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

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

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

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October 2007

# 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 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, but suggests that the effort to conceal rather than the effort to reveal the information should play a role when deciding whether or not trade secret protection should be granted.

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). Under certain conditions, trade-secret protection can also limit investments in concealing and revealing technologies, thereby preventing a wasteful "war of attrition".<sup>1</sup>

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 his valuation of the product since this can worsen his 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 urgent the buyer needs additional power (as this influences the price the seller would charge), the buyer is interested in keeping the breakdown of his 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

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<sup>1</sup>See, 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).

electricity supplied by the power plant into the grid.<sup>2</sup> Electricity traders can buy this information (almost) in real time. Since this reveals the power plant's ability 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 his 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 a well-understood 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" and "investment incentives" in a simple model. A buyer and a seller trade one unit of an indivisible good. The buyer might or might not have an (inefficient) outside option. This 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. We interpret trade-secret protection as an instrument that keeps information private, i.e. which makes it prohibitively costly to reveal it.

There are two main findings. First, from an efficiency point of view, trade-secret protection is ambiguous. It increases efficiency if the moral hazard dimension is more important than the adverse selection dimension of the problem. More precisely: It is beneficial if the probability that the buyer has an outside option is high

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<sup>2</sup>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 for measuring fluid flows in gas and oil pipelines are pending.

and her relation-specific investment is very effective. Otherwise, it is inefficient to legally protect the asymmetric information, and social surplus would be higher if information was symmetric.

However, in practice, it will often be difficult to judge which of the two alternatives actually applies. Our second main result refers to a simple "conditional trade secret protection" rule. This rule states that trade secret protection shall be granted if and only if the informed party has undertaken a small but significant investment to conceal his information. This does not require information on the type distribution but yields – except for an intermediate range of parameters<sup>3</sup> – the same social surplus as if the application of trade secret protection could condition directly on the type distribution; i.e. it implies that trade secret protection is granted if and only if it increases the social surplus.

The intuition for this result is simple. By his pricing policy, the seller can determine whether both types of buyers get served or only one type. If only one type is served, inefficient trade occurs and it would better to have symmetric information, i.e. trade secret protection should not be enforced. However, in such an equilibrium the seller basically knows the buyer's type. Thus, there will be little information rent for the buyer. Thus, the buyer has no incentive to significantly invest in protecting her information which, under "conditional trade secret protection", implies that no legal protection applies – as it should, from a social welfare point of view.

Alternatively, if both types get served, inefficient trade is not an issue. However, the "weak type" receives an information rent since he pays a low price which is set only to ensure that "strong types" with an outside option participate in the trade. If the weak type buyers could undertake surplus increasing investments, they would do so, since the participation constraint of the strong types fixes the price – i.e. asymmetric information can also solve hold-up problems in vertical relationships. Since the buyer now receives an information rent, he will be willing to invest in protecting it, implying that trade secret protection can be sought – as it should, since efficient trade occurs and asymmetry of information protects investment incentives.<sup>4</sup>

The main implications of this analysis are first that – due to the ambiguity of the welfare effects of trade-secret protection in vertical relationships – there are good efficiency arguments for the legal practice of being cautious in granting such protection and of deciding it on a case-by-case basis. Second, making the application conditional on concealing efforts is a sensible mechanism. This, again, is close to legal practice where some effort needs to be undertaken for the information to be protected and some effort undertaken to reveal it in order to be sued for violating trade secret laws. However, our results highlight that it is more important to look at the efforts to keep the information secret than to condition on the effort to reveal

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<sup>3</sup>In the intermediate range, the potential welfare losses from this rule are bounded above.

<sup>4</sup>In addition, such a rule prevents inefficient investments in revealing investments, and sets an upper limit to inefficient concealing investments. However, we neglect enforcement costs created by trade-secret law itself (Bone, 1998, 272-279).

it. The analysis recommends that the latter should play less of a role when deciding whether or not information is protected by trade-secret laws.

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.

Our paper also differs from the literature on the "lemons problem" (Akerlof (1970)), which deals with cases in which the parties have asymmetric information about the value of the trade. In our paper, in the basic version without investments, the asymmetry of information is about the parties' bargaining position which influences the division of a pie of given size.

Furthermore, our paper is also related to the literature on disclosure duties in contract law, like 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 but leaves the probability of trade unaltered. More technically, in our setting, the "type" of an agent is known to the agent, while in the contracting literature it is usually not; e.g. in the contracting literature, the contractor does not know the cost of the project (i.e. its own type), but might find it out when undertaking some information investment. In our model, the buyer always knows whether he 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 to five present the formal analysis. Section six applies the analysis to cases in trade-secret law and beyond. Section seven 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<sup>5</sup> and the Uniform Trade Secrets Act,<sup>6</sup> 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

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<sup>5</sup>Restatement (Third) of Unfair Competition §§ 39-45 (1995), superseding the Restatement (First) of Torts §§ 757-759 (1939).

<sup>6</sup>Uniform Trade Secrets Act, 14 U.L.A. 433 (1985).



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 (2005), §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.<sup>7</sup>

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 (2006), §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.<sup>8</sup> 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.<sup>9</sup> 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.

### 3 The model

In order to investigate the trade-off between efficient trade and investment incentives described above, we will use a very simple model of a buyer-seller relation. In order to circumvent problems of finding bargaining solutions under asymmetric information, we will give one party all the bargaining power and investigate how trade-secret protection affects efficiency, both in terms of the probability of trade taking place as well as in terms of the investment incentives.

A seller (he) wants to sell an indivisible good to a buyer (she). The production costs for the seller are normalized to zero. There are two types of buyers. A fraction

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<sup>7</sup>What constitutes other "improper means" is subject to a considerable debate; see only *E.I. duPont deNemours & Company, Inc., v. Christopher*, 431 F.2d 1012, 1016 (5th Cir. 1970).

<sup>8</sup>For U.S. trade-secret law, see Milgrim (2005), §1.03. For German trade-secret law, see Hefermehl, Köhler, and Bornkamm (2006), §17 UWG Rdnr. 10.

