How Do Start-up Acquisitions Affect the Direction of Innovation?*

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Abstract

A start-up engages in an investment portfolio problem by choosing how much to invest in a "rival" project, which threatens the position of an existing incumbent, and a "non-rival" project. Anticipating its acquisition by the incumbent, the start-up strategically distorts its portfolio of projects to increase the (expected) acquisition rents. We show that, depending on parameters, such a strategic distortion may result in an alignment or a misalignment of the direction in which innovation goes relative to what is socially optimal. When the direction of innovation worsens, consumers suffer from acquisitions; when the direction of innovation improves, consumer surplus may increase despite the usual quantity distortion associated to an acquisition. These results are robust to acquisitions where the acquirer takes over the research facilities of the start-up. Prohibiting acquisitions may thus result in an increase or a decrease in consumer surplus.

Keywords: start-ups, mergers and acquisitions, innovation portfolios, antitrust

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1 Introduction

The potential (anti-)competitive effects of start-up acquisitions have recently raised much scholarly and practitioner attention. Though consolidation processes between firms are certainly not new, big companies in sectors as varied as digital, pharmaceutical and healthcare have acquired a disproportional number of start-ups in the last few years. For example, according to McLaughlin (2020), Amazon, Facebook, Google, Apple and Microsoft bought 21 firms in 2019 and only in the first half of 2020, these big five corporations had already acquired 27 smaller companies. Admittedly, many of the start-up acquisitions we have recently witnessed may have been motivated by the creation of value via quality upgrading and the filling of gaps in the acquirer's product portfolio. However, the acquiring companies have grown so large that, absent strong competition within the market, the fear is that start-up acquisitions are suppressing nascent competition that would otherwise benefit consumers. In fact, Cunningham et al. (2019) provide empirical support for the idea that a significant share of the acquisitions observed in the pharmaceutical industry are aimed at discontinuing the innovative products of the target firms and so forestall future competition. As a result, there has recently emerged a general debate among academicians and policy makers (see e.g. Bryan and Hovenkamp (2020b); Cabral (2020); Katz (2020); Scott-Morton et al. (2019); Crémer et al. (2019); Furman et al. (2019)) about whether a more active antitrust intervention is sufficient or merger policy needs reform to address start-up acquisitions.[1]

There are at least two important reasons that make start-up acquisitions different from standard mergers. The first is that the mere anticipation that start-ups may be bought by giant companies may heavily influence their business strategy. While building their portfolio of research projects, and anticipating an acquisition, start-ups may pay close attention to the direction large corporations go and give more or less weight to projects that might fit the interests of potential acquirers compared to other, non-rival, projects. Interestingly, the way in which this "innovation for buyout" (Rasmusen, 1988) effect may affect the direction of innovation is *a priori* indeterminate (see also Cabral (2020)). On the one hand, projects that create much added value for the incumbent firms may be given priority because these projects generate in turn high negotiation rents for the start-ups. On the other hand, projects that highly disrupt the dominant position of potential acquirers and thus generate little added acquisition value may fall out of the start-ups' priority agenda because they create low negotiation rents. Whether such project portfolio adjustment is socially desirable may depend on whether upgrades of existing products or alternative, new, products create

[1]Though the literature on mergers is extensive, most of the merger writings focus on the acquisition of existing firms with mature technologies and products. The earlier literature studied the impact of mergers on prices, insider and outsider profits and consumer surplus (Salant et al., 1983; Deneckere and Davidson, 1985). Subsequent work examined the trade-off between the increase in market power implied by mergers and the potential efficiency gains arising from either the supply-side (Williamson, 1968; Farrell and Shapiro, 1990) or the demand-side (Klemperer and Padilla, 1997; Moraga-González and Petrikaitė, 2013). Only very recently has the literature incorporated innovation incentives into the analysis of mergers (Federico et al., 2018; Motta and Tarantino, 2017). In doing this, a couple of papers have pointed out that it is important to look at how mergers affect the portfolio of research projects firms choose to engage in (Gilbert, 2019; Letina, 2016; Moraga-González et al., 2019). It is this latest angle that this paper intends to develop within the context of start-up acquisitions.

more value for consumers.

The second important reason is that many start-up acquisitions occur at a time in which the target firm is still hardly, or not al all, active in the (relevant) market. Instead, many start-ups are bought during the early stages of their research and development program. A canonical example is that of pharmaceutical firms, which often buy start-ups at their incipient phases of their maturation (Krieger et al., 2017). By taking over the research facilities of the target firms, decisions over the project portfolio change hands from the start-ups to the acquirers. Because the acquirers also anticipate an increase in market power in the product market, their choice of project portfolio is modulated by a different "replacement effect" (Arrow, 1962) compared to the start-ups. *A priori*, it is not clear whether this replacement effect is stronger for incumbents than for start-ups (Motta and Peitz, 2020).

These reflections lead us to ask how these strategic project portfolio decisions affect the direction of innovation, the pace at which projects develop and, as a result, the society's well-being as a whole. To address this question we formulate a novel model of an industry with an incumbent operating in a single market and an entrant start-up. The start-up engages in an investment portfolio problem. Specifically, the start-up chooses how to allocate its funding across two projects. One of the projects is a "rival" project, in the sense that it is meant to challenge the incumbent's dominant position in its traditional market. If successful, this rival project results in a product of higher quality than that of the incumbent. In case of failure, the start-up enters the incumbent's market with the same product as the incumbent. The alternative project is a "non-rival" project, that is, a project intended for the opening of a new market in which the start-up does not face competition. The two projects also differ from one another in their difficulty, that is, in the probability with which a given effort results in innovative success, and in their social returns.

Because firms are motivated by the private returns of the projects in which they engage and they thus neglect part of the social return, start-ups tend to hold biased portfolios of projects. We then ask whether start-up acquisitions aggravate or ameliorate, at least partially, such market distortion. We address this question in two settings. In the first setting, a start-up, anticipating its acquisition, strategically invests to maximize the rents it gets from the integration process. This modelling, which is well suited to identify the "innovation for buyout" effect on project portfolio choice, fits well the case of acquisitions in the digital world where it is often the case that acquirers buy start-ups after the outcome of their research projects is (to a large extent) known. A recent example is the acquisition of *Vilnyx* by *Apple* to incorporate the former's technology of analysis of video's visual, text and audio content into Apple's apps (Gurman, 2020). In the second setting, the acquirer takes over the research labs of the start-up, and thereby over its investment portfolio choice. This setting, which serves well to examine how the strength of the "replacement effect" shapes portfolio choice, is better tailored to markets such as those for pharmaceuticals, in which many start-up acquisitions occur during the early phases of drug development (Krieger et al., 2017; Cunningham et al., 2019). Another similar example, but in a different sector, is the recent acquisition of *Keybase* by *Zoom*.

To identify the "strategic" portfolio effect of start-up acquisitions, we compare the outcome of a three-stage acquisition game with the outcome of a benchmark two-stage no-acquisition game. Specifically, in the three-stage acquisition game, the start-up first chooses its portfolio of investments; in the second stage, after observing the outcome of its research efforts, the start-up and the incumbent bargain over the surplus generated by the acquisition; finally, in the last stage, firms compete in the market. In the benchmark no-acquisition two-stage game, the start-up first chooses its portfolio of investments and then, upon observing the results of the research projects, the start-up and the incumbent engage in competition.

We first show that, anticipating an acquisition, the start-up strategically distorts its investment to maximize its acquisition rents. The direction in which the portfolio of projects is adjusted depends on whether the acquisition rents when the rival project turns successful are greater or smaller than the acquisition rents when the rival project fails. The acquisition rents stem from the monopolization of the product market and it turns out that which acquisition rents are greater depends on parameters. Specifically, the acquisition rents when the rival project turns successful are larger than when the project fails provided that the difference in the quality of the existing product and that of the innovative product is not very large. In such a case, anticipating an acquisition, the start-up strategically increases investment in the rival project and, correspondingly, decreases investment in the non-rival one. By contrast, when the rival project is highly disruptive because the difference in the quality of the existing product and that of the innovative product is very large, the acquisition rents when the rival project turns successful are very small and the start-up strategically reduces investment in the rival project and, correspondingly, raises investment in the non-rival one.

We then examine the social impact of the start-up's strategic adjustment of the investment portfolio. We show that an acquisition may result in an alignment or misalignment of the private and the social incentives to invest. This implies that an acquisition may improve the direction of innovation or worsen it. The former occurs when the project that generates larger social gains receives more investment in anticipation of an acquisition. Specifically, when the quality gap is small and the start-up reallocates funding by reducing investment in the non-rival project and increasing it in the rival project, the acquisition improves the direction of innovation provided that the consumer gains from the non-rival project are relatively small compared to the private gains. Likewise, when the quality gap is large and the start-up invests less in the rival project and more in the non-rival project, this reduces the portfolio distortion when consumers benefit significantly from the non-rival project compared to the private gains.

Although the acquisition of the start-up may reduce the project portfolio distortion, this is not necessarily welfare improving because the acquisition also increases the quantity distortion. Therefore, prohibiting acquisitions of potential competitors involves a trade-off. We show conditions under which a reduction in the innovation distortion is sufficiently large so as to make an acquisition welfare improving, despite its associated quantity distortion. When the quality difference is relatively small, prohibiting the acquisition of the start-up is always consumer welfare reducing. Despite the fact that the start-up's portfolio of investments may be more in line with what consumers prefer, the consumer welfare gains associated to a smaller innovation distortion are too little to offset the consumer welfare losses originating from the negative price effects associated to a larger quantity distortion. When the quality difference is high, things are different. The negative price effects need not dominate the positive portfolio adjustment effect. In fact, when consumer benefits associated with the non-rival market are large enough, then prohibiting the acquisition of potential entrants is consumer welfare reducing.

In the second part of the paper we turn our attention to settings in which the acquirer takes over the research facilities of the start-up. We find that when the quality gap between the incumbent's product and the successful start-up's product is small, the acquirer benefits relatively more from obtaining a high-quality product than the entrant does, while both benefit equally from the non-rival project. Hence, the acquirer invests more in the rival project and less in the non-rival one than the start-up. When the quality difference is sufficiently large, it is the opposite and investment in the rival project decreases after an acquisition.

This result that the acquirer may invest more in the rival project compared to the start-up is in contrast with the theoretical result in Cunningham et al. (2019) and Motta and Peitz (2020).The difference in results stems from the facts that in our model both the start-up and the acquirer face replacement effects and that these are of different magnitude. In equilibrium, both the start-up and the acquirer choose an investment portfolio so that the marginal returns from the rival and non-rival projects are equalised. The start-up's marginal returns from the rival project are proportional to the profits difference between a Cournot seller of high quality and a Cournot seller of low quality. That is, a successful start-up that sells high quality replaces an unsuccessful start-up that sells low quality. By contrast, the acquirer's marginal returns are proportional to the difference in the profits of a monopolist of high quality and a monopolist of low quality. As it turns out, the relative magnitude of these two replacement effects depend on parameters. When the quality difference is small, the start-up's marginal gains from investing in the rival project are lower than the acquirer's marginal gains. By contrast, when the quality difference is large, it is the opposite.[2]

From a social welfare point of view, also in this setting the acquisition of the start-up by the incumbent may result in an alignment between the private incentives to invest and the social incentives, thereby putting the market to work in a direction more in line with the socially optimal one. Moreover, we find that prohibiting the acquisition of potential entrants is consumer welfare reducing under conditions similar to those when the acquisition takes place after the outcome of the research projects become known.

[2]Motta and Peitz (2020) present a result similar to Cunningham *et al.* (2018) but conjecture that it is theoretically possible that an entrant may have greater incentives to invest than an incumbent. In this regard, our model of vertical product differentiation with Cournot competition provides an instance in which the Arrow replacement effect of an entrant can be larger or smaller that that of an incumbent.

