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An economic analysis of trade-secret protection in buyer-seller relationships*

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Abstract

The economic analysis of trade-secret protection has traditionally focused on the interests of companies to conceal information from competitors in order to gain a competitive advantage through trade-secret law. This has neglected cases in which the interest is not in concealing information from competitors, but from trading partners. We investigate the social efficiency effects of trade-secret protection in such cases. Many results from economic theory state that asymmetric information (and therefore also its legal protection) is socially undesirable since it leads to inefficient trade. At the same time, protecting private information might create incentives for socially desirable investments. We model this trade-off in a simple buyer-seller model and find that, indeed, trade-secret protection has ambiguous welfare effects. However, a simple, informationally undemanding rule, conditioning the applicability of legal protection on a minimum investment by the informed party to conceal the information, helps to apply trade-secret protection only when it increases welfare. This rationalizes important features of current legal practice.

JEL-Classification: K2, D82

Keywords: disclosure of information, hold-up problems, trade secrets.

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1 Introduction

Confidentiality of information is often legally protected by trade-secret laws. A large literature exists which analyzes trade-secret protection, and which typically defines a trade-secret as follows:

> A trade secret is an item of information...that has commercial value and that the firm possessing the information wants to conceal from its competitors in order to prevent them from duplicating it. (Friedman, Landes, and Posner, 1991, 61)

Keeping such information secret seems warranted since – similar to patent protection – it creates incentives to invest in the generation of such valuable information in the first place, see, e.g., Friedman, Landes, and Posner (1991), Kitch (1980) and Bone (1998).

Although these aspects are very important, such analysis neglects that confidentiality is desired not only in "horizontal" relationships between competitors, but also "vertically" between trading partners. For instance, a buyer usually does not want the seller to know exactly her valuation of the product since this can worsen her bargaining position. While it is obvious that concealing such information is often valuable to the buyer, it is less clear whether such concealment is also socially beneficial.

An example of such a vertical case recently arose in the German energy industry. One of the key issues in the production of electric power is uninterrupted power supply. Power plants usually commit at least a day ahead to deliver a certain amount of electricity into the power grid. If the energy production at the power plant breaks down, the plant operator has to buy energy on a short-term basis in order to fulfill his commitment. While, in such a situation, the potential seller would like to know how urgently the buyer needs additional power (as this influences the price the seller would charge), the buyer is interested in keeping the breakdown of her plant secret.

While power producers have traditionally been able to keep the production levels of their power plants secret, in recent years several companies have interfered with these attempts. In various countries, service companies provide real-time information on the energy production of power plants to potential electricity sellers and traders. These companies install measuring equipment under power supply lines leading out of power plants. By measuring the electromagnetic field emitted by the transmission lines, the equipment allows the service company to measure the electricity supplied by the power plant into the grid.[1] Electricity traders can buy this information (almost) in real time. Since this reveals the power plant's ability

[1] In the United States, e.g., Genscape, Inc., has been granted four patents on related measuring technologies; see, e.g., Genscape, Inc. (2006) and Genscape, Inc. (2004). Similar patents exist for measuring fluid flows in gas and oil pipelines, see, e.g., Genscape, Inc. (2007).

to sell electricity – or, in case of outages, their need to procure additional electricity – power plant operators filed lawsuits against service companies that offer this information, arguing that the information is protected as a trade secret. As these service companies do not only operate in Germany, but all over Europe and North America, similar cases may arise in other jurisdictions.

This raises the question to what extent a buyer should be able to keep information about her own valuation of a potential deal with a seller confidential, or whether such information should always be divulged to the potential seller. Applying trade-secret law in such cases protects the asymmetry of information. From an efficiency point, this is irritating since it is well-understood that asymmetric information can lead to inefficiencies in buyer-seller relationships. Asymmetric information creates information rents and thereby gives rise to the well-known trade-off between rents and efficiency. The uninformed party might rather abstain from trading than have to pay high information rents; thus, inefficient trade results in the presence of asymmetric information. Myerson and Satterthwaite (1983) have shown that, under rather general conditions, no mechanism exists which guarantees efficient trade under asymmetric information which is incentive compatible, individually rational and exhibits a balanced budget.

However, information rents can also be socially beneficial if they result from investments by the informed party. If, in the absence of secrecy, the informed party were deprived of all rents, it would have no incentive to undertake efficient investments in the first place. This resembles the patent-like efficiency argument in "horizontal" trade-secret cases.

We investigate this trade-off between "efficient trade" (adverse selection) and "investment incentives" (moral hazard) in a simple model. A buyer and a seller trade one unit of an indivisible good. The buyer has an outside option, but its value is her private information. The seller makes a take-it-or-leave-it offer to trade the good. Before that, the buyer might undertake a non-verifiable relation-specific investment, increasing her valuation of the good, but leaving the outside option unaltered. We also allow for ex-ante investments in concealing and revealing the information by the buyer and the seller, respectively. The size of the investments determines the likelihood of the information to be revealed to the seller, who, in case of revelation, can appropriate all gains from trade. Trade- secret protection implies that – ex post – the seller is fined in case he tries to find out the buyer's information.

There are two main findings. First, having trade-secret protection is always beneficial, i.e., there should always be a remedy for violation of trade secrets. The reason is that the uninformed party (the seller) has a socially excessive interest to invest in revelation of the information. With symmetric information, the seller is able to appropriate all gains from trade, i.e., can use perfect price discrimination. This leads to ex post efficient trade. However, the seller's incentive to make information symmetric is not only motivated by the additional social surplus, but also by appropriating the buyer's information rent. Remedies for trade-secret violation work against this socially excessive rent seeking motive. Furthermore, asymmetric information and its protection is socially beneficial since it protects the buyer's information rent which increases in the relation-specific investment. Thus, returns on the relation-specific investment are protected and thereby trade-secret laws safeguard investment incentives.

The second main finding refers to a robust rule for the application of trade-secret protection. The optimum size of the fine depends on which of the underlying efficiency problems is dominant: the fine should be large if the underinvestment problem in the relation-specific investment is large; the fine should be small if the danger of (ex post) inefficient trade is dominant. A "conditional trade-secret protection rule" helps to apply trade-secret protection only when it is beneficial. This rule is often found in trade-secret laws. It says that for trade-secret protection to be applicable, the informed party must have undertaken some minimum effort to conceal the information.

In buyer-seller relationships, such an effort will be small if the adverse selection problem is large. In this case, there should be little trade-secret protection, and – indeed – with the conditional trade-secret protection rule the expected fine for the uninformed seller will be small; i.e., he has a large incentive to reveal the buyer's type, which increases the likelihood of efficient trade. To understand why this is the case, consider a situation where most buyers have an attractive outside option. Thus, many of them will anticipate that it is best for them to go for the outside option. Since investments are relation-specific, they will not invest at all. Thus, they never have any information rent – and thus no incentive to engage in costly concealing of information. This, in turn, reduces the expected fine for the seller, increases his incentive to invest in revelation, and thereby reduces the danger of inefficient trade.

For the opposite case, assume that the outside option is unattractive but the relation-specific investment is very effective. In such a case, the seller will set a price which all types of buyers will accept. Thus, there is no adverse selection problem. However, the moral hazard problem is severe, and therefore high expected fines are sensible. The conditional trade-secret protection rule works in this direction: all types of buyers receive an information rent in case of asymmetric information, therefore all of them invest in concealing. This increases the expected fine and discourages revealing efforts – as it should from a social welfare perspective.

A key driver of our results, namely that private incentives for information revelation can be excessive, goes back at least to Hirshleifer (1971), who introduced the notion of "foreknowledge" which is valuable to its holder only due to its distributive effect, not to its efficiency effect. This constitutes already an important argument contrary to the view that protection of secrecy of information generally tends to be welfare decreasing, since more symmetric information should usually increase the efficiency of the allocation (see Posner (1981) and Stigler (1980), in particular for the case of private information in employer-employee relationships). This discussion was taken up by Levin (2001) who – similar to our findings – finds ambiguous welfare effects of information revelation in buyer-seller relations.

