Conversation With Secrets[*]

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Abstract

We analyze the sustainability of a conversation when one agent might be endowed with a piece of private information that affects the payoff distribution to its benefit. Such a secret can compromise the sustainability of conversation. Even without an obligation, the secret holder will disclose its secret if it prevents preemptive termination of the conversation. The non-secret holder lacks this possibility and stops the conversation. Competition and limited effectiveness of the conversation amplify this result of early disclosure and render the conversation process less sustainable. We discuss policy and managerial implications for industry standard development and joint ventures.

1 Introduction

Information is a valuable resource (Stigler, 1961) and information exchange fosters scientific progress and the accumulation of knowledge. Innovation often begins with an initial idea that must be shared with others for further improvements. Stein (2008) studies the sustainability of such conversations. In this context, a conversation is a collaborative exchange of *ideas* between competing agents for the purpose of improving the value of a technology or a business venture. We study how the sustainability of this innovation process through exchange of ideas is affected when one party holds a *secret* the disclosure of which is a strategic decision.

We define a *secret* as a piece of private information that is payoff-relevant, allowing its holder to extract larger rents from the conversation at the expense of the other agents. For example, a secret could be a patent protecting one of the essential technologies comprising an innovation under development or an exclusive contract over the supply of an essential input. An *idea*, the exchange of which is at the heart of the conversation, is a privately observed piece of information that increases the value of the conversation. Different from a secret that affects only the distribution of payoffs, if an idea is shared it increases both agents' payoffs but increases only its holder's payoffs if not shared.

An example discussed in Wade (1980) and Nelkin (1982) illustrates the working of secrets and the resulting strategic tensions. In 1977, research hematologists at the *University of California School of Medicine* succeeded in creating a new cell line that was found to produce interferon. They decided to share this half-baked (and unprotected) discovery with a colleague at a *Hoffmann-La Roche* funded research center. Without knowledge by the *UC School of Medicine* researchers, at the *Hoffmann-La Roche* funded center researchers had been working on a patent application which was missing such a medium for interferon production. Whereas the initial exchange of information resulted in the advancement of knowledge, the *UC School of Medicine* was deprived of potential licensing rents. Wade (1980) concludes that such rent expropriation has "the capacity to strain and rupture the informal traditions of scientific exchange." Similarly, Donald Kennedy, then president of Stanford University, predicts that "the

fragile network of informal communication that characterizes every especially active field is liable to rupture" (Nelkin, 1982).[1]

We develop a formal model to shed light on conversation incentives when one of the agents may or may not hold a secret. We ask: What is the impact of secrets and the disclosure of those secrets on the sustainability of the conversation? And, when does the secret holder disclose its secret? We address these questions by means of a dynamic model with asymmetric information that builds upon the conversation model in Stein (2008) where two agents, A and B, take turns in suggesting new ideas that increase the value of the conversation. Agents may be competitors, and if one does not share its new idea it obtains a competitive advantage over its rival. Our analytical framework builds on three key assumptions: *First*, as in Stein (2008) or Hellmann and Perotti (2011), ideas are complementary and an agent can find a new idea *only* if the other agent has previously shared an idea. *Second*, agent A but not agent B may be endowed with a secret which is private information and *ex ante* fully verifiable if disclosed. This implies a *secret-holder* and a *non-secret holder* agent A type. We assume, as is natural, that although a secret can be disclosed, the non-secret state cannot be verified. *Third*, the secret holder can extract a share of agent B's product-market profits. This share reflects the secret holder's bargaining leverage in *ex-post* negotiations. It is endogenously determined by assuming an increase in bargaining leverage with later disclosure of the secret. In our baseline model with private information about a secret there exists no obligation to disclose,[2] i.e., the secret holder can disclose *ex post* (after the end of the conversation) and fully exploit its bargaining leverage without incurring any costs.

When there is no secret the conversation is always sustainable if the two agents are not in competition (Proposition 1, as in Stein, 2008). When a secret has been disclosed the conditions for sustainable conversation are even *less* restrictive (Proposition 2). The actual existence of a secret therefore has a positive effect on conversation. However, when the secret has not been

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[1]Filed law suits were dropped after Hoffmann-La Roche had paid an undisclosed sum (Culliton, 1983).

[2]This initial assumption relates our model to Grossman and Hart (1980) who study voluntary disclosure of information when lying is illegal (in our model a lie would be detected immediately due to *ex-ante* verifiability) and no positive disclosure laws are in place (in our model there is no obligation to disclose).

disclosed, this outcome ceases to apply. We show that when a secret holder cannot rely on agent B to always share its ideas, in equilibrium the secret holder may be inclined to disclose *ex ante*, i.e., before the end of the conversation. This result is driven by the observation that, absent disclosure, agent B is inclined to preemptively terminate the conversation, depending on its beliefs about agent A's type. When agent B expects with sufficiently low probability that agent A holds a secret, then private information by way of a secret does not affect the sustainability of conversation. Agent B's conversation incentives are indeed not binding and the secret holder can delay disclosure to increase rent extraction until after the conversation ends. However, when agent B expects with high probability to face a secret holder (and thus expects with high probability to have a fraction of its product-market profits extracted), the secret holder will in equilibrium decide to disclose the secret and relinquish its private information to salvage the conversation process.