We examine the robustness of these results in a number of additional extensions. In one of the extensions we consider the case in which there are N incumbent firms. Interestingly, we observe that as the number of incumbent firms increases, it becomes less likely that the acquisition of the potential entrant results in a lower investment in the rival project and a higher investment in the non-rival project. The reason for this is that the incremental profit of a Cournot seller from selling high quality rather than low quality goes up in the number of sellers. Because the acquisition of the potential entrant de facto reduces the number of sellers, the result follows. In the limiting situation in which the number of incumbents goes to infinity, in fact it becomes impossible that the acquisition of the potential entrant results in a lower investment in the rival project and a higher investment in the non-rival project.

what does this imply for consumer surplus?

In two other extensions we consider the cases of drastic innovations and the impossibility for the startup to enter the market in case of project failure. When the innovation is drastic, a successful start-up can monopolize the market. In this situation, the incentives of the start-up to invest in the rival project is always higher than that of the acquirer because the Arrow replacement effect is larger. These incentives are also larger when the startup cannot enter the market in case of project failure. As a result, in these two extensions, the investment in the rival project of the acquirer will be lower than that of the startup. Therefore, the parts of our propositions where the acquirer decreases its investment in the rival project relative to the startup continue to hold in these two extensions. Consequently, an acquisition may still improve or worsen the direction of innovation and result in an increase or decrease in consumer surplus.

Related literature

Our paper contributes to the recent surge in the academic interest about the effects of mergers on innovation. One branch of this literature focuses on the impact of mergers between existing firms on innovation. Some papers look at the case of single-project firms and centre around the question how mergers affect expenditures in R&D (e.g. Motta and Tarantino (2017); Federico et al. (2018); Bourreau et al. (2018). Other papers, more related to ours, have examined how mergers impact the variety and diversity of R&D projects firms engage in (e.g. Letina (2016); Gilbert (2019); Moraga-González et al. (2019)).[3]

A second branch of the literature focuses on the acquisition of potential competitors. The first paper is by Cunningham et al. (2019). They first present a model where an entrant with a single project may be acquired by an existing firm. The focus of their theoretical analysis is on whether the entrant or the acquirer has greater incentives to continue to develop the project further. Because of the replacement effect, the acquirer has weaker incentives to develop the project so under some

[3]In fact, in terms of its model, our paper is related to Moraga-González et al. (2019) where mergers between existing firms are examined in a symmetric setting in which firms invest in a portfolio of research projects of different profitability and social value. The main difference between our paper and theirs is that our model is tailored to the phenomenon of start-up acquisitions, which allows us to identify the innovation for buyout effect on project portfolio choice. Moreover, we explicitly model the trade-off between the portfolio effects and the price effects of acquisitions.

parameters the project is discontinued upon acquisition. This is more likely the greater the overlap between the interests of the acquirer and the entrant's project and the fewer competitors are in the market. Their empirical analysis of the pharmaceutical industry corroborates these insights and they estimate that around 5-7% of the acquisitions are killer acquisitions.

Motta and Peitz (2020) feature a single-project entrant that may be acquired by an existing incumbent. Like Cunningham et al. (2019), their focus is on the likelihood of project killing after the acquisition of the potential entrant. They also study the probable impact of acquisitions on consumer surplus. They find that whenever the start-up company has the ability to continue to develop its project, an acquisition (weakly) reduces consumer surplus. Acquisitions may only be competitive when the entrant does not have the resources to develop the project and the incumbent does (see also Fumagalli et al. (2020)).

Our model differs from these two papers in two important regards. First, we examine how an acquisition impacts project portfolio choice. Moreover, in our paper the decision of a firm is not whether to continue or discontinue a project, but how much effort to allocate across a portfolio of projects. Second, we assume that if the entrant fails to improve upon the product of the incumbent, the entrant can still enter the market and compete face-to-face with the incumbent. In this sense, our model is better suited to describe situations where a potential entrant enters the market after incumbent's patent expiration. These two distinctions are the source of our novel conclusions. An acquisition does not necessarily result in a decrease in the investment in the rival project. Moreover, lowering investment in a project is not per se consumer welfare reducing because such a decision frees up resources that can be allocated to other projects. We show that an acquisition can (hurt) benefit consumers by (mis-)aligning the portfolio of investments with their interests.

The strategic innovation effect of start-up acquisitions is also studied in Cabral (2020) and Bryan and Hovenkamp (2020b). Cabral (2018) presents a dynamic model where fringe and dominant firms can innovate over time. He shows that when fringe firms can transfer their inventions to dominant firms via acquisitions, the "innovation for buyout" effect kicks in and their innovation incentives are boosted (see also the discussion in Cabral (2020)). Our paper also identifies his innovation for buyout effect but we focus on how it impacts the direction of innovation. Bryan and Hovenkamp (2020b) consider a market where a start-up can transfer its technology to a dominant, more efficient, firm or to its competitor, less efficient firm. They show that anticipating its acquisition, the start-up gears its innovative effort towards the interests of the dominant firm. This results in more market power arising from both more product differentiation and more firm asymmetry (see also Bryan and Hovenkamp (2020a)). While this paper also has an important message in terms of the direction of innovation, ours is different because of two reasons. First, we model start-ups that are prospective competitors, which allows us to engage the notion of replacement effect to evaluate how innovation incentives are affected by acquisitions. Second, in our model the start-up engages in a portfolio problem with rival and non-rival projects, which opens up the possibility that an acquisition distorts investment incentives in the right direction.

Finally, another paper on the acquisition of potential competitors is by Letina et al. (2020). In contrast to the work of Cunningham et al. (2019) and Motta and Peitz (2020), they focus on the impact of acquisitions on the variety of projects undertaken by an entrant firm and an incumbent firm. Further, in their model the incumbent decides to acquire the entrant firm upon observing the outcome of the innovation effort of the entrant. Furthermore, the incumbent is assumed to also have research capability so the paper centres around the question how an acquisition changes the variety of projects that an entrant and an incumbent choose to activate. They show that prohibiting start-up acquisitions lowers the variety of projects activated and hence the likelihood of successful innovation and increases project duplication, which reduces welfare. Our paper differs from theirs is that the portfolio of projects firms can invest in are intended for different markets, with different profitability and social value. Moreover, we explicitly model the trade-off between the portfolio effects and the price effects of acquisitions.

The rest of the paper is organized as follows. Section 2 describes the model. In section 3 we solve for the socially optimal investment portfolio. In sections 4 and 5 we derive the market outcomes in the case of no acquisition and acquisition. Section 6 examines how, anticipating its acquisition by the incumbent, the start-up distorts its investment portfolio to maximize the acquisition rents. This section also presents the impact of prohibiting acquisitions on the direction of innovation and consumer welfare. Section 7 models acquisitions in which the acquirer takes over the research facilities of the start-up, compares the project portfolio of the start-up with that of the acquirer and derives the implications for the direction of innovation and consumer welfare. Section 8 shows that our results are robust to the relaxation of some assumptions. Finally, Section 9 provides some concluding remarks. Proofs not provided in the main text are relegated to an Appendix.

2 Model

We consider an industry with an incumbent (I) and a start-up (E). The incumbent operates in a single market, referred to as market A, where it sells a product of quality $\underline{s} > 0$. The start-up faces an investment portfolio problem, namely, it may make an investment to challenge the incumbents' position in market A, or it may put effort to introduce an alternative, independent, product B. Specifically, the start-up has a fixed budget (or a fixed number of scientists) and its decision is how to allocate the funding (or the researchers) across two projects, denoted A and B. Project A is a *rival* project in the sense that it is meant to enter the incumbent's market A. Project B is a *non-rival* project in which the start-up does not face competition.

We normalise the entrant's fixed investment budget to 1. Let x denote the start-up's investment in project A and, correspondingly, let $1 - x$ be the start-up's investment in project B. We assume that investment in a project does not guarantee success, but increases the probability of success. Specifically, let $p(x, \epsilon_A)$ denote the probability with which project A is successful, in which case the start-up enters the incumbent's market A offering a product of higher quality $\overline{s}$ than that of the incumbent, with $\underline{s} < \overline{s} < 2\underline{s}$.[4] The probability of success $p(x, \epsilon_A)$ is increasing in x and decreasing in ϵ_A, which is a shift parameter that proxies for the difficulty of the project. If investment in project A results in failure, which occurs with probability $1 - p(x, \epsilon_A)$, then the start-up competes face-to-face with the incumbent in market A offering the same quality $\underline{s}$.[5] Demand in market A stems from a unit mass of consumers with the well-known quality-augmented quadratic utility function Sutton (1997, 2001):

$$U^A = \sum_{i=1}^{2} \left[\alpha q_i - \left(\frac{\beta q_i}{s_i} \right)^2 \right] - \sigma \sum_{i=1}^{2} \sum_{i<j} \frac{\beta q_i}{s_i} \frac{\beta q_j}{s_j} - \sum_{i=1}^{2} p_i q_i.$$

For tractability reasons, we assume away horizontal product differentiation by setting the parameter $\sigma = 2$. Utility maximization yields the system of demands for the (possibly) vertically differentiated products of the start-up and the incumbent:

$$p_i = \alpha - \frac{2\beta^2 q_i}{s_i^2} - \frac{2\beta^2}{s_i} \sum_{j \neq i} \frac{q_j}{s_j}, \; i, j = E, I, \; i \neq j.$$

The start-up and the incumbent engage in quantity competition in market A. We normalise the marginal cost of production to zero.

Similarly, the probability with which product B is successful is denoted by $q(1 - x, \epsilon_B)$, where $1 - x$ is the investment in project B and ϵ_B is its intrinsic difficulty. This probability is increasing in $1 - x$ and decreasing in ϵ_B. As mentioned before, project B is non-rival. We assume that project B delivers a profit π_B to the start-up in case of success and a surplus U^B to consumers. Otherwise, in case of failure, the project does not deliver anything.

We further specify the success probabilities as in Tullock contests:

$$p(x, \epsilon_A) = \frac{x}{x + \epsilon_A}, \text{ and } q(1 - x, \epsilon_B) = \frac{1 - x}{1 - x + \epsilon_B},$$

where $\epsilon_A, \epsilon_B > 0$. With this formulation, a project becomes a sure success if its difficulty goes to zero, and a sure failure if its difficulty goes to infinity. This well-known functional form ensures that all our investment portfolio problems are strictly concave in own investment effort and therefore the first order conditions (FOCs) for expected profits maximisation are necessary and sufficient for maxima. Moreover, when $\epsilon_A, \epsilon_B \to 0$ all our decision problems have interior solutions.

We start our analysis with a comparison of the outcome of a three-stage *acquisition* game with the outcome of a benchmark two-stage *no-acquisition* game. In the first stage of the three-stage *acquisition* game, *the portfolio investment stage*, the start-up chooses its portfolio of investments. In

[4] The assumption that $\overline{s} < 2\underline{s}$ rules out drastic innovations, that is, situations in which the incumbent firm would be forced to exit the market after a successful innovation of the entrepreneur. This assumption does not alter the main insights of our paper. For a detailed discussion, see Section 8.

[5] We have also examined the case in which the start-up cannot enter the market in case of failure to innovate in project A. It turns out that this case leads to exactly the same results as that of drastic innovations (see Section 8).

the second stage, *the acquisition stage*, after observing the outcome of its research efforts in projects A and B, the start-up and the incumbent bargain over the surplus generated by the acquisition. In this stage, we implement the Nash bargaining solution and assume that δ is the bargaining power of the start-up and, correspondingly, $1-\delta$ that of the incumbent. In the third stage, *the market competition stage*, firms set their optimal quantities in market A to maximize their profits. In the benchmark *no-acquisition* two-stage game, the start-up first chooses its portfolio of investments and then, upon observing the results of the research projects, the start-up and the incumbent engage in Cournot competition. We solve for the subgame perfect Nash equilibria of these games. By comparing them we identify the impact of allowing for the acquisition of the start-up.

