Economic Espionage*

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2018

Abstract

We explore the efficacy of counterespionage measures in the realm of Economic Espionage. Although it is possible that increasing counterespionage measures has the desired effect of increasing domestic research and development (R&D) and reducing espionage by foreign entities, it is also possible that these increased measures actually do just the opposite: domestic R&D suffers and foreign stealing increases. We identify the appropriate settings for increased counterespionage measures and provide some policy advice.

Keywords: economic espionage; research and development; intellectual property; counterespionage policy.

*For their valuable comments, we would like to thank Alex Barrachina and the participants of the Workshop on Strategic Aspects of Terrorism, Security, and Espionage.

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"'We are going to aggressively protect our intellectual property. Our single greatest asset is the innovation and the ingenuity and creativity of the American people. It is essential to our prosperity and it will only become more so in this century."

President Barack Obama

1 Introduction

Intellectual property is essential to both the economy generally and companies specifically. Indeed, some companies have recently spent more money protecting intellectual property than creating it, as shown by Apple and Google in 2012.[1] And the importance of intellectual property seems only to be increasing as economies become more technology-based. Meanwhile, corporate intellectual property remains subject to theft, especially theft that benefits foreign enterprises. The U.S. law calls this type of stealing Economic Espionage.[2]

It is extremely difficult, if not impossible, to identify the magnitude of Economic Espionage. As opposed to other crimes, victims of espionage might not be aware that they are the victims. After a successful theft, there need not be any evidence left and a spying firm has no incentive to reveal their use of Economic Espionage. In addition, firms which know to be the victims are naturally reluctant to report all such theft and there is no law obliging them to do so. According to the "Foreign Spies Stealing US Economic Secrets In Cyberspace" report published in October 2011 by the Office of the National Counterintelligence Executive[3], "losses from economic espionage range so widely as to be meaningless – from $2 billion to $400 billion or more a year – reflecting the scarcity of data and the variety of methods used to calculate losses." Nonetheless, the same report indicates that "foreign economic collection and industrial espionage against the United States represent significant and growing threats to the nations prosperity and security." Consequently, the governments become more concerned with Economic Espionage and take actions to protect domestic corporations from Economic Espionage by foreign firms. For example, recently, the US passed two new laws bolstering such protection: The Theft of Trade Secrets Clarification Act of 2012 and The Foreign and Economic Espionage Penalty Enhancement Act of 2012. These new laws both

[1] http://www.nytimes.com/2012/10/08/technology/patent-wars-among-tech-giants-can-stifle-competition.html?pagewanted=all&_r=0

[2] The Economic Espionage Act of 1996; http://www.gpo.gov/fdsys/pkg/PLAW-104publ294/html/PLAW-104publ294.htm.

[3] http://www.ncix.gov/publications/reports/fecie_all/Foreign_Economic_Collection_2011.pdf

broadened those cases defined as Economic Espionage and increased penalties for engaging in Economic Espionage.

In this paper, we explore the efficacy of increasing the protection of domestic corporations from Economic Espionage by foreign firms. We explore those settings where such policy is helpful, but also uncover some settings where such policy actually *decreases* domestic innovation and *increases* Economic Espionage.

For a country that already provides moderate levels of Economic Espionage protection, if domestic firms are currently at lower levels of research and development (R&D), we find that increasing protection has the desired and expected effect: domestic R&D increases and Economic Espionage decreases. However, for those firms that are at higher levels of R&D, we find exactly the opposite effect of increased protection: domestic R&D decreases and stealing increases. Intuitively, at higher levels of domestic R&D, there is an asymmetry between domestic and foreign firms; the domestic firm is much more likely to dominate in innovations than is the foreign firm. Hence, increasing protection has the effect of causing the stronger domestic firm to ease its pace of R&D. In response, although the foreign firm faces an increased expected cost of spying, a second effect—an encouragement effect—dwarfs the former effect, resulting in increased espionage. This latter effect is analogous to the lessening of the discouragement effect found in asymmetric tournaments (e.g., see Moldovanu and Sela (2001) and Minor (2013)).