For this type of revelation (or signaling) game, we derive a *separating equilibrium* in which the secret holder type A discloses the secret and the non-secret holder type A (not having a secret to disclose) terminates the conversation (Proposition 3). This equilibrium survives the *Intuitive Criterion* and *D1* (Cho and Kreps, 1987) when the agents are direct competitors in the product market. The intuition for this equilibrium is straightforward: For the case with competition, when agent B stops the conversation absent disclosure, then the secret holder agent A discloses to allow for the conversation to continue. The non-secret holder agent A stops to gain a product-market advantage which reflects the agent's advantage from not sharing an idea. For the scenario in which the agents do not directly compete in the product market, we characterize a *hybrid equilibrium* in which the secret holder discloses the secret to salvage the conversation with a probability strictly between zero and one (Proposition 4).

These results warrant a few words of discussion. The secret holder reveals the secret when agent B has sufficiently high beliefs that A is endowed with a secret. In other words, the secret holder relinquishes its private information when in expectation such private information proves sufficiently costly for agent B. Because there exists no obligation to disclose, not disclosing comes only at the indirect cost of lower payoffs from conversation as it may induce agent

B to terminate preemptively. At the same time, the mere possibility that a secret exists creates an inefficiency that is standard in models where asymmetric information results in adverse selection. Because the non-secret holder cannot credibly communicate a secret, in the separating equilibrium the conversation comes to an end when agent A does not hold a secret. From an *ex-ante* perspective, then, private information negatively affects the sustainability of a conversation.[3] A similar logic applies in the hybrid equilibrium. We show that this inefficiency is more likely to arise with fiercer competition between the agents and a slower flow of new ideas (less effective conversation) (Proposition 5).

We discuss two specific applications of our model of conversation with secrets. In the literature on *industry standard development*, a prominent approach is to model the process of standardization as one of *ex-post* coordination on one out of a number of competing, existing technologies. We provide a model of *ex-ante* cooperation that addresses the alternative view of standardization as a "design process" to develop an "ideal technology" (Farrell and Saloner, 1988). Our approach thus complements the existing literature on the functioning of standard-setting organizations (SSO) (Rosenkopf, Metiu, and George, 2001; Simcoe, 2012b; Farrell and Simcoe, 2012; among others).[4] The results suggest that *ex-post* disclosure of standard-essential patents is more prevalent in committees that are more effective in their development process and characterized by soft competition among its members. Conversely, ineffective committees with competitive members experience early termination of the development process and standards of lower quality. We conclude by discussing *ex-ante license commitments* (e.g., *RAND* commitments), *implied waivers* of patent rights, and *certificates* as remedies of the inefficiency caused by private information about the existence of standard-essential patents.

Business (or joint) ventures demonstrate another example for conversation among competitors when there is *ex-ante* asymmetric information. We apply our framework to the question of sustainability of a joint venture in the presence of asymmetric information. In our illustration,

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[3]A secret holder in our model is analogous to the seller of a "lemon" in Akerlof (1970), a high-risk buyer of insurance in Rothschild and Stiglitz (1976), or a high-risk borrower in Stiglitz and Weiss (1981). The presence of asymmetric information creates scope for market breakdown which is analogous to the inefficient termination of conversation in our model.

[4]For a more general treatment of committees see Li, Rosen, and Suen (2001) or Visser and Swank (2007).

private information held by one of the partners is an exclusive contract over the supply of an essential input. Through this, the secret holder can *ex post* extract side payments from its partner. The model predicts inefficient termination of ventures for fiercer competition between the partners and a lower potential value of the partnership. We briefly discuss results from the management literature consistent with our theoretical findings.

Our model relates to the literature on disclosure of (protected and unprotected) ideas and rent expropriation. One strand of this literature has focused on the role of information disclosure in innovation processes, developing on the seminal work by Arrow (1962) and his "disclosure paradox." In an environment where intellectual property protection is poor or absent, Anton and Yao (1994) show how inventors can limit the risk of expropriation of their ideas from users by means of contingent contracts, and Anton and Yao (2002) show that innovators can engage in partial disclosure to optimally sell their ideas. Furthermore, Gans, Murray, and Stern (2013) determine the conditions under which it is optimal to disclose scientific knowledge via publication, patenting, or both. A second strand of the literature studies the incentives of agents with competing interests to exchange information. Stein (2008) studies the sustainability of such conversation between competitors, and Hellmann and Perotti (2011) look at the performance of different organizational forms (firms versus markets) in fostering new ideas and technologies. Moreover, Dziuda and Gradwohl (2013) analyze agents' incentives to jointly develop a project under privacy concerns, in Augenblick and Bodoh-Creed (2012) agents exchange information about their types to determine whether a profitable match is viable, and Guttman, Kremer, and Skrzypacz (2012) study the problem of voluntary disclosure of multiple pieces of private information in a dynamic environment. We develop on both strands of the literature by studying how the sustainability of a communication process between competing agents through exchange of *ideas* is affected when a party in the conversation holds a *secret*.

The article is structured as follows: Section 2 presents the model of conversation with secrets, in Section 3 we summarize the results on the sustainability of conversation without private information, and in Section 4 we present the main results on conversation with private information and provide welfare effects. We discuss our results in the context of industry

standard development and business ventures in Section 5. Section 6 concludes. The formal proofs of the results are relegated to Appendix A.

2 Model

Structure

Two agents, A and B, take actions in periods $t \geq 1$. A moves in odd periods and B moves in even periods. The two agents engage in a conversation that requires the exchange of ideas.

