research \( b \) so as to maximize its profit and the resulting investment equates marginal cost and marginal benefits: \( V_b(a, b) = 1 \).

Notice that the solutions are symmetric in Subsections (3.1) and (3.2), that is, case (2) represents the mirror image of case (1). Therefore, we have:

\[ \frac{\partial W^{(2)}}{\partial \beta_A} > 0 \iff (\beta_A)^2 < \beta_H \beta_B. \]  
(3.20)

and

\[ \beta_B > \frac{(\beta_A)^2}{\beta_H} > \beta_A > \beta_H. \]  
(3.21)

Hence, for \( W^{(2)} \) to be increasing in \( \beta_A \), the basic research lab’s negotiation power \( \beta_B \) must be sufficiently higher than the negotiation powers of the other two agents.

Combining results expressed in (3.12)-(3.13) and (3.20)-(3.21) we can state the following lemma:

**Lemma 2.** If the bargaining power of the upstream lab is sufficiently higher than the ones of the health authority and of the downstream lab, then (i) the payoff of the downstream lab increases with the bargaining power of the health authority when \( \beta_H > \beta_A \); (ii) the payoff of the health authority increases with the bargaining power of the downstream lab when \( \beta_A > \beta_H \).

Hence, a sufficiently ‘strong’ lab producing basic research affects the negotiation between the health authority and the downstream lab in an unexpected way, irrespective of which agent is funding basic research. When basic research is financed by the health authority (\( \beta_H > \beta_A \)), the payoff of the downstream lab benefits from an increase in the negotiation power of the health authority. When instead basic research is financed by the downstream lab (\( \beta_A > \beta_H \)), the payoff of the health authority benefits from an increase in the negotiation power of the downstream lab, provided that the latter remains low relative to the negotiating power of the upstream lab. Intuitively, the stronger the funding agent who negotiates the basic research payment, the higher the total surplus (net of the payment) to be ultimately shared by both the health authority and the firm when negotiating the final drug price.

It is interesting to analyze the payoffs in the case in which the health authority and the downstream lab have the same bargaining power (\( \beta_H = \beta_A = \beta \)). To do this, we can use expressions (3.7)-(3.9) or (3.17)-(3.19) interchangeably. The three agents share the
surplus in such a way that:

\[ \Pi_B \leq W = \Pi_A \iff \beta_B \leq \frac{1}{2} \beta_H = \frac{1}{2} \beta_A \]
\[ \Pi_B > W = \Pi_A \iff \beta_B > \frac{1}{2} \beta_H = \frac{1}{2} \beta_A. \]

(3.22)

The case of symmetry between \( H \) and \( A \) illustrates how the sequence of events impairs \( H \) and \( A \) and benefits the upstream lab. Indeed, the bargaining power of both final negotiators need to be twice as high as the one of the upstream firm to earn the same payoff. Such an imbalance is confirmed under full symmetry (\( \beta_H = \beta_A = \beta_B = \beta \)):

\[ \Pi_B = 2W = 2\Pi_A \iff \beta_H = \beta_A = \beta_B, \]

which corresponds to a special case of (3.22) and quantifies the advantage of the upstream lab.

Consider now the expenditures of the health authority in the two scenarios. We observe that the latter pays \( P^{(1)} + X^{(1)}_H \) when it finances basic research, while it pays \( P^{(2)} \) when basic research is financed by the downstream lab. Comparing public expenses in the two scenarios using (3.6) and (3.14), one can easily see that either:

\[ P^{(1)} + X^{(1)}_H < P^{(2)} \iff \beta_H > \beta_A, \]

or

\[ P^{(1)} + X^{(1)}_H \geq P^{(2)} \iff \beta_H \leq \beta_A, \]

meaning that the health authority faces lower expenditures in scenario (1) when it has a larger bargaining power than the downstream lab (and the opposite when \( \beta_H < \beta_A \)). But when the health authority has a larger bargaining power, scenario (1) is precisely the outcome; hence the health authority is always better off under exclusive financing of basic research, no matter the agent financing it. We can generalize the comparison as follows. Either:

\[ P^{(1)} + X^{(1)}_H < P^{(2)} \iff W^{(1)}_H < W^{(2)}_H \iff \Pi^{(1)}_B > \Pi^{(2)}_B \iff \Pi^{(1)}_A < \Pi^{(2)}_A \iff \beta_H > \beta_A; \]

