Research funding and price negotiation for new drugs

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WP 1902 – January 2019

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JEL codes:
D8

Working Paper

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This version: December 20, 2018

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1. Introduction

Pharmaceutical innovations result from the successful achievement of basic and applied research. Basic research generally precedes applied research, which makes use of the fundamentals from basic research to develop tradable innovations and, doing so, translates basic research into operational medical knowledge. Applied research mostly lies in the hands of private companies, precisely because they lead to tradable innovations, while basic research is traditionally financed by the government or is developed in the public sector. Aghion *et al.* (2008) provides 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, 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. Gonzalez *et al.* (2016) provide another interesting argument to discuss the pros

*We thank for very helpful comments and discussions David Bardey, Paula Gonzalez, Robert Nuscheler, Lorenzo Zirulia, participants to the 19th EHEW in Paris and seminar participants at the University of Augsburg.

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and cons of private research. They distinguish between breakthrough and incremental innovations. They show that pharmaceutical firms' incentives for conducting R&D activities searching for breakthrough drugs are inferior to those socially optimal and that firms devote too many resources to R&D activities that lead to incremental innovations. But the authors disregard the different roles played by basic and applied research labs.

Nowadays, private forms of basic research are emerging so that basic research takes place no more only in public universities and institutes. In the United States, for example, where basic research was funded mainly by federal government and done mainly at universities and institutes, the government funding has diminished in the 2010s and private funding is increasingly important (see Broad, 2014). Independent spin-offs, start-ups, joint ventures appear and independent basic research labs are sometimes integrated in the research department of big private corporations such as pharmaceutical firms (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. It is not our goal to question the patent system and the corresponding market power for the innovators. However, the existence of public insurance for drug consumption justifies this public concern for such rising prices. In 2015, 118 US cancer physicians co-signed a commentary in Mayo Clinic Proceedings (Tefferi, Ayalev et al. 2015) to raise concerns about fast-increasing prices of innovative cancer drugs. They report the following: "In 2014, all new US Food and Drug Administration (FDA)–approved cancer drugs were priced above $120,000 per year of use. The average annual household gross income in the United States is about $52,000. For a patient with cancer who needs one cancer drug that costs $120,000 per year, the out-of-pocket expenses could be as high as $25,000 to $30,000—more than half the average household income and possibly more than the median take-home pay for a year." They advocate, among other actions, to allow Medicare to negotiate drug prices. Recently, the US administration has adopted the Medicare Prescription Drug Price Negotiation Act of 2017, which "amends title XVIII (Medicare) of the Social Security Act to require the Centers for Medicare and Medicaid Services (CMS) to negotiate with pharmaceutical companies regarding prices for drugs covered under the Medicare prescription drug benefit." Until then, the law prohibits CMS from doing so.

In France, cancer physicians led by Maraninci and Vernant (2016) have followed their US pairs by launching a petition against rising cancer drug prices. Even if in France, drug prices are negotiated and patients are protected against catastrophic out-of-pocket expenses, prices of innovative drugs are high and increasing. The Cour des Comptes (2017), a French administrative court charged with conducting financial and legislative audits of most public institutions, recommends to provide the Comité Économique des Produits de Santé, which is the public authority in charge of drug price negotiations, with increased financial and legal resources to raise its negotiation power. On top of this, Maraninci and Vernant (2016) recommend to take into account not only private R&D expenses when negotiating drug prices, but also the costs of public R&D that contributed to the production of such drugs. In different words, in countries with public provision of health insurance, one should avoid that taxpayers first pay basic research for the development of a new drug and then pay the full price of the new drugs by financing the health authority when the latter purchase the drug from the pharmaceutical firm.

We offer a contribution to this debate by proposing a very simple three-side negotiation model where the health authority, the lab producing basic research and the one 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. This implies that the decision about the amount invested in basic research is always made before the decision about the amount invested in applied research. In addition, the downstream lab 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 is suited to describe the current situation in many NHS-type countries: the public sector can actually influence drug prices because it partially or totally pays these prices to the pharmaceutical firms.[1]

When we analyze the funding of basic research, we consider both public and private research grants, which are also negotiated. The health authority negotiates public grants with the basic research lab and the pharmaceutical firm negotiates private grants with the same lab. We also investigate integration, either private or public, as an alternative to research grants. Private integration reflects the possibility of a merger between the basic research lab and the firm. Public integration illustrates the case of basic research within the public sector.