Finally, a paper closely related is Hermalin and Katz (2006). They are concerned with the problem of "privacy" in particular of information of consumers or employees. They think of the private information as being in principle verifiable in form of an "indicator variable" and ask who should have the "property rights" on this indicator variable: the informed party or the uninformed party? They also find that the effects are ambiguous. The informed party need not be worse off when giving the property rights to the uninformed party, and welfare need not be higher in this case. The major difference to our paper is that Hermalin and Katz focus on a detailed analysis of the adverse selection problem, while we look also at a moral hazard problem with respect to relation-specific investments. Furthermore, we model trade-secret protection as a mechanism influencing the likelihood of symmetric information, rather than comparing different property rights regimes.

Our analysis is complementary to the existing literature on trade secrets mentioned in the beginning (Friedman, Landes, and Posner (1991), Kitch (1980) and Bone (1998)), though clearly distinct since we focus on asymmetric information in vertical trading relationships, while the existing literature is concerned primarily with horizontal cases.

Furthermore, our paper is also related to the literature on disclosure duties in contract law, such as Kronman (1978), Shavell (1994), or Grosskopf and Medina (2008). This literature is concerned with investments which increase the probability of efficient trade, while in our model the investment increases the ex post surplus. More technically, in our setting, the "type" of an agent is known to the agent, while in the disclosure duties literature it is usually not; e.g., a contractor does not know the cost of the project (i.e., his own type), but might find it out when undertaking some information investment. In our model, the buyer always knows whether she has a strong or weak position vis-a-vis the seller. The investment always increases the value of the trade, given that trade occurs.

The remainder of the paper is organized as follows. Section two discusses the legal framework we are considering. Sections three introduces the basic intuition why trade-secret protection might be welfare reducing. Section four sets up the model, which is analyzed in Section five. Section six discusses private damages and conditional trade-secret protection as institutions to implement trade-secret protection. Section seven briefly discusses applications in and beyond trade-secret laws, Section eight concludes.

2 Legal Framework

Information about the buyer's valuation of a potential secret may, under certain circumstances, be protected as a trade secret. While, in the United States, trade-secret protection is a matter of state law, the general rules are very similar across all states. Current state-level trade-secret protection is strongly influenced by the Third Restatement on Unfair Competition[2] and the Uniform Trade Secrets Act,[3] which codify traditional common law rules and which most states used as a point of reference when creating their trade-secret statutes.

In general, in order to qualify as a trade secret, information must confer an economic advantage when kept secret, it must be secret in fact, and it must be protected from disclosure by reasonable secrecy safeguards. Such safeguards may include confidentiality agreements, constructing fences or walls to block public view, using passwords, and restricting employee access to sensitive areas; see Uniform Trade Secrets Act §1(4), Milgrim (2008), §1.01, and Bone (1998), 248-249. Trade-secret protection is violated if the information is acquired, used or disclosed in breach of confidence, by violating an independent legal norm (such as laws against trespass, fraud or theft) or by other improper means.[4]

Under the German Act Against Unfair Competition, in order to qualify as a trade-secret, information must be related to a firm, it must be known only to a limited number of people, the firm must have a legitimate interest in the secrecy, and it must be obvious that the firm wants to keep the information secret, see Hefermehl, Köhler, and Bornkamm (2008), §17 UWG Rdnr. 4. Trade-secret protection is violated if the information is acquired, used or disclosed without authorization by technical means or by creating or taking away a fixed copy of the information; see Section 17 of the German Act Against Unfair Competition.

While the details of trade-secret protection differ across jurisdictions, the general requirements and limitations are very similar. In many jurisdictions, information can only be protected as a trade secret if the owner of the secret takes reasonable precautions to prevent disclosure.[5] Without such precautions, there is no indication that the owner has a real interest in keeping the information secret. However, the law does not require such precautions to be perfect. In particular, it does not require the owner to guard against unanticipated, undetectable, or unpreventable methods of espionage that are very costly or even impossible to prevent.[6] Hence, a party can seek trade-secret protection only if it has shown some effort to conceal the information. At the same time, trade-secret protection puts a limit on the amount of effort required for this.

[2] Restatement (Third) of Unfair Competition §§ 39-45 (1995), superseding the Restatement (First) of Torts §§ 757-759 (1939).

[3] Uniform Trade Secrets Act, 14 U.L.A. 433 (1985).

[4] What constitutes other "improper means" is subject to considerable debate; see only E.I. duPont deNemours & Company, Inc., v. Christopher, 431 F.2d 1012, 1016 (5th Cir. 1970).

[5] For U.S. trade-secret law, see Milgrim (2008), §1.03. For German trade-secret law, see Hefermehl, Köhler, and Bornkamm (2008), §17 UWG Rdnr. 10.

[6] E.I. duPont deNemours & Company, Inc., v. Christopher, 431 F.2d 1012, 1016 (5th Cir. 1970).

3 Tradeoffs of Trade-Secret Protection

To formalize the tradeoffs of trade-secret protection as a means to protect the secrecy of information, we discuss a simple buyer-seller relationship. Consider a buyer (she) and a seller (he) who can trade one unit of an indivisible good. Production costs for the seller are normalized to zero. The buyer's valuation for the good is $b > 0$. The buyer has an alternative sourcing option at cost c, $b > c > 0$. We assume that c reflects the actual production cost of the good in the outside option (e.g., c might be the cost at which the buyer could produce the good herself). The value c is drawn from a smooth distribution F with compact support on $[\underline{c}, \overline{c}]$, and its realization is private information to the buyer. The seller has all bargaining power, i.e., he posts a take-it-or-leave-it offer by demanding a price p. The seller's payoff equals zero if no trade happens, otherwise it equals p. For the buyer, the payoff when trading with the seller is $b - p$, and $b - c$ otherwise. Therefore, trade will only happen if $p \leq c$.

The solution to this bilateral trading under asymmetric information is very similar to a standard monopoly problem. The probability that trade at price p occurs equals $1 - F(p)$, thus we can interpret $1 - F(p)$ as a demand function. Therefore, the seller maximizes expected profits by maximizing:

$$\pi_S = p\,(1 - F(p)) \rightarrow \max_p . \tag{1}$$

If – what we want to assume in the following – $F(p)$ is log-concave and thereby also $1 - F(p)$ is log-concave, this problem has a unique solution (see Bagnoli and Bergstrom (2005) and the references cited there), which we call p^m. The seller sets a monopoly price such that, for all realizations of $c < p^m$, inefficient trade occurs, while for all higher values of c, $c \geq p^m$, efficient trade takes place, and the buyer receives an information rent. Figure 1 shows the similarity of the problem to the standard monopoly problem, where the area A reflects the deadweight loss from monopoly, and the area B the information rent (or consumer surplus).

With symmetric information, the seller would be able to set the price identical to c, implying efficient trade and no information rent. This welfare improvement from symmetric information is similar to the welfare improvement gained from perfect price discrimination in the standard monopoly problem. Helping to create symmetric information, e.g., by abolishing trade-secret protection, therefore has the potential to increase efficiency.

However, this simple setup already suggests potentially beneficial effects of trade-secret protection. If buyers and sellers could engage in efforts to conceal or to reveal the information, they would have a strict incentive to do so. The buyer would invest up to B to protect the information. In the current framework, this is clearly socially wasteful. However, also the seller's effort to reveal will be socially excessive. The maximum the seller could gain from revealing the buyer's type to him is not only A, but $A + B$.

Trade-secret protection, or, more precisely, punishments for its violation, might

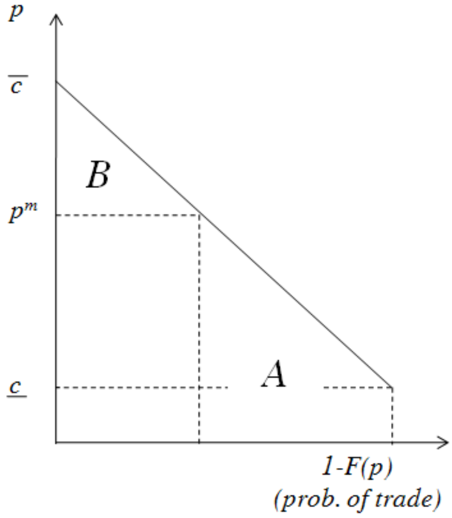

Figure 1: Optimum pricing without relation-specific investments

prevent the seller from engaging in (excessive) revealing effort. This, in turn, might reduce the wasteful concealing effort by the buyer. Therefore, trade-secret protection might be beneficial by reducing wasteful rent seeking activities.