The above timing of moves in the acquisition game is adequate to model acquisitions in environments in which start-ups have developed their products before they are bought. This timing of moves, which is in line with Letina et al. (2020) seems a good modelling choice for the acquisitions of big-tech firms such as Facebook. An alternative modelling choice is one in which the incumbent buys the start-up during the research phase, thus taking over its research facilities and the portfolio investment decision process. This modelling, which is in line with Cunningham et al. (2019), seems more suited to pharmaceutical markets where the acquirer intervenes in the last stages of drug development. We examine the implications of this alternative modelling in Section 7.

3 Social optimum

Before solving the games outlined above, we examine the social optimum. Specifically, we consider a social planner who chooses investment levels in projects A and B, as well as the production level in market A to maximize consumer surplus.[6]

In the production stage, conditional on the outcome of the investment stage, the social planner chooses the quantity that maximizes consumer surplus. Suppose that project A is successful. In that case, the social planner only offers the high-quality product and continues to do so till the price equals the marginal cost. Otherwise, when project A fails, the planner offers the existing, previously available, low-quality product at marginal cost. It is straightforward to derive the planner's optimal quantities. The corresponding levels of the surplus consumers obtain at the optimal quantities is given by:

$$\overline{U}_A^o = \frac{\alpha^2 \overline{s}^2}{4\beta^2}, \quad \underline{U}_A^o = \frac{\alpha^2 \underline{s}^2}{4\beta^2},$$

where $\overline{U}_A^o$ denotes the level of surplus in case of success and $\underline{U}_A^o$ in case of failure.

In the portfolio investment stage, the social planner chooses a portfolio of investments to maximize consumer surplus. Let x_o denote the socially optimal investment in project A, and correspondingly, $1-x_o$ be the optimal investment in project B. The socially optimal investment x_o

[6]During the last decade, using consumer welfare as the standard for competition enforcement has become the European norm. Our results can easily be extended to situations where the standard is total welfare.

must maximize the expression:

$$\mathbb{E}U^o(x_o) = \frac{x_o}{x_o+\epsilon_A}\overline{U}^o_A + \frac{\epsilon_A}{x_o+\epsilon_A}\underline{U}^o_A + \frac{1-x_o}{1-x_o+\epsilon_B}U_B.$$

The first two terms of this expression represent the expected consumer surplus from investing in project A. With probability $\frac{x_o}{x_o+\epsilon_A}$, the social planner's investment in project A is successful and the surplus $\overline{U}^o_A$ corresponding to the high-quality product is realized. With probability $\frac{\epsilon_A}{x_o+\epsilon_A}$ project A fails, in which case the surplus $\underline{U}^o_A$ corresponding to the low-quality project is obtained. The third term is the expected surplus from investing in project B. With probability $\frac{1-x_o}{1-x_o+\epsilon_B}$, project B is successful, which yields the consumer surplus U_B. With the remaining probability, project B fails and no surplus is obtained.

The FOC for consumer surplus maximization is given by:

$$\frac{\epsilon_A}{(x_o+\epsilon_A)^2}\left(\overline{U}^o_A - \underline{U}^o_A\right) - \frac{\epsilon_B}{(1-x_o+\epsilon_B)^2}U_B = 0$$

This FOC, which is necessary and sufficient for an interior social optimum, implies that the social planner should continue to increase its investment in project A until the marginal surplus from project A equals the marginal surplus from project B. Note that the marginal surplus from a project is proportional to the increase in the innovation surplus that results from success in such a project relative to failure. This innovation surplus is $\overline{U}^o_A - \underline{U}^o_A$ for project A and U_B for project B. Solving for x_o gives the socially optimal investment portfolio.

Lemma 1. *Assume that* $\frac{\epsilon_A\epsilon_B}{(1+\epsilon_A)^2} < \frac{4\beta^2}{\alpha^2(\bar{s}^2-\underline{s}^2)}U_B < \frac{(1+\epsilon_B)^2}{\epsilon_A\epsilon_B}$. *Then, the socially optimal investment in project A is equal to:*

$$\hat{x}_o = \frac{1+\epsilon_B - \epsilon_A\sqrt{\frac{\epsilon_B U_B}{\epsilon_A(\overline{U}^o_A-\underline{U}^o_A)}}}{1+\sqrt{\frac{\epsilon_B U_B}{\epsilon_A(\overline{U}^o_A-\underline{U}^o_A)}}}. \tag{1}$$

The corresponding socially optimal investment in project B is $1-\hat{x}_o$.

The parameter condition given in the proposition ensures that the socially optimal investment level $\hat{x}_o$ is strictly interior. In such a case, the social planner chooses to activate both projects A and B. Notice that this is always the case when $\epsilon_A, \epsilon_B \to 0$. Obviously, parameters can be chosen for which the planner chooses to "kill" one of the projects. In what follows we shall ignore those cases.[7]

The socially optimal investment level $\hat{x}_o$ depends on the parameters of the model in a natural way. First, it is increasing in ϵ_B and decreasing in ϵ_A. That is, the optimal investment shifts towards a particular project when such a project gets easier to realize relative to the alternative

[7] The recent literature on the acquisitions of potential competitors (see e.g. Cunningham et al. (2019) and Motta and Peitz (2020)) has emphasized this "killing" by modelling the decisions of the acquirer as a discrete choice between "continue" and "discontinue." In our model, the investment decision is a continuous variable and draining the resources allocated to a project may also be interpreted as slowly killing it.

project. Further, $\hat{x}_o$ is increasing in $\overline{U}_A^o - \underline{U}_A^o$ and decreasing in U_B. That is, investment shifts towards a given project when the innovation surplus increase due to success in such a project gets higher relative to the innovation surplus increase from success in the alternative project. The surplus increase from innovation in project A is increasing in α, decreasing in β, increasing in $\overline{s}$ and decreasing in $\underline{s}$.

In the two next sections, we solve for the subgame perfect equilibria of the benchmark no-acquisition game and the acquisition game. We shall compare the outcomes of these two games in Section 6 from the stand point of Lemma 1 on social welfare maximization.

4 The no-acquisition game

In the benchmark no- acquisition two-stage game, the start-up first chooses its portfolio of investments and then, upon observing the results of the research projects, the start-up and the incumbent engage in Cournot competition. To solve the game, we proceed by backward induction. We start the analysis of the game by the market competition stage. After this, we fold the game backwards and examine the investment portfolio stage.

4.1 Market competition stage

In this stage the start-up and the incumbent engage in Cournot competition. When setting their quantities, the start-up and the incumbent take into account whether or not the start-up has succeeded in project A. Hence, there are two types of subgames to examine.

In the first subgame, the start-up's effort in project A is successful and it enters market A offering quality $\overline{s}$, while the incumbent offers a product of quality $\underline{s}$. It is straightforward to solve for the quantities that constitute a Nash equilibrium. The corresponding profits of the start-up and the incumbent, denoted $\overline{\pi}_A^E$ and $\underline{\pi}_A^I$ respectively, are equal to:

$$\overline{\pi}_A^E = \frac{\alpha^2(2\overline{s} - \underline{s})^2}{18\beta^2}, \quad \underline{\pi}_A^I = \frac{\alpha^2(2\underline{s} - \overline{s})^2}{18\beta^2},$$

while consumer surplus is given by:

$$\overline{U}_A = \frac{\alpha^2}{36\beta^2}(\overline{s} + \underline{s})^2.$$

In the second subgame, the start-up fails to innovate and both firms, the start-up and the incumbent, offer quality $\underline{s}$. Standard derivations yield the start-up and the incumbent equilibrium profits:

$$\pi_A^E = \pi_A^I = \pi_A^* = \frac{\alpha^2\underline{s}^2}{18\beta^2}.$$

Consumer surplus is given by:

$$\underline{U}_A = \frac{\alpha^2 \underline{s}^2}{9\beta^2}.$$

4.2 Investment portfolio stage

In this stage, the start-up chooses its portfolio of investments to maximize its (expected) profits. In doing so, the start-up anticipates the outcomes of the quantity-setting games that ensue after the result of its research effort in project A is realized.

The expected payoff to a start-up that chooses to invest an amount x_E in project A and correspondingly an amount $1 - x_E$ in project B equals:

$$\mathbb{E}\pi^E(x_E) = \frac{x_E}{x_E + \epsilon_A}\overline{\pi}_A^E + \frac{\epsilon_A}{x_E + \epsilon_A}\pi_A^* + \frac{1 - x_E}{1 - x_E + \epsilon_B}\pi_B. \tag{2}$$

The first two terms of this expression represent the expected payoff from investing in project A. With a probability equal to $\frac{x_E}{x_E+\epsilon_A}$, the start-up's investment in project A is successful, in which case it obtains the Cournot profit corresponding to a firm selling a high-quality product and competing with an incumbent selling a low-quality product, i.e. $\overline{\pi}_A^E$. With probability $\frac{\epsilon_A}{x_E+\epsilon_A}$, the start-up's effort in project A is unsuccessful and then the start-up gets the symmetric Cournot profit that both the start-up and the incumbent get when they both offer a low-quality product, i.e. π_A^*. The third term is the expected profit from investing in project B. With probability $\frac{1-x_E}{1-x_E+\epsilon_B}$, the B innovation is successful, which yields a profit of π_B to the start-up. With the remaining probability, the project is unsuccessful and the start-up gets zero profits in market B.

The necessary and sufficient condition for profit maximization is:

$$\frac{\epsilon_A}{(x_E + \epsilon_A)^2}\left(\overline{\pi}_A^E - \pi_A^*\right) - \frac{\epsilon_B}{(1 - x_E + \epsilon_B)^2}\pi_B = 0.$$

This equation says that the start-up will continue to invest in project A until the marginal profit from project A equals the marginal profit from project B. Note that the marginal profit from project A is proportional to the increase in the profit that results from success in such a project relative to failure. This profit increase is $\overline{\pi}_A^E - \pi_A^*$ for project A, and π_B for project B. Solving for x_E gives the start-up's profit-maximizing investment portfolio.

Lemma 2. *Assume that* $\frac{\epsilon_A\epsilon_B}{(1+\epsilon_A)^2} < \frac{9\beta^2}{2\alpha^2\overline{s}(\overline{s}-\underline{s})}\pi_B < \frac{(1+\epsilon_B)^2}{\epsilon_A\epsilon_B}$. *Then, the start-up's profit-maximizing investment in project A is:*

$$\hat{x}_E = \frac{1 + \epsilon_B - \epsilon_A\sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A(\overline{\pi}_A^E - \pi_A^*)}}}{1 + \sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A(\overline{\pi}_A^E - \pi_A^*)}}}. \tag{3}$$

The corresponding investment in project B is equal to $1 - \hat{x}_E$.

The parameter constellation given in the proposition ensures that the start-up's profit-maximizing investment level $\hat{x}_E$ is strictly interior. Notice that when $\epsilon_A, \epsilon_B \to 0$, $\hat{x}_E$ is always strictly interior.

As it was the case for the socially optimal investment portfolio, the investment level $\hat{x}_E$ is increasing in ϵ_B and decreasing in ϵ_A, reflecting the fact that the more difficult project B is relative to A, the more attractive project A becomes compared to project B. Furthermore, $\hat{x}_E$ is increasing in $\overline{\pi}_A^E - \pi_A^*$ and decreasing in π_B. Thus, the start-up's investment incentives depend on the relative profitability of the projects. The higher the extra profits a successful innovation in project A delivers relative to a successful innovation in B, the higher the investment level $\hat{x}_E$. The relative gains from successful innovation in project A are increasing in α, decreasing in β, increasing in $\overline{s}$ and decreasing in $\underline{s}$. Obviously, the previously mentioned parameters have the opposite impact on $1 - \hat{x}_E$.

4.3 Portfolio efficiency

In this section, we compare the equilibrium of the benchmark no-acquisition game with the social optimum.