Although Economic Espionage is an important policy topic, there has been little economic research to date on the issue of espionage, even when construed more broadly. Solan and Yariv (2004) study a two-stage game in which one player can spy for an exogenous cost on the other player to deduce their second-stage move. They find the intensity of spying is unrelated to its cost. They also find settings where players choose not to spy. Anderson and Smith (2013) study a continuous-time model of a player with information that others attempt to obtain through sleuthing, while the informed player attempts to maintain information privacy through both obfuscation and leaking disinformation to the uniformed players. Billand et al. (2009) explore oligopoly competition in a network setting in which firms can spy on other firms to obtain improved product quality at a later stage of the game. They find cases in which firms choose not to spy, even when it is costless. Barrachina et al. (2014) consider a model in which an incumbent (monopolist) attempts to deter an entry by investing in a new capacity. A potential entrant spies on the incumbent using an inaccurate intelligence system to determine whether or not the incumbent, indeed, expanded the capacity. They analyze how the precision of intelligence system determines incumbent's decision to expand and potential entrant's decision to enter. Biran and Tauman (2008) study the role of intelligence system in nuclear deterrence. Our paper complements these studies of player behavior in the face of espionage by exploring instead how a policymaker should protect firms that are competing in an environment of Economic Espionage. To the best of our knowledge, ours is the first paper to analyze this problem.

Our work is also related to the extensive work in patent policy and intellectual property. A primary argument for the value of patents is that they provide the protection of monopoly rents from innovation—often through licensing agreements—and thus incentivizing innovation (e.g., see Hegde (2014)). Gilbert and Shapiro (1990) formally consider optimal protection in terms of patent length and breadth to bring about innovation. To consider patent policy empirically, Lerner (2002) provides an analysis of 177 policy changes over 150 years. He finds that strengthening patents has a greater effect for those nations that are developing and initially have weaker protection. However, he finds little effect for those entities located within the countries that strengthen patent protection. Moser (2013), who also reports on long periods of historical data, finds patents may aid innovation in certain settings but discourage it in others. Meanwhile, Farrell and Shapiro (2008) show that weaker patents can create adverse economic consequences, and thus suggest that stronger patents, at least for commercially valuable innovations, are to be preferred.

Independent of the issue of patent strength, a number of researchers have argued that in practice the patent system is less than perfect (e.g., see Hegde (2012) and Hagiu and Yoffie (2013)); in fact, some go so far as to suggest that the patent system is broken and should be abolished altogether. Boldrin and Levine (2013) provide theoretical and empirical evidence that patent protection does not in fact spur innovation, though it can increase the number of patents. However, they argue that patents are not correlated with innovative productivity and when the political economy issues of patent policy are added in, patents produce, on net, adverse economic effects. In conclusion, different scholars argue for patent policy along a whole continuum of protection possibilities.

Our paper parallels this patent literature: whereas the extant patent policy work is debating the appropriate strength of intellectual property (IP) protection by means of patent policy, we explore the appropriate degree of IP protection in terms of policy against Economic Espionage. In addition to studying a different mechanism than the aforementioned literature does, the policymaker in our setting also has different objectives. Typically, in patent policy, the objective is maximizing overall R&D while minimizing wasteful activities. For policy against Economic Espionage, in contrast, the policymaker is attempting to minimize stealing while maximizing only domestic R&D, not total R&D.

The balance of the paper is organized as follows. The next section provides our model. Section 3 provides our results and discussion. Our final section concludes.