Definition 1 (Idea). *An idea is a payoff relevant and privately observed piece of information. If shared, it has a positive effect on both agents' payoffs. If not shared it has a positive effect on the holder's payoffs and no effect on the non-holder's payoffs.*

Each period t consists of two sub-stages: In sub-stage 1 an *idea* arrives with probability $p_t \in [0, 1)$. Concurrently with its first idea, agent A may have a *secret*.[5] If no new idea arrives in this sub-stage, the game ends and payoffs are realized. If a new idea has arrived in sub-stage 1, then in sub-stage 2 agents take actions s_t. For our purposes a *secret* is defined as follows:

Definition 2 (Secret). *A secret is a payoff relevant and privately observed verifiable piece of information. It has a positive effect on the secret holder A's payoffs and a negative effect on agent B's payoffs.*

Our setup comprises two distinct types of private information. First, *ideas* arrive continually. If shared an *idea* has a positive impact on both agents' payoffs. However, the holder of an idea may have a private incentive to conceal if the payoff increase from sharing is lower than from not sharing. For conversation to take place in each period, the sharing of this private information must be incentive compatible. Second, agent A may enter the game endowed with a *secret*. By observing the actions of a potential secret holder, agent B can infer the existence of a secret.

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[5]Our results do not change qualitatively when asymmetric information is two-sided, i.e., both agents may have a secret (Ganglmair and Tarantino, 2012).

This second type of private information endogenously affects the distribution of final payoffs and may thus compromise the sustainability of the conversation.

[Figure 1 about here.]

We depict the structure of the game when agent A holds a secret in Figure 1. After an idea has arrived, in any period $t \in T_B$ agent B can *continue (C)* the conversation by sharing the new idea with agent A. In this case the conversation proceeds to period $t+1 \in T_A$. Otherwise agent B can *stop (S)* the conversation by not sharing the idea, in which case the game ends and payoffs are realized. Here, T_A and T_B denote the sets of odd and even integers when agents A and B move. Agent B's action set is $\mathscr{B}_t = \{C, S\}$ if $t \in T_B$ and $\mathscr{B}_t = \emptyset$ for $t \notin T_B$.

Agent A's action set in $t \in T_A$ depends on its type. For a non-secret holder, denoted by $A = A_0$, the action set is the same as for B, $\mathscr{A}_t = \{C, S\}$ if $A = A_0$. A secret holder, denoted by $A = A_1$, must also decide whether to reveal its secret, giving rise to three distinct actions. The secret holder can *disclose (D)*, which means share the new idea and reveal its secret. We will refer to this as *ex-ante disclosure* as the secret is disclosed during the conversation. Second, the secret holder can *continue (C)* the conversation by sharing the new idea but not revealing the secret. In both D and C the conversation proceeds to the next period. Third, the secret holder can *stop (S)* the conversation by not sharing the new idea. In this case, the conversation ends and payoffs are realized. Once the secret holder has disclosed the secret, its action set is the same as a non-secret holder's: $\mathscr{A}_t = \emptyset$ if $t \notin T_A$ and

$$
\mathscr{A}_t = \begin{cases} \{C, D, S\} & \text{if } t \in T_A,\ A = A_1 \text{ before disclosure,} \\ \{C, S\} & \text{if } t \in T_A,\ A = A_0, \text{ or if } A = A_1 \text{ after disclosure} \end{cases}
$$

Note that the secret is fully verifiable *ex ante*, implying that a non-secret holder agent A_0 cannot credibly claim that it *does* have a secret, nor can a secret holder credibly communicate that it *does not* have a secret.

We assume that whenever the conversation ends and the secret has not yet been revealed, the secret holder will disclose after the end of the conversation.[6] We refer to this as *ex-post disclosure*, which can occur when B stops, A_1 stops, or a new idea fails to arrive.

The probability with which a new idea arrives in sub-stage 1 of any given period t is

$$
p_t(s_{t-1}) = \begin{cases} 0 & \text{if } s_{t-1} = S \\ p \in (0,1) & \text{if } s_{t-1} \in \{C, D\}. \end{cases} \tag{1}
$$

This arrival process captures the complementarity in the production of ideas, as in Stein (2008) or Hellmann and Perotti (2011), that is, ideas foster the arrival of new ideas to be exchanged in conversation.

At the beginning of any given period $t \in T_i$, an agent $i = A, B$ observes the history $\Omega(t)$ of the actions taken in all periods $t' < t$,

$$
\Omega(t) := \left\{ s_{t'} | t' < t, s_{t'} \in \mathscr{A}_{t'} \text{ if } t' \in T_A \text{ and } s_{t'} \in \mathscr{B}_{t'} \text{ if } t' \in T_B \right\}. \tag{2}
$$

The arrival of a new idea in t is privately observed. Moreover, agent A's type is private information. Agent B has a prior belief $\pi > 0$ that A holds a secret, and beliefs $\pi = Pr(A = A_1)$ and $1 - \pi = Pr(A = A_0)$ are common knowledge. We solve this game of asymmetric information using perfect Bayesian equilibrium as the equilibrium concept. Our interest lies in a secret holder's voluntary disclosure. We therefore assume for the main results that in any period t the agents cannot precommit to any actions taken in $t' > t$. As part of our treatment of possible applications in Section 5 we discuss the effect of contractual and institutional policies.

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[6]The reason for this assumption is the simple observation that, once the conversation has ended, revealing the secret is strictly dominant.