Proposition 1. *In the no-acquisition game, the investment effort put into project A is excessive (and therefore investment put into project B is insufficient) from the point of view of consumer surplus maximization if and only if $\pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})} U_B$.*

Proof. See the Appendix. □

Proposition 1 demonstrates that the portfolio of investments of the start-up is generally misaligned with the social incentives. The proposition also shows that the bias may be in favor of project A or in favor of project B, depending on parameters. To understand the condition in the proposition, note that both the social planner and the start-up make their choice of portfolio to equalize the expected gains from a successful project A relative to failure, and the expected gains from a successful project B relative to failure. However, while the start-up cares about profit gains, the planner cares about consumer gains. The condition thus stems from a comparison of the relative consumer surplus gains across projects, i.e. the ratio $\frac{\overline{U}_A^o - U_A^o}{U_B}$, with the relative profit gains across projects, i.e. the ratio $\frac{\overline{\pi}_A^E - \underline{\pi}_A^E}{\pi_B}$. Everything else constant, a bias in favor of project A is more likely to occur when project B is not very profitable (low π_B) but however has a large social value attached to it (large U_B). Likewise, this is more probable the higher $\overline{s}$ and the lower $\underline{s}$, which increases the private gains from project A relative to those of project B. It is obvious that this portfolio bias causes the innovation to go in a socially suboptimal direction.

5 The acquisition game

We now solve the three-stage acquisition game. In the first stage of this game, the start-up chooses its portfolio of investments. In the second stage, after observing the outcome of the research effort, the start-up and the incumbent bargain over the surplus generated by the acquisition. In the third stage, firms choose their quantities to maximize their profits. To solve the game we proceed backwards.

5.1 Market competition stage

Here we start by considering subgames in which the acquirer and the start-up have not reached an agreement in the acquisition stage and therefore the acquisition does not materialize. In such a case, the start-up and the incumbent produce as in the no-acquisition game of Section 5. The profits the start-up and the incumbent make in case the start-up's investment in project A is successful are $\overline{\pi}_A^E$ and $\underline{\pi}_A^I$, otherwise they make a profit equal to π^*.

Consider now subgames in which the acquirer and the start-up agree to the merger. In that case, the acquirer becomes a monopolist in market A. Again, there are two types of subgames to consider. In the first subgame, the start-up's effort in project A is successful, in which case the acquirer offers a high-quality product in market A. In the alternative subgame, the start-up's effort in project A is unsuccessful and the acquirer offers a low-quality product.

Standard derivations yield the acquirer's profits from market A conditional on the project being successful or unsuccessful, denoted $\overline{\pi}_A^m$ and $\underline{\pi}_A^m$ respectively:

$$\overline{\pi}_A^m = \frac{\alpha^2 \overline{s}^2}{8\beta^2}, \quad \underline{\pi}_A^m = \frac{\alpha^2 \underline{s}^2}{8\beta^2}.$$

The corresponding consumer surplus levels, denoted $\overline{U}_A^m$ and $\underline{U}_A^m$, are equal to:

$$\overline{U}_A^m = \frac{\alpha^2 \overline{s}^2}{16\beta^2}, \quad \underline{U}_A^m = \frac{\alpha^2 \underline{s}^2}{16\beta^2}.$$

5.2 Acquisition stage

In this stage, the incumbent and the start-up negotiate over the surplus that the acquisition generates. We implement the Nash bargaining solution.

Suppose the start-up's investment effort is successful. In this case, the surplus generated by the acquisition is $\overline{\pi}_A^m - (\overline{\pi}_A^E + \underline{\pi}_A^I)$, where $\overline{\pi}_A^E$ and $\underline{\pi}_A^I$ play the role of disagreement payoffs. The bargaining outcome is the result of the problem:

$$\max_{s_E, s_I} (s_E - \overline{\pi}_A^E)^\delta (s_I - \underline{\pi}_A^I)^{1-\delta}$$
$$\text{subject to } s_E + s_I = \overline{\pi}_A^m,$$

where the parameter δ captures the bargaining power of the start-up and $1-\delta$ that of the incumbent. Substituting the constraint into the objective function, taking the FOC and solving we obtain the

Nash bargaining solution:

$$\overline{s}_E = \overline{\pi}_A^E + \delta(\overline{\pi}_A^m - (\overline{\pi}_A^E + \underline{\pi}_A^I))$$
$$\overline{s}_I = \underline{\pi}_A^I + (1-\delta)(\overline{\pi}_A^m - (\overline{\pi}_A^E + \underline{\pi}_A^I))$$

The Nash bargaining outcome prescribes that each agent receives its disagreement payoff plus a share of the bargaining surplus that is proportional to its bargaining power.

When the start-up's investment effort is not successful, the surplus generated by the acquisition is $\underline{\pi}_A^m - 2\pi_A^*$, where π_A^* plays the role of disagreement payoff for each of the firms. The bargaining outcome is then the result of the problem:

$$\max_{s_E, s_I} (s_E - \pi_A^*)^\delta (s_I - \pi_A^*)^{1-\delta}$$
$$\text{subject to } s_E + s_I = \underline{\pi}_A^m.$$

Proceeding as before, we obtain the Nash bargaining solution:

$$\underline{s}_E = \pi_A^* + \delta(\underline{\pi}_A^m - 2\pi_A^*)$$
$$\underline{s}_I = \pi_A^* + (1-\delta)(\underline{\pi}_A^m - 2\pi_A^*).$$

Because the surplus created by an acquisition is strictly positive no matter the outcome of the research project, the acquisition always occurs in equilibrium.

5.3 Investment portfolio stage

In this stage, the start-up chooses its portfolio of investments to maximize its (expected) profits. In doing so, the start-up anticipates the outcomes of the bargaining games that ensue after the result of its research effort in project A is realized.

The expected profit of the start-up that invests x_E into project A and correspondingly $1 - x^E$ into project B is:

$$\mathbb{E}\pi^E(x_E) = \frac{x_E}{x_E + \epsilon_A}\left(\overline{\pi}_A^E + \delta(\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I)\right) + \frac{\epsilon_A}{x_E + \epsilon_A}\left(\pi_A^* + \delta(\underline{\pi}_A^m - 2\pi_A^*)\right) + \frac{1 - x_E}{1 - x_E + \epsilon_B}\pi_B \tag{4}$$

As before the first two terms show the expected payoff from investing in project A. With probability $\frac{x_E}{x_E+\epsilon_A}$, the start-up's project is successful and obtains the high quality product, in which case the start-up gets its disagreement payoff $\overline{\pi}_A^E$ plus a share δ of the surplus created by the acquisition, $\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I$. With probability $\frac{\epsilon_A}{x_E+\epsilon_A}$, the entrant fails to obtain the high quality product and obtains the competitive profit π_A^* plus a share δ of the surplus created by the acquisition, $\underline{\pi}_A^m - 2\pi_A^*$. The third term shows the expected profit from investing in project B, which yields a payoff of π_B

with probability $\frac{1-x_E}{1-x_E+\epsilon_B}$.

The necessary and sufficient condition for profit maximization is:

$$\frac{\epsilon_A}{(x_E+\epsilon_A)^2}\left[\overline{\pi}_A^E+\delta(\overline{\pi}_A^m-\overline{\pi}_A^E-\underline{\pi}_A^I)-(\pi_A^*+\delta(\underline{\pi}_A^m-2\pi_A^*))\right]+\frac{\epsilon_B}{(1-x_E+\epsilon_B)^2}\pi_B=0$$

This FOC can be interpreted similarly as those above. The start-up will continue to invest in project A until the marginal profit from project A equals the marginal profit from project B. The difference is that the marginal profit from investing in project A now incorporates the negotiation outcome of the bargaining game. As a result, provided that the start-up's bargaining power is sizable, the start-up will distort its portfolio of investments in anticipation of the rents it can obtain in the bargaining process. Solving for the equilibrium investment gives:

Lemma 3. *Assume that* $\frac{\epsilon_A\epsilon_B}{(1+\epsilon_A)^2}<\frac{72\beta^2}{\alpha^2((16\overline{s}-\delta(11\overline{s}-21\underline{s}))(\overline{s}-\underline{s}))}\pi_B<\frac{(1+\epsilon_B)^2}{\epsilon_A\epsilon_B}$ *Then, anticipating that the start-up will be acquired after the outcome of its research projects are realized, the start-up's profit-maximizing investment in project A is:*

$$\tilde{x}_E=\frac{1+\epsilon_B-\epsilon_A\sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A\left(\overline{\pi}_A^E+\delta(\overline{\pi}_A^m-\overline{\pi}_A^E-\underline{\pi}_A^I)-\pi_A^*-\delta(\underline{\pi}_A^m-2\pi_A^*)\right)}}}{1+\sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A\left(\overline{\pi}_A^E+\delta(\overline{\pi}_A^m-\overline{\pi}_A^E-\underline{\pi}_A^I)-\pi_A^*-\delta(\underline{\pi}_A^m-2\pi_A^*)\right)}}} \tag{5}$$

The corresponding investment in project B is $1-\tilde{x}_E$.

5.4 Portfolio efficiency

As we did for the benchmark no-acquisition game, we now compare the equilibrium investment of the acquisition game with the social optimum.

Proposition 2. *In the acquisition game, the investment effort put into project A is excessive (and therefore investment put into project B is insufficient) from the point of view of consumer surplus maximization if and only if* $\pi_B<\frac{16\overline{s}-\delta(11\overline{s}-21\underline{s})}{18(\overline{s}+\underline{s})}U_B$.

Proof. See the Appendix. □

Also in the case of an acquisition, depending on parameters, the portfolio of investments of the start-up may be biased towards project A or project B compared to the socially optimal portfolio of investments. As explained above for the no-acquisition game, the condition in the proposition stems from a comparison of the relative consumer surplus gains across projects, i.e. the ratio $\frac{\overline{U}_A^o-\underline{U}_A^o}{U_B}$, with the relative profit gains across projects after an acquisition, i.e. the ratio $\frac{\overline{\pi}_A^E+\delta(\overline{\pi}_A^m-\overline{\pi}_A^E-\underline{\pi}_A^I)-(\pi_A^*+\delta(\underline{\pi}_A^m-2\pi_A^*))}{\pi_B}$. It is obvious that this bias causes the innovation to go in a socially suboptimal direction. The question that arises is whether an acquisition improves or worsens the direction of innovation. We address this question in the next section.

6 The impact of an acquisition

In this section we compare the outcome of the benchmark no-acquisition game with that of the acquisition game. We start with the impact of an acquisition on the portfolio of investments of the start-up.

Proposition 3. *For any* $\delta \in (0, 1]$*:*

(i) Relative to the no-acquisition case, the start-up puts less effort into project A (and therefore more effort into project B), i.e. $\tilde{x}_E < \hat{x}_E$*, if and only if* $\frac{21}{11}\underline{s} < \overline{s} < 2\underline{s}$*.*

(ii) Relative to the no-acquisition case, the start-up puts more effort into project A (and therefore less effort into project B), i.e. $\hat{x}_E < \tilde{x}_E$*, if and only if* $\underline{s} < \overline{s} < \frac{21}{11}\underline{s}$*.*

Moreover, the difference $\hat{x}_E - \tilde{x}_E$ *is greater the larger the start-up's bargaining power* δ*.*

Proof. See the Appendix. □

Proposition 3 describes how the start-up adjusts its investment portfolio in anticipation of an acquisition. As explained after Propositions 2 and 3, the start-up invests so as to equalize the marginal gains from investing in project A to the marginal gains from investing in project B. Each of these marginal gains are proportional to the additional rents a successful innovation generates compared to failure. Because in the acquisition game the start-up shares in the bargaining surplus, it is precisely the additional rents of a successful innovation in market A what changes in the acquisition game compared to the no-acquisition one. Specifically, in the no-acquisition game, the additional rents a successful innovation generates in market A are equal to $\overline{\pi}_A^E - \pi_A^*$ while in the acquisition game they are equal to $\overline{\pi}_A^E + \delta(\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I) - (\pi_A^* + \delta(\underline{\pi}_A^m - 2\pi_A^*))$. Thus, anticipating an acquisition, the start-up distorts its investment in a direction that depends on whether the bargaining surplus generated by the acquisition in case of a successful project is greater or smaller than the bargaining surplus in case of an unsuccessful project. That is, when

$$\underbrace{\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I}_{\text{bargaining surplus if } A \text{ succeeds}} < \underbrace{\underline{\pi}_A^m - 2\pi_A^*}_{\text{bargaining surplus if } A \text{ fails}} \tag{6}$$

the start-up will invest less in project A (and more in B) in anticipation of the acquisition as compared to when an acquisition is not possible. In terms of the primitive parameters of the model, this inequality holds whenever $\overline{s}$ is very large compared to $\underline{s}$. The reason for this is intuitive. When $\overline{s}$ is very large compared to $\underline{s}$, the rents from monopolization of the product market are very limited because $\overline{\pi}_A^m$ and $\overline{\pi}_A^E$ are very close to one another. In fact, in the limit when $\underline{s} \to \overline{s}$, $\overline{\pi}_A^E \to \overline{\pi}_A^m$ and $\underline{\pi}_A^I \to 0$ and therefore the LHS of (6) converges to zero. Meanwhile, the RHS of (6) is bounded above zero. When the inequality is reversed, the start-up will invest more in project A (and less in B), which occurs when the difference between $\overline{s}$ and $\underline{s}$ is relatively small. We finally remark that when the start-up does not have bargaining power whatsoever ($\delta = 0$), the start-up's investment portfolio remains the same as in the no-acquisition game. This is natural because the start-up does not share in the extra rents the acquisition generates.