2 Model

We use a simple model to illustrate the primary tradeoffs. We assume that there are two firms: a domestic firm, denoted by subscript D, and a foreign firm, denoted by subscript F. Firms attempt to innovate competitively. If only one firm is successful, then their gain is V, while the other firm gets zero. Thus, V can be thought of as the total profits from the innovation as a monopolist. If both firms are successful, however, then each firm receives $\delta \times V$. The parameter δ captures the degree of competitiveness of the market in which the firms operate. A lower δ represents increased market competition. In the extreme, if $\delta = 0$, then firms face perfect competition and earn zero economic profits if both successfully innovate. Since we are interested in analyzing competitive markets (i.e., not ones in which firms coordinate and share monopolistic profits), we impose Assumption 1.[4]

Assumption 1

$\frac{1}{2} > \delta \geq 0$

A firm's probability of making a successful innovation is equal to the firm's total R&D input, denoted by P_D and P_F for the domestic and foreign firm, respectively. We consider a simple setup in which it is only the domestic firm that exerts an R&D effort, r, and it is only the foreign firm that exerts an espionage effort, s. In addition, firms make their choices simultaneously. We interpret r and s as R&D and espionage intensities, respectively. Although only r affects the domestic firms R&D output, both r and s determine the foreign firm's total R&D; the effectiveness of the foreign firm's R&D depends both on the intensity of stealing and the intensity of R&D of its targeted domestic firm. We define the foreign firm's total R&D input as $s \times r$. Since a firm's total R&D input is also a firm's probability of making a successful innovation, we require that both r and s are in $[0, 1]$:

$$P_D = r \qquad \text{and} \qquad P_F = s \times r. \tag{1}$$

We also assume that domestic and foreign firms face quadratic cost functions $\frac{1}{2}\beta r^2$ and $\frac{1}{2}\alpha s^2$, respectively. Parameter β characterizes the net cost of the domestic firm's R&D activities.

[4]Note that Cournot competition implies $\frac{1}{2} > \delta \geq 0$ and Bertrand price competition implies $\delta = 0$.

This net-cost factor depends both on the difficulty of innovation and possibly on government R&D subsidies (or taxes). In this paper, we assume that β is exogenous.

The parameter α is our primary focus, as it characterizes the cost for Economic Espionage of the foreign firm. This factor is determined both by the direct cost of Economic Espionage for the foreign firm and the domestic government's counterespionage policy. We will consider how the domestic government's changing this parameter will help or hurt the domestic firm and Economic Espionage. There are several ways in which the domestic government can affect the value of α. One way is to spend resources on helping firms better prevent Economic Espionage. Another way is to increase resources spent on policy enforcement, thus increasing the probability of detection. Finally, the domestic government can also increase the expected cost of Economic Espionage by both broadening the definition of espionage and increasing penalties, as the US government did in 2012.

We assume that firms are risk-neutral and, therefore, carry the following objective functions:

$$U_D = rV - (1-\delta)sr^2V - \frac{1}{2}\beta r^2; \tag{2}$$

$$U_F = srV - (1-\delta)sr^2V - \frac{1}{2}\alpha s^2. \tag{3}$$

We also assume that the value of successfully innovating V is large enough compared to the domestic firm's cost parameter β. This assures innovation effort in equilibrium and leads to Assumption 2.

Assumption 2

$V > \beta$

We can now derive the firms' best-response functions.

$$r^*(s) = \frac{V}{\beta + 2(1-\delta)Vs}; \tag{4}$$

$$s^*(r) = -\frac{(1-\delta)V}{\alpha}r^2 + \frac{V}{\alpha}r. \tag{5}$$

First note that $r^*(s)$ is only indirectly affected by changes in protection α through s, whereas $s^*(r)$ is directly affected by α. Analysis of $r^*(s)$ indicates that $r^*(s)$ is constant and equal to 1 for $s \leq \bar{s}$ where $\bar{s} = \frac{V-\beta}{2(1-\delta)V}$, and $r^*(s)$ is a strictly decreasing function for $s > \bar{s}$. Our Assumption 1 implies that $\bar{s} < 1$. As for $s^*(r)$, note first that this is a quadratic function of

r with two roots, $r_0 = 0$ and $r_1 = \frac{1}{1-\delta}$. Observe also that r_1 is weakly larger than 1, where $r_1 = 1$ only for $\delta = 0$. Second, note that $s^*(r)$ reaches its maximum at $\tilde{r} = \frac{1}{2(1-\delta)}$, and $\tilde{r}$ is strictly less than 1. Third, observe that neither the roots nor the maximum is affected by changes in α. These features will be important in identifying our equilibria.