Surprisingly, we find that the interest of the regulator and of the downstream lab are aligned: both agents are better off when the one with the higher bargaining power is the unique funder of basic research. As an intuition, the timing of the game favors both the health authority and the downstream firm (i.e. the final negotiators), at the expense of the upstream research lab that would prefer to negotiate a grant with the least powerful negotiator.

Moving to integration 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 decision makers and benefits the decision maker remaining independent. Combining results with and without integration, we observe that the health authority can benefit from the interaction / merger of the two labs and, in the same way, the downstream lab can benefit from the interaction / merger of the health authority and the upstream lab. The intuition is that the decision-makers at the two extremes of the negotiation chain are able to obtain a larger share of the surplus when they leave negotiation with the intermediate decision-maker (the lab producing basic research) to the stronger one of the two. However, in case of very important 'increasing returns to merger', the previous results are reversed and we are back to the intuitive case in which the merging decision-makers are better off.

Our policy implications are the following. When the bargaining power does not display very important 'increasing returns to merger' and the bargaining power of the health authority (alone) is relatively high, the latter should be the unique funder of 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 full funding of basic research to the downstream lab and would benefit from the integration of the labs producing basic

[1]The recent legislative change in the US in favor of drug price negotiation is likely to influence prices downwards. This effect would be even stronger with higher Medicare reimbursements. Indeed, considering that drugs are listed for insurance reimbursement only if prices are negotiated, the (public) health insurer and a drug producer would negotiate lower prices the higher the health insurance reimbursements (Jelovac, 2015). Moreover, as mentioned above, the drug price should not only compensate for the applied research undertaken by the pharmaceutical firm itself, but it should also be discounted for all of the basic research outside the firm.

and applied research. This strategy assures the highest share of the surplus to the health authority and the lowest 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 decision makers: A public 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 public 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 public health agency, which corresponds to a public research grant. Lab B can also negotiate some compensation X_A from firm A, which is equivalent to a private grant or 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 public 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 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:

$$W_H = V(a, b) - X_H - P; \tag{2.1}$$

$$\Pi_B = X_H + X_A - b; \tag{2.2}$$

$$\Pi_A = P - X_A - a; \tag{2.3}$$

where $X_H, X_A \geq 0$ and at least one of the two payments is positive, meaning that basic research must be financed. We define β_H, β_B and β_A the negotiation power of the three decision makers. In any bargaining stage, the relative negotiation powers of any two bargaining decision makers must sum at one.

The total surplus is thus $TS = V(a, b) - a - b$. The resulting efficient investment in basic and applied research maximizes this total surplus by equating marginal cost and marginal benefit : $V_a(a, b) = V_b(a, b) = 1$.

We consider that payments X_H and X_A for basic research and P for applied research, are negotiated after the corresponding investments b and a have been chosen. This guarantees that all participants choose the efficient investments in basic and applied

research. This is easy to show along the whole analysis and we decided to skip these steps.

3. How should basic research be funded?

The timing of the game is as follows. The research lab B first plans 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.

Solving the game backwards, we start deriving the final negotiated price, which is the solution to the following Nash Bargaining Program.

$$\max_P \beta_H ln(V(a,b) - X_H - P) + \beta_A ln(P - X_A - a). \tag{3.1}$$

The Nash Bargaining Solution provides the following negotiated final price:

$$P = \frac{\beta_H(a + X_A) + \beta_A(V(a,b) - X_H)}{\beta_H + \beta_A}. \tag{3.2}$$

The negotiated price thus positively depends on the contribution to innovation from firm A, a and X_A, and it negatively depends on the contribution from the health authority, X_H. If price setting was not regulated, the pharmaceutical firm, owner of a patent for the final innovation, 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 is 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:

$$W_H = \frac{\beta_H}{\beta_H + \beta_A}(V(a,b) - X_A - X_H - a); \tag{3.3}$$

$$\Pi_A = \frac{\beta_A}{\beta_H + \beta_A}(V(a,b) - X_A - X_H - a). \tag{3.4}$$

The total surplus so far still depends on the grants 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, lab A and lab B negotiate their transfer X_A according to the following Nash Bargaining Program:

$$\max_{X_A} \beta_A ln \frac{\beta_A}{\beta_H + \beta_A}(V(a,b) - X_A - X_H - a) + \beta_B ln(X_A + X_H - b). \tag{3.5}$$