Payoffs

The payoffs are realized only after the conversation game ends. Suppose the agents are competitors and $\theta \geq 0$ is the degree of product-market competition. More specifically, suppose each agent holds a monopoly in a fraction $1-\theta$ of a unit-sized market and competes on the remaining fraction. Agent i's monopoly profits are $v(n_i)$, where n_i is the number of ideas to which the agent i has access.[7] The competitive profits depend on the agents' respective number of ideas: If they both have the same stock of ideas, $n_i = n_{-i}$, competition washes out the value of conversation and profits equal zero. If an agent i has an additional idea, $n_i = n_{-i} + 1$, and decides to not reveal it, then it has a competitive advantage and generates profits $v(n_i) - v(n_i - 1)$ in the competitive segment. An agent i's product-market profits then become

$$R_i = (1 - \theta)\, v(n_i) + \theta \max \left\{0, v(n_i) - v(n_{-i})\right\}. \tag{3}$$

Function $v(n_i)$ increases at a diminishing rate, with $v(0) = 0$. It captures the product-market effects of conversation: The conversation can increase the consumers' reservation value of a good (at constant costs), or it lowers the costs of production of a good (at constant value).

If agent A holds a secret, it can extract a fraction of B's product-market profits. Let $\sigma \in [0, 1]$ denote this fraction and be common knowledge. It depends on the timing of disclosure, $\tau \in \mathbb{N}^+$, and increases in τ at a diminishing rate, with $\sigma(\tau) > 0$ for all $\tau > 1$ and $\sigma(1) = 0$.[8] The payoffs arising from the conversation are as follows: The secret holder's payoffs are $R_A + \sigma(\tau)R_B$ and agent B's payoffs are $(1 - \sigma(\tau))\,R_B$.[9] When there is no secret, the payoffs equal R_i for $i = A, B$.

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[7]The number of ideas is the sum of the ideas generated by agent i and the ideas shared by agent $-i$.

[8]In our application of the model to standard setting, this bargaining leverage is the result of holdup due to lock-in. For instance, firms in innovative and dynamic industries invest in standard-specific technologies already during the process when they expect a short-lived market for the final product.

[9]Because the secret induces the payment of a transfer equal to a share $\sigma(\tau)$ of agent B's product-market profits but affects neither the value of ideas nor the production of ideas, the realized joint value of conversation is independent of agent A's disclosure.

Conversational Equilibrium

We derive the conditions under which a *conversational equilibrium* can be sustained. Following Stein (2008), we define such an equilibrium as one in which agents always share new ideas. The conversation then continues until a new idea fails to arrive, with each agent having access to the same number of ideas, $n_i = n_{-i}$. We postulate such an equilibrium exists and verify that no agent has an incentive to deviate. In particular, we look at the conditions under which a conversational equilibrium can be sustained in the absence and in the presence of secrets. Moreover, in the latter scenario we specify the timing of equilibrium disclosure.

3 Conversation Without Secrets

We first present the benchmark case without a secret and characterize the conditions that sustain a conversational equilibrium in this environment. This means A does not hold any secret and this is common knowledge.[10] The model then boils down to the conversation model in Stein (2008) in which asymmetric information concerns only the arrival of a new idea.[11]

In the model of conversation without secrets, agent i's payoffs under the conversational equilibrium are equal to $(1 - \theta) V(t)$, where

$$V(t) \;=\; \sum_{k=0}^{\infty} p^k (1-p) \, v(t+k). \tag{4}$$

Given agent i shares the idea in t, both agents have access to t ideas. With probability $(1-p)$, there will be no further ideas after time t, and agents' payoffs are $(1-\theta) v(t)$; with probability $p(1-p)$, there will be exactly one further idea after t, so payoffs equal $(1-\theta) v(t+1)$; with probability $p^2(1-p)$ there are exactly two further ideas; and so forth.

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[10]This *no-secret* scenario is equivalent to the one in which agent A reveals the secret in $t = 1$ so that $\tau = 1$ and $\sigma(\tau) = 0$.

[11]Comparing our main results with this benchmark helps us understand the effect a secret has on the sustainability of conversation. Moreover, in order to isolate the effect of uncertainty about a secret from the effect of the secret itself we introduce in Proposition 7 below a benchmark in which agent B knows for sure it will be held up ($\pi = 1$) but does not know what the secret entails.

If in period t agent i decides to stop and not share its idea with agent $-i$, so that $n_i = t = n_{-i} + 1$, its payoffs equal

$$(1 - \theta)\, v(t) + \theta\, [v(t) - v(t-1)] = v(t) - \theta v(t-1). \tag{5}$$

Thus agent i in t chooses to continue the conversation by sharing its idea as long as

$$\frac{V(t) - v(t-1)}{v(t) - v(t-1)} \geq \frac{1}{1 - \theta}. \tag{6}$$

For the conversational equilibrium to be sustainable, this condition must hold for *all t*.

Proposition 1 (Stein (2008) (Proposition 2)). *A conversational equilibrium is sustainable if, and only if, condition* (6) *holds for all t. Condition* (6) *is less restrictive for more effective conversation processes (higher p) and a lower degree of competition (lower θ). For $\theta = 0$, the condition always holds.*

Proposition 1 sets out the benchmark condition that determines the sustainability of the conversation in the absence of asymmetric information about the existence of a secret. The expected joint payoffs from the conversational equilibrium are

$$W = 2\,(1 - \theta)\, V(1). \tag{7}$$

Because (6) always holds if $\theta = 0$, the conversational equilibrium in absence of a secret is always sustainable when the two agents are not in competition. We show that this does not necessarily hold true when there is asymmetric information about a secret. Agent B might threaten to (preemptively) stop the conversation even when it does not compete with agent A.