Another argument in favor of trade-secret protection refers to the information rent B : Assume the buyer could engage in activities that increase her valuation for the good. If this increases her information rent, she will have an incentive to engage in such investment. However, if, with symmetric information, the buyer would be able to appropriate all consumer surplus, symmetric information removes investment incentives. To make these arguments more precise, we need a more complete model.

4 Model

We maintain the basic assumptions of the last section, but add explicitly rent seeking activities of the parties, as well as investment of the buyer in the valuation of the good. Finally, we specify how trade-secret protection works in this context.

In $t = 0$, the buyer's type is determined. The realization of c is private information. In $t = 1$, the buyer and the seller can simultaneously engage in concealing and revealing effort. Call the concealing effort of the buyer γ_B, and the seller's revealing effort γ_S. The cost of these investments to the subjects are given by $\phi(\gamma_i)$, $i = B, S$, where $\phi'(0) = 0$, $\phi' > 0$ for $\gamma_i > 0$, and $\phi'' > 0$. Investment levels cannot be observed by the other party.

In $t = 2$, the buyer can make a relation-specific investment e to increase the value from trading with the seller. Thus, the valuation is now $b(e)$, with $b' > 0$, $b'' < 0$. The benefit from choosing the outside option is not affected by this investment:

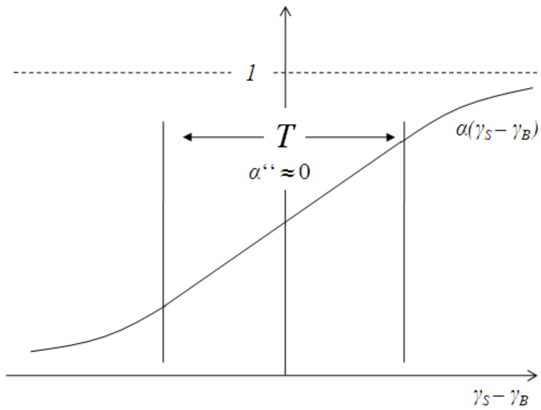

Figure 2: Effect of concealing and revealing effort

it always equals $b(0) - c$. The investment e is non-observable and non-verifiable. Therefore, with symmetric information, the hold-up problem would arise, since the seller would demand the total ex post surplus equal to $b(e) - [b(0) - c]$; anticipating this, the buyer would not invest at all, $e = 0$.

After the choice of the investment, nature determines in $t = 3$ whether the private information of the buyer, i.e., her type c and her investment level e, is revealed to the seller or not. Revelation happens with probability α, where α is a function of the difference between the revealing and concealing efforts: $\alpha = \alpha(\gamma_S - \gamma_B)$, with $\alpha' > 0$. If the seller has invested a lot to reveal, while the buyer has invested little to conceal, the probability of revelation will be large.

To facilitate the analysis, we want to restrict attention to outcomes with the following properties: (i) $\alpha'' = 0$ in the relevant parameter region, and (ii) in equilibrium $\alpha \in]0,1[$. A sufficient condition for the two properties to apply in equilibrium would be that $\alpha'' = 0$ at all $\alpha \in]0,1[$ and that $\phi(\gamma_i)$ is sufficiently convex. More generally, we think of a function $\alpha(\gamma_S - \gamma_B)$ taking the form depicted in Figure 2, where, due to ϕ being sufficiently convex, we can restrict attention to the parameter region T.[7]

Note that we consider only cases where $\alpha > 0$, which implies that the private information could always be revealed to the seller even if the seller had not undertaken any effort to reveal it. In many applications, it seems plausible that the information could become public just by chance (e.g., it could be published in a newspaper).

In $t = 4$, the seller makes a take-it-or-leave-it offer to the buyer. In $t = 5$, the seller might be punished for the violation of trade-secret protection. With probability β, the seller has to pay a fine D if he tried to reveal the private information. The harder he tried to find out, i.e., the higher γ_S, the higher the probability β, $\beta(\gamma_S)$,

[7] In the Appendix, we discuss an extension of the model to incorporate alternative functional forms of $\alpha(\gamma_S - \gamma_B)$ where we do not have to impose properties of the equilibrium outcome.

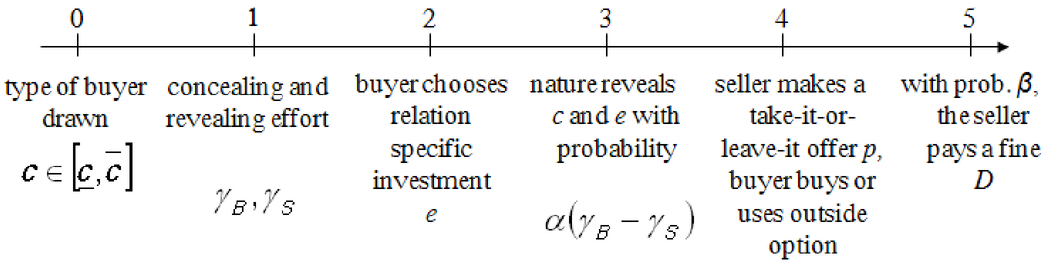

Figure 3: Timing

with $\beta' > 0$. If he did not try to reveal, he will not be fined, i.e., $\beta(0) = 0$. We will later discuss whether making the probability of a fine to apply conditionally also on γ_B would make sense. Figure 3 summarizes the timing of the events.

That punishments are conditional on attempts to reveal the private information is in line with currently used trade-secret law, as pointed out in section 2. The same is true for assuming $\beta(0) = 0$: without a deed, there is no punishment.[8] Note that our assumptions imply that trade-secret protection can never prevent the seller from using the information once it is revealed to him. This captures the idea that it is impossible to credibly commit to forget something. However, trade-secret protection can reduce the seller's effort to reveal the information by the threat of punishment in case of detection.

The fine D reduces the seller's payoff but does not (directly) affect the buyer's payoff. This would be the case, e.g., for a prison sentence or a fine payable to the public budget (trade-secret laws allow for prison sentences).[9] We will later discuss the case of private damages (potentially including punitive damages), i.e., a compensation payable by the seller that, at least some extent, increases the buyer's payoff.

The overall payoffs of the buyer and the seller are given by:

$$\pi_B = \begin{cases} b(e) - p - e - \phi(\gamma_B) & \text{if trading with the seller,} \\ b(0) - c - e - \phi(\gamma_B) & \text{if using the outside option.} \end{cases}$$

$$\pi_S = \begin{cases} p - \phi(\gamma_S) - \beta D & \text{if trading with the buyer,} \\ -\phi(\gamma_S) - \beta D & \text{if no trade occurs.} \end{cases}$$

We look for a subgame perfect equilibrium of this game.

[8] An alternative assumption could be to condition the punishment on the actual use of the information. We will later take up this point when discussing "private damages".

[9] See, e.g., § 499c of the California Penal Code and Section 17 of the German Act Against Unfair Competition which allows for prison sentences of up to five years for severe trade-secret violations.

5 Analysis

5.1 Relation-Specific Investment and Pricing

We solve the game backwards and start by analyzing stages $t = 2$ to $t = 5$. Assume some equilibrium choice of the concealing and revealing efforts γ_B and γ_S, determining a certain probability of revelation of the private information α. The first proposition describes the optimal choices of the buyer's relation-specific investment and the seller's pricing behavior in $t = 4$.