We graphically depict $r^*(s)$ and $s^*(r)$ in Figure 1 and Figure 2, respectively. That is, Figure 1 plots the best-response of R&D level $r^*(s)$ as a function of the level of Economic Espionage s. Figure 2 describes the level of Economic Espionage $s^*(r)$ for a given level of R&D r. The effect of the government's increasing the cost of Economic Espionage α on $s^*(r)$ is also given with $\alpha_1 < \alpha_2$.

[Figure 1 about here.]

[Figure 2 about here.]

Except for small values, Economic Espionage has a negative impact on domestic R&D. This is a rather unsurprising result since Economic Espionage acts like a discouragement. At the same time, we might also expect that an increase in R&D encourages the foreign firm to increase their level of Economic Espionage because larger R&D implies a larger gain from theft. However, it is true only if both α and r are small enough. With α large enough, there is a level of R&D $\tilde{r}$ above which R&D discourages the Economic Espionage effort. This is because the foreign firm faces a trade-off between increasing their chances of winning the prize and costs of effort. When the domestic firm exerts high R&D effort, then the foreign firm must exert high Economic Espionage effort. However, with high level of α, Economic Espionage becomes too costly and the foreign firm can not afford to increase the Economic Espionage effort when the domestic firm increases their R&D effort. That is, the race of efforts is becoming to costly for the foreign firm which decides to decrease their engagement in Economic Espionage.

3 Equilibrium Analysis and Policy Implications

In our equilibrium analysis, we limit our attention to the gross benefit from counterespionage measures (increasing the R&D effort or decreasing the Economic Espionage effort). However, increasing α is not, of course, costless. All of our previous examples of increased protection from Economic Espionage would require taxpayer money. Consequently, among those cases for which we show that increased protection both increases domestic R&D and reduces stealing, there might still be some cases for which increasing such a protection is not optimal when analyzed on a net-cost basis. However, for those cases for which we show that imposing more restrictive counterespionage measures is counterproductive, adding costs to this scenario only strengthens the result.

In equation (4), we replace s by s^* as depicted in equation (5) and obtain a third-degree polynomial describing the equilibrium R&D effort of the domestic firm, $\hat{r}$.

$$-\frac{2(1-\delta)^2V^2}{\alpha}\hat{r}^3 + \frac{2(1-\delta)V^2}{\alpha}\hat{r}^2 + \beta\hat{r} - V = 0 \tag{6}$$

Given $\hat{r}$, we would be able to derive the equilibrium espionage effort of the foreign firm, $\hat{s}$. Unfortunately, we are unable to obtain a tractable general closed-form solution of $\hat{r}$. However, doing so is neither necessary nor illuminating, since we can determine how changes in α affect both $\hat{r}$ and $\hat{s}$ via graphical analysis based on the best-response functions depicted in Figures 1 and 2. Recall that the best-response function $r^*(s)$ does not directly change as a function of α. Hence, we need to consider only how the best-response function $s^*(r)$ shifts as a function of α to determine equilibrium outcome changes.

In our analysis, we determine how an increase of the value of α affects the equilibrium values of the R&D effort and the Economic Espionage effort. We will ignore two regions of α that are uninteresting as in these regions we obtain corner solutions: when α is too low (depicted in Figure 3) or too high (depicted in Figure 4).

[Figure 3 about here.]

[Figure 4 about here.]

We are left with the intermediate region of the values of α where we have three equilibria. Since one of these equilibria is a corner solution (R&D at its maximum), we disregard it and focus on the interior equilibria. Figure 5 captures the main result of our paper.