4 Conversation and Disclosure of Secrets

We now introduce the secret and analyze the role it plays in the conversation model. In this scenario agent B forms beliefs about agent A's type. We proceed in three steps. First, we

derive conditions under which the conversational equilibrium is sustainable given the secret has been disclosed. We then study the disclosure of the secret as a signaling game in any given t. Finally, we derive conditions under which the signaling game in this period t is reached, thus determining the timing of equilibrium disclosure. Note that Proposition 1 describes the communication incentives for the non-secret holder (A_0) for this game with a secret: Not having any secret to disclose, A_0 continues if condition (6) holds true and, if $\theta > 0$, stops whenever it anticipates B to stop the conversation.

Conversation After Disclosure

Denote by $\tilde{\tau}$ the period in which secret holder A_1 discloses the secret during the conversation (*ex ante*) and suppose the secret has been disclosed by A_1, so that $t > \tilde{\tau}$. Agent i's payoffs are denoted by a function $U_i(s_t|\tilde{\tau})$, $i = A, B$, of its action $s_t \in \mathscr{A}_t = \mathscr{B}_t = \{C, S\}$.

First, let agent A move in t. As before, under a conversational equilibrium for agent A's payoffs when it continues we assume that agent B always continues. In that case, both agents have access to the same number of ideas and expect product-market profits of $(1 - \theta) V(t)$. On top of this, disclosure in $\tilde{\tau}$ allows agent A to extract a constant fraction $\sigma(\tilde{\tau})$ of B's product-market profits. Thus, A's payoffs when it continues in t are

$$U_A(C|\tilde{\tau}) = (1 + \sigma(\tilde{\tau})) (1 - \theta) V(t). \tag{8}$$

Agent A's payoffs when it stops in t are

$$U_A(S|\tilde{\tau}) = (1 - \theta) v(t) + \theta [v(t) - v(t-1)] + \sigma(\tilde{\tau}) (1 - \theta) v(t-1). \tag{9}$$

Disclosure allows A to extract a share of B's product-market profits $(1 - \theta) v(t-1)$. Note that because the number of ideas is not symmetric (i.e., $n_A = t$ whereas $n_B = t - 1$) agent A has an advantage $v(t) - v(t-1)$ in the competitive segment of its market. Agent A prefers to continue

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in t if $U_A(C|\tilde{\tau}) \geq U_A(S|\tilde{\tau})$ or

$$(1 + \sigma(\tilde{\tau})) \frac{V(t) - v(t-1)}{v(t) - v(t-1)} \geq \frac{1}{1 - \theta}. \tag{10}$$

Because $\sigma(\tau) \geq 0$ for $\tau \geq 1$, this condition is less restrictive than condition (6).

Agent B's payoffs when it continues in t under a conversational equilibrium are

$$U_B(C|\tilde{\tau}) = (1 - \sigma(\tilde{\tau})) (1 - \theta) V(t). \tag{11}$$

Its payoffs when it stops in t are

$$U_B(S|\tilde{\tau}) = (1 - \sigma(\tilde{\tau})) [v(t) - \theta v(t-1)]. \tag{12}$$

Agent B prefers to continue in t if $U_B(C|\tilde{\tau}) \geq U_B(S|\tilde{\tau})$ or

$$\frac{V(t) - v(t-1)}{v(t) - v(t-1)} \geq \frac{1}{1 - \theta}. \tag{13}$$

This condition is equivalent to condition (6) in the scenario without a secret. As a result, if condition (6) holds for all $t > \tilde{\tau}$, both agents will always continue conversation after disclosure of the secret until a new idea fails to arrive.

Proposition 2 (Post-Disclosure Communication). *If the conversational equilibrium is sustainable in the scenario without a secret then it is sustainable in the scenario with a secret after the secret has been disclosed.*

The intuition for this result is straightforward. Once the secret has been revealed and $\sigma(\tilde{\tau})$ fixed, it is in the agents' best interest to maximize the continuation payoffs by contributing to the process as long as possible. This is because agent A receives a fraction $\frac{1+\sigma(\tilde{\tau})}{2} > 0$ of the total benefits of continuing the conversation. Moreover, if condition (6) holds, there are no gains for B from stopping the process.

In the next section, we will show that agent B's expectations of the secret compromise the sustainability of the conversation, because the threat of a secret induces agent B to preemptively stop for fear of excessive rent seeking by A. Proposition 2 then implies that the existence of the secret and its disclosure renders the conversational equilibrium (weakly) more sustainable than in the presence of asymmetric information about the secret. Our working assumption in what follows is that after the secret is disclosed the conversational equilibrium is sustainable with condition (6) satisfied.

Disclosure of the Secret

The conversation before disclosure of the secret and the disclosure of the secret are characterized by a conflict of interest between the agents: A secret holder aspires to disclose the secret as late as possible. Agent B on the other hand prefers early disclosure to late disclosure as the negative payoff effects from a secret are stronger the later the secret is revealed. Indeed, not having seen a secret revealed, agent B may stop the conversation in order to avoid excessive extraction of its product-market profits. This may in return induce agent A to disclose the secret earlier than aspired.

In a setting in which agent A is never constrained by agent B's continuation decision, a secret holder will seek to disclose only after the end of the conversation. In this case the timing of such *ex-post* disclosure coincides with the final period of the conversation. Alternatively, disclosure may take place during the conversation in $\tilde{\tau} \in T_A$. A necessary condition for such *ex-ante* disclosure is that agent B's pre-disclosure communication condition is violated.