(3.23)

or

\[ P^{(1)} + X^{(1)}_H \geq P^{(2)} \iff W^{(1)}_H \geq W^{(2)}_H \iff \Pi^{(1)}_B \leq \Pi^{(2)}_B \iff \Pi^{(1)}_A \geq \Pi^{(2)}_A \iff \beta_H \leq \beta_A. \]

(3.24)

The previous chain of inequalities show that the downstream lab is better off when the health authority has high bargaining power and funds basic research. In the same way, the health authority is better off when the downstream lab is ‘strong’ and negotiates with the upstream lab. Hence, despite the fact that the health authority and the downstream lab negotiate price \( P \) together and thus have conflicting objectives in the last stage of the game, their payoffs turn out to be aligned precisely because they anticipate a bilateral sharing of the remaining surplus during the last price negotiation stage. This occurs at the expense of the upstream lab which is always worse off and would prefer to negotiate the payment for basic research with the least powerful negotiator.

From the discussions above we conclude that:

**Proposition 1.** (i) The objectives of the health authority and of the downstream lab are perfectly aligned: the two agents are better off when the one with the highest bargaining
power is the unique funder of basic research. (ii) The objective of the upstream lab is conflicting with that of the health authority and that of the downstream lab. Exclusive funding of basic research is detrimental to the upstream lab. (iii) The two previous outcomes are exacerbated when the upstream lab is sufficiently ‘stronger’ than the other agents. (iv) When the health authority and the downstream lab have the same bargaining power it is sufficient that the upstream lab has half of their bargaining power to appropriate a larger share of the surplus.

Notice that the outcome from the three negotiations favors both the health authority and the downstream firm, because of the timing of negotiations. Part (iii) of the proposition is a direct consequence of Lemma 2. Part (iv) directly comes from inequalities (3.22).

4. Integration of basic research

In this section, we ask the following question. Is integration with the basic research lab desirable from the perspective of the three agents? This is interesting because basic research has been traditionally carried out in public institutions but private forms of basic research are currently emerging.

Recall that the choice of basic and applied research is always efficient in our model. Hence, integration only affects the negotiation process and how the surplus is shared between the different agents. We consider two types of integration. Public integration occurs when the health authority and the upstream lab merge. Private integration realizes instead when the applied research lab and the basic research lab merge.

4.1. Public integration of basic research

Suppose that the public health authority and the basic research lab are integrated; they jointly decide on the investment in basic research \( b \). They also negotiate the final price \( P \) with the pharmaceutical lab. Therefore, the objectives of the integrated public body and of the downstream lab respectively are:

\[
W_{HB} = V(a, b) - P - b;
\]

\[
\Pi_A = P - a.
\]

Notice that, in case the downstream lab directly contributes to basic research with some payment \( X_A > 0 \), then the price \( P \) paid by the integrated body has to be interpreted as a total price incorporating the reimbursement for such “private contribution” to public basic research.