[Figure 5 about here.]

For each value of α_i, we obtain two equilibria, $E_{i.1}$ and $E_{i.2}$, which form as a result of the Economic Espionage best-response curve $s^*(r)$ being parabolic. Equilibrium $E_{i.1}$ is the low R&D equilibrium while $E_{i.2}$ is the high R&D equilibrium.

When protection α is increased – in Figure 5 from α_1 to α_2 – we witness opposite outcomes, since the Economic Espionage best-response curve $s^*(r)$ shifts downward. For the low R&D

equilibrium, increasing α means the new equilibrium $E_{2.1}$ results in higher R&D and lower Economic Espionage, as expected. An increase in protection makes domestic innovative firm feel more secure which induces an increase in R&D effort. However, from the perspective of foreign firm, that increase in R&D is not big enough to compensate for higher costs of stealing; hence, espionage decreases.

However, the high R&D equilibrium moves from $E_{1.2}$ to $E_{2.2}$, which means *lower* R&D and *greater* Economic Espionage. Intuitively, the high R&D equilibrium is analogous to an asymmetric contest in that the domestic firm has a much higher chance of successfully innovating than does the foreign firm. Thus, two forces operate when protection is increased: the cost of stealing goes up but the domestic firm will also ease up on its R&D activities, as the firms are now even more asymmetric. In an asymmetric setting, the disadvantaged firm is discouraged by the increased effort of the dominant firm but encouraged by any reduced effort. In our setting, the net result of these two forces is increased stealing coupled with reduced R&D.

We support our graphical analysis with the analysis based on the Implicit Function Theorem that we use to compute $\frac{\partial \hat{r}}{\partial \alpha}$.

$$\frac{\partial \hat{r}}{\partial \alpha} = -\frac{\frac{2(1-\delta)^2 V^2}{\alpha^2}\hat{r}^3 - \frac{2(1-\delta)V^2}{\alpha^2}\hat{r}^2}{-\frac{6(1-\delta)^2 V^2}{\alpha}\hat{r}^2 + \frac{4(1-\delta)V^2}{\alpha}\hat{r} + \beta} \tag{7}$$

We observe that the numerator is always negative: after we write $\frac{2(1-\delta)^2 V^2}{\alpha^2}\hat{r}^3 - \frac{2(1-\delta)V^2}{\alpha^2}\hat{r}^2 = \frac{2(1-\delta)V^2}{\alpha^2}\hat{r}^2[(1-\delta)\hat{r} - 1]$, we note that $(1-\delta)\hat{r} - 1 < 0$ as $(1-\delta)\hat{r} < 1$ because both $1-\delta$ and $\hat{r}$ are smaller than one.

Hence, the sign of $\frac{\partial \hat{r}}{\partial \alpha}$ is the same as the sign of the denominator $-\frac{6(1-\delta)^2 V^2}{\alpha}\hat{r}^2 + \frac{4(1-\delta)V^2}{\alpha}\hat{r} + \beta$. The analysis of this quadratic polynomial indicates that it has two roots, one negative $\hat{r}_1$ and one positive $\hat{r}_2$. Of course, we are only interested in the behavior of $-\frac{6(1-\delta)^2 V^2}{\alpha}\hat{r}^2 + \frac{4(1-\delta)V^2}{\alpha}\hat{r} + \beta$ for the values of $\hat{r} \in [0,1]$. If $\hat{r} \in [0, \hat{r}_2)$, the polynomial is positive while for $\hat{r} \in (\hat{r}_2, 1]$ it is negative. Also, for α large enough, $\hat{r}_2$ is bigger than one. In short, if α is not large enough, then the denominator is positive for small values of $\hat{r}$ and negative for large values of $\hat{r}$. If α is large enough, then the denominator is always positive.