<sup>9</sup>*E.I. duPont deNemours & Company, Inc., v. Christopher*, 431 F.2d 1012, 1016 (5th Cir. 1970).

$\beta$  of buyers has a strong position against the seller, since they can also obtain the good from an alternative source at a cost of  $c > 0$ . We assume that  $c$  reflects the production cost, which implies that using the outside option is inefficient.<sup>10</sup> The remaining buyers have no outside option available. We call the former "strong" types and the latter "weak" types. The type, i.e. the availability of the outside option, is private information of the buyers.

*In the electricity example described above, the good could be a certain amount of electricity which electricity company B has committed to deliver. Delivering less than the contracted amount will impose a fine on B, delivering more than contracted will not increase the revenues company B is entitled to from her customers. Now assume B approaches producer S to buy the electricity from S. There might be two possible scenarios for this: First, B just wants to check whether S's offer is more attractive than producing with the own power plant; second, B's power plant faces an outage, i.e. B cannot produce by itself the electricity it has already contracted. In the first scenario, the buyer is "strong", in the second, she has a weak position. Which of the two scenarios applies is private information of B.*

The buyer has a valuation  $b(e) > 0$  for the good. She can increase the value from trade with the seller by undertaking an ex-ante effort  $e \in \{0, e^*\}$ , where

$$b(0) > c, \tag{1}$$

$$b(e^*) - b(0) > e^*. \tag{2}$$

The first condition says that the outside option is valuable, the second states that the investment is efficient. For simplicity, we will assume that only the "weak type" can undertake such an investment. This effort is unobservable to the seller and non-contractable. The valuation of the buyer from using the outside option sourcing opportunity is always  $b(0)$ . The non-contractability of the effort creates the usual hold-up problem.

*In the electricity example, the non-contractable investment could be an investment by B in back-up transmission capacities for electricity transport from the network of company S to the network of company B. It increases the "quality" of the electricity from company S since it improves the reliability. However, it might not affect the reliability of the delivery from the own power plant of B. It is realistic to assume that the network planning and operation are private information to company B such that the level of reliability is unobservable to third parties and to courts.*

Before the type is realized at  $t = 2$ , the buyer might invest  $\gamma_B$  in a concealing technology  $f_B(\gamma_B)$  to conceal her type. After that, the seller, having observed

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<sup>10</sup>The outside option can be interpreted as a "make or buy" decision, or as the choice between different sellers. As a "make or buy" decision, the buyer might or might not be able to produce the good herself. As a choice between different sellers, the buyer might or might not have an alternative offer. If she has an alternative offer,  $\tilde{c}$  is the price of the alternative offer. This need not be equal to the production cost of the alternative source. However, we want to concentrate on the case where the outside option is always inefficient, thus we just need to assume that a potential rival supplier is less efficient than the seller.

$f_B(\gamma_B)$ , can invest  $\gamma_S$  in a revealing technology  $f_S(\gamma_S)$ . We assume  $f'_i > 0$ ,  $i = B, S$ . If  $f_B(\gamma_B) > f_S(\gamma_S)$ , the type remains private information; otherwise the seller learns the buyer's type in  $t = 2$ .

*In the electricity example, the revealing technology would be the technology used by the company Genscape to measure the electro-magnetic field emanating from the transmission lines that leave the power plant site. By using this information, the seller could infer whether the buyer is in urgent need of additional electricity and therefore probably has no outside option (i.e. is a weak buyer) or whether he is just a regular electricity buyer (i.e. is a strong buyer). A possible concealing "technology" could be that company B makes side payments to the owners of the property below the transmission lines such that the property owner will not allow the installation of such equipment on their property. Alternatively, they might invest in some shielding to absorb the electromagnetic field. As a response, company S might offer higher side payments or invest in more sensitive measuring equipment.*

The seller has all the bargaining power and makes a take-it-or-leave-it offer  $p$  to sell the good to the buyer at  $t = 4$ . Finally, the buyer decides whether to buy the good from the seller or to procure it from the outside option. The timing is depicted in Figure 1. Note that, since the decision on the investment in the concealing technology predates the determination of the types, concealing investments cannot serve as a signal of the type. We discuss this point further in the conclusion.

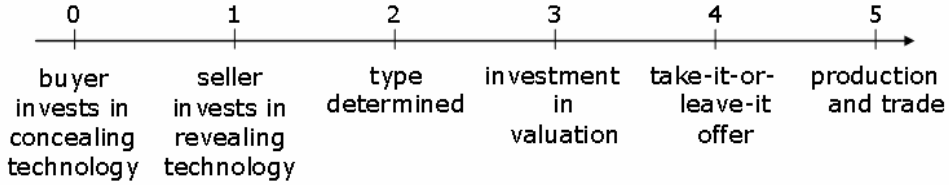


Figure 1: Timing

The buyer and the seller are risk-neutral. The buyer's payoff function is:

$$\Pi_B = \begin{cases} b(e) - p - e - \gamma_B & \text{if the buyer trades with the seller,} \\ b(0) - c - e - \gamma_B & \text{if the buyer uses the outside option,} \end{cases} \quad (3)$$

where  $e = 0$  for the strong type, by definition, and  $e \geq 0$  for the weak type. The seller's payoff equals

$$\Pi_S = \begin{cases} p - \gamma_S & \text{if the buyer trades with the seller,} \\ -\gamma_S & \text{if the buyer uses the outside option.} \end{cases} \quad (4)$$

We interpret trade secret protection as an instrument which makes revelation of the buyer's type prohibitively costly, e.g. due to large expected fines if trade secret laws are violated. Thus, in a system with trade secret protection, the type always remains private information, and thus  $\gamma_B = \gamma_S = 0$ .

## 4 No effort to increase the buyer's valuation

### 4.1 No revealing and concealing investments

Let us start with the simplest case in which there are no investment opportunities, neither in the valuation of the good, nor in concealing or revealing technologies. In this case, it is straightforward that asymmetry of information is not socially desirable and therefore should not be protected by law (for ease of notation, denote  $b(0) =: b$ ).