Our next result combines Propositions 1, 2 and 3 to derive a result on how an acquisition affects the direction of innovation activity from the point of view of surplus maximization.

Proposition 4. *(i) Assume that* $\frac{21}{11}\underline{s} < \overline{s} < 2\underline{s}$ *so that the start-up, anticipating its acquisition, reduces investment in project A and increases it in project B. Then:*

- *if* $\pi_B < \frac{16\overline{s}-\delta(11\overline{s}-21\underline{s})}{18(\overline{s}+\underline{s})}U_B$*, then* $\hat{x}_o < \tilde{x}_E < \hat{x}_E$ *and thus an acquisition improves the direction of innovation;*
- *if* $\pi_B > \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$*, then* $\tilde{x}_E < \hat{x}_E < \hat{x}_o$ *and thus an acquisition worsens the direction of innovation;*
- *finally, if* $\frac{16\overline{s}-\delta(11\overline{s}-21\underline{s})}{18(\overline{s}+\underline{s})}U_B < \pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$*, then* $\tilde{x}_E < \hat{x}_o < \hat{x}_E$ *and thus an acquisition causes a move from over- to underinvestment in project A.*

(ii) Assume that $\overline{s} < \frac{21}{11}\underline{s}$ *so that the start-up, anticipating its acquisition, increases investment in project A and decreases it in project B. Then:*

- *if* $\pi_B > \frac{16\overline{s}-\delta(11\overline{s}-21\underline{s})}{18(\overline{s}+\underline{s})}U_B$*, then* $\hat{x}_E < \tilde{x}_E < \hat{x}_o$ *and thus an acquisition improves the direction of innovation;*
- *if* $\pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$*, then* $\hat{x}_o < \hat{x}_E < \tilde{x}_E$ *and thus an acquisition worsens the direction of innovation;*
- *finally, if* $\frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B < \pi_B < \frac{16\overline{s}-\delta(11\overline{s}-21\underline{s})}{18(\overline{s}+\underline{s})}U_B$*, then* $\hat{x}_E < \hat{x}_o < \tilde{x}_E$ *and thus an acquisition causes a move from under- to overinvestment in project A.*

Proposition 4 shows that an acquisition may result either in an alignment or in a misalignment of the private incentives to invest with the social incentives. In particular, Proposition 4 points out two regions of parameters in which the direction of innovation improves when the start-up anticipates its acquisition, and two regions of parameters in which the direction of innovation worsens. These four regions of parameters are depicted in Figure 1, along with two parameter regions for which it is not clear whether an acquisition results in an alignment or misalignment of the private incentives to invest and the social incentives. In this figure, the blue curve depicts the boundary of the region of parameters described by the condition in Proposition 1, while the red curve shows the boundary of the region of parameters described by the condition in Proposition 2.

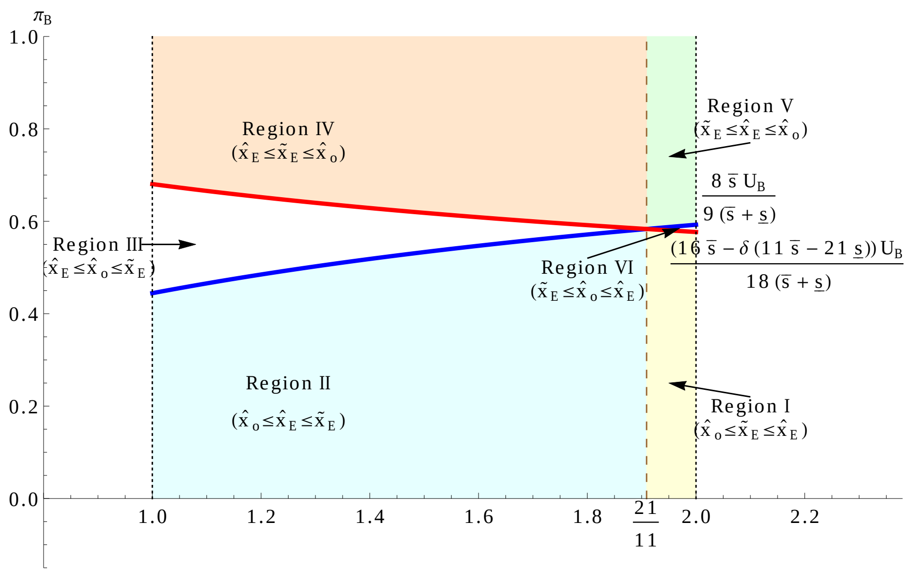

Figure 1: Private and socially optimal innovation portfolios

Specifically, when parameters fall in region I, the start-up, anticipating its acquisition, will decrease its investment in project A and increase it in project B. Because in this region of parameters, investment in A is excessive and in B insufficient from the point of view of social welfare maximization, it follows that the direction of innovation shall improve when the start-up anticipates its acquisition. A similar result holds in Region IV. When the parameters of the model fall in this region, the start-up, anticipating its acquisition, will increase its investment in project A and decrease it in project B. Because in this region of parameters, investment in A is insufficient while investment in B is excessive from the point of view of social welfare maximization, it follows that the direction of innovation will also improve when acquisitions are allowed.

By contrast, when parameters fall in regions II and V, allowing for acquisitions will worsen the direction of innovation. In Region II, an acquisition results in an increase in investment in A and a decrease in investment in B. Because in this region of parameters, investment in A is excessive while investment in B is insufficient from the point of view of social welfare maximization, the direction of innovation worsens when the start-up anticipates its acquisition. In Region V we have a similar observation because this is a region of parameters in which investment in A is insufficient and in B excessive and an acquisition results in even less investment in A and more in B.

Finally, Regions III and VI represent parameter spaces where the impact of an acquisition on the direction of innovation is ambiguous. The reason for this is that in these two regions of parameters the market moves from a portfolio where investment in project A is excessive and in B insufficient to a portfolio where investment in A is insufficient and in B excessive, or viceversa. Whether the direction of innovation improves or worsens depends on the other parameters of the model.

Proposition 4 shows that, depending on parameters, a prohibition of start-up acquisitions may reduce the innovation distortion by aligning the portfolio of investments of the start-up with the socially optimal one. This is the case in Regions II and V of Figure 1. For those parameters, definitely, prohibiting start-up acquisitions will increase consumer welfare because a prohibition of start-up acquisitions will not only reduce the innovation distortion but also the quantity distortion.

In Regions I and IV, by contrast, a prohibition of start-up acquisitions increases the innovation distortion but at the same time it reduces the quantity distortion. The question that arises is then which of these two effects has a dominating influence in these parameter regions. To address this question, we need to compare the expression for consumer surplus corresponding to the no-acquisition case:

$$\mathbb{E}U(\hat{x}_E) = \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A + \frac{1 - \hat{x}_E}{1 - \hat{x}_E + \epsilon_B}U_B, \tag{7}$$

to the one corresponding to the acquisition case:

$$\mathbb{E}U(\tilde{x}_E) = \frac{\tilde{x}_E}{\tilde{x}_E + \epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\tilde{x}_E + \epsilon_A}\underline{U}_A^m + \frac{1 - \tilde{x}_E}{1 - \tilde{x}_E + \epsilon_B}U_B. \tag{8}$$

The following result provides the consumer surplus implications of a prohibition of start-up acquisitions.

Proposition 5. *(i) Assume that* $\frac{21}{11}\underline{s} < \overline{s} < 2\underline{s}$ *so that, by Proposition 3,* $\tilde{x}_E < \hat{x}_E$*. Then, there exists* $\tilde{U}_B > 0$ *such that for all* $U_B < \tilde{U}_B$*, a prohibition of acquisitions results in an increase in consumer surplus. For* $U_B > \tilde{U}_B$*, a prohibition of acquisitions results in an decrease in consumer surplus.*

(ii) Alternatively, assume that $\overline{s} < \frac{21}{11}\underline{s}$ *so that, by Proposition 3,* $\tilde{x}_E > \hat{x}_E$*. Then, a prohibition of acquisitions results in an increase in consumer surplus.*

Proof. See the Appendix. □

Proposition 5(i) implies that when the quality difference is relatively large, whether the investment portfolio effects or the price effects of an acquisition have a dominating influence is ambiguous. The investment portfolio effect decreases consumer surplus in market A but increases consumer surplus in market B. However, when $\overline{s}$ is large compared to $\underline{s}$, the decrease in consumer surplus in market A is relatively small because the increase in the quantity distortion is insignificant. As a result, when consumer surplus in market B is sufficiently large, i.e. $U_B > \tilde{U}_B$, the decrease in the innovation distortion has a dominating influence over the increase in the quantity distortion in market A. As a result, a prohibition of acquisitions reduces the overall expected consumer surplus. Otherwise, when $U_B < \tilde{U}_B$, expected consumer surplus increases if acquisitions are prohibited.

Proposition 5(ii) states that when the quality difference is relatively small, prohibiting acquisitions results in an increase in consumer surplus. When $\overline{s}$ is not very large compared to $\underline{s}$, the increase in the quantity distortion is quite significant and, even though the innovation distortion may become smaller after an acquisition, this effect is not sufficiently strong to offset the negative effects that arise from the increase in the quantity distortion. In different words, when the quality difference is not very large, the associated negative price effects of an acquisition dominate the investment portfolio effects.

We illustrate Proposition 5 in Figure 2. In this graph we illustrate the parameter region where consumer surplus is higher when acquisitions are allowed relative to the case in which acquisitions are forbidden. In this graph we fix $U_B = 1$ which in this case satisfies the condition in the Proposition $U_B > \tilde{U}_B$. As U_B increases, the shaded region covers a larger space of Region I.