This means that when α is within the intermediate region of values that we focus on, then $\frac{\partial \hat{r}}{\partial \alpha}$ is positive (and $\frac{\partial \hat{s}}{\partial \alpha}$ is negative) for small values of $\hat{r}$ and negative (and $\frac{\partial \hat{s}}{\partial \alpha}$ is positive) for large values of $\hat{r}$. This is precisely what we deduced from the graphical analysis.

Our results can be summarized as follows:

Proposition 1 *If the domestic government's foreign Economic Espionage protection is neither too low nor too high, then increasing protection*

1. *yields the expected and desired result (i.e., domestic R&D increases and Economic Espionage decreases) if domestic R&D is low, and*
2. *has an adverse effect (i.e., domestic R&D decreases and foreign Economic Espionage increases) if domestic R&D is high.*

4 Conclusion

Using a simple model to analyze Economic Espionage, we found that for some settings increasing counterespionage measures has the expected consequences—increased R&D and reduced Economic Espionage—whereas for some other settings increasing such measures yield just the opposite effect. In particular, for those settings in which firms are currently engaged in high levels of R&D, and there already exists at least a modest level of Economic Espionage protection, introducing increased protection causes a domestic firm to respond to increased protection by reducing R&D intensity. Meanwhile, the foreign firm, which was at a significant disadvantage to begin with, is encouraged to then increase its espionage, as it now has an increased chance of succeeding. Hence, the optimal policy against Economic Espionage is not always so straightforward.

We note that we did not explore the case in which a foreign government is also intervening. Neither did we explore symmetric stealing, a situation in which the domestic firm attempts to steal from the foreign firm. We leave these areas to further research.

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Figure 1: R&D best-response.

To prepare this figure, we assumed the following values: $V = 4$, $\beta = 1$, and $\delta = 0.1$.

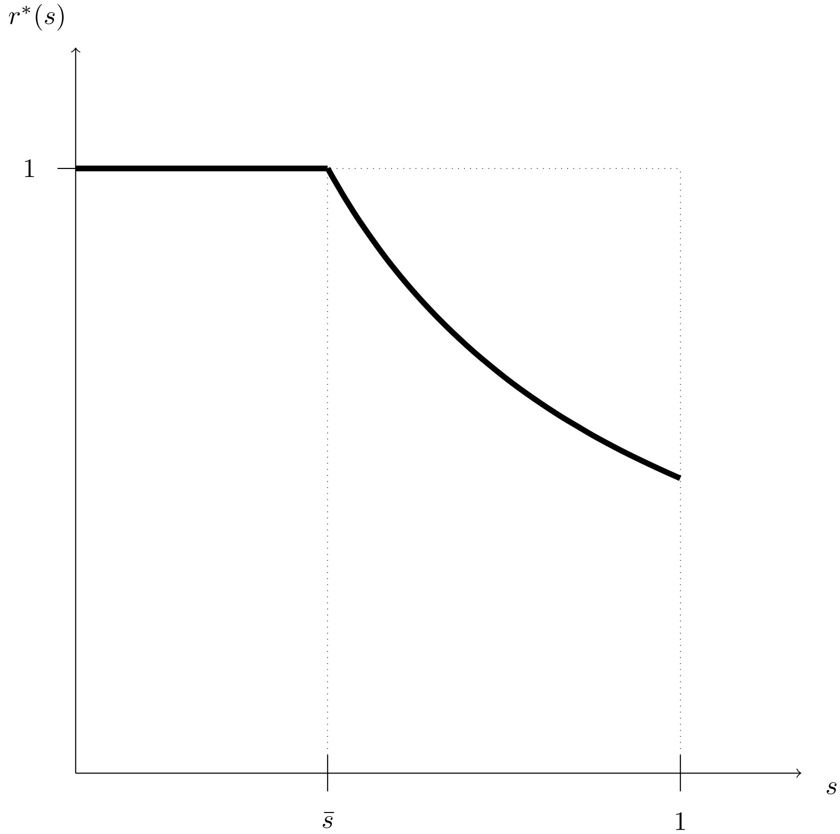

Figure 2: Economic Espionage best-response.