**Proposition 1** *Without efforts to increase the buyer's valuation, and without investments in concealing or revealing technologies, asymmetric information and its protection through trade secret laws is welfare decreasing for  $\beta \leq \beta^* = (b - c) / b$  and does not affect the social surplus for  $\beta > \beta^*$ .*

**Proof.** Whenever the probability of a strong type is sufficiently high,  $\beta > \beta^*$ , the seller serves both types even under asymmetric information. If,  $\beta \leq \beta^* = (b - c) / b$ , the seller finds it optimal to serve only the weak types and the ex ante welfare loss from asymmetric information is:

$$\begin{aligned}\Delta W &= W^{sym} - W^{asym} & (5) \\ &= b - [(1 - \beta)b + \beta(b - c)] \\ &= \beta c > 0.\end{aligned}$$

■

This is just the observation that with asymmetric information not all gains from trade will be realized, since the seller wants to save on the information rent he has to pay in order to ensure that trade always takes place. The optimum offer of the seller depends on the type distribution. If the probability of a weak type is very high (i.e.  $(1 - \beta)$  is large), the seller will demand all the surplus, i.e.  $p = b$ , which implies that trade will occur only if the buyer turns out to be the weak type. If there are only few weak types, the seller will find it optimal to demand a lower price  $p = c$  to ensure that also the strong types buy the product. In the former case, with  $p = b$ , inefficient trade occurs, since with probability  $\beta$  the buyer is of the strong type and will prefer her less expensive outside option to the seller's offer. The cutoff value is

$$\beta^* = (b - c) / b, \quad (6)$$

and the equilibrium price is

$$p = \begin{cases} b & \text{if } \beta \leq \beta^*, \\ c & \text{if } \beta > \beta^*. \end{cases} \quad (7)$$

The difference  $(b - c)$  is the information rent the weak buyer receives from her private information whenever the seller serves both types, i.e. if he sets the low

price. If this becomes large because either  $b$  is very high or the outside option price  $c$  is very low, the seller will abstain from serving also the strong types even if they are very frequent. The reason is that, when the seller changes from selling only to the weak types to serving both types, he always has to pay an information rent. If this is large, he is better off serving only weak types and giving no information rent. This illustrates the basic trade-off of an uninformed party between increasing efficiency and reducing the information rent.

## 4.2 Revealing and concealing investments

Let us now consider investments in a revealing technology to find out the buyer's type (e.g. buy a helicopter to fly over the buyer's property to find out whether she could produce the good herself). The buyer, anticipating such a revealing effort, could try to conceal the information (e.g. by building a roof over the production facilities). In light of the preceding section, any incentive to conceal the information is welfare decreasing. Investments in revealing the information tend to be welfare increasing, if, without such an investment, the information could be kept secret and no other way exists to disclose the information.

If  $f_B(\gamma_B) > f_S(\gamma_S)$ , the buyer's type will remain secret. Otherwise, the seller will learn the buyer's type at  $t = 2$ . If the seller learns the buyer's type, he will set type-dependent prices at  $t = 4$ : a high price  $p = b$  if the seller is the weak type, and  $p = c$  otherwise.

Since investments in revealing or concealing the information are deviations from the first best (which would require symmetry of information without any investments), trade secret protection can now have socially beneficial as well as wasteful effects.

**Proposition 2** *Without efforts to increase the buyer's valuation, but with investments in concealing and revealing the information, asymmetric information, and its protection through trade secret laws is (i) socially wasteful for  $\beta \leq \beta^*$ , while, (ii) for  $\beta > \beta^*$ , it is socially beneficial.*

To see why this is true, consider first the case that  $\beta \leq \beta^*$  such that inefficient trade occurs if the information remains private. With private information, the seller sets the price  $p = b$  and the buyer is indifferent between asymmetric and symmetric information, since she gets no information rent in either case (i.e. whether she turns out to be the strong type or the weak type). She will therefore never invest in any concealing technology; consequently  $\gamma_B^* = 0$ . The seller, however, can gain from learning the buyer's type, since this prevents inefficient trade, and the seller can appropriate all gains from trade. The maximum amount he would invest is:

$$\underbrace{(1 - \beta)b + \beta c}_{\text{profit from type contingent prices}} - \underbrace{(1 - \beta)b}_{\text{profit under asym. information}} = \beta c. \quad (8)$$

Denote by  $\gamma_S^0$  the level of investment which reveals the buyer's type, given zero investment of the buyer:

$$\gamma_S^0 : f_S(\gamma_S^0) = f_B(0). \quad (9)$$

Thus, the optimum investment decision in the revealing technology is given by:

$$\gamma_S^* = \begin{cases} \gamma_S^0 & \text{if } \gamma_S^0 \leq \beta c, \\ 0 & \text{otherwise.} \end{cases} \quad (10)$$

There will be no overinvestment in the revealing technology from a social welfare perspective: If there is no other way to reveal the private information, also a social planner would invest up to  $\beta c$  since this is exactly the welfare gain from symmetric information. If the uninformed party did not have all the bargaining power, as assumed in our model, this result would even be strengthened: no socially excessive investment incentives exist for the uninformed party to invest into the revealing technology.

Since we identify trade secret protection as an instrument that increases the cost of revealing the buyer's type such that revelation becomes prohibitively costly, we conclude that for  $\beta \leq \beta^*$  there should be no trade secret protection. Making the revelation of information more difficult only reduces the social surplus by hindering the welfare-increasing revelation.