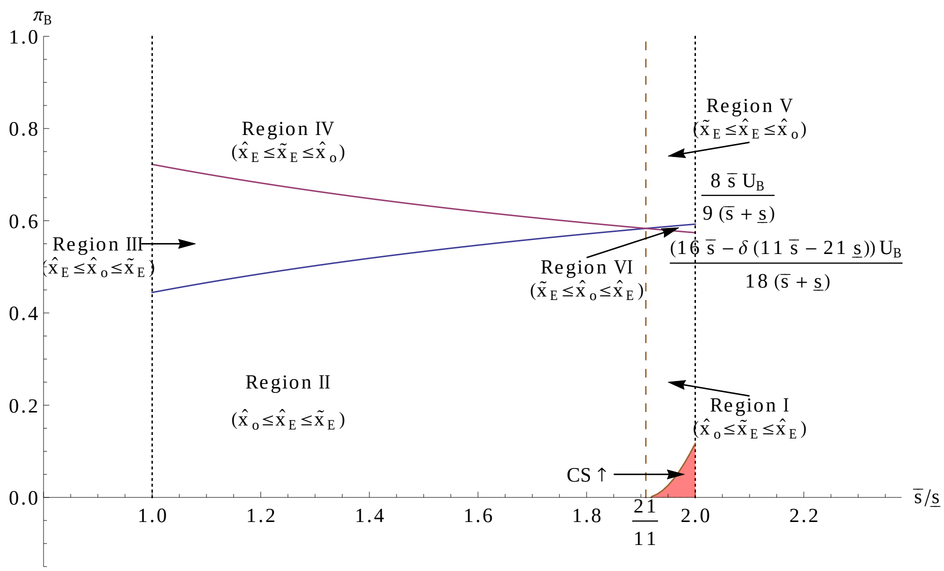

Figure 2: Consumer surplus improving start-up acquisitions

7 On the timing of acquisitions

In our main model, we have assumed that the incumbent acquires the start-up once the outcome of its research effort is known. As we have argued in the Introduction, this timing seems a sensible modelling choice to model start-up acquisitions in the digital world. However, in the pharmaceutical industry, many acquisitions take place much earlier in the process. In this section, we assume that the incumbent may acquire the start-up before the outcome of its research effort is known, which means that the acquirer takes over the start-up's research facilities and the innovation portfolio decisions. We then solve an alternative acquisition game where, first, the incumbent and the start-up negotiate over the expected acquisition surplus, second, the acquirer chooses its portfolio of investments and finally the acquirer produces after knowing the outcome of its research efforts in projects A and B.

As before, we solve the game backwards. Because the market competition stage is exactly the same as that in Section 5.1, we move directly to the investment portfolio stage.

7.1 Investment portfolio stage

Let x_m denote the investment effort the acquirer puts in project A and, correspondingly, $1 - x_m$ be its investment in project B. The expected payoff to the acquirer from investing x_m in project A and $1 - x_m$ in project B is:

$$\mathbb{E}\pi^m(x_m) = \frac{x_m}{x_m + \epsilon_A}\overline{\pi}_A^m + \frac{\epsilon_A}{x_m + \epsilon_A}\underline{\pi}_A^m + \frac{1 - x_m}{1 - x_m + \epsilon_B}\pi_B \tag{9}$$

The interpretation of this expected payoff is similar to the interpretation of the payoff in (2).

The FOC is given by:

$$\frac{\epsilon_A}{(x_m + \epsilon_A)^2}\left(\overline{\pi}_A^m - \underline{\pi}_A^m\right) - \frac{\epsilon_B}{(1 - x_m + \epsilon_B)^2}\pi_B = 0$$

As in the no-acquisition case, this equation says that the acquirer will continue to invest in project A until the marginal profit from project A equals the marginal profit from project B. While the marginal profit from project B is exactly identical to that in the no-acquisition case, the marginal profit from project A is different. In particular, the marginal profit from project A is proportional to $\overline{\pi}_A^m - \underline{\pi}_A^m$, which represents the difference between a successful project A and an unsuccessful project B. This difference is thus the reason for the acquirer to hold a distinct investment portfolio compared to that of the start-up. Solving for x_m we obtain the acquirer's optimal investment portfolio.

Lemma 4. *Assume that* $\frac{\epsilon_A\epsilon_B}{(1+\epsilon_A)^2} < \frac{8\beta^2}{\alpha^2(\overline{s}^2-\underline{s}^2)}\pi_B < \frac{(1+\epsilon_B)^2}{\epsilon_A\epsilon_B}$. *When the acquirer takes over the research facilities of the start-up, the acquirer's profit-maximizing investment in project A is:*

$$\hat{x}_m = \frac{1 + \epsilon_B - \epsilon_A\sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A(\overline{\pi}_A^m - \underline{\pi}_A^m)}}}{1 + \sqrt{\frac{\epsilon_B\pi_B}{\epsilon_A(\overline{\pi}_A^m - \underline{\pi}_A^m)}}} \tag{10}$$

The corresponding investment in project B is $1 - \hat{x}^m$.

The parameters of the model have the same effect on $\hat{x}_m$ as they do on $\hat{x}_E$ in (3).

As we did before, we can examine the nature of the portfolio bias in the case of an acquisition. A comparison of the acquirer's investment portfolio $\hat{x}_m$ with that chosen by the social planner $\hat{x}_o$ leads to the following result:

Proposition 6. *When the acquirer takes over the research facilities of the start-up, the investment effort put into project A is excessive (and therefore investment put into project B is insufficient) from the social point of view if and only if* $\pi_B < \frac{U_B}{2}$.

Proof. See the Appendix. □

As discussed in Section 3, the incentives of the planner are governed by the difference between the social gains from a successful project A and the social gains from a successful project B.

Meanwhile, the acquirer cares about the private gains from a successful project A and the private gains from a successful project B. The result follows from a comparison of the relative consumer surplus gains across projects, i.e. the ratio $\frac{\overline{U}_A^o - \underline{U}_A^o}{U_B}$, with the relative profit gains across projects, i.e. the ratio $\frac{\overline{\pi}_A^m - \underline{\pi}_A^m}{\pi_B}$.

7.2 Acquisition stage

Finally, we study the acquisition stage. In this stage, the incumbent and the start-up negotiate over the surplus that the acquisition generates. We implement the Nash bargaining solution. A rejection of the offer of the incumbent yields the profits corresponding to the no-acquisition continuation game, in which case the start-up invests an amount $\hat{x}_E$, which yields a profit $\overline{\pi}_A^E$ in case of project success and a profit π_A^* in case of project failure. Therefore, the start-up's expected profits from rejection are equal to:

$$\mathbb{E}\pi^E(\hat{x}_E) = \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{\pi}_A^E + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\pi_A^* + \frac{1 - \hat{x}_E}{1 - \hat{x}_E + \epsilon_B}\pi_B \tag{11}$$

Meanwhile, the expected profits of the incumbent in case of rejection are given by:

$$\mathbb{E}\pi^I(\hat{x}_E) = \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\underline{\pi}_A^I + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\pi_A^*$$

The disagreement payoffs for the incumbent and the start-up are thus $\mathbb{E}\pi^I(\hat{x}_E)$ and $\mathbb{E}\pi^E(\hat{x}_E)$, respectively, and the surplus from an acquisition is given by:

$$\mathbb{E}\pi^m(\hat{x}_m) - [\mathbb{E}\pi^E(\hat{x}_E) + \mathbb{E}\pi^I(\hat{x}_E)],$$

which is strictly positive.[8]

The bargaining outcome is therefore the result of the problem:

$$\max_{s_E, s_I}(s_E - \mathbb{E}\pi^E(\hat{x}_E))^\delta(s_I - \mathbb{E}\pi^I(\hat{x}_E))^{1-\delta}$$
$$\text{subject to } s_E + s_I = \mathbb{E}\pi^m(\hat{x}_m)$$

Substituting the constraint into the objective function, taking the FOC and solving we obtain the

[8]This is because

$$\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{\pi}_A^m + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A}\underline{\pi}_A^m + \frac{1 - \hat{x}_m}{1 - \hat{x}_m + \epsilon_B}\pi_B \geq \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\left(\overline{\pi}_A^E + \underline{\pi}_A^I\right) + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}2\pi_A^* + \frac{1 - \hat{x}_E}{1 - \hat{x}_E + \epsilon_B}\pi_B.$$

This inequality holds true because of the following remarks. First, notice that both the LHS and the RHS of this inequality are exactly the same function of x. Second, observe that $\underline{\pi}_A^m \geq 2\pi_A^*$ and $\overline{\pi}_A^m \geq \overline{\pi}_A^E + \underline{\pi}_A^I$. Finally, given these two observations, an application of the envelope theorem implies the result.

Nash bargaining solution:

$$s_E^* = \mathbb{E}\pi^E(\hat{x}_E) + \delta[\mathbb{E}\pi^m(\hat{x}_m) - (\mathbb{E}\pi^I(\hat{x}_E) + \mathbb{E}\pi^E(\hat{x}_E))]$$
$$s_I^* = \mathbb{E}\pi^I(\hat{x}_E) + (1-\delta)[\mathbb{E}\pi^m(\hat{x}_m) - (\mathbb{E}\pi^I(\hat{x}_E) + \mathbb{E}\pi^E(\hat{x}_E))].$$

When the bargaining power of the start-up is zero, it is obvious that the subgame perfect equilibrium offer of the incumbent is equal $\mathbb{E}\pi^E(\hat{x}_E)$.

7.3 Comparing the start-up's and acquirer's investment portfolios

A comparison of the equilibrium investment portfolio under no-acquisition with that under acquisition leads to the following result:

Proposition 7. *(i) The investment effort put into project A by the acquirer is lower than (and therefore that in project B higher than) that of the start-up, i.e.* $\hat{x}_m < \hat{x}^E$*, when* $\frac{9}{7}\underline{s} < \overline{s} < 2\underline{s}$*.*

(ii) The investment effort put into project A by the acquirer is higher than (and therefore that in project B is lower than) that of the start-up, i.e. $\hat{x}_E < \hat{x}^m$*, when* $\overline{s} < \frac{9}{7}\underline{s}$*.*

Proof. See the Appendix. □

The start-up and the acquirer hold distinct investment portfolios. The reason for this is that the marginal gains from investing in project A differ across the two cases. In the no-acquisition case, the marginal gains from investing in project A are governed by the profits difference $\overline{\pi}_A^E - \pi_A^*$. By contrast, in the acquisition case, the marginal gains from investing in project A are related to the profits difference $\overline{\pi}_A^m - \underline{\pi}_A^m$. When $\overline{\pi}_A^E - \pi_A^* > \overline{\pi}_A^m - \underline{\pi}_A^m$, the start-up's incentive to invest in project A is greater than the acquirer'sacquirer incentive.

These profits differences represent the incremental gains of the two actors from selling a high-quality product in market A relative to selling a low-quality product. For both actors, we observe the so-called Arrow's (1962) *replacement effect.* In fact, when project A turns out to be successful, the start-up replaces its Cournot competitor-self with a low-quality product by a Cournot competitor-self with a high-quality product. By contrast, the acquirer replaces a monopoly-self with a low-quality product by a monopoly-self with a high-quality product. Depending on parameters, the replacement effect of the entrant can be more severe than that of the acquirer. As Proposition 7 states, this is the case when the difference in the quality of the products is small ($\overline{s} < 9\underline{s}/7$). In such a situation, the monopolist benefits relatively more from obtaining the high quality product than the entrant does. Hence, the acquirer invests more in project A in the acquisition case than the entrant does in the no-acquisition case. When the difference in the quality of the products is large ($9\underline{s}/7 < \overline{s} < 2\underline{s}$), it is the opposite and investment in project A decreases after an acquisition.

7.4 Welfare effects of acquisitions

Proposition 7 has compared the investment portfolios of the start-up and the acquirer. Specifically, it has provided conditions under which the investment effort put into project A by the start-up is lower (higher) than that of the acquirer, and correspondingly investment effort put into project B is higher (lower). We now ask whether the acquirer's portfolio of investments is more or less aligned with the socially optimal investment portfolio than that of the start-up.

Combining Propositions 1, 6 and 7, we obtain a result on the impact of an acquisition on the direction of innovation.