To prepare this figure, we assumed the following values: $V = 4$, $\beta = 1$, $\delta = 0.1$, $\alpha_1 = 1.2$, and $\alpha_2 = 1.5$.

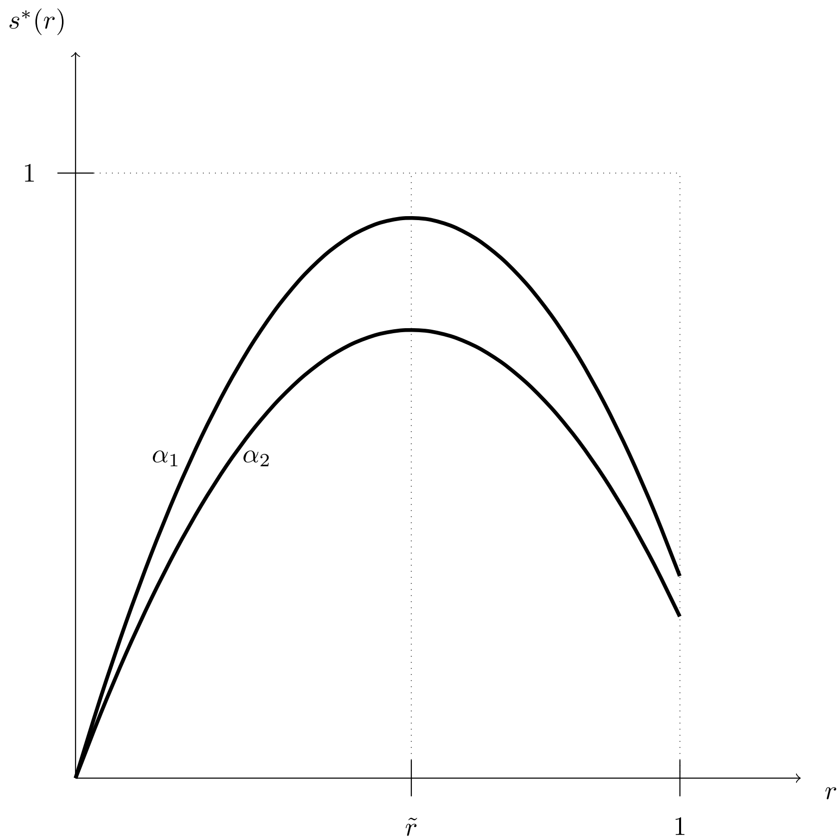

Figure 3: When α is too low.

To prepare this figure, we assumed the following values: $V = 4$, $\beta = 1$, $\delta = 0.1$, and $\alpha = 0.9$. Solid line is the Economic Espionage best-response and dashed line is the R&D best-response.