In the sequel, at the beginning of any period t the secret has not yet been revealed and agent A types are indexed by $h = 1, 0$. Agent i's payoffs in t are a function $U_i(s_t|\tau)$, $i = A_h, B$, of its action $s_t \in \mathscr{A}_t$ if $t \in T_A$ or $s_t \in \mathscr{B}_t$ if $t \in T_B$.

Aspired Disclosure

Consider the case in which agent B does not constrain a secret holder A_1's decision, meaning B continues in all t as in the conversational equilibrium. This allows us to determine the period τ^a

for which it is individually optimal for a secret holder A_1 to disclose when it is not constrained by agent B's communication incentives. We will refer to this disclosure date τ^a as *aspired disclosure.*

Suppose agent A_1 aspires to disclose in $\tilde{\tau}$. Its payoffs in t when it continues in t and all $t' > t$, except $t = \tilde{\tau}$ when it discloses, and when B continues in all $t' > t$, are

$$U_{A_1}(C|\tilde{\tau}) = (1 - \theta) \left[V(t) + P(t|\tilde{\tau}) \right] \tag{14}$$

with

$$P(t|\tilde{\tau}) \;=\; \sum_{k=0}^{\tilde{\tau}-t-1} p^k (1-p) \, v(t+k)\sigma(t+1+k) + p^{\tilde{\tau}-t}\sigma(\tilde{\tau})V(\tilde{\tau}). \tag{15}$$

This $P(t|\tilde{\tau})$, increasing in $\tilde{\tau}$, is the portion a secret holder can extract from B's expected product-market profits. Conversation reaches $\tilde{\tau}$ with probability $p^{\tilde{\tau}-t}$; the associated continuation payoff the secret holder can extract is $\sigma(\tilde{\tau})V(\tilde{\tau})$. If conversation does not reach $\tilde{\tau}$, then the secret holder discloses in the terminal period (when a new idea has failed to arrive).

The secret holder's payoffs from disclosing in t are

$$U_{A_1}(D|t) = (1 - \theta) \left[V(t) + P(t|t) \right]. \tag{16}$$

When A_1 decides to continue in t and disclose in its next decision period, $\tilde{\tau} = t + 2$, if that period is reached, then its payoffs are

$$U_{A_1}(C|t+2) = (1 - \theta) \left[V(t) + P(t|t+2) \right], \tag{17}$$

which is larger than the payoffs from disclosing in t. Finally, agent A_1's payoffs when it stops

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in t are

$$U_{A_1}(S|t) = v(t) + [(1-\theta)\,\sigma(t) - \theta]\,v(t-1), \tag{18}$$

which is equivalent to equation (9) when $\tilde{\tau} = t$. Lemma 1 describes a secret holder A_1's best response when agent B always continues.

Lemma 1. *Let condition* (6) *be satisfied and let B continue in all t. Agent A_1's aspired disclosure date is $\tau^a = \infty$. It continues in all t until a new idea fails to arrive and discloses the secret ex post after conversation ends.*

Constrained Disclosure

Agent A being able to anticipate that B continues in all t (as in the derivation of *aspired disclosure* in Lemma 1) is not necessarily a reasonable assumption. This is because agent B faces the following tradeoff: Continuing the conversation by sharing a new idea increases the value of conversation and agent B's product-market profits; however, it does so at the cost of a higher fraction $\sigma(\cdot)$ of its profits that agent A can extract. Similarly, stopping the conversation limits this rent extraction, but comes at the cost of unrealized future values of conversation. The optimal action by agent B may be to preemptively terminate the conversation.

To formalize the problem of a secret holder constrained by B's continuation decision, let π_t denote B's beliefs in $t \in T_B$ about agent A's type, where $\pi_t = Pr(A = A_1|\Omega_t)$ and Ω_t denotes the history of all actions taken in all periods $t' < t$. Suppose B anticipates a secret holder A_1 to disclose the secret in $\tilde{\tau} \geq t$. Then B's payoffs from continuing in t under a conversational equilibrium are

$$U_B(C|\tilde{\tau}) = (1-\theta)\,[V(t) - \pi_t P(t|\tilde{\tau})]. \tag{19}$$

If agent B stops in t so that A_1 discloses (*ex post*) in t, then B's payoffs are

$$U_B(S|t) = (1 - \pi_t \sigma(t)) \left[v(t) - \theta v(t-1)\right]. \tag{20}$$

Lemma 2 describes agent B's best response when it anticipates a secret holder A_1 to disclose the secret in $\tilde{\tau} \in T_A$ and to continue in all other $t \in T_A \setminus \{\tilde{\tau}\}$.

Lemma 2. *Let condition* (6) *be satisfied and let agent B anticipate a secret holder A_1's ex-ante disclosure in $\tilde{\tau}$. Agent B continues in $t < \tilde{\tau}$ if, and only if,*

$$\pi_t \leq \bar{\pi}_t(\tilde{\tau}) \equiv \frac{(1 - \theta)V(t) - [v(t) - \theta v(t-1)]}{(1 - \theta) P(t|\tilde{\tau}) - \sigma(t) [v(t) - \theta v(t-1)]}. \tag{21}$$

1. *The cutoff value $\bar{\pi}_t(\tilde{\tau})$ is strictly decreasing in $\tilde{\tau}$.*

2. *If condition* (6) *holds with strict inequality, then $\bar{\pi}_t(\tilde{\tau})$ is strictly positive, zero otherwise. It is strictly less than one if*

$$(1 - \sigma(t)) [v(t) - \theta v(t-1)] > (1 - \theta) [V(t) - P(t|\tilde{\tau})]. \tag{22}$$

Agent B is more inclined to continue the conversation in t when *(i)* its beliefs π_t are low (so that $\pi_t \leq \bar{\pi}_t(\tilde{\tau})$), and *(ii)* it anticipates a secret holder A_1 to disclose early (because $\bar{\pi}_t(\tilde{\tau})$ is decreasing in $\tilde{\tau}$). When condition (6) is slack so that $\bar{\pi}_t(\tilde{\tau}) > 0$, then there exist values for the prior belief $\pi > 0$ such that agent B will never stop the conversation.