Proposition 8. *Suppose that the incumbent takes over the research facilities of the start-up. Then:*

(i) Assume that $\frac{9}{7}\underline{s} < \overline{s} < 2\underline{s}$ *so that the acquirer reduces investment in project* A *and increases it in project* B*. Then:*

- *if* $\pi_B < \frac{U_B}{2}$*, and thus* $\hat{x}_o < \hat{x}_m < \hat{x}_E$*, the acquisition improves the direction of innovation;*
- *if* $\frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B < \pi_B$*, and thus* $\hat{x}_m < \hat{x}_E < \hat{x}_o$*, the acquisition worsens the direction of innovation;*
- *finally, if* $\frac{U_B}{2} < \pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$ *, and thus* $\hat{x}_m < \hat{x}_o < \hat{x}_E$*, an acquisition causes a move from overinvestment to underinvestment in* A*;*

(ii) Assume that $\overline{s} < \frac{9}{7}\underline{s}$ *so that the acquirer increases investment in project* A *and decreases it in project* B*. Then:*

- *if* $\frac{U_B}{2} < \pi_B$*, and thus* $\hat{x}_E < \hat{x}_m < \hat{x}_o$*, an acquisition improves the direction of innovation;*
- *if* $\pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$ *, and thus* $\hat{x}_o < \hat{x}_E < \hat{x}_m$*, an acquisition worsens the direction of innovation;*
- *finally, if* $\frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B < \pi_B < \frac{U_B}{2}$*, and thus* $\hat{x}_E < \hat{x}_o < \hat{x}_m$*, an acquisition causes a move from underinvestment to overinvestment in* A*;*

The result in Proposition 8 is similar to that in Proposition 4 in that it provides conditions under which an acquisition may result in an alignment or in a misalignment of the private incentives to invest with the social incentives. Building on this proposition, we construct Figure 3 which is quite similar in nature to Figure 1. Specifically, we observe a similar split of the parameter space into 6 regions; for two of these regions, the direction of innovation improves after an acquisition takes place.

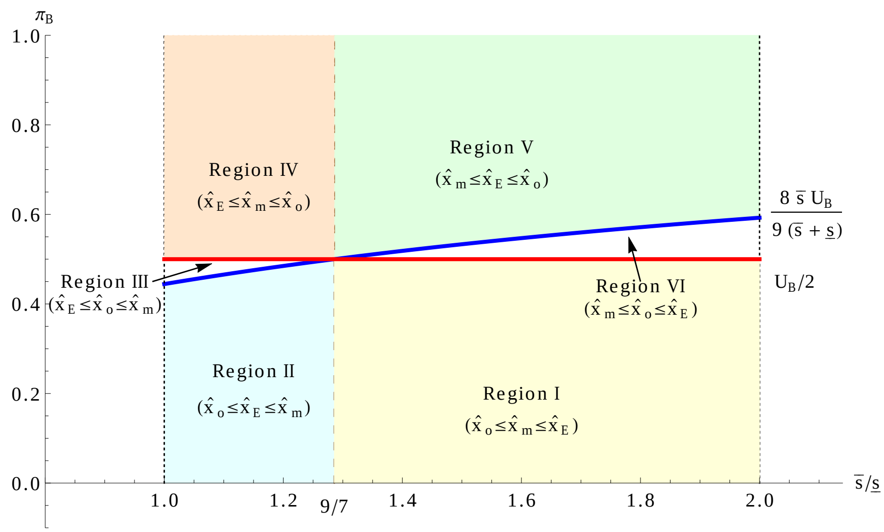

Figure 3: Private and socially optimal innovation portfolios

Our final result in this section takes into account the quantity and the innovation distortions of an acquisition to assess whether its prohibition is consumer welfare improving or not. For this, we compare the expression for consumer surplus corresponding to the case in which the start-up chooses the innovation portfolio:

$$\mathbb{E}U(\hat{x}_E) = \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A + \frac{1-\hat{x}_E}{1-\hat{x}_E+\epsilon_B}U_B, \tag{12}$$

to the one corresponding to the case in which the acquirer picks the investment levels:

$$\mathbb{E}U(\hat{x}_m) = \frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A}\underline{U}_A^m + \frac{1-\hat{x}_m}{1-\hat{x}_m+\epsilon_B}U_B. \tag{13}$$

Proposition 9. *Suppose that the incumbent takes over the research facilities of the start-up. Then:*

(i) Assume that $\frac{9}{7}\underline{s} < \overline{s} < 2\underline{s}$ so that, by Proposition 7, $\hat{x}_m < \hat{x}_E$. Then, there exists $\tilde{U}_B > 0$ such that for all $U_B < \tilde{U}_B$, a prohibition of acquisitions results in an increase in consumer surplus. For $\tilde{U}_B < U_B$, a prohibition of acquisitions results in a decrease in consumer surplus.

(ii) Alternatively, assume that $\overline{s} < \frac{9}{7}\underline{s}$ so that, by Proposition 7, $\hat{x}_E < \hat{x}_m$. Then, a prohibition of acquisitions results in an increase in consumer surplus.

Proof. See the Appendix. □

Proposition 9 is quite similar to Proposition 5 in that it illustrates that prohibiting acquisitions may increase or decrease consumer surplus. We illustrate Proposition 9 in Figure 4. In this graph we illustrate the parameter region where consumer surplus is higher in the case of acquisition relative to the case of no acquisition for $U_B = 1$, which satisfies the condition in the Proposition $U_B > \tilde{U}_B$.

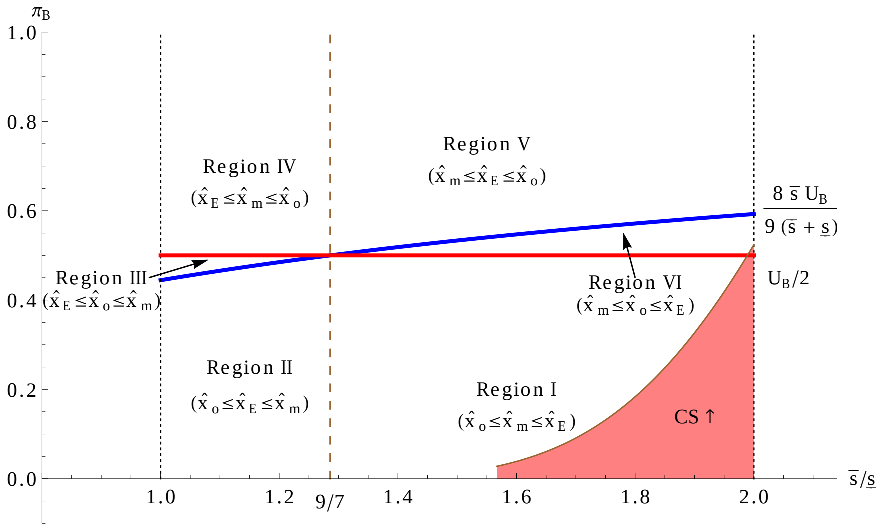

Figure 4: Consumer surplus improving start-up acquisitions

What we conclude is that also in this case in which the acquirer takes over the research facilities of the start-up, there exists a region of parameters for which an acquisition causes an increase in consumer surplus.

8 Other extensions

8.1 Drastic innovations

Up to now, we have assumed that $\underline{s} < \overline{s} < 2\underline{s}$. This assumption has signified that both the high- and the low-quality products obtain demand. Suppose now that $\overline{s} > 2\underline{s}$. In this case, if the innovator happens to obtain a high-quality product out of its research effort in project A, then the innovator monopolizes market A. How are our results modified? For details, we refer the reader to our working paper Dijk et al. (2020). It turns out that our results are not affected much if we consider this case of disruptive innovations, neither for the timing in which the acquisition takes place after the research results are realised nor for that in which the acquisition occurs before the outcomes of the research projects are known.

To see this, note first that the benchmark no-acquisition investment portfolio is exactly the same as in Lemma 2 but replacing $\overline{\pi}_A^E$ by the monopoly profits $\overline{\pi}_A^m$. Second, anticipating an acquisition, the start-up will always decrease investment in project A, and increase it in project B by implication. The reason for this should be obvious by now. Because the acquisition rents are equal to zero in case project A is successful, and positive in case project A fails, investing in project A only becomes more attractive than in the no-acquisition case if the project fails, thereby the decreased incentives to invest in it. Third, by the same arguments as in Proposition 4, this innovation portfolio adjustment may improve the direction of innovation. Moreover, provided that project B is sufficiently attractive for consumers, start-up acquisitions may be consumer welfare improving. Similar observations apply to acquisition that occur before the outcomes of the research projects are known.

8.2 Oligopoly

Throughout the paper we have assumed that there is only one incumbent operating in the "rival" market. What would happen if there were n incumbents? The first observation we would like make here is that our model is not well-suited to study such a case with multiple incumbents. However, it can easily be modified to

The reason is that our model is a model of Cournot competition and the *merger paradox* would hold under some conditions. To be more specific, suppose that the start-up innovation effort in project A fails. In that case, the start-up would produce the same quality as the rest of the incumbents. Because the products are otherwise homogeneous, the acquisition would not take place as it is well-known. By contrast, suppose that the start-up innovation effort in project A succeeds. In that case, the incentive-compatibility of the acquisition would depend on the relative magnitude of $\overline{s}$ compared to $\underline{s}$. For $\overline{s}$ sufficiently close to $\underline{s}$, the merger paradox would still hold and the acquisition would not take place. For $\overline{s}$ sufficiently large compared to $\underline{s}$, the acquisition would occur.

9 Conclusions

Start-up acquisitions have recently spurred much interest among politicians, policy makers and academicians. Many have argued that merger policy has been extremely lenient when it comes to start-up acquisitions and have called for reform. Others have warned that blanket prohibitions are not desirable because they may reduce the incentive for innovation. This paper has contributed to this debate by examining start-up acquisitions from a new angle. In particular, we have asked how the palette of innovation projects of a start-up is affected by acquisitions.

To this end, we have formulated a novel model of an industry with an incumbent operating in a single market and an entrant start-up. The start-up engages in an investment portfolio problem by choosing how to allocate funds across a rival project, intended to challenge the incumbent dominant position, and a non-rival project intended for the opening of a new market. We have shown how, motivated by the private returns of the projects, a start-up picks a socially suboptimal portfolio of projects. We have then examined how an acquisition impacts the optimality of the equilibrium portfolio of projects.

We have shown that, anticipating an acquisition, the start-up strategically distorts its investment portfolio in a way that may improve of worsen the direction in which innovation goes. Moreover, when the direction of innovation improves, its improvement may be so large so as to dominate the usual quantity distortion. This result has added to the literature by pointing out a new way in which the "innovation for buyout" argument may increase consumer surplus. Later in the paper we have turned to settings in which the acquirer takes over the research facilities of the start-up. In those settings, we have seen how both the start-up and the acquirer face the so-called "replacement effects" and that it is not necessarily the case that the replacement effect is stronger for acquirers than for start-ups. Also in such settings we have demonstrated that acquisitions may improve or worsen the direction of innovation.

Our results have some policy recommendation packaged. Acquisitions will tend to displace investment from rival projects to non-rival projects when the former are highly disruptive for existing firms. Because in those situations quantity distortions are quite bounded, provided that the direction of innovation improves because non-rival projects benefit consumers much, start-up acquisitions may enhance consumer surplus. By contrast, when rival projects are moderately of little disruptive, quantity distortions are so large that start-up reduce consumer welfare.