Consider now  $\beta > \beta^*$  such that efficient trade occurs even under asymmetric information. In this case, any investment in revealing or concealing the private information is socially wasteful. In contrast to the former case, investments by the uninformed party now do not increase the social surplus, but lead only to a shift of rents: the seller wants to appropriate the buyer's information rent. The maximum willingness to invest in either revealing technology or concealing technology is now equal to the expected information rent:

$$\begin{aligned} \text{buyer} & : (b - c) - [(1 - \beta)(b - b) + \beta(b - c)] = (1 - \beta)(b - c), \\ \text{seller} & : (1 - \beta)b + \beta c - c = (1 - \beta)(b - c). \end{aligned}$$

The solution now depends on whose technology is more effective. If the seller's technology is at least as effective,  $f_S(\gamma) \geq f_B(\gamma)$ , the subgame perfect equilibrium of the investment game is that the buyer – anticipating that the seller could always outpace her – does not invest and the seller invests just enough to reveal the information if this is profitable. That is, the outcome is identical to the former case (10). Note, however, that now this investment is socially wasteful.

Alternatively, assume that the concealing technology is more effective than the revealing technology,  $f_B(\gamma) > f_S(\gamma)$ . The buyer will invest just enough in order to deter revelation of her information. Let  $\bar{\gamma}_B$  be defined as:  $\bar{\gamma}_B : f_B(\bar{\gamma}_B) = f_S((1 - \beta)(b - c))$ . Then the optimum investment is given by (assuming a minimum

increment  $\delta$  in which investments can be altered):

$$\gamma_B^* = \begin{cases} \bar{\gamma}_B + \delta & \text{if } \bar{\gamma}_B + \delta \leq (1 - \beta)(b - c), \\ 0 & \text{otherwise.} \end{cases} \quad (11)$$

Given that the buyer has invested  $\gamma_B^*$ , the seller has no incentive to invest in revelation; thus  $\gamma_S^* = 0$ .

Trade secret protection can now serve a welfare enhancing purpose in avoiding wasteful investments in concealing or revealing of the information. If the costs for violating trade secrets are sufficiently high, the seller will abstain from investing and always choose  $\gamma_S = 0$ . Thus, the buyer also avoids the wasteful investment and chooses  $\gamma_B = 0$ . Trade will still be efficient and the informed party receives an information rent.

Table 1: No Investments in the Buyer's Valuation

	$\beta > \beta^*$	$\beta \leq \beta^*$
Efficient trade?	Yes (trade always takes place)	No (trade only with weak types)
Information rent?	Yes	No
Incentive to conceal?	Yes (inefficient)	No
Incentive to reveal?	Yes (inefficient)	Yes (efficient)
Trade secret protection	Socially beneficial	Socially wasteful

Table 1 summarizes the results for the case with no investment in the valuation. If the probability that the buyer has an outside option is high, the seller chooses a low price  $p = c$ , resulting in efficient trade. Since the weak types without an outside option also enjoy the low price, they receive an information rent, compared to their reservation utility of zero. Hence, the buyer has a strict incentive to invest in concealing her type in order to preserve this rent. Since concealing and revealing investments are just for the distribution of the information rent, they are socially wasteful. Trade secret protection renders them unnecessary and ineffective and is therefore socially beneficial. However, it shifts the rents towards the uninformed party.

If the probability of an outside option is small, the seller chooses a high price  $p = b$ , such that, in case the buyer turns out to have an outside option, inefficient trade occurs (the buyer buys from the outside option at  $c < b$ ). In this case, there is no information rent. Hence, the buyer has nothing she could protect by investing in concealing her type. The investment in revealing the buyer's type is now efficient (given there is no other way to reveal it), since it prevents inefficient trade from occurring. Also, from a social point of view, the seller never overinvests, since his maximum willingness to pay for revealing the type is the additional social surplus resulting from efficient trade. Trade secret protection hinders the revelation of the information and thereby hampers efforts of the seller to establish efficient trade.

## 5 Efforts to increase the buyer's valuation

### 5.1 No revealing and concealing investments

We now want to analyze investments efforts by the buyer into her own valuation of the good. As noted earlier, we focus on non-contractable investments. Therefore, if all information is symmetric, i.e. the seller can find out the type and the investment level, the usual hold-up problem arises: the seller would demand the total ex-post surplus, i.e. the buyer would not get her ex-ante investment  $e$  reimbursed, and, anticipating this, would not invest. Thus, there are now two potential sources of inefficiencies: inefficient trade and too low effort levels. The benchmark case of symmetric information (i.e. trade secret protection does not apply and the seller could (costlessly) observe both the type and the effort level) is therefore characterized by the following Lemma (expected values refer to expectations before  $t = 0$ ):

**Lemma 1 (*Symmetric Information*)** *With symmetric information, the seller sets type dependent prices,  $\bar{p} = b(0)$  for the weak type and  $\underline{p} = c$  for the strong type, implying expected profits of  $E[\Pi^S] = \beta c + (1 - \beta)b(0)$ . The weak type buyer chooses  $e = 0$ , implying expected profits of  $E[\Pi^B] = \beta[b(0) - c]$ , and a social surplus of  $E[W^{sym}] = b(0)$ .*

This is just an immediate implication of the hold-up problem implied by the non-contractable relation specific investments and the fact that the seller has all the bargaining power.

With asymmetric information, we again need to carefully distinguish between different realizations of  $\beta$ , i. e. the result depends critically on the type distribution. If the fraction of strong types is high, the following Lemma describes the equilibrium outcome.

**Lemma 2 (*High  $\beta$* )** *For  $\beta \geq \beta^{**} = \frac{b(e^*) - c}{b(e^*)}$ , the unique pure strategy equilibrium is characterized by  $p_{high} = c$  and  $e_{high} = e^*$ , implying  $E[\Pi_{high}^S] = c$ ,  $E[\Pi_{high}^B] = \beta b(0) + (1 - \beta)[b(e^*) - c]$ , and  $E[W_{high}^{asym}] = \beta b(0) + (1 - \beta)[b(e^*) - c]$ .*

**Proof.** See Appendix. ■

If the fraction of strong types is sufficiently high,  $\beta \geq \beta^{**}$ , the seller wants to serve both types. This requires to demand a low price,  $p = c$ , in order to ensure that also the strong types participate. Hence, the price is independent of the effort level of the weak type. The weak type can increase his information rent by choosing a positive effort level – thus, his optimal choice is  $e = e^*$ . The asymmetric information protects his investment and avoids the hold-up problem. Therefore, with asymmetric information, the first best is realized for large values of  $\beta$ : trade always takes place and the efficient effort level is selected. Obviously, making information symmetric strictly reduces the social surplus. Trade secret protection therefore clearly is welfare enhancing in this case.