Proposition 1 *For the subgame starting at $t = 2$, there exists a unique subgame perfect equilibrium. It is characterized as follows. The buyer chooses an inefficiently low investment level e^*, defined by $b'(e^*) = \frac{1}{1-\alpha}$ if she is of type $c \geq \widehat{c}$, where $\widehat{c}$ is defined by $b(e^*) - p^m = b(0) - \widehat{c}$; for $c < \widehat{c}$, the investment level is zero. The seller posts a price $p^m = \arg\max p(1 - F[p - (b(e^*) - b(0))])$ if information is asymmetric; otherwise, the price equals $b(e^*) - [b(0) - c]$ for $c \geq \widehat{c}$ and c for $c < \widehat{c}$.*

Proof. Assume information was not revealed in $t = 3$. Then, the seller maximizes

$$\pi_S = p(1 - F(p - (b(e^*) - b(0)))).$$

Since in $t = 4$, α and e^* are already fixed, this reduces to maximizing with respect to p, which has a unique solution p^m if $F(.)$ is log-concave, as assumed (see Bagnoli and Bergstrom (2005) and the literature cited there). If the information is revealed, perfect price discrimination occurs. Buyers anticipate p^m, and – if they expect to trade with the seller – maximize $(1 - \alpha)[b(e) - p^m] - e$, implying e^* being defined as in the Proposition, while efficient investment requires $b'\left(e^{FB}\right) = 1$. Only those buyers for which the resulting payoff $b(e^*) - p^m$ exceeds the outside option payoff $b(0) - c$, will choose positive investment levels. All lower c types will not invest at all and choose the outside option, implying a cutoff type $\widehat{c}$. ■

If, in $t = 3$, the information on the type c and the effort choice e is revealed, the seller will execute perfect price discrimination, i.e., he will demand a price equal to the buyer's ex post surplus in excess of her outside option payoff. This implies not only that the buyer has no information rent, but also that she is expropriated of all gains from her relation-specific investment e, since e does not affect the outside option.

If no revelation of information occurs, buyers get an information rent and can increase this information rent by investing e. Therefore, asymmetric information protects investment incentives. However, since information will be revealed with probability α, this protection is imperfect and underinvestment occurs (the hold-up problem is only partially solved). The investment incentives are decreasing in α.

However, not all types may get an information rent. Buyers can anticipate the price p^m the seller will demand. Buyers with a very attractive outside option (a low c) anticipate that, with asymmetric information, they will still prefer the

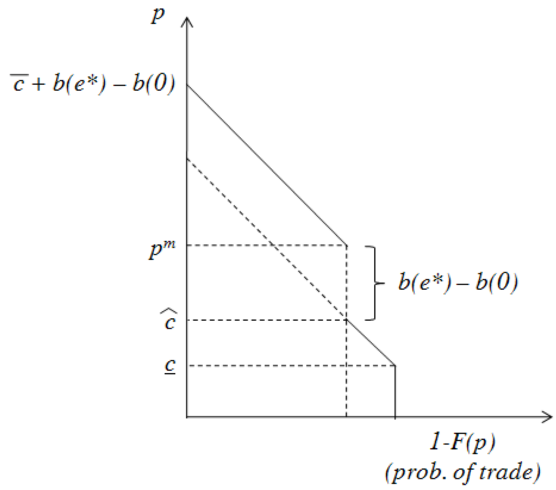

Figure 4: relation-specific investment

outside option, even if they invested in increasing the valuation from inside trading. These low c types therefore never receive a return on investing (not with asymmetric information, and obviously not with symmetric information) and therefore abstain from investing. An indifferent type $\widehat{c}$ exists who anticipates that – if investing optimally (i.e., taking care of the fact that, with probability α, she will lose the returns on the relation-specific investment) – she will be indifferent between trading with the seller and the outside option. The seller, in turn, anticipates the optimal investment decision and demands the monopoly price p^m in case that information is not revealed. Figure 4 depicts this situation.

Note that, in particular if investments are very effective, i.e., $b(e^*) - b(0)$ is large, the seller might find it optimal to serve all types, i.e., $\widehat{c} = \underline{c}$ and $p^m = \underline{c} + b(e^*) - b(0)$. In this case, efficient trade always occurs (the outside option is never used); unfortunately, the hold-up problem is not solved: since $\alpha > 0$, underinvestment still happens.

5.2 Concealing and Revealing Investments

In $t = 1$, the buyer and the seller simultaneously choose their concealing (γ_B) and revealing (γ_S) effort, respectively. By doing so, they determine the probability of symmetric information, $\alpha(\gamma_B - \gamma_S)$. The buyer wants to protect her information rent and, for $c \geq \widehat{c}$, also the returns on the relation-specific investment. The seller wants to reveal the information in order to be able to execute perfect price discrimination by appropriating the total ex post surplus of each type. However, the seller is aware of the fact that, by increasing the "espionage" effort, he increases the likelihood $\beta(\gamma_S)$ of having to pay a fine D at the end of the game.

As noted before, types $c < \widehat{c}$ never receive any information rent and never undertake relation-specific investments. Hence, they have no interest in asymmetric information, implying that they do not invest in concealing efforts: $\gamma_B = 0$ for $c < \widehat{c}$. The remaining buyers of type $c \geq \widehat{c}$ do have an incentive to conceal their type, since, anticipating p^m, they would be willing to trade with the seller and would get an information rent. In equilibrium, buyers and seller correctly anticipate p^m and e^*. The buyers maximize:

$$\max_{\gamma_B} \pi_B = [1 - \alpha(\gamma_S - \gamma_B)](b(e) - p^m) - \phi(\gamma_B) - e^*(\gamma_B, \gamma_S), \tag{2}$$

where e^* is the solution to $(1 - \alpha(\gamma_S - \gamma_B)) b'(e) = 1$. Due to the envelope theorem, the first-order conditions reduce to:

$$\phi'(\gamma_B) = \alpha'(b(e^*) - p^m), \text{ for } c \geq \widehat{c}. \tag{3}$$

The seller's expected payoff equals:

$$\begin{aligned} \pi_S &= [1 - \alpha(\gamma_S - \gamma_B)] p^m [1 - F(p^m - (b(e^*) - b(0)))] \\ &\quad + \alpha(\gamma_S - \gamma_B) \int_{\underline{c}}^{\overline{c}} b(e(c)) - b(0) + c dF(c) - \phi(\gamma_S) - \beta(\gamma_S) D, \end{aligned} \tag{4}$$

where the term in the first line refers to the profit in case that the information is not revealed, while the term in the second line refers to the profit in case of type revelation (minus the investment cost and the expected fine). Note that, here, we have (in slight abuse of notation) written the optimum relation-specific investment e as a function of the type to indicate that the optimum effort is positive if $c \geq \widehat{c}$, and zero otherwise.

Alternatively, we can write the seller's payoff as:

$$\begin{aligned} \pi_S &= \alpha(\gamma_S - \gamma_B) \int_{\underline{c}}^{\widehat{c}} c dF(c) \\ &\quad + \int_{\widehat{c}}^{\overline{c}} p^m + \alpha(\gamma_S - \gamma_B)[b(e^*) - b(0) + c - p^m] dF(c) \\ &\quad - \phi(\gamma_S) - \beta(\gamma_S) D. \end{aligned} \tag{5}$$

The term in the first line is the expected gain from buyers with a good outside option, the term in line two is the expected profit from those with a bad outside option. Taking the first-order condition yields:

$$\phi'(\gamma_S) = \frac{\partial \alpha}{\partial \gamma_S} \left[\int_{\underline{c}}^{\widehat{c}} c dF(c) + \int_{\widehat{c}}^{\overline{c}} [b(e^*) - b(0) + c - p^m] dF(c) \right] - \beta'(\gamma_S) D. \tag{6}$$

The two first-order conditions (3) and (6) determine the best-response functions in the "revelation-concealing" game. In this game, there exists a unique Nash equilibrium, implying that the total game has a unique subgame perfect equilibrium.