The timing of the game is as follows. The integrated public body, \( HB \), decides its investment in basic research, \( b \). Then, lab \( A \) decides on her investment in applied research \( a \). Last, the integrated public body, \( HB \), and the downstream lab, \( A \), negotiate the price of the drug \( P \). Solving the game backwards, we start deriving the final negotiated price, which is the solution to the following Nash Bargaining Program, where \( \beta_{HB} \) is the negotiation power of the integrated public body:

\[
\max_P \beta_{HB} \ln(V(a, b) - P - b) + \beta_A \ln(P - a).
\]
The Nash Bargaining Solution provides the following negotiated price:

\[ P^{(3)} = \frac{\beta_{HB}a + \beta_A(V(a, b) - b)}{\beta_{HB} + \beta_A}. \]  (4.2)

That is, the higher the integrated public body’s negotiation power, the smallest the difference between price and private research costs. Conversely, the higher the firm negotiation power, the lower the difference between the price and the value of the innovation net of the public research investment. The total surplus is split between the integrated agent and the lab according to their respective negotiation powers:

\[
W_{HB}^{(3)} = \frac{\beta_{HB}}{\beta_{HB} + \beta_A}(V(a, b) - a - b); \quad (4.3)
\]

\[ \Pi_A^{(3)} = \frac{\beta_A}{\beta_{HB} + \beta_A}(V(a, b) - a - b). \]  (4.4)

In the preceding steps, the public integrated agency and the pharmaceutical lab efficiently decide on their investment, as described before.

Using (4.2), the resulting total expenses for the integrated public body can be rewritten as:

\[ P^{(3)} + b = V(a, b) - \frac{\beta_{HB}}{\beta_{HB} + \beta_A}(V(a, b) - a - b). \]  (4.5)

The comparison between the downstream lab’s payoff without integration given by either (3.9) or (3.19), and \( \Pi_A^{(3)} \) leads to the following lemma:

**Lemma 3.** With respect to case (1), public integration of basic research implies (i) an increase in the payoff of the downstream lab if \( \beta_{HB} < \beta_H + \beta_B + \frac{\beta_A \beta_B}{\beta_H} \), (ii) a decrease in the payoff of the downstream lab if the opposite condition holds. With respect to case (2), the same results hold by replacing the condition in (i) by \( \beta_{HB} < \beta_H + \beta_B + \frac{\beta_H \beta_B}{\beta_A} \).

How the payoffs of the agents change with integration depends on the bargaining power of the new public body. Specifically, unless \( \beta_{HB} \) increases dramatically, the downstream lab is better off after the integration of the health authority with the basic research lab. In different words, we expect Lemma 3(i) to represent the most plausible instance.

As an intuition for this result consider that two negotiations were necessary in the case of independent basic research lab, whereas we have only one negotiation with integration. The total surplus is unchanged because efficiency is granted anyway. From the point of view of the downstream lab now the surplus is shared only between two agents while it was shared among three agents in cases (1) and (2). The downstream lab, thus, gains from the integration between the health authority and the basic research lab unless the bargaining power of the new integrated body is very high. Conversely, the public integrated body obtains a share of the total surplus that is lower than the sum of the two previous shares unless its bargaining power is very high.

This reasoning on the effects of integration is reminiscent of the consequences of a merger on merging parties and outsiders in oligopolistic markets (Stigler, 1950). In a Cournot model, for example, outsiders are better off after a merger if the increase in

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5 Notice that we are comparing here the payoffs of the agent that is not merging (lab A in this section) in scenarios (1), (2) and (3).

6 In particular we expect \( \beta_{HB} \leq \beta_H + \beta_B \).
market power due to increased concentration more than compensates the negative effect generated by possible efficiency gains for the merging parties.

4.2. Private integration of basic research

Suppose now that the upstream and downstream labs are integrated. The objectives functions of the health authority and of the integrated lab are as follows:

\[ W = V(a, b) - P; \]
\[ \Pi_{AB} = P - a - b. \]

The integrated lab \( AB \) decides investments in basic research \( X_A = b \) and in applied research \( a \). Last, \( AB \) negotiates with \( H \) the final price \( P \).