Now consider the other extreme where  $\beta$  is low, such that the seller finds it optimal to demand a relatively high price and to serve only the weak types. In this case the equilibrium is characterized as follows:

**Lemma 3 (Low  $\beta$ )** For  $\beta \leq \beta^* = \frac{b(0)-c}{b(0)}$ , there exists a unique mixed strategies equilibrium, where  $E[\Pi_{low}^S] = (1 - \beta)b(0)$ ,  $E[\Pi_{low}^B] = \beta[b(0) - c]$ , and  $E[W_{low}^{asym}] = b(0) - \beta c$ .

**Proof.** See Appendix. ■

If only the weak types get served no pure strategy equilibrium exist. Imagine the buyer chooses some  $e > 0$  with certainty; in equilibrium, the seller can infer this effort choice and would demand  $p = b(e)$ , leaving the buyer with an overall loss of  $-e$ . Thus, the only candidate for a pure strategy equilibrium is  $e = 0$ . This would imply that  $p = b(0)$ . However, if  $p = b(0)$  with certainty, the buyer has an incentive to deviate to  $e > 0$ . In any mixed strategy equilibrium, the seller does not know the buyer's effort choice (the buyer mixes between  $e = 0$  and  $e = e^*$ ) and the buyer does not know which price the seller will set (the seller mixes between  $p = b(0)$  and  $p = b(e^*)$ ).

Apart from these rather technical complications, the outcome of the mixed strategy equilibria exactly resembles the case without efforts to increase the buyer's valuation. The weak type buyer receives (on average) his reservation payoff of zero; and the welfare loss from asymmetric information is again equal to  $\beta c$ , the (average) cost from inefficient trade, resulting from the case where the buyer turns out to be a strong type who prefers the outside option to the price offered by the seller.<sup>11</sup> Therefore, making information symmetric in this case increases the social surplus by ensuring that trade between buyer and seller always takes place (although it cannot solve the hold-up problem).

What is left to analyze are intermediate levels of  $\beta$ , since  $\beta^* < \beta^{**}$  :

**Lemma 4 (Medium  $\beta$ )** For  $\beta^* < \beta < \beta^{**}$ , there exists a unique mixed strategy equilibrium, where  $E[\Pi_{medium}^S] = c$ ,  $E[\Pi_{medium}^B] > \beta[b(0) - c]$ , and,  $b(0) > E[W_{medium}^{asym}]$ .

**Proof.** See Appendix. ■

For the medium range of  $\beta$ , the outcome is indeed in-between the two other cases. The strong types are sometimes served by the seller, though not always (the seller mixes between  $p = c$  and  $p = b(e^*)$ ), while the buyer mixes between  $e = 0$  and  $e = e^*$ ). Since sometimes the seller serves the strong types, he mixes such that with some probability the price equals  $c$ , which implies that the weak type buyer can ensure herself a strictly positive expected payoff (by choosing  $e = 0$ , since

<sup>11</sup>There is a slight difference since, on average, the effort choice is strictly positive. However, sometimes no trade happens at all, namely, if the buyer has chosen  $e = 0$  and the buyer has chosen  $p = b(e^*)$ . Both effects (positive effort and no trade) exactly cancel out.

then, whenever  $p$  turns out to be equal to  $c$ , she realizes  $b(0) - c > 0$ ). The social surplus is, however, smaller under asymmetric information compared to symmetric information. As for small values of  $\beta$ , there are two source of inefficiencies: First, sometimes the strong types have to use the outside option (as it always happens for small values of  $\beta$ ); second, sometimes the weak types do not get served at all (when they have chosen zero effort but the seller demands a high price).

Putting all cases together, we find that asymmetric information can increase the social surplus, even in the absence of concealing and revealing investments. The reason is that it can improve investment incentives. However, this welfare increasing effect of asymmetric information applies only for certain type distributions, namely, if  $\beta$  is not too low.

**Proposition 3** *With efforts to increase the buyer's valuation, but without investments in concealing or revealing technologies, asymmetric information and its protection through trade secret laws is (i) socially wasteful if  $\beta < \beta^{**}$ , (ii) socially beneficial if  $\beta \geq \beta^{**}$ , where*

$$\beta^{**} = \frac{b(e^*) - c}{b(e^*)}.$$

**Proof.** Follows immediately from comparing the welfare levels:  $E[W_{high}^{asym}] > E[W^{sym}] > E[W_{medium}^{asym}]$  and  $E[W^{sym}] > E[W_{low}^{asym}]$ . ■

## 5.2 Revealing and concealing investments

When we allow for revealing and concealing investments in the presence of valuation-increasing efforts, the results by and large resemble the ones for the case without valuation-increasing efforts. However, the case in which  $\beta \geq \beta^*$ , i.e. when both types get served (at least with some probability), is now slightly altered. Trade secret protection does not only avoid wasteful investments in revealing or concealing information which are motivated only by rent shifting. It also protects the efficiency-enhancing effort to increase the buyer's valuation.

**Proposition 4** *With efforts to increase the buyer's valuation, and with investments in concealing and revealing the information, asymmetry of information and its protection through trade secret laws are (i) socially wasteful for  $\beta \leq \beta^*$ , and are (ii) socially beneficial for  $\beta \geq \beta^{**}$ .*

Consider first the case in which only the weak types get served,  $\beta \leq \beta^*$ . The buyer has no incentive to invest in concealing, since her payoff from the trade is always zero. Since in equilibrium the seller will set  $p = b(e)$ , the optimal ex-ante choice is  $e = 0$ . The seller's investment incentive again equals the welfare gain from ensuring that efficient trade will always happen, as in the case without investment. This resembles the result of section 4.2 concerning the case without valuation-enhancing

investments and the positive judgement on symmetric information (and hence a negative view on trade secret protection) for circumstances where asymmetry leads to inefficient trade.