The resulting best-reply private transfer is:

$$X_A = \frac{\beta_A}{\beta_B + \beta_A} b + \frac{\beta_B}{\beta_B + \beta_A}(V(a,b) - a) - X_H. \tag{3.6}$$

Simultaneously, lab B and the health authority H negotiate their transfer X_H according to the following Nash Bargaining Program:

$$\max_{X_H} \beta_H ln \frac{\beta_H}{\beta_H + \beta_A}(V(a,b) - X_A - X_H - a) + \beta_B ln(X_A + X_H - b). \tag{3.7}$$

The resulting best-reply private transfer is:

$$X_H = \frac{\beta_H}{\beta_B + \beta_H} b + \frac{\beta_B}{\beta_B + \beta_H}(V(a,b) - a) - X_A. \tag{3.8}$$

Solving the system of equations given by (3.6) and (3.8) for the transfers X_A and X_H, we have either $X_A = 0$ or $X_H = 0$. Specifically:

LEMMA 1 (Exclusive financing of basic research). *If the health authority H 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. If the health authority H 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.*

Given quasilinear payoff functions, we obtain a corner solution: the agent with the largest bargaining power is the only one to finance basic research. If the health authority has a comparative advantage in negotiating with the upstream lab, then basic research is financed by the public body; otherwise basic research is financed by the downstream firm. This depends on the fact that the health authority and the downstream lab negotiate price P in the last stage of the game and basic research is an intermediate input in the innovation process.

We are now going to study the two possible situations in turn.

3.1. Basic research financed by the public sector

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

$$W_H = V(a,b) - X_H - P; \tag{3.9}$$

$$\Pi_B = X_H - b; \tag{3.10}$$

$$\Pi_A = P - a. \tag{3.11}$$

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 (3.2) and (3.8), then solving for drug price P and public

grant X_H, we obtain the following solution holding when $\beta_H > \beta_A$:

$$P^{(1)} = a + \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a,b) - a - b). \tag{3.12}$$

$$X_H^{(1)} = \frac{\beta_H}{\beta_B + \beta_H} b + \frac{\beta_B}{\beta_B + \beta_H}(V(a,b) - a). \tag{3.13}$$

$$X_A^{(1)} = 0. \tag{3.14}$$

Superscript (1) refers to the solution to the present case where the lab B receives a grant from the health authority only.

The resulting total expenses for the health authority are:

$$P^{(1)} + X_H^{(1)} = V(a,b) - \frac{(\beta_H)^2}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a,b) - a - b). \tag{3.15}$$

Each participant then obtain, respectively:

$$W_H^{(1)} = \frac{(\beta_H)^2}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a,b) - a - b); \tag{3.16}$$

$$\Pi_B^{(1)} = \frac{\beta_B}{\beta_H + \beta_B}(V(a,b) - a - b); \tag{3.17}$$

$$\Pi_A^{(1)} = \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_H + \beta_B)}(V(a,b) - a - b). \tag{3.18}$$

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. Indeed, we can show that

$$\frac{\partial \Pi_A^{(1)}}{\partial \beta_H} > 0 \iff (\beta_H)^2 < \beta_A \beta_B. \tag{3.19}$$

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: $(\beta_H)^2 < \beta_A \beta_B < \beta_H \beta_B$. Hence, for $\Pi_A^{(1)}$ to be increasing in β_H it must be: $(\beta_H)^2 < \beta_H \beta_B$ or $\beta_B > \beta_H$. To sum up, a necessary condition for $\Pi_A^{(1)}$ to be increasing in β_H is that negotiating powers are such that $\beta_B > \beta_H > \beta_A$ (see Lemma 2 below).