Proceeding as before, price \( P \) writes:

\[ P^{(4)} = V(a, b) - \frac{\beta_H}{\beta_H + \beta_{AB}} (V(a, b) - a - b). \quad (4.6) \]

The total surplus is shared between the health authority and the integrated lab according to their respective negotiation power:

\[ W^{(4)} = \frac{\beta_H}{\beta_H + \beta_{AB}} (V(a, b) - a - b); \]
\[ \Pi_{AB}^{(4)} = \frac{\beta_{AB}}{\beta_H + \beta_{AB}} (V(a, b) - a - b). \]

Comparing the health authority’s payoff \( W^{(4)} \) with the one obtained without integration as in either (3.7) or (3.17), results in the following lemma:

**Lemma 4.** With respect to case (2), integration of the two labs implies (i) an increase in the final surplus of the health authority if \( \beta_{AB} < \beta_A + \beta_B + \frac{\beta_{AB} \beta_H}{\beta_H} \), (ii) a decrease in the final surplus of the health authority if the opposite condition holds.

With respect to case (1), the same results hold by replacing the condition in (i) by \( \beta_{AB} < \beta_A + \beta_B + \frac{\beta_{AB} \beta_H}{\beta_H} \).

As before, points (i) and (ii) show that the change in the negotiators’ payoffs depends on the bargaining power of the new integrated body. In the likely case (i), where the bargaining power of the integrated firm is not too high, the health authority is better off after the integration between the two labs. Private integration is the mirror image of public integration and the intuition behind this result is the same as before.

Combining results of Lemmas 3 and 4:

**Proposition 2.** In the plausible situation in which the bargaining power does not display very important increasing returns to merger, integration with the lab producing basic research impairs the merging agents and benefits the agent remaining independent.

As a last observation, let us consider the case of fully symmetric bargaining powers \( \beta_H = \beta_A = \beta_B = \beta \). Previous results are confirmed. Take the case of public integration. If \( \beta_{HB} \leq 2 \beta \), then \( W^{(3)}_{HB} \leq \frac{2}{3} (V(a, b) - a - b) \) and \( \Pi^{(3)}_A \geq \frac{1}{3} (V(a, b) - a - b) > \Pi^{(1)}_A = \Pi^{(2)}_A = \frac{1}{4} (V(a, b) - a - b) \). Similarly, in the case of private integration, \( \beta_{AB} \leq 2 \beta \) implies that \( W^{(4)} \geq \frac{1}{3} (V(a, b) - a - b) > W^{(1)} = W^{(2)} = \frac{1}{4} (V(a, b) - a - b) \) and \( \Pi^{(4)}_{AB} \leq \frac{2}{3} (V(a, b) - a - b) \).
4.3. Should basic research be publicly funded?

We now take the perspective of the health authority whose objective is to maximize consumers’ welfare. The reason why we focus here on consumers’ surplus rather than on total surplus is threefold. First, the total surplus is invariant in our setting because we avoid efficiency issues. Second, the downstream lab already enjoys a monopoly rent associated to patent. Third, the recent debate on excessive pricing of pharmaceuticals mentioned in the introduction suggests that consumers’ welfare is currently a more appropriate policy target.

Consumers’ welfare obviously decreases with the negotiated price paid to the downstream lab. The following corollary directly follows from Propositions 1 and 2:

**Corollary 1.** Let us consider the perspective of the health authority. In the plausible situation in which the bargaining power does not display very important increasing returns to merger, (i) if $\beta_H > \beta_A$, the health authority should be the unique funder of basic research but should not integrate with the upstream lab; (ii) If $\beta_A > \beta_H$, the health authority should leave the full funding of basic research to the downstream lab; (iii) In the two previous cases, the health authority would benefit from the integration of the labs producing basic and applied research.

Corollary 1 provides a new rationale for the public financing of basic research. Our argument focuses on the negotiation process to set public and private compensations for basic research and to set the final price of a new drug. As long as the gain in bargaining power after integration is not extremely high, integration between the health authority and the public research lab is never desirable while integration between basic and applied research is always desirable. If however the basic research lab remains independent and the health authority has a relatively large bargaining power ($\beta_H > \beta_A$), then the health authority should fund basic research.