If both types get served with certainty, we know from Proposition 3 that, with asymmetric information, the hold-up problem is solved, and a positive effort level is induced. Investments in revealing the type therefore are socially undesired, since – if they were successful – we would have symmetric information, implying no incentives to exert effort. Investments in concealing are – for the same reason – beneficial, if they succeed in keeping information private. However, trade secret protection can again act as a superior substitute to wasting money on building walls to conceal information; hence, if both types get served, trade secret protection is socially beneficial since it induces positive effort and prevents wasteful concealing and revealing investments.

In the intermediate range, trade secret protection has an ambiguous effect. Symmetric information yields a higher surplus than asymmetric information, which suggests that trade secret protection should not be applied. However, the buyer has a – socially undesirable – incentive to protect her type, which, assuming sufficiently effective concealing technologies, would lead to wasteful investments in concealing. These wasteful investments can be avoided by trade secret protection.

The next table summarizes this section’s findings.

Table 2: Investments in the Buyer’s Valuation

	$\beta \leq \beta^*$	$\beta^{**} < \beta < \beta^*$	$\beta \geq \beta^{**}$
Efficient trade?	No	Sometimes	Yes
Information rent?	No	Yes	Yes
Investment incentive?	No	Yes	Yes
Incentive to conceal?	No	Yes (inefficient)	Yes
Incentive to reveal?	Yes (efficient)	Yes	Yes (inefficient)
Trade secret protection	Socially wasteful	Ambiguous	Socially beneficial

### 5.3 Conditional Trade Secret Protection Rule

The last two sections have shown that trade secret protection can but need not increase the social surplus. Whether it does depends on the type distribution. As a point of reference, we denote by  $W^{informed}$  the social surplus a social planner, who is informed about the type distribution but cannot solve the other information problems, could realize.

Assuming such an informed social planner is problematic. In practice, this would require that, depending on the judge’s information on the type distribution, trade secret protection can be sought or not. This seems a rather unrealistic scenario. However, there exists a simple rule which approximates  $W^{informed}$  without requiring any information on the type distribution. We call this rule "conditional trade secret protection". Call  $\varepsilon$  the minimum observable investment level of the buyer, i.e.

for all  $\gamma_B \geq \varepsilon$ , a court can observe that the buyer has invested in concealing her information. Now assume that trade secret protection is granted if and only if  $\gamma_B \geq \varepsilon$ . Given our previous results, it can be shown that:

**Proposition 5** *For  $\varepsilon \rightarrow 0$ , a conditional trade secret protection approaches  $W^{informed}$ , the same welfare level an informed social planner could obtain when conditioning trade secret protection on the type distribution, for  $\beta \leq \beta^*$  and for  $\beta \geq \beta^{**}$ . For  $\beta^* < \beta < \beta^{**}$  the welfare loss of the conditional trade secret protection rule compared to  $W^{informed}$  is bounded above.*

**Proof.** See Appendix. ■

The intuition for this result can be best derived from interpreting the results of Table 2. If the fraction of strong types is low,  $\beta \leq \beta^*$ , with asymmetric information inefficient trade occurs. The buyer will not receive any information rent, hence he lacks any incentive to keep her type private and will choose  $\gamma_B = 0 < \varepsilon$ , and no trade secret protection applies under the conditional trade secret rule – as it should, since for low values of  $\beta$ , trade secret protection is socially wasteful.

If  $\beta$  is large,  $\beta \geq \beta^{**}$ , efficient trade takes places and the weak type buyer receives an information rent. This rent provides a strict incentive to keep the type private, thus  $\gamma_B = \varepsilon$  for  $\varepsilon$  sufficiently small. Thus, trade secret protection would be granted by a court – as it should, since for large values of  $\beta$ , asymmetric information is socially beneficial and should be protected by law. At the same time, trade secret protection sets an upper limit to the (per se wasteful) investments in concealing the buyer’s type: therefore, for  $\varepsilon$  small, also the waste on concealing investments is limited. The seller, anticipating that trade secret protection will be granted, also abstains from investing in revealing technologies, since, by assumption, this will lead to prohibitively costly punishment under trade secret law.

The conditional trade secret protection rule does not work as well for intermediate values  $\beta$ . For these values, the buyer has a strict incentive to invest to reveal his types, i.e. he would invest  $\varepsilon$  and could therefore seek legal protection, although from an efficiency point of view such protection should not be granted. It is, however, interesting to note that the resulting loss in social surplus is bounded above for all parameter constellations.

This stands in contrast to the case of  $\beta \leq \beta^*$  and  $\beta \geq \beta^{**}$ . If for these parameter regions the wrong approach to trade secret protection is chosen (i.e. trade secret protection is granted for  $\beta \leq \beta^*$ , and not granted for  $\beta \geq \beta^{**}$ ), the potential welfare loss can become arbitrarily large. For  $\beta \leq \beta^*$ , the welfare loss from keeping information private is (see (5))  $\beta c$ , which becomes large for large values of  $c$ , i.e. if the outside option is very inefficient. For  $\beta \geq \beta^{**}$ , by use of Lemma 2, the welfare loss equals  $(1 - \beta) [b(e^*) - e^* - b(0)]$ . This can become arbitrarily large if the investment is very efficient, i.e. if  $[b(e^*) - e^* - b(0)] \rightarrow \infty$ .

Thus, whenever losses from a wrong approach to trade secret protection can be very severe, the conditional trade secret protection rule avoids such a wrong application, even without any knowledge of the type distribution. In the intermediate

$\beta$ -range, where the rule implies falsely that trade secret protection is granted, the loss caused by this is limited. The conditional trade secret protection rule therefore can be seen as a "second best" solution, given a lack of knowledge of the type distribution.

## 6 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<sup>12</sup> or because the informed party took no measures to keep the information confidential.<sup>13</sup> 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,<sup>14</sup> rulemaking procedures of the Federal Energy Regulatory Commission,<sup>15</sup> and securities regulation.<sup>16</sup> Second, while

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<sup>12</sup>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).