Lemma 3 describes A's best response when it anticipates agent B to continue in all periods up to $t - 1$ and to stop in $t + 1$.

Lemma 3. *Suppose period t is reached. Let condition* (6) *be satisfied and let condition* (21) *be violated so that agent B stops in $t + 1$ if $s_t = C$.*

1. *The non-secret holder A_0 stops in t if $\theta > 0$. For $\theta = 0$, A_0 is indifferent.*

2. *The secret holder A_1 discloses in t if, and only if,*

$$\frac{(1 + \sigma(t)) V(t) - v(t)}{\sigma(t+1) [p [v(t+1) - \theta v(t)] + (1-p)(1-\theta) v(t)]} \geq \frac{1}{1-\theta}. \quad (23)$$

Otherwise, the secret holder continues in t.

For a secret holder it is never optimal to stop in t. Whether or not it continues or discloses depends on how its tradeoff is resolved: Continuing in t jeopardizes future conversation because B stops in $t+1$, but it allows A_1 to delay disclosure of the secret until $t+1$, implying a larger fraction $\sigma(t+1)$. Disclosing in t, on the other hand, salvages the conversation process because, given condition (6) holds, B will continue in $t+1$ and all future periods. However, disclosing in t comes at the cost of lower rent extraction as $\sigma(t) < \sigma(t+1)$.

Combining our findings from Lemmata 1, 2, and 3 for the agents' best responses gives rise to two distinct scenarios. In the first condition (21) is satisfied in $t+1$ so that B continues in $t+1$ when A continues in t. Here, the unique pure-strategy PBE of the signaling game played in this t is a *pooling equilibrium* in which both agent A types continue the conversation in t and B continues in $t+1$. The second case is the one in which condition (21) is violated for $t+1$ so that B stops if A continues in t. The unique pure-strategy PBE is a *separating equilibrium* in which the secret holder A_1 discloses its secret in t, the non-secret holder A_0 stops conversation, and agent B continues in $t+1$ when the secret holder discloses. For this equilibrium and the analysis to follow we assume that condition (23) holds true. This means that for the secret holder it is more important to continue the conversation than concealing the secret and extracting higher rents in $t+1$.[12] Note that for these results period t has been reached without disclosure as a result of both agents continuing in all $t' < t$. We return to this in Proposition 6.

Definition 3 (Pure-Strategy Perfect Bayesian Equilibrium (PBE)). *Let (s_t^1, s_t^0) with $s_t^h \in \mathscr{A}_t$ be agent A's pure strategy profile, with $h = 1, 0$; let $\left(s_{t+1}^C, s_{t+1}^D\right)$ with $s_{t+1}^{s_t} \in \mathscr{B}_{t+1}$ be agent B's*

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[12]In the Online Appendix, we derive a separating equilibrium in pure strategies when condition (23) is violated. In this equilibrium, a secret holder agent A continues and a non-secret holder agent A stops in t when anticipating B stopping in $t+1$. We do not further focus on this equilibrium because we are interested in the conditions under which a secret holder relinquishes its private information during a conversation.

pure-strategy profile, and let $\left(\pi_{t+1}^C, \pi_{t+1}^D\right)$ *with* $\pi_{t+1}^{s_t} \equiv Pr(A_1|s_t, \Omega_{t-1}) \in [0,1]$ *be agent B's beliefs in its information sets. A perfect Bayesian equilibrium (PBE) in pure strategies is denoted by* $\{(s_t^1, s_t^0), (s_{t+1}^C, s_{t+1}^D); (\pi_{t+1}^C, \pi_{t+1}^D)\}$.

Proposition 3 (Pure-Strategy PBE). *Let conditions* (6) *and* (23) *be satisfied.*

1. *If B's prior beliefs are low,* $\pi \leq \bar{\pi}_{t+1}(\tau^a)$*, the game of conversation with secrets has a unique pure-strategy PBE. This pooling equilibrium is*

$$\{(C,C), (C,C); (\pi_{t+1}^C = \pi, \pi_{t+1}^D = 1)\}. \tag{PE}$$

2. *If B's prior beliefs are high,* $\pi > \bar{\pi}_{t+1}(\tau^a)$*, the game of conversation with secrets has a unique pure-strategy PBE. This separating equilibrium is*

$$\{(D,S), (S,C); (\pi_{t+1}^C > \bar{\pi}_{t+1}(\tau^a), \pi_{t+1}^D = 1)\}. \tag{SE}$$

Lemma 4. *With competition,* $\theta > 0$*, the pure-strategy PBE* (PE) *and* (SE) *survive the Intuitive Criterion and D1. Without competition,* $\theta = 0$*,* (PE) *survives and* (SE) *fails to survive the criteria.*

In the pooling equilibrium (PE) for sufficiently low π, the threat of a secret holder and the associated expected negative payoff effects for B are relatively small. Agent B will continue the conversation in $t + 1$ when agent A continues in t. Therefore, the secret holder has no incentive to disclose. Both agent A types will then continue in t. For higher values of π the continuation of the conversation depends on A's decision in t. In the separating equilibrium (SE), A_1 discloses the secret in t because B would otherwise stop. A non-secret holder A_0 cannot disclose a secret it does not hold to prevent B from stopping in $t + 1$ and will therefore stop the conversation in t to gain from the product-market advantage it has at this point.