3.2. Basic research financed by the pharmaceutical firm

Here basic research is funded by the downstream firm only. Given that $\beta_H < \beta_A$ and $X_H = 0$, the decision makers payoff functions simplify to:

$$W_H = V(a,b) - P; \tag{3.20}$$

$$\Pi_B = X_A - b; \tag{3.21}$$

$$\Pi_A = P - X_A - a. \tag{3.22}$$

Substituting $X_H = 0$, into (3.2) and (3.6), then solving for drug price and funding of basic research X_A, we obtain the following solution holding when $\beta_A > \beta_H$:

$$P^{(2)} = V(a,b) - \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_B + \beta_A)}(V(a,b) - a - b). \tag{3.23}$$

$$X_A^{(2)} = \frac{\beta_A}{\beta_B + \beta_A} b + \frac{\beta_B}{\beta_B + \beta_A}(V(a,b) - a). \tag{3.24}$$

$$X_H^{(2)} = 0. \tag{3.25}$$

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

The total expenses for the regulator are given by the final negotiated price, $P^{(2)}$ in (3.23). Each participant then obtain, respectively:

$$W_H^{(2)} = \frac{\beta_H \beta_A}{(\beta_H + \beta_A)(\beta_B + \beta_A)}(V(a,b) - a - b); \tag{3.26}$$

$$\Pi_B^{(2)} = \frac{\beta_B}{\beta_B + \beta_A}(V(a,b) - a - b); \tag{3.27}$$

$$\Pi_A^{(2)} = \frac{(\beta_A)^2}{(\beta_H + \beta_A)(\beta_B + \beta_A)}(V(a,b) - a - b). \tag{3.28}$$

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: $V_b(a,b) = 1$.

Again, the comparative statics of the payoff functions show intuitive relationships between solution and parameters except for the effect of the downstream lab's negotiation power β_A on the health authority payoff $W_H^{(2)}$. Proceeding as before, we can show that

$$\frac{\partial W_H^{(2)}}{\partial \beta_A} > 0 \Longleftrightarrow (\beta_A)^2 < \beta_H \beta_B. \tag{3.29}$$

and that $\beta_H < \beta_A < \beta_B$ is a necessary condition for $(\beta_A)^2 < \beta_H \beta_B$. Combining results expressed in (3.19) and (3.29) we can state the following lemma:

LEMMA 2. *If the upstream lab has the highest negotiating power ($\beta_B > \max\{\beta_H, \beta_A\} > \min\{\beta_H, \beta_A\}$), then the payoff of the downstream lab (of the health authority) can increase with the bargaining power of the health authority (downstream lab) when $\beta_H > \beta_A$ ($\beta_A > \beta_H$).*

Hence, a 'strong' lab producing basic research has unexpected effects on the negotiation between the health authority and the downstream lab, irrespective of whether the former or the latter decision maker finances basic research. When basic research is financed by the health authority ($\beta_H > \beta_A$), the payoff of the downstream lab can benefit 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 can benefit 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.

Comparing health expenditures of the public agency H in the two scenarios we observe that H pays $P^{(1)} + X_H^{(1)}$ when it finances basic research, while it pays $P^{(2)}$ when basic research is financed by the downstream lab. Comparing public expenses using (3.15) and (3.23), we show that:

$$P^{(1)} + X_H^{(1)} \lesseqgtr P^{(2)} \Longleftrightarrow \beta_H \gtreqless \beta_A, \tag{3.30}$$

which is precisely the case. We can generalize the comparison as follows:

$$P^{(1)} + X_H^{(1)} \lesseqgtr P^{(2)} \Longleftrightarrow W_H^{(1)} \lesseqgtr W_H^{(2)} \Longleftrightarrow \Pi_B^{(1)} \gtreqless \Pi_B^{(2)} \Longleftrightarrow \Pi_A^{(1)} \lesseqgtr \Pi_A^{(2)} \Longleftrightarrow \beta_H \gtreqless \beta_A. \tag{3.31}$$

The previous chain of inequalities shows 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. Despite the fact that they negotiate price P together and thus have conflicting objectives in the last stage of the game, H and A have aligned payoffs in the whole negotiation.

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 higher 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) These outcomes are exacerbated when the upstream lab is the 'strongest' among the three agents.*

To understand Part *(i)* and *(ii)* of the proposition consider that the final negotiators H and A are determinant as to how basic research is funded, at the expense of the upstream lab. Indeed, when $\beta_H > \beta_A$, then both the health authority and the pharmaceutical lab are better off with public financing of basic research, while the basic research lab would prefer to negotiate a grant with the least powerful negotiator, i.e., the downstream firm in this case (see inequalities 3.31). Conversely, when $\beta_H < \beta_A$, then the upstream lab would prefer to negotiate with the health authority. However, both the latter and the downstream lab prefer to have exclusive funding of basic research by the 'stronger' A. 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 stating that $\beta_B > \beta_A > \beta_H$ ($\beta_B > \beta_H > \beta_A$) is a necessary condition such that the payoff of H (respectively A) is increasing in the bargaining power of A (respectively H).