<sup>13</sup>*Carpetmaster of Latham, Ltd., v. Dupont Flooring Sys., Inc.*, 12 F.Supp.2d 257, 261-262 (N.D.N.Y. 1998).

<sup>14</sup>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)).

<sup>15</sup>*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.

<sup>16</sup>*American Sumatra T. Corp. v. Securities and Exch. Comm'n*, 110 F.2d 117 (D.C. Cir. 1940)

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.<sup>17</sup> 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.<sup>18</sup>

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.

## 7 Conclusion

We have investigated the effect of protecting private information in vertical relationships, using a simple buyer-seller model in which the buyer's outside option is private information. In this framework, the welfare effect of legally protecting the asymmetry of information is ambiguous. It has negative effects if the "type" dimension of the buyer-seller interaction is important, i.e. if there is the danger of inefficient trade. It has positive effects if this problem is less severe than potential moral hazard problems. If trade always takes place, the informed party receives an information rent. If it can undertake investments to increase these rents, trade secret protection preserves the investment incentives. Therefore, trade secret protection increases efficiency if the moral hazard dimension is more important than the adverse selection dimension of the problem. Furthermore, trade secret protection can help to prevent wasteful investments in revealing or concealing technologies.

An interesting theoretical observation is that making the application of trade secret protection conditional on a minimum effort by the informed party to conceal her information can be seen a pragmatic "second best" rule. For important parameter regions, it tailors the application of trade secret protection to those circumstances in which maintaining asymmetric information is indeed socially beneficial. Where it

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(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).

<sup>17</sup>See only §220(b) Delaware General Corporation Law. The same analysis applies to the right of inspection under common law.

<sup>18</sup>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).

yields a suboptimal application of trade secret protection, the resulting welfare loss is bounded. These desirable properties of the rule are interesting since the rule rationalizes legal practice in many jurisdictions, in which, as described in sections two and six, trade secret protection can only be sought if reasonable secrecy safeguards have been undertaken.

However, a further recommendation on theoretical grounds is that the applicability of trade secret protection should not be conditional on the effort of the uninformed party. In the model, the uninformed party's incentive to reveal the type of the buyer never exceeds the social welfare gain. Thus, courts and legal rules should be less concerned with whether the uninformed party has undertaken a little or a lot of effort to gain the information – e.g. whether it could see directly what it wanted to see, or whether it needed complex technologies, such as in the case of the electricity industry, mentioned in the introduction. In general, this supports the case against making a violation of trade secret protection too heavily dependent on the way the information was acquired, used, or disclosed by the defendant.

Our relatively clear-cut results hinge upon strong assumptions of the model. In particular, we consider only two types of buyers, and we assume all bargaining power to rest with the uninformed party. While these assumptions considerably simplify the analysis,<sup>19</sup> the qualitative results should still hold in a broader context. Even with more than two types and if the buyer had some bargaining power, whenever the information should be revealed, the informed party will still have a relatively small (though not zero, like in our model) incentive to conceal her type.

Finally, it should be pointed out that the timing of events we have looked at is one in which the decision on the investment in concealing technologies predates the point in time where the type is revealed. In many circumstances, this seems reasonable (a firm might implement general precautions to protect information, and concrete technological specifications might be realized at a later point in time). However, this need not always be the case. Our approach avoids that the decision on the concealing investment can serve as a signal of the type; this significantly facilitates the analysis. If this was not the case, and the concealing decision was taken after the type had been learnt, the issue of voluntary type revelation would become relevant. Quite general unraveling results have shown that in adverse selection problems the informed party often has an incentive to reveal her type (Grossman and Hart (1980)). In such cases of "full unraveling", trade secret protection would not be sought.

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<sup>19</sup>In particular, the assumption that the seller makes a take-it-or-leave-it offer simplifies the analysis considerably. Otherwise, we would need to model bargaining between the two parties as bargaining under asymmetric information, which is far more complex than bargaining under symmetric information, where solutions like the Nash bargaining solution can be applied.

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## Appendix: Proofs

### Proof of Lemma 2:

Consider large values of  $\beta$ , such that the seller finds it optimal to serve both types. This requires  $p = c$ , implying a payoff of the seller of  $\Pi^S = c$ . The payoff maximizing choice of  $e$  is  $e = e^*$ . Hence, social surplus equals  $W_{high}^{asym} = \beta b(0) +$



$(1 - \beta) [b(e^*) - e^*]$ . The equilibrium of Lemma 3 exists if  $\beta \geq \beta^{**} = \frac{b(e^*) - c}{b(e^*)}$ . Given the buyer's behavior in this equilibrium, the optimal seller's deviation when serving only the weak types is  $\tilde{p} = b(e^*)$ , implying a deviation payoff of  $\tilde{\Pi}^S = (1 - \beta) b(e^*)$ . This deviation is not profitable if  $\beta \geq \frac{b(e^*) - c}{b(e^*)} =: \beta^{**} > \beta^*$ . No other equilibrium exists, in particular, no equilibrium for lower prices, since, for lower prices, the seller could always deviate to  $p = c$ , which does not alter the probability of trade but increases the payoff in case of trade. ■

Proof of Lemma 3:

(a) Non-existence of pure strategy equilibria: Consider a pure strategy  $e > 0$ . In equilibrium, the seller would know the buyer's strategy and choose  $p = b(e)$ , implying  $\Pi^B = -e$  for the buyer if he is of the weak type. Consider  $e = 0$ . The best response of the seller would be  $p = b(0)$ , allowing a profitable deviation for the buyer to  $e > 0$ . Thus, no pure strategy equilibrium exists.