Appendix

Proof of Proposition 1

(i) $\hat{x}_o < \hat{x}_E$ occurs when

$$\frac{1+\epsilon_B-\epsilon_A\sqrt{\frac{\epsilon_B U_B}{\epsilon_A(\overline{U}_A^o-\underline{U}_A^o)}}}{1+\sqrt{\frac{\epsilon_B U_B}{\epsilon_A(\overline{U}_A^o-\underline{U}_A^o)}}} < \frac{1+\epsilon_B-\epsilon_A\sqrt{\frac{\epsilon_B \pi_B}{\epsilon_A(\overline{\pi}_A^E-\pi_A^*)}}}{1+\sqrt{\frac{\epsilon_B \pi_B}{\epsilon_A(\overline{\pi}_A^E-\pi_A^*)}}}$$

Since the LHS and RHS of this expression are decreasing in the term under the square root we have

$$\sqrt{\frac{\epsilon_B \pi_B}{\epsilon_A(\overline{\pi}_A^E-\pi_A^*)}} < \sqrt{\frac{\epsilon_B U_B}{\epsilon_A(\overline{U}_A^o-\underline{U}_A^o)}}$$

So

$$(\overline{U}_A^o-\underline{U}_A^o)\pi_B < (\overline{\pi}_A^E-\pi_A^*)U_B$$

Using the expression for surplus given in (3), and for profits given in (4.1) we obtain

$$\frac{\alpha^2(\overline{s}^2-\underline{s}^2)}{4\beta^2}\pi_B < \frac{2\alpha^2\overline{s}(\overline{s}-\underline{s})}{9\beta^2}U_B$$

Solving we find

$$\pi_B < \frac{8\overline{s}(\overline{s}-\underline{s})}{9(\overline{s}^2-\underline{s}^2)}U_B$$

Which can be rewritten as

$$\pi_B < \frac{8\overline{s}}{9(\overline{s}+\underline{s})}U_B$$

Proof of Proposition 2

(i) $\hat{x}_o < \tilde{x}_E$ occurs when

$$(\overline{U}_A^o - \underline{U}_A^o)\pi_B < \left(\overline{\pi}_A^E + \delta(\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I) - \pi_A^* - \delta(\underline{\pi}_A^m - 2\pi_A^*)\right) U_B$$

Using the expression for surplus given in (3), and for profits given in (4.1) and (5.1) we obtain

$$\frac{\alpha^2(\overline{s}^2 - \underline{s}^2)}{4\beta^2}\pi_B < \frac{\alpha^2\left(16\overline{s}(\overline{s} - \underline{s}) + \delta(-11\overline{s}^2 - 3\underline{s}^2 + 32\overline{s}\underline{s})\right)}{72\beta^2} U_B$$

Solving we find

$$\pi_B < \frac{16\overline{s}(\overline{s} - \underline{s}) + \delta(-11\overline{s}^2 - 3\underline{s}^2 + 32\overline{s}\underline{s})}{18(\overline{s}^2 - \underline{s}^2)} U_B$$

Which can be rewritten as

$$\pi_B < \frac{16\overline{s} - \delta(11\overline{s} - 21\underline{s})}{18(\overline{s} + \underline{s})} U_B$$

Proof of Proposition 3

(i) $\tilde{x}_E < \hat{x}_E$ occurs when

$$\overline{\pi}_A^E + \delta(\overline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I) - \pi_A^* - \delta(\underline{\pi}_A^m - 2\pi_A^*) < \overline{\pi}_A^E - \pi_A^*$$

Dropping the common terms gives

$$\delta\left(\overline{\pi}_A^m - \underline{\pi}_A^m - \overline{\pi}_A^E - \underline{\pi}_A^I + 2\pi_A^*\right) < 0$$

Using the expression for profits given in (4.1) and (5.1) we obtain

$$\frac{\alpha^2(-11\overline{s}^2 - 21\underline{s}^2 + 32\overline{s}\underline{s})}{72\beta^2} < 0$$

Simplifying gives

$$0 < (11\overline{s} - 21\underline{s})(\overline{s} - \underline{s})$$

Solving we find

$$\frac{21}{11}\underline{s} < \overline{s} < 2\underline{s}$$

(ii) $\hat{x}_E < \tilde{x}_E$ occurs when

$$\underline{s} < \overline{s} < \frac{21}{11}\underline{s}$$

Proof of Proposition 5

(i) Suppose that $\frac{21}{11}\underline{s} < \overline{s} < 2\underline{s}$, in which case, $\tilde{x}_E < \hat{x}_E$ and therefore the expected consumer surplus in market B is lower if acquisitions are prohibited.

$$\frac{1-\hat{x}_E}{1-\hat{x}_E+\epsilon_B}U_B < \frac{1-\tilde{x}_E}{1-\tilde{x}_E+\epsilon_B}U_B. \tag{14}$$

To show the result, we start by noticing that, for $\overline{s} < 2\underline{s}$, we have $\overline{U}_A^m < \overline{U}_A$ so

$$\frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A^m = \left(\frac{\tilde{x}_E}{\tilde{x}_E+\epsilon_A} + \frac{\epsilon_A}{\tilde{x}_E+\epsilon_A} - \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\right)\overline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A$$

Further, because $\underline{U}_A^m < \overline{U}_A^m$,

$$\frac{\tilde{x}_E}{\tilde{x}_E+\epsilon_A}\overline{U}_A^m + \left(\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A} - \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\right)\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A$$

Furthermore, because $\underline{U}_A^m < \underline{U}_A$, we can write

$$\frac{\tilde{x}_E}{\tilde{x}_E+\epsilon_A}\overline{U}_A^m + \left(\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A} - \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\right)\underline{U}_A^m + \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A$$

Simplifying gives:

$$\frac{\tilde{x}_E}{\tilde{x}_E+\epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A, \tag{15}$$

which means that the expected consumer surplus in market A is higher if acquisitions are prohibited.

Because the expected consumer surplus is a continuous function of U_B, putting together (14) and (15) implies the result.

(ii) Suppose that $\overline{s} < \frac{21}{11}\underline{s}$, in which case, $\hat{x}_E < \tilde{x}_E$ and therefore the expected consumer surplus in market B is higher if acquisitions are prohibited.

$$\frac{1-\tilde{x}_E}{1-\tilde{x}_E+\epsilon_B}U_B < \frac{1-\hat{x}_E}{1-\hat{x}_E+\epsilon_B}U_B \tag{16}$$

In market A we can rank consumer surplus in two different ways depending on the quality differences.

1. for all $\frac{\overline{s}}{\underline{s}} \in [1, \frac{4}{3})$ we have $\underline{U}_A^m < \overline{U}_A^m < \underline{U}_A < \overline{U}_A$
2. for all $\frac{\overline{s}}{\underline{s}} \in (\frac{4}{3}, \frac{21}{11})$ we have $\underline{U}_A^m < \underline{U}_A < \overline{U}_A^m < \overline{U}_A$

The expected consumer surplus in market A is higher if acquisitions are prohibited when:

$$\frac{\tilde{x}_E}{\tilde{x}_E+\epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A \tag{17}$$

We can rewrite this as:

$$\left(\frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}+\frac{\epsilon_A}{\hat{x}_E+\epsilon_A}-\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\right)\overline{U}_A^m+\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\underline{U}_A^m<\frac{\hat{x}_E}{\hat{x}_E+\epsilon_A}\overline{U}_A+\frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A$$

We have $\overline{U}_A^m<\overline{U}_A$ so:

$$\left(\frac{\epsilon_A}{\hat{x}_E+\epsilon_A}-\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\right)\overline{U}_A^m+\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\underline{U}_A^m<\frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\underline{U}_A$$

Rewriting gives:

$$\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\left(\underline{U}_A^m-\overline{U}_A^m\right)+\frac{\epsilon_A}{\hat{x}_E+\epsilon_A}\left(\overline{U}_A^m-\underline{U}_A\right)<0 \tag{18}$$

The first term is negative since $\underline{U}_A^m<\overline{U}_A^m$. There are two cases for the second term:

1. $\frac{\overline{s}}{\underline{s}}\in[1,\frac{4}{3})$ and $\overline{U}_A^m<\underline{U}_A$. The second term is also negative, so (18) holds.

2. $\frac{\overline{s}}{\underline{s}}\in(\frac{4}{3},\frac{21}{11})$ and $\underline{U}_A<\overline{U}_A^m$. The second term is positive and $\hat{x}_E<\tilde{x}_E$, so we can write:

$$\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\left(\underline{U}_A^m-\overline{U}_A^m\right)+\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\left(\overline{U}_A^m-\underline{U}_A\right)<0$$

   Rewriting gives

$$\frac{\epsilon_A}{\tilde{x}_E+\epsilon_A}\left(\underline{U}_A^m-\underline{U}_A\right)<0 \tag{19}$$

   This term is negative since $\underline{U}_A^m<\underline{U}_A$.

So for all $\overline{s}<\frac{21}{11}\underline{s}$, equation (17) holds and consumer surplus in market A is higher if acquisitions are prohibited. Putting together (16) and (17) imply the result.

Proof of Proposition 6

$\hat{x}_o<\hat{x}_m$ occurs when

$$(\overline{U}_A^o-\underline{U}_A^o)\pi_B<(\overline{\pi}_A^m-\underline{\pi}_A^m)U_B$$

Using the expression for surplus given in (3), and for profits given in (4.1) and (5.1) we obtain

$$\frac{\alpha^2(\overline{s}^2-\underline{s}^2)}{4\beta^2}\pi_B<\frac{\alpha^2(\overline{s}^2-\underline{s}^2)}{8\beta^2}U_B$$

Solving we find

$$\pi_B<\frac{U_B}{2}$$

Proof of Proposition 7

(i) $\hat{x}_m < \hat{x}_E$ occurs when

$$\overline{\pi}_A^m - \underline{\pi}_A^m < \overline{\pi}_A^E - \pi_A^*$$

Using the expression for profits given in (4.1) and (5.1) we obtain

$$\frac{\alpha^2(\overline{s}^2 - \underline{s}^2)}{8\beta^2} < \frac{2\alpha^2\overline{s}(\overline{s} - \underline{s})}{9\beta^2}$$

Simplifying gives

$$0 < (7\overline{s} - 9\underline{s})(\overline{s} - \underline{s})$$

Solving we find

$$\frac{9}{7}\underline{s} < \overline{s} < 2\underline{s}$$

(ii) $\hat{x}_E < \hat{x}_m$ occurs when

$$\underline{s} < \overline{s} < \frac{9}{7}\underline{s}$$

Proof of Proposition 9

(i) Suppose now that $\frac{9}{7}\underline{s} < \overline{s} < 2\underline{s}$, in which case, $\hat{x}_m < \hat{x}_E$ and therefore the expected consumer surplus in market B is lower if acquisitions are prohibited.

$$\frac{1 - \hat{x}_E}{1 - \hat{x}_E + \epsilon_B} U_B < \frac{1 - \hat{x}_m}{1 - \hat{x}_m + \epsilon_B} U_B \tag{20}$$

To show the result, we start by noticing that, for $\overline{s} < 2\underline{s}$, we have $\overline{U}_A^m < \overline{U}_A$ so

$$\frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A^m = \left(\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A} + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A} - \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\right)\overline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A$$

Further, because $\underline{U}_A^m < \overline{U}_A^m$,

$$\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{U}_A^m + \left(\frac{\epsilon_A}{\hat{x}_m + \epsilon_A} - \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\right)\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A.$$

Furthermore, because $\underline{U}_A^m < \underline{U}_A$, we can write

$$\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{U}_A^m + \left(\frac{\epsilon_A}{\hat{x}_m + \epsilon_A} - \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\right)\underline{U}_A^m + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A$$

Simplifying gives:

$$\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A, \tag{21}$$

which means that the expected consumer surplus in market A is higher if acquisitions are prohibited.

Because the expected consumer surplus is a continuous function of U_B, putting together (20) and (21) implies the result.

(ii) Suppose that $\overline{s} < \frac{9}{7}\underline{s}$, in which case, $\hat{x}_E < \hat{x}_m$. To show that $\mathbb{E}U(\hat{x}_m) < \mathbb{E}U(\hat{x}_E)$ we start by noticing that, given that $\overline{s} < \frac{9}{7}\underline{s}$, we have $\overline{U}_A^m < \underline{U}_A$. Therefore,

$$\left(\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A} + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A}\right)\overline{U}_A^m < \left(\frac{\hat{x}_E}{\hat{x}_E + \epsilon_A} + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\right)\underline{U}_A$$

Further, because $\underline{U}_A^m < \overline{U}_A^m$ and $\underline{U}_A < \overline{U}_A$, we then have that

$$\frac{\hat{x}_m}{\hat{x}_m + \epsilon_A}\overline{U}_A^m + \frac{\epsilon_A}{\hat{x}_m + \epsilon_A}\underline{U}_A^m < \frac{\hat{x}_E}{\hat{x}_E + \epsilon_A}\overline{U}_A + \frac{\epsilon_A}{\hat{x}_E + \epsilon_A}\underline{U}_A \tag{22}$$

Furthermore, because $\hat{x}_E < \hat{x}_m$, it holds that

$$\frac{1 - \hat{x}_m}{1 - \hat{x}_m + \epsilon_B}U_B < \frac{1 - \hat{x}_E}{1 - \hat{x}_E + \epsilon_B}U_B \tag{23}$$

Combining (22) and (23), the result follows. ■

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