4. INTEGRATION OF BASIC RESEARCH

In this section, we ask the following questions. Is integration between the health authority and the basic research lab desirable from the perspective of the three decision makers? Should basic research be done in public institutions?

Recall that financing is always efficient in our model so that integration only affects the negotiation process and how the surplus is shared between the different decision-makers. Integration can be of two different kinds. When the health authority and the upstream lab merge (public integration), basic research takes place in a public lab or in a public funded research center. According to our results in the previous section, we expect

integration to be public when $\beta_H > \beta_A$, or when the health authority finances basic research by exclusively negotiating with the upstream lab (see Lemma 1). When the two labs merge (private integration), the applied research lab acquires the basic research lab. This is relevant when $\beta_H < \beta_A$, or when the downstream lab finances basic research.

4.1. Public integration of basic research

Suppose that $\beta_H > \beta_A$ so that, absent integration, the health authority finances basic research by exclusively negotiating with the upstream lab.

When the public health authority and the basic research lab are integrated, they jointly decide on the investment in basic research and on its internal compensation (that will be such that $X_H = b$). They also negotiate the final price P with the pharmaceutical lab. Therefore, the objectives of the integrated public body and of the downstream lab are as follows:

$$W_{HB} = V(a,b) - P - b; \tag{4.1}$$

$$\Pi_A = P - a. \tag{4.2}$$

We prefer to simplify our expressions omitting X_A. In the unlikely case in which the downstream lab directly contributes to basic research with a payment $X_A > 0$, then the price P paid by the integrated body has to be interpreted as a total price incorporating such contribution.

The timing of the game is as follows. The integrated public research entity, HB, decides its investment in basic research, b. Then, lab A decides on her investment in applied research a. Last, the integrated public research entity 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 β_{HB} is the negotiation power of the integrated public research entity, and β_A is the negotiation power of the lab:

$$\max_P \beta_{HB} ln(V(a,b) - P - b) + \beta_A ln(P - a). \tag{4.3}$$

The Nash Bargaining Solution provides the following negotiated price:

$$P^{(3)} = \frac{\beta_{HB} a + \beta_A (V(a,b) - b)}{\beta_{HB} + \beta_A}. \tag{4.4}$$

That is, the higher the public agency'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 public research entity and the lab according to their respective negotiation powers:

$$W_{HB}^{(3)} = \frac{\beta_{HB}}{\beta_{HB} + \beta_A}(V(a,b) - a - b); \tag{4.5}$$

$$\Pi_A^{(3)} = \frac{\beta_A}{\beta_{HB} + \beta_A}(V(a,b) - a - b). \tag{4.6}$$

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

The resulting total expenses for the public integrated body are:

$$P^{(3)} + b = V(a,b) - \frac{\beta_{HB}}{\beta_{HB} + \beta_A}(V(a,b) - a - b). \tag{4.7}$$

The comparison between the firm's payoff without integration when $\beta_H > \beta_A$ (that is, the payoff $\Pi_A^{(1)}$ in Section 3.1) and $\Pi_A^{(3)}$ leads to the following lemma:[2]

LEMMA 3. *Suppose that $\beta_H > \beta_A$ so that, without integration, we would observe exclusive financing of basic research by the health authority (case 1). With respect to case (1), integration of basic research by the health authority implies (i) an increase in the final surplus of the downstream lab if $\beta_{HB} < \beta_H + \beta_B + \frac{\beta_A \beta_B}{\beta_H}$, (ii) a decrease in the final surplus of the downstream lab if the opposite condition holds.*

How the payoffs of the decision makers change with integration depends on the bargaining power of the new public body. Specifically, unless β_{HB} increases dramatically and $\beta_{HB} > \beta_H + \beta_B + \frac{\beta_A \beta_B}{\beta_H}$, the downstream lab is better off after the integration of the health authority with the basic research lab. Lemma 3(i) represents the most plausible instance in our view, indicating that the bargaining power of the new public body is larger than the one of the 'stronger' merging agent but not larger than the sum of the bargaining power of H and B.