(b) Mixed strategy equilibrium: The buyer chooses  $e = 0$  with probability  $r$ ,  $0 < r < 1$ , and  $e = e^*$  with probability  $1 - r$ . The seller chooses  $p = b(0)$  with probability  $q$ ,  $0 < q < 1$ , and  $p = b(e^*)$  with probability  $1 - q$  (obviously, any price in-between does not alter the probability of trade but does only reduce the payoff in case that trade occurs, and therefore is suboptimal). For the buyer to be indifferent, we need:

$$\begin{aligned} 0 &= q [b(e^*) - b(0)] - e^* \rightarrow \\ q &= \frac{e^*}{b(e^*) - b(0)}. \end{aligned}$$

For the seller to be indifferent, we need:

$$\begin{aligned} b(0) &= (1 - r) b(e^*) \rightarrow \\ r &= \frac{b(e^*) - b(0)}{b(e^*)}. \end{aligned}$$

Using this and summing over the four possible combinations of effort choices and prices, it is straightforward to calculate that the expected social surplus, conditional on the buyer being a weak type, is  $b(0)$  and that in expectation it fully accrues to the seller. This implies for the overall game the welfare and profit levels stated in the lemma. ■

Proof of Lemma 4:

(a) For the same reason as in Lemma 3, all equilibria are in mixed strategies.

(b) Mixed strategy equilibrium:

(i) In any mixed strategy equilibrium, the seller must attach positive probability to  $p = c$ . Hence, in equilibrium,  $E[\Pi^S] = c$ .

(ii) In any mixed strategy equilibrium, the seller must not attach positive probability to  $p = b(0)$ . Suppose she did. Then, in a mixed strategy equilibrium, we need to have that  $c = (1 - \beta) b(0)$ , which cannot hold for  $\beta^* < \beta < \beta^{**}$ .

(iii) The seller mixes between  $p = c$  (with probability  $q$ ,  $0 < q < 1$ ) and  $p = b(e^*)$  (with probability  $1 - q$ ). Thus, the expected profit of a weak type buyer is strictly positive since he can ensure a profit of at least  $E[\Pi^B(e = 0)] = q[b(0) - c] > 0$  by choosing  $e = 0$  with certainty. This proves that  $E[\Pi^B] > \beta[b(0) - c]$ .

(iv) For the buyer to be indifferent, we need:

$$\begin{aligned} q[b(0) - c] &= q[b(e^*) - c] - e^* \rightarrow \\ q &= \frac{e^*}{b(e^*) - b(0)}. \end{aligned}$$

For the seller to be indifferent, we need:

$$\begin{aligned} c &= (1 - \beta)[(1 - r)b(e^*)] \rightarrow \\ r &= \frac{b(e^*) - \frac{c}{1 - \beta}}{b(e^*)}. \end{aligned}$$

Going through the different cases of prices and effort choices, one gets:

$$\begin{aligned} E[W] &= \beta b(0) - \beta(1 - q)c + (1 - \beta)rqb(0) + \frac{c}{b(e^*)}[b(e^*) - e^*] \\ &= \frac{(1 - \beta)[b(e^*) - e^* - c] - b(0)[(1 - \beta)e^* + \beta](b(e^*) - b(0))}{b(e^*) - e^*}. \end{aligned} \quad (12)$$

Comparing this to the welfare level under symmetric information (which is  $b(0)$ ) yields:

$$E[W_{medium}^{asym}] - b(0) \quad (13)$$

$$= -(1 - \beta) \frac{(b(0) - c)(b(e^*) - e^* - b(0))}{b(e^*) - b(0)} < 0. \blacksquare \quad (14)$$

Proof of Proposition 5: First, consider the case without investment in enhancing the buyer's valuation. Assume  $\beta \leq \beta^*$ ; then, the buyer has no incentive to invest in concealing, trade secret protection does not apply, and the seller invests in revealing if and only if this increases efficiency. Alternatively, if  $\beta \geq \beta^*$ , the buyer will invest  $\gamma_B = \varepsilon$ , trade secret protection applies, and the seller will invest nothing,  $\gamma_S = 0$ . Efficient trade occurs, and for  $\varepsilon \rightarrow 0$ ,  $W^{informed}$  is approached.

Second, consider the case with investment in enhancing the buyer's valuation. For  $\beta \leq \beta^{**}$ , the buyer has no incentive to invest in concealing, trade secret protection does not apply, and the seller invests in revealing if and only if this increases efficiency (the welfare gain from making information symmetric is again equal to  $\beta c$ , and this is equal to the increase in profits of the seller if information becomes symmetric for  $\beta \leq \beta^{**}$ ). For  $\beta \geq \beta^{**}$  the buyer invests  $\gamma_B = \varepsilon$ , trade secret protection applies, the seller invests nothing,  $\gamma_S = 0$ , and  $W^{informed}$  is approached for  $\varepsilon \rightarrow 0$ . For  $\beta \leq \beta^{**}$ , the buyer again has no incentive to invest in concealing, the

seller invests in revealing if and only if this increases efficiency. For  $\beta^* < \beta < \beta^{**}$ , by Lemma 4, the expected profits from keeping the type private are positive (the expected profits in case of symmetric information are  $\beta [b(0) - c]$ ). Thus, the buyer would be willing to invest  $\varepsilon$  to obtain trade secret protection. According to (14), the resulting welfare loss compared to the case with symmetric information is:

$$(1 - \beta) \frac{(b(0) - c)(b(e^*) - e^* - b(0))}{b(e^*) - b(0)}.$$

This term is bounded above for all values of  $c \geq 0$ . It is also bounded above for  $(b(e^*) - b(0)) \rightarrow \infty$ , i.e. even if the gain from investing effort becomes arbitrarily large, the welfare loss never exceeds  $(1 - \beta)(b(0) - c)$ . Finally note, that for  $b(0) \rightarrow b(e^*)$ , since we impose by assumption (2) that  $b(e^*) - e^* > b(0)$ , we have  $(b(e^*) - e^* - b(0)) \rightarrow 0$  as well; thus, we get by l'Hospital's rule:

$$\lim_{b(0) \rightarrow b(e^*)} (1 - \beta) \frac{(b(0) - c)(b(e^*) - e^* - b(0))}{b(e^*) - b(0)} = (1 - \beta) [b(e^*) + e^* - c]. \blacksquare$$