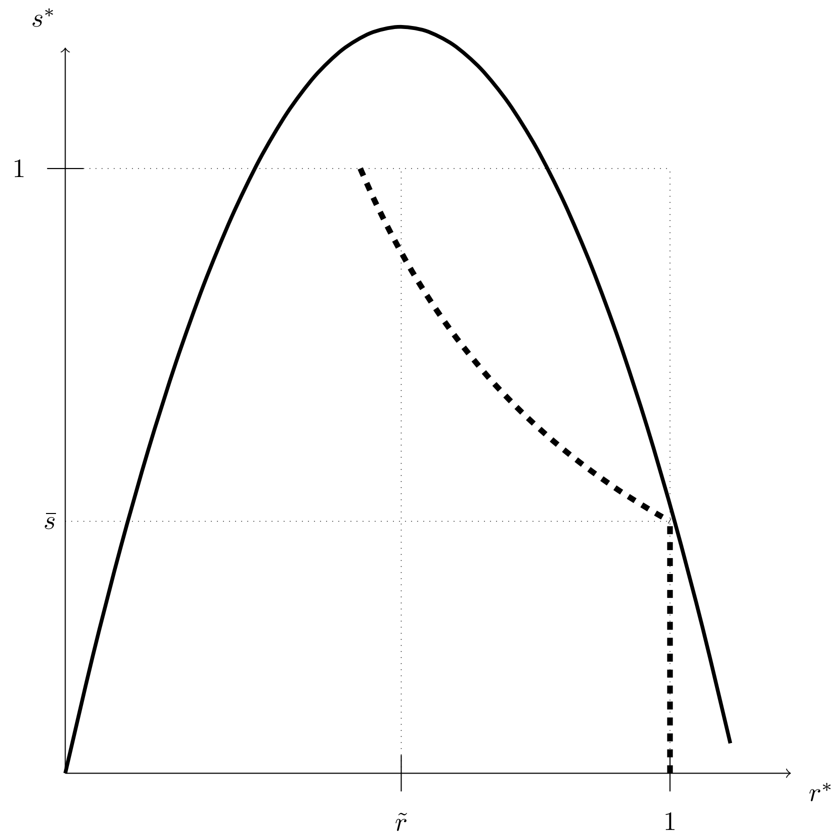

Figure 4: When α is too high.

To prepare this figure, we assumed the following values: $V = 4$, $\beta = 1$, $\delta = 0.1$, and $\alpha = 2$. Solid line is the Economic Espionage best-response and dashed line is the R&D best-response.

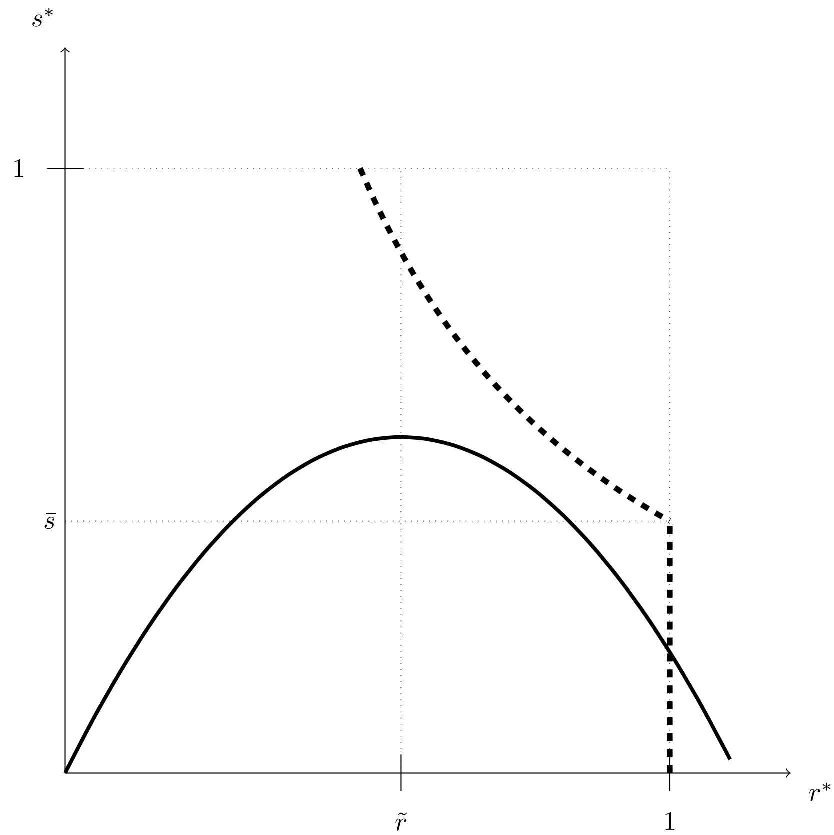

Figure 5: Equilibria for intermediate values of α

To prepare this figure, we assumed the following values: $V = 4$, $\beta = 1$, $\delta = 0.1$, $\alpha_1 = 1.2$, and $\alpha_2 = 1.5$. Solid line is the Economic Espionage best-response and dashed line is the R&D best-response.