As an explanation for this counterintuitive result consider that two negotiations were necessary in the case of independent basic research, whereas we have only one negotiation with integration. The total surplus is unchanged because efficiency is granted anyway thanks to the final price negotiation. The only difference is the sharing of the total surplus among two entities, i.e., the integrated public body and the downstream firm, instead of three. The downstream pharmaceutical firm gains from the integration between the health authority and the basic research lab if the bargaining power of the integrated body is not too high. The public integrated body thus obtains a lower share of the total surplus than if basic research was independent.

4.2. Private integration of basic research

Suppose now that $\beta_A > \beta_H$ so that, absent integration, the downstream lab finances basic research by exclusively negotiating with the upstream lab.

When both upstream and downstream labs are integrated, the objectives of the regulator and of the integrated labs are as follows:

$$W_H = V(a,b) - P; \tag{4.8}$$

$$\Pi_{AB} = P - a - b.$$

The labs A and B jointly decide their investments in upstream basic research $X_A = b$ first, and then in downstream applied research a. Last, A and B jointly negotiate with H the final price P.

[2]Notice that we are comparing here the final payoff of the decision-maker that is not merging (lab A in this section) with and without vertical integration of the other two decision-makers (H and B in this section). This allows us to reach clear conclusion about who benefits from the integration.

Proceeding as before, the Nash Bargaining Solution provides price P as follows:

$$P^{(4)} = V(a,b) - \frac{\beta_H}{\beta_H + \beta_{AB}}(V(a,b) - a - b). \tag{4.9}$$

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

$$W_H^{(4)} = \frac{\beta_H}{\beta_H + \beta_{AB}}(V(a,b) - a - b); \tag{4.10}$$

$$\Pi_{AB}^{(4)} = \frac{\beta_{AB}}{\beta_H + \beta_{AB}}(V(a,b) - a - b). \tag{4.11}$$

Comparing the health authority payoff $W_H^{(4)}$ with the one obtained without integration when $\beta_A > \beta_H$ (that is, the payoff $W_H^{(2)}$ in Section 3.2), results in the following lemma:

LEMMA 4. *Suppose that $\beta_A > \beta_H$ so that, without integration, we would observe exclusive financing of basic research by the downstream lab (case 2). With respect to case (2), integration of the two labs implies (i) an increase in the final surplus of the health authority if $\beta_{AB} < \beta_A + \beta_B + \frac{\beta_H \beta_B}{\beta_A}$, (ii) a decrease in the final surplus of the health authority if the opposite condition holds.*

As before, points (*ii*) and (*iii*) show that the change in the payoffs of the decision makers depends on the bargaining power of the new integrated body. In the likely case (*ii*), 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.

The intuition is the same as before: integration reduces the number of negotiations. The total surplus is unchanged because efficiency is granted anyway, the only difference is the sharing of the total surplus between the health authority and the integrated labs. The health authority gains from the integration between the two labs if the bargaining power of the integrated pharmaceutical firm is not too high. The integrated lab instead is worse off.

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 decision makers and benefits the decision maker remaining independent.*

Proposition 2 complements and extends Proposition 1. The health authority benefits from the interaction / integration of the two labs and, in the same way, the downstream lab benefits from the interaction / integration of the health authority and the upstream lab.

The following directly follows from Propositions 1 and 2:

COROLLARY 1. *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 benefits from being the unique funder of basic research but not from integrating with the lab producing it. (ii) If $\beta_A > \beta_H$, the health authority benefits from leaving the full funding of basic research to the downstream lab and from the integration of the labs producing basic and applied research.*

Indeed, in the model a higher share of the surplus for the health authority always goes hand in hand with a reduction of the negotiated price P. Hence the previous corollary takes the perspective of the health authority and indicates the strategy that increases consumers' welfare and reduces the negotiated price paid to the downstream lab.

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 grants for basic research and to agree on the final price of a new drug. Even in the absence of efficiency gains, in order to increase consumers' surplus and reduce negotiated prices for new drugs, the two labs should merge if the downstream lab has a relatively large bargaining power ($\beta_A > \beta_H$). When instead the health authority is relatively stronger ($\beta_H > \beta_A$), integration with the producer of basic research increases negotiated prices for new drugs, unless the gain in bargaining power after the integration is extremely high ($\beta_{HB} > \beta_H + \beta_B + \frac{\beta_A \beta_B}{\beta_H}$).