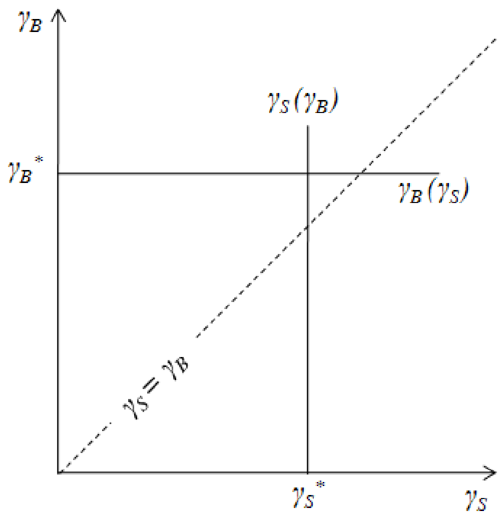

Figure 5: Nash equilibrium for concealing (γ_B) and revealing (γ_S) efforts

Proposition 2 *There exists a unique subgame perfect equilibrium of the game.*

Proof. We know from Proposition 1 that the continuation game has a unique subgame perfect equilibrium for given γ_B and γ_S. What is left to show is that γ_B and γ_S are uniquely defined by the best-response functions (3) and (6). Recall that γ_B and γ_S are chosen simultaneously and are not revealed to the other party. Thus, in equilibrium each player will predict the equilibrium levels of γ_B and γ_S, implying that changes in γ_B will not affect p^m, and changes in γ_S will not affect e^*. By the implicit function theorem we find for the slope of the best response function of the buyer $\gamma_B(\gamma_S)$:

$$\frac{\partial \gamma_B}{\partial \gamma_S} = \frac{\alpha'' \left(b\left(e\right) - p^m\right)}{\phi'' + \alpha'' \left(b\left(e\right) - p^m\right)} \tag{7}$$

which is zero by our assumption that $\alpha'' = 0$ in the relevant parameter region. Again, by the implicit function theorem, we find for the seller's best response function $\gamma_S(\gamma_B)$:

$$\frac{\partial \gamma_S}{\partial \gamma_B} = \frac{\alpha'' \left[\int_{\underline{c}}^{\widehat{c}} c dF\left(c\right) + \int_{\widehat{c}}^{\overline{c}} \left[b\left(e^*\right) - b\left(0\right) + c - p^m\right] dF\left(c\right)\right]}{\alpha'' \left[\int_{\underline{c}}^{\widehat{c}} c dF\left(c\right) + \int_{\widehat{c}}^{\overline{c}} \left[b\left(e^*\right) - b\left(0\right) + c - p^m\right] dF\left(c\right)\right] - \beta'' D - \phi''} \tag{8}$$

which also equals zero for the same reason. Thus, the best-response functions intersect exactly once. Figure 5 depicts the two best-response functions derived from the first-order conditions. ■

Due to our assumption that $\alpha'' = 0$ (at least for the relevant parameter region), the best responses are independent of the effort choice of the other party, since the marginal productivity of concealing and revealing does not depend on the choice of the other party. Since γ_S and γ_B will always be positive (we assumed that the first (marginal) unit is costless, $\phi'(0) = 0$), the best-response functions both equal positive constants.

5.3 Optimal Expected Fine

We now want to investigate variations in the expected fine, βD. We want to assume that they are triggered by variations in D; variations in β (increasing the likelihood of punishment for given levels of espionage effort γ_S) would have similar effects.

An increase in the fine D obviously reduces the incentive to invest in revealing effort, since the probability β of a fine increases in γ_S (see (4)). Since the fine D does not directly affect the buyer's payoff (only indirectly via the seller's reaction to variations in γ_S), an increase in D shifts only the reaction function of the seller to the left, implying that γ_S decreases and therefore the probability α of symmetric information decreases as well. Compared to a situation without a fine, i.e., compared to $D = 0$, introducing a (potentially small) fine is welfare-increasing, as stated in the next Proposition.

Proposition 3 *The socially optimal fine D is positive, $D^* > 0$.*

Proof. The expected social surplus equals:

$$TS = [1 - F(\widehat{c})]\,[b(e) - e] + F(\widehat{c})\,b(0) - (1-\alpha)\int_{\underline{c}}^{\widehat{c}} c dF(c) - \phi(\gamma_S) - \phi(\gamma_B)\,. \quad (9)$$

For any given level of e, and therefore for fixed $\widehat{c}$, the optimal level of γ_S is determined by:

$$\frac{\partial \alpha}{\partial \gamma_S}\int_{\underline{c}}^{\widehat{c}} c dF(c) = \frac{\partial \phi}{\partial \gamma_S}, \quad (10)$$

implying a strictly lower γ_S than chosen by the seller for $D = 0$, as it can be seen from (6). Thus, reducing the private incentive by increasing D (as can again be seen from (6)) above zero increases the social surplus. ■

The seller's incentive to reveal the asymmetric information is excessive from a social welfare perspective, as can be seen directly from (6). There, the first term in the square brackets reflects the social gain from increasing the likelihood of symmetric information (it corresponds to the area A in Figure 1), and the second term in the square brackets reflects the redistribution gain for the seller (it corresponds to the area B in Figure 1). Introducing a positive fine for trying to reveal the information works against this excessive private (rent seeking) incentive to invest in revelation.

What influence the optimal size of the fine? There are two opposing welfare effects. First, increasing the fine helps to reduce the hold-up problem. It reduces the probability α of symmetric information and thereby increases the expected returns on the buyer's relation-specific investment. Second, because it increases the probability of asymmetric information, it increases the likelihood of inefficient trade, since – if the information is not revealed – with probability $F(\widehat{c})$ the inefficient outside option is realized. Note that an increase in D does not only increase $(1-\alpha)$, but also decreases $\widehat{c}$. A higher value of $(1-\alpha)$ increases e^*, and thereby increases $b(e^*)$. We know that $\widehat{c} = p^m - [b(e^*) - b(0)]$. An increase in $b(e^*)$ also increases p^m, but to a smaller extent than $b(e^*)$ is increased, implying that $\widehat{c}$ decreases.

More formally, the opposing effects can be seen when taking the first derivative of the total surplus given in (9) with respect to D:

$$\begin{aligned}\frac{\partial TS}{\partial D} &= [1-F(\widehat{c})]\frac{\partial e}{\partial \alpha}\frac{\partial \alpha}{\partial \gamma_S}\frac{\partial \gamma_S}{\partial D}\left(\frac{\partial b}{\partial e}-1\right) - \frac{\partial F}{\partial c}\frac{\partial \widehat{c}}{\partial D}[b(e)-b(0)-e] \\ &\quad -\frac{\partial \phi}{\partial \gamma_S}\frac{\partial \gamma_S}{\partial D} - (1-\alpha)\frac{\partial \widehat{c}}{\partial D}\widehat{c}\frac{\partial F(\widehat{c})}{\partial c} + \frac{\partial \alpha}{\partial \gamma_S}\frac{\partial \gamma_S}{\partial D}\int_{\underline{c}}^{\widehat{c}} c dF(c). \qquad (11)\end{aligned}$$

The first four terms are positive (note that for $\alpha > 0$, the buyer's optimization problem with respect to e always yields $\partial b/\partial e > 1$), while the last one is negative. The first term reflects the social gain from reducing the moral hazard problem: buyers are willing to choose higher relation-specific investment levels, when the probability of symmetric information decreases due to an increase of the fine. The second term reflects the decrease in the cutoff type $\widehat{c}$: more types are willing to choose a positive investment level if the danger of symmetric information decreases. Term three describes the saved revealing effort costs, term four accounts for the fact that the marginal buyer who is now willing to trade with the seller no longer wastes c in case of asymmetric information by taking the outside option. Term five reflects that an increase in the fine D reduces the probability of symmetric information, which leads all buyer types who will not trade with the seller under asymmetric information to use the inefficient outside option under asymmetric information. From (11) we can immediately derive the following Proposition:

Proposition 4 *The optimum fine D^* is small if the relation-specific investment is ineffective, i.e., for $b' \to 0$. D^* goes to infinity for $\widehat{c} = \underline{c}$.*

If $\widehat{c} = \underline{c}$, no adverse selection problem exists any longer, i.e., the only negative term in (11) vanishes. This is intuitive: if $\widehat{c} = \underline{c}$, all types will trade with the seller at a given level of α; reducing α will therefore only have the beneficial effect of curing the hold-up problem. Therefore, the fine should be prohibitively high in case that no adverse selection problem exists.[10]

$\widehat{c} = \underline{c}$ will occur either if $\underline{c}$ is large. Just like a monopolist who faces only customers with a high willingness to pay, such that the marginal revenues on the last customer still exceed the marginal cost, the seller will set a price such that all

[10] Recall that, if $b(e)$ increases, also p^m increases, but to a smaller extent. Therefore, if all types traded with the buyer initially, they will still trade after the increase in $b(e)$.

types get served. The same effect can be obtained if $\underline{c}$ is small but the relation-specific investment is very effective, i.e., b' is large. Then, even the lowest type will find it worthwhile to invest e^*, implying a large value of $b(e^*)$ and a large marginal revenue on the lowest type such that again all types get served.