5. Conclusion

We presented an extremely simple and parsimonious model of price and research contributions negotiations. We disregarded efficiency motives and focused on the bargaining process between a health authority and a downstream lab when basic research is produced by an upstream lab. We show that basic research is financed by the health authority (downstream lab) if the former has more (less) negotiation power than the latter and that the exclusive financing of basic research benefits both the health authority and the downstream lab. In the three-side negotiation analyzed in this note, the payoffs of the ‘final negotiators’ (i.e. the health authority and the downstream lab) are fully aligned while the ‘intermediate negotiator’ (i.e. the upstream lab) is always worse off negotiating with the strongest final negotiator. Despite this conflict, the sequence of events favors the independent upstream lab and impairs the final negotiators. This is why, the upstream lab looses from integration (either upstream or downstream), unless the bargaining power after integration displays very high ‘increasing returns to integration’. So that, starting from a situation with three independent agents, integration will not occur.

In the real world we observe different possible arrangements as for the financing and the production of basic research; however, basic research is still mainly financed by the government in many countries. Our model suggests that public funding of basic research is desirable if the bargaining power of the health authority is higher than the one of the
pharmaceutical firm commercializing the new drug. The widespread cases of excessive pricing reported in Footnote 1 and the hot debate on drugs’ raising prices in OECD countries cast some doubts on the health authorities being today the strong negotiators; especially when negotiating with big pharma companies characterized by high market shares. If health authorities are indeed ‘weaker’ than big pharma companies, our model suggests that a better arrangement is the one in which basic research is financed by the pharmaceutical firm. In this case it would be even better if the health authority could negotiate prices with a pharmaceutical firm integrated with the lab producing basic research (provided the bargaining power of the firm does not increase too much after integration). This implies that the current trend towards the development of spin-offs, start-ups and joint ventures producing basic research with big private corporations could be a desirable practice. If health authorities are instead ‘stronger’ than big pharma companies, our model suggests that public funding of basic research can still be desirable if the lab producing basic research is not integrated with the health authority; as it seems the case in the real world given that public research centers, labs and Universities are fully autonomous institutions.

In our model, public contribution to basic research is appropriately accounted for when bargaining on the price of the new drug takes place. In our setting, accounting for the public contribution to basic research translates in the explicit negotiation of the payment $X_{H}$. Such a setting satisfies the recommendation by Maraninchi and Vernant (2016) to take into account both private R&D expenses and the costs of public R&D that contributed to the production of a new drug when negotiating its price. In different words, in countries with public provision of health insurance and public funding of basic research, taxpayers should receive a “discount” on the price of a new drug proportional to the public contribution to its development. Unfortunately, in the real world, health authorities may have a hard time internalizing the public contribution to public research when negotiating prices of innovations. However, efforts should be made in this direction and, if successful, this practice would help to contain the current increase in drug prices.

Drug price negotiations have been adopted in many countries and the US has just started expanding their use. Given the dominant position of the US in the international pharmaceutical market, the impact of negotiations on the price of drugs may become more relevant in a near future. The setting we propose in this note offers an extremely simple but useful framework to study the effects of different arrangements as for the financing of basic research on negotiated prices for new drugs. It also shows how public contributions to basic research should be properly taken into account by the regulator in the different scenarios when negotiating prices with the downstream lab.

One reason why internalizing the public contribution to basic research during price negotiations is difficult is that a given piece of basic research generally results in various applications and possibly leads to various commercialized items. Disentangling the very contribution of basic research to some specific innovation is therefore uneasy. Our model does not account for positive spillovers of public basic research, whose investigation requires a more complex market structure than the simple monopolistic one analyzed in this note. We leave this issue for future research. We can however conjecture that our current results underestimate the importance of public funding of basic research.
REFERENCES