5. Conclusion

We presented an extremely simple and parsimonious model of price and research grant negotiations. We disregarded efficiency motives and focused on the bargaining process between the health authority and the downstream lab when basic research is produced by an upstream lab. We show that basic research is financed with public (private) grants if the health authority has more (less) negotiation power than the pharmaceutical firm and that the exclusive financing of basic research benefits both the health authority and the downstream lab. This shows that, in the three-side negotiation analyzed in this note, the 'intermediate negotiator' (i.e. the upstream lab) is always worse off while the payoff of the 'extreme negotiators' (i.e. the health authority and the downstream lab) are fully aligned.

The disadvantaged position of the upstream lab is confirmed in the case of vertical integration. Specifically, the upstream lab looses from integration (either upstream or downstream), unless the bargaining power after integration displays very high 'increasing returns to integration'.

From the point of view of the regulator, results can be interpreted as follows. When the bargaining power does not display very important 'increasing returns to merger' and the bargaining power of the health authority (alone) is relatively high, the latter should be the unique funder of 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 full funding of basic research to the downstream lab and would benefit from the integration of the labs producing basic and applied research. This strategy assures the highest share of the surplus to the health authority and the lowest negotiated price paid by the health authority to the downstream lab.

Our results are specific to the use of negotiations to determine pharmaceutical prices and the grants to finance basic research. In the real world we observe different possible arrangements as for the financing and the production of basic research; however, basic research is mainly financed by the government in many countries or is directly developed in the public sector. In our model, this corresponds to vertical integration between the health authority and the lab producing basic research. Our results suggest that this arrangement increases consumers' surplus and reduces negotiated prices for new drugs only if the bargaining power of the health authority is lower than the one of the firm commercializing the innovation, provided the public contribution to basic research is

appropriately accounted for. In our setting, accounting for the public contribution to basic research translates in the explicit negotiation of the public grant X_H (which is equal to b in the case of vertical integration between health authority and basic research lab). Unfortunately, in the real world, health authorities do not seem to internalize the public contribution to public research when negotiating prices of innovations, which could in part explain the dramatic increase in drug prices in past decades.[3] The model also highlights some unexpected complementarities between the payoff of the 'extreme negotiators' (i.e. the health authority and the downstream lab) in the negotiation process.

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 appropriate framework to study the effects of different arrangements in the financing of basic research on negotiated prices for new drugs. It shows how public contributions to basic research should be properly taken into account by the regulator when negotiating prices with the downstream lab.

REFERENCES

[1] Aghion, Dewatripont, Stein (2008). "Academic freedom, private-sector focus, and the process of innovation", *RAND Journal of Economics* 39(3), 617-635.

[2] Billette de Villemeur, Versaevel (2017). "One Lab, Two Firms, Many Possibilities: On R&D Outsourcing in the Biopharmaceutical Industry"(July 18, 2017). Available at SSRN: https://ssrn.com/abstract=2916229

[3] Broad (2014). "Billionaires with big ideas are privatizing American science ". March 15, 2014. New York Times.

[4] Cour des Comptes (2017). "La sécurité sociale. Rapport sur l'application des lois de financement de la sécurité sociale". Septembre 2017. https://www.ccomptes.fr/sites/default/files/2017-09/20170920-rapport-securite-sociale-2017_1.pdf

[5] Gonzalez, Macho-Stadler, Perez-Castrillo (2016). "Private versus Social Incentives for Pharmaceutical Innovation", *Journal of Health Economics* 50, 286-297.

[6] Jelovac (2015). "On the relationship between negotiated prices of pharmaceuticals and the patients' co-payment".Economics Bulletin 35(1), 481-493.

[7] Maraninci, Vernant (2016). "L'urgence de maîtriser les prix des nouveaux medicaments contre le cancer". Le Figaro 16-03-2016. http://sante.lefigaro.fr/actualite/2016/03/14/24739-lurgence-maitriser-prix-nouveaux-medicaments-contre-cancer

[8] Medicare Prescription Drug Price Negotiation Act of 2017, "S.41", 115th Congress (2017-2018).

[3] In practice, the regulator seems to behave according to a model in which, when the negotiation for the final price of the drug is tackled, the payment X_H is fully disregarded.

[9] Tefferi, Ayalew et al. (2015), "In Support of a Patient-Driven Initiative and Petition to Lower the High Price of Cancer Drugs." Mayo Clinic proceedings 90.8: 996–1000.