However, if we reduce the efficiency of the relation-specific investment, it will no longer be the case that all types will invest, and that nobody wants to use the outside option. Taken to the extreme, when the relation-specific investment becomes ineffective, $b' \to 0$, the first-order condition derived from (11) reduces to (10).[11] All reasons for a fine (terms one, two, and four in (11)) have vanished, apart from the motivation to reduce the excessive seller's interest to engage in revelation. Thus, the fine should still be positive, as we know already from Proposition 3, but it should be small.

6 Implementation in Legal Institutions

The preceding section showed that the optimum fine is positive and the size of the fine should be large if the moral hazard dimension of the problem is large, compared to the adverse selection problem. However, the detailed parameters of the problem (such as the effectiveness of the relation-specific investment, b') are rarely observable for courts. Even more importantly for practical applications, legal trade-secret protection should apply under well-defined general conditions and its application should not depend on details of the situation which are hard to verify. In this section, we are looking for "robust" institutions in the sense that their application will lead to an application of trade-secret protection only in the cases in which it is most beneficial. We discuss two legal institutions, private damages and a "conditional trade-secret protection rule", which capture important aspects of current legal practice.

6.1 Private Damages

So far we have assumed an exogenous remedy D which did not affect the buyer's payoff directly. However, punishment for trade-secret violation frequently takes the form of private damages,[12] i.e., the level of the punishment is endogenous and it directly increases the buyer's payoff.

A key question is: What is the damage? In our model, the damage to the buyer is her lost information rent. Let us assume that a court could ex post verify the size of the lost information rent. For instance, it could compare the "usual" price (in

[11] Note that in this case $e = 0$. Therefore, the first term in (11) vanishes and $\widehat{c}$ is independent of D.

[12] Along these lines, Section 3 of the Uniform Trade Secrets Act provides several ways to calculate damages: punitive damages, as well as the calculation of the actual loss caused by misappropriation, the additional unjust enrichment caused by misappropriation, or the calculation of a reasonable royalty.

case of no trade-secret violation) to the price charged in case of a violation. In this case, the expected punishment would no longer be $\beta(\gamma_S) D$, but would equal:

$$\alpha\beta(\gamma_S)\int_{\widehat{c}}^{\overline{c}} b(e^*) - b(0) + c - p^m dF(c). \tag{12}$$

If information becomes symmetric and litigation happens, the seller has to pay damages to the buyer. The size of this payment is equal to the information rent which the buyer would have received, if the information had been kept secret.

There are two important observations. First, the size of punishment varies with the information rent, which is beneficial in welfare terms. If the relation-specific investment is very effective (b' is very large), then not only the gain from making information symmetric increases, but also the punishment. Therefore, γ_S tends to be small and therefore also α will be small, implying high investment incentives for the buyer, which is particularly beneficial if b' is large. In the opposite extreme, if the investment is not effective ($b' = 0$), – automatically – the expected fine is low since the term $b(e^*) - b(0)$ vanishes.

The second observation is that (merely compensatory) damages imply too low punishments. The reason is the same as pointed out in the proof of Proposition 3: the seller has excessive incentives to invest in revealing due to rent seeking. With private damages, these excessive rent seeking incentives stem from the case that the rent need not be returned to the buyer (which happens with probability $1 - \alpha\beta$). Therefore, private damages need to be "punitive damages".[13]

6.2 Conditional Trade-Secret Protection

Private (punitive) damages rely on the assumption that the size of the damage can be verified by courts. In "horizontal" cases of trade-secret violation, this might be relatively easy. Similar to a patent case, the court could try to calculate an equivalent to foregone licensing royalties to estimate the damage. In our "vertical" cases, calculating the information rent is much more difficult. Furthermore, it is questionable if a court would accept an argument based just on a change in bargaining power.

We now want to discuss an alternative approach which does not need to rely on this – arguably unrealistic – assumption that private damages tailored to the size of the lost information rent are possible. We return to the assumption of an ex-ante fixed fine D.

In most legal systems, trade-secret protection can only be sought – and therefore its violation can only be sued – if the informed party has undertaken some effort to keep the information secret (see Section 2, footnote 5). In the terminology of the

[13] Note that in our context, punitive damages do not change the buyer's incentive to invest in concealing. They only increase the incentive to invest in the relation-specific investment.

model: trade-secret protection is conditional of γ_B to be positive, i.e.,

$$D \begin{cases} > 0 & \text{if } \gamma_B \geq \varepsilon > 0, \\ = 0 & \text{otherwise.} \end{cases} \tag{13}$$

We call this a "conditional trade-secret protection rule".

One concern with such a rule could be that it triggers inefficient concealing investments. This is, however, not true in our model. Such a rule does not increase the buyer's incentive to invest into concealing, which is determined by (3). In the absence of any private claims against the seller, the buyer has no interest in an ex-post punishment of the seller. Her incentives for concealing the private investment stem only from the information rent which types with a weak outside option ($c \geq \widehat{c}$) can gain from asymmetric information.

Therefore, the conditional trade-secret protection rule helps to apply trade-secret protection in those cases in which it should be applied, and reduces its application in the other cases. To see this, note that the seller cares about the expected fine. With a conditional trade-secret protection rule, the expected fine is no longer βD, since it applies only if the buyer has invested at least ε into concealing. However, only buyers with a type $c \geq \widehat{c}$ do so. Conditional trade-secret protection now states that, without any concealing effort, no violation of trade-secret protection will be punished. Since the seller – when deciding on γ_S and on p^m – does not know whether the buyer he is facing is above or below $\widehat{c}$, he calculates with an expected fine of $\beta DF(\widehat{c})$.

As discussed before, $\widehat{c}$ is small if the moral hazard problem is large: in the extreme, with very effective relation-specific investments, we will find $\widehat{c} = \underline{c}$. In this case, the expected fine is large and equals βD. From Proposition 4 we know that in this case the optimum fine should indeed be large.

In the opposite case, with a large adverse selection problem, i.e., a large value of $\widehat{c}$, the expected fine is small, since $F(\widehat{c})$ is small, as it should be, according to Proposition 4. Therefore, the conditional trade-secret protection rule helps to apply trade-secret protection only in those cases in which private information is socially very valuable. It deters revelation efforts less in those cases in which the social benefit of private information is small. To the extent that the private parties engaged in the interaction are better informed than a court about the details of their interaction, such a rule seems beneficial. It helps an uninformed legislator or court to apply trade-secret protection if and only if it tends to be socially beneficial.

7 Application In and Beyond Trade-Secret Law

Conflicts involving asymmetric information in buyer-seller relationships, as analyzed in this paper, can be traced in trade-secret case law, both in Germany and in the United States. The German electricity case, which was described in the introduction, was settled before a district court in early 2006. It seems unlikely that a court would have found the service company installing the electromagnetic measuring devices to violate German trade-secret law. This is in line with our model, which shows that trade-secret protection should only be granted if the informed party has made some effort to conceal its information, which was not the case in the electricity example. In the United States, whether trade-secret protection applies to information in buyer-seller relationships depends on the factual circumstances of the case. Often, costs and input factors cannot be protected as trade secrets as they are either well-known throughout the industry[14] or because the informed party took no measures to keep the information confidential.[15] In general, whether information about a buyer's willingness to pay can be protected as a trade secret depends on whether the information in question is easily available by other means and whether the owner is able to and does in fact make attempts to keep the information secret.