Given that t has been reached, the expected joint payoffs from the pooling equilibrium (PE) when both agents continue in all t are

$$W^{PE} = 2\left(1 - \theta\right)V(1). \tag{24}$$

For the separating equilibrium (SE), let $t = \tau^*$ denote the period in which the secret holder discloses and the non-secret holder stops the conversation. The expected joint payoffs from the separating equilibrium are then equal to

$$
\begin{aligned}
W^{SE} =\ & 2\pi\left(1 - \theta\right)V(1) + \\
& \left(1 - \pi\right)\left[2\left(1 - \theta\right)\sum_{k=0}^{\tau^*-1} p^k\left(1 - p\right)v(1 + k) + p^{\tau^*}\left[v(\tau^*) - \theta v(\tau^* - 1)\right]\right]. \tag{25}
\end{aligned}
$$

In Proposition 4 we present a mixed-strategy PBE (*hybrid equilibrium*) for the scenario in which the agents do not compete, $\theta = 0$, and the separating equilibrium (SE) does not survive the refinements when condition (21) is violated.[13]

Definition 4 (Mixed-Strategy Perfect Bayesian Equilibrium (PBE)). *Let $\alpha_h^{s_t} = Pr(s_t^h)$ denote the probability agent A_h assigns to action $s_t^h \in \mathscr{A}_t$. Then $((\alpha_1^C, \alpha_1^D, \alpha_1^S), (\alpha_0^C, \alpha_0^S))$ is agent A's mixed strategy profile. Let $\beta_{s_t}^{s_{t+1}} = Pr(s_{t+1}|s_t)$ denote the probability agent B assigns to action $s_{t+1} \in \mathscr{B}_{t+1}$ when agent A plays s_t in t. Then $((\beta_C^C, \beta_C^S), (\beta_D^C, \beta_D^S))$ is agent B's mixed strategy profile. A perfect Bayesian equilibrium in mixed strategies (hybrid equilibrium) is denoted by $\{((\alpha_1^C, \alpha_1^D, \alpha_1^S), (\alpha_0^C, \alpha_0^S)), ((\beta_C^C, \beta_C^S), (\beta_D^C, \beta_D^S)); (\pi_{t+1}^C, \pi_{t+1}^D)\}$.*

Proposition 4 (Mixed-Strategy PBE). *Let conditions (6) and (23) be satisfied and $\theta = 0$. If B's prior beliefs are high so that condition (21) is violated but less than one, there exists a mixed-strategy PBE*

$$\left\{((\alpha_1^*, 1 - \alpha_1^*, 0), (1, 0), ((\beta^*, 1 - \beta^*), (1, 0)); (\pi_{t+1}^C > \bar{\pi}_{t+1}(\tau^a), \pi_{t+1}^D = 1)\right\} \tag{HE}$$

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[13]There also exist mixed-strategy PBE for $\theta > 0$. We do not present these equilibria for the sake of brevity, because for this case with competition the pure-strategy equilibrium (SE) survives the equilibrium refinements.

with $0 < \alpha_1^* < 1$, $0 < \beta^* < 1$, *and*

$$\pi_{t+1}^C = \frac{\pi \alpha_1^*}{\pi \alpha_1^* + (1 - \pi)}.$$

Lemma 5. *The mixed-strategy PBE* (HE) *survives the Intuitive Criterion and D1.*

Without competition, the non-secret holder A_0 is indifferent between continue and stop (see Lemma 3) if agent B terminates the conversation in $t + 1$. In equilibrium the agent prefers continue to stop when agent B continues with strictly positive probability. Although a pooling equilibrium, in which both agent A types continue, is not feasible (condition (21) is violated), a situation in which the secret holder can seek to delay disclosure by continuing with strictly positive probability, $\alpha_1^* > 0$, is an equilibrium outcome. In this *hybrid equilibrium*, agent B responds by continuing with strictly positive probability, $\beta^* > 0$, to render the secret holder indifferent between continuation and disclosure, and to induce the non-secret holder A_0 to continue with certainty.

Because for $\theta = 0$ the separating equilibrium (SE) in Proposition 3 does not survive the refinements, this hybrid equilibrium is the only surviving equilibrium when $\theta = 0$. Therefore, without competition and with condition (21) violated, there cannot be a perfect Bayesian equilibrium in which the secret holder A_1 discloses with certainty, and the non-secret holder A_0 stops with strictly positive probability.

Discussion of the Results for the Signaling Game

Both agents continue in t if the prior belief π is low and the perfect Bayesian equilibrium is the pooling equilibrium. If this is true in all t, then the conversational equilibrium is sustainable. Consequently, asymmetric information does not undermine the sustainability of the conversation for sufficiently low prior beliefs about agent A's type. The expected joint payoffs from the conversation, W^{PE}, in equation (24) are equal to the benchmark payoffs, W, in equation (7).

As π rises above the critical threshold in a given $t + 1$, the pure-strategy perfect Bayesian equilibrium is the separating equilibrium (SE) and calls for the disclosure of the secret in order

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for the conversation to continue. There are two immediate implications: First, the secret holder relinquishes private information without the obligation to do so. This allows for the conversation to continue and presents a positive effect on the