It is worth noting that the basic idea that the legal protection of asymmetric information about outside options has ambiguous welfare effects in some particular buyer-seller relationships also applies to many other legal areas outside trade-secret law. First, U.S. courts sometimes deny requests in buyer-seller relationships for disclosing information collected by the government. Such decisions concern the trade-secret exemption to the Freedom of Information Act,[16] rulemaking procedures of the Federal Energy Regulatory Commission,[17] and securities regulation.[18] Second, while corporate law usually grants stockholders a broad right to inspect the corporation's books and records, the stockholder is not allowed to use his right to do so in order to inform a customer of the corporation; nor is he allowed to use this information in contract negotiations with the corporation.[19] Third, such cases can arise if a company engages in price discrimination and wants to prevent its various customer groups from finding out the different prices offered.[20]

[14]See, e.g., Aetna Bldg. Maintenance Co. v. West, 39 Cal.2d 198, 206 (Cal. 1952); Rigging Intern. Maint Co. v. Gwin, 128 Cal.App.3d 594, 611-612 (Cal. Ct. App. 1982); Simmons Hardware Co. v. Waibel, 47 N.W. 814 (S.D. 1891).

[15]Carpetmaster of Latham, Ltd., v. Dupont Flooring Sys., Inc., 12 F.Supp.2d 257, 261-262 (N.D.N.Y. 1998).

[16]See McDonnell Douglas Corp. v. NASA, 180 F.3d 303 (D.C. Cir. 1999); Gulf & Western Industries, Inc., v. United States of America, 615 F.2d 527 (D.D.C. 1979) (denying requests under 5 U.S.C. §552 (b)(4)).

[17]Alabama Power Company v. Federal Power Commission, 511 F.2d 383, 391 note 13 (D.C. Cir. 1974) (upholding a rulemaking by the predecessor of today's FERC which eliminates information asymmetries). The rulemaking exists, in modified form, up to the present day, see 16 U.S.C. §824d, §824e, 18 C.F.R. §141.61.

[18]American Sumatra T. Corp. v. Securities and Exch. Comm'n, 110 F.2d 117 (D.C. Cir. 1940) (upholding a decision by the SEC which denied a request for confidential treatment of the plaintiff's filings which could be the plaintiff's customers to calculate the plaintiff's profit margin).

[19]See only §220(b) Delaware General Corporation Law. The same analysis applies to the right of inspection under common law.

[20]See, e.g., the American Airlines, Inc. v. FareChase, Inc. controversy, which was ultimately settled out of court. For more information, see http://cyberlaw.stanford.edu/taxonomy/term/4, and Southwest Airlines Co. v. FareChase, Inc., 318 F.Supp.2d 324 (D.S.C. 2004).

This short survey demonstrates that the question whether information asymmetries about outside options should be legally protected in buyer-seller relationships is not confined to trade-secret law. While most decisions are very fact-dependant, in general, courts seem somewhat reluctant to grant legal protection in such cases. Generally, this is in line with the model presented in this paper. In many cases, firms either do not need incentives in order to create the information they attempt to protect, or they do not make any attempts to conceal this information. In such cases, our model argues against legal protection. When, however, our model argues for legal protection, the law is flexible enough to grant such protection.

8 Conclusion

Information is valuable in vertical buyer-seller relations. We have analyzed whether it should be protected by trade-secret laws. The answer is generally yes: Introducing a fine for the violation of a trade secret is welfare-increasing. What is less clear is the optimal size of the fine. We found two ambiguous effects. Protecting the information with high fines is undesirable if the adverse-selection dimension of the problem is important, i.e., if there is significant danger that inefficient trade occurs. If, however, the informed party can undertake relation-specific investments to increase the gains from trade, asymmetry of information and therefore trade-secret protection is desirable as it protects the investment incentives.

Since in legal practice the relative size of the two effects is difficult to measure, we investigated private damages and conditional trade-secret protection as institutions to implement trade-secret protection which are less informationally demanding, and which are both part of the current legal practice. We find that both institutions tend into the socially beneficial direction of limiting the application of trade-secret protection to cases in which its benefits are large. However, identifying the size of private damages in vertical relationships is usually difficult, and therefore conditional trade-secret protection with a fixed fine might be a superior solution.

Current legal practice combines both instruments. While our analysis points out that this can be beneficial, it also highlights important drawbacks of such a combination. Imagine that buyers can expect to receive punitive damages in excess of their actually accrued damages. In this case, a combination of punitive damages and conditional trade-secret protection is dangerous. It sets incentives for buyers with a good outside option (who, in the absence of an expected damage payment, would not invest in concealing), to start investing just in order to be eligible for receiving damage payments. With punitive damages in particular, this can result in significant welfare losses (due to wasteful concealing and due to the increasing probability of inefficient trade).

One "compromise" to solve this is to decouple the payment to the plaintiff from the damages accrued by the defendant. If courts can vary the size of the punishment depending on the ex-post observed size of actually accrued damages in terms of the lost information rent, only a fraction of this amount should be passed to the plaintiff. This provides additional arguments for "split awards" in addition to the arguments in favor of such arrangements that result from the attempt to reduce litigation costs.[21] Combining this strand of literature with our view on trade-secret protection opens interesting new research questions.

[21]See the original argument by Polinsky and Che (1991) in favor of decoupling payment to the plaintiff from damages accrued by the defendant in order to save on litigation cost in case of a fixed probability of success in trial in case of litigation. Alternative results are derived for the case in which the size of litigation costs affects the probability of trial success, see, e.g., Landeo and Nikitin (2006) or Choi and Sanchirico (2004).

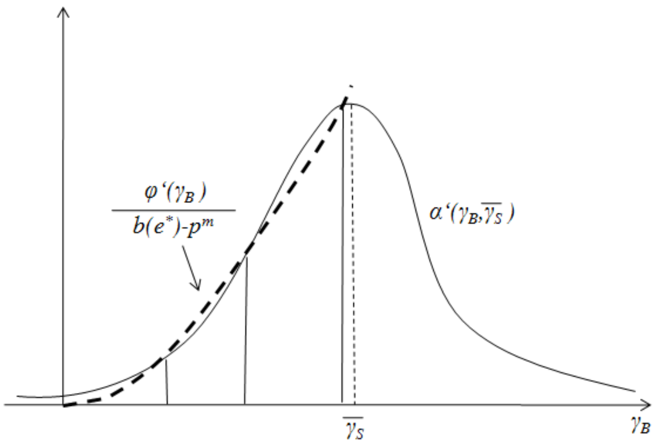

Figure 6: Non-unique solution to the buyer's first-order condition

9 Appendix: Alternative Assumptions on $\alpha(\gamma_s - \gamma_B)$

In the main body of the text, we have assumed that the probability of symmetric information α is a linear function of the difference between the revealing and concealing effort. This implied that the marginal productivity of investments in either revealing or concealing is unaffected by the level of other parties' effort. In the Appendix, we want to drop this assumption. In particular, we want to incorporate the idea of a "decreasing marginal productivity" of such investment. We want to assume that $\alpha = \alpha(\gamma_S - \gamma_B)$, with $\alpha' > 0$, and that α is convex on $[-\infty, 0]$ and concave on $[0, +\infty]$. Thus, if one party has invested much more than the other, the marginal productivity with the larger investment is small, while the marginal productivity of the smaller investment is large. In the absence of strong asymmetries, this would imply that, in equilibrium, γ_S and γ_B cannot be too different.

In the following, we will show that, if the solution to the profit maximization game at stage 2 (the simultaneous choice of concealing and revealing effort) is uniquely defined by the first-order conditions, essentially all of our results of the main body of the text hold. Furthermore, the analysis of the concealing/revealing game becomes more interesting since changes in the fine D will no longer only affect the equilibrium level of γ_S, but also γ_B.

However, it is not ensured that the solution to the profits maximization problem of both firms is uniquely determined by the first-order conditions. Figure 6 illustrates this for the first condition for the buyer, given by (3): Since we assumed $\phi'(0) = 0$, there is at least one maximum, but there can be two local maxima.[22]

[22] An alternative assumption that ensures that the maximum is uniquely defined by the first-order condition would be that the marginal cost of revealing and concealing, $\phi'(\gamma_S)$ and $\phi'(\gamma_B)$, are constant. Then we would have to focus on equilibria in which γ_S and γ_B are positive.

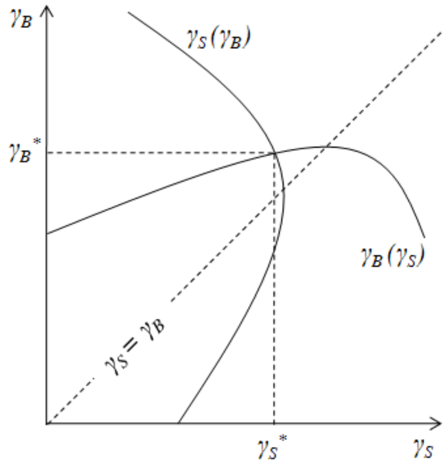

Figure 7: Best-response functions for alternative assumptions on α

However, if the first-order condition has a unique equilibrium solution, we can argue as follows; Propositions 1-3 still hold under this alternative setup. To see this, note that – as in the main body of the text – for an expected level of $e(c)$ and an expected price p^m in case that the information is not revealed, the slope of the best-response functions in the game determining concealing and revealing efforts are still given by (7) and (8), respectively. However, we have dropped our assumption that $\alpha'' = 0$, therefore the slope of the best-response functions is no longer zero. Since we assumed that $\alpha'' > 0$ for $\gamma_S - \gamma_B < 0$ and $\gamma'' < 0$ for $\gamma_S - \gamma_B > 0$, $\gamma_B(\gamma_S)$ has a slope smaller than one, and the slope is positive for $\gamma_B > \gamma_S$, negative for $\gamma_B < \gamma_S$ and goes to zero for $\gamma_B \to \gamma_S$. By the same reasoning, for $\gamma_B < \gamma_S$, the slope of $\gamma_S(\gamma_B)$ is positive and smaller than one, for $\gamma_B > \gamma_S$, the slope is negative and it goes to zero for $\gamma_B \to \gamma_S$. Therefore, the two best-response functions intersect exactly once. Figure 7 illustrates this.

In this setup, an introduction of a fine again reduces γ_S for each level of γ_B, i.e., shifts the best response function of the seller to the left. For the same reason given in the proof of Proposition 3, the optimum fine is positive, due to the excessive private interest of the seller to invest in revealing.

However, a shift in the best response function of the seller now also affects the equilibrium concealing effort of the buyer. This has additional welfare effects, since the concealing effort of the buyer is wasteful as such, and the private incentive to invest in concealing exceeds the social benefit, since the private incentive includes rent seeking (protection of the information rent concerning the type). A reduction of the buyer's concealing effort γ_B is therefore desirable from a social welfare perspective.

In "most" cases, an introduction of a fine $D > 0$ will reduce at least the sum of the concealing and revealing effort. This happens if $\gamma_S - \gamma_B$ is not too large. Figure 8 illustrates these cases.

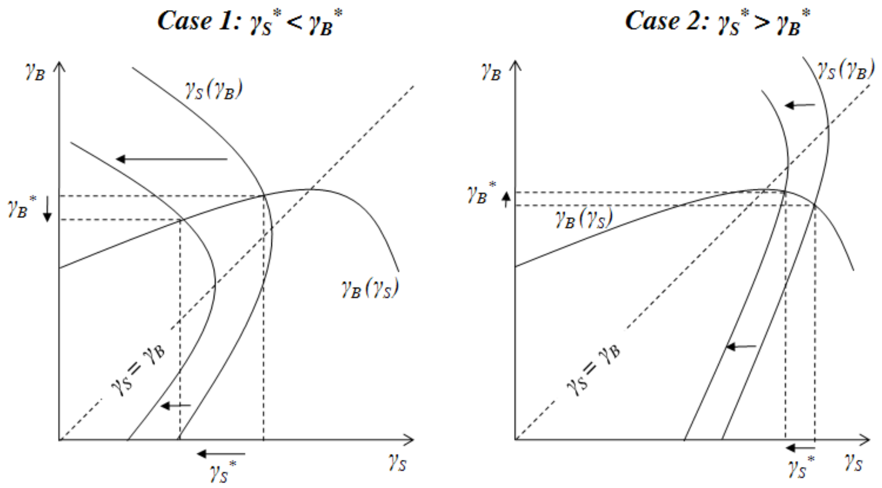

Figure 8: Effect of increasing D if $\gamma_S - \gamma_B$ is not too large

In case 1, where initially $\gamma_S < \gamma_B$, the shift in the seller's best response function also leads to a reduction of γ_B, which is socially beneficial. In case 2, initially γ_S is slightly larger than γ_B. In that case, the reduction in $\gamma_S(\gamma_B)$ triggers an increase of the equilibrium value of γ_B. However, since for γ_B only slightly smaller than γ_S, the slope of the best response function $\gamma_B(\gamma_S)$ is smaller than one, therefore, γ_B is reduced less than γ_S, and the welfare effect of a fine in terms of reducing wasteful concealing and revealing investments is still positive.

The last case to discuss is what happens if γ_S is much larger than γ_B. In this case, the increase of γ_B can be larger than the reduction of γ_S, such that the total $\gamma_S + \gamma_B$ will increase, as illustrated in Figure 9. In all three cases, α decreases if D is increased, thereby leading to a higher equilibrium level of e, and a lower $\widehat{c}$. Therefore, all our arguments with respect to the effects of a conditional trade-secret protection rule and with respect to damages apply as well in this framework.

The additional effect captured here is that – due to the strategic interaction in concealing and revealing efforts – for $\gamma_S >> \gamma_B$, the socially wasteful incentive to invest in concealing will increase as a reaction to an increase in D. This runs counter the standard intuition that a fine for trade-secret violation is beneficial since it can serve as a substitute for costly efforts of the informed party to protect her information.[23] The reason why this intuition is misleading is immediate from the fact that the best-response functions are not strictly increasing. For instance, if the seller has invested more than the buyer, $\gamma_S > \gamma_B$, each additional investment

[23]The idea that trade-secret protection can limit investments in concealing and revealing technologies, thereby preventing a wasteful "war of attrition" can be found in, e.g., Friedman, Landes, and Posner (1991), 67-70, Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 485-486 (1974), and E.I. duPont deNemours & Company, Inc., v. Christopher, 431 F.2d 1012, 1016 (5th Cir. 1970).

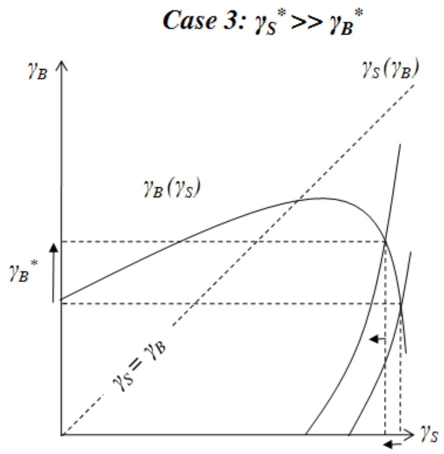

Figure 9: Effect of increasing D if $\gamma_S - \gamma_B$ is large

by the seller increases the marginal productivity of the buyer's investment, due to our assumption on α :

$$\frac{\partial}{\partial \gamma_S}\left(\frac{\partial \alpha}{\partial \gamma_B}\right) = -\alpha'' > 0 \text{ for } \gamma_S > \gamma_B.$$

Thus, the buyer's best response to an increase in γ_S is to decrease γ_B. The fine works in the opposite direction by reducing γ_S, which in turn triggers a best response of increasing γ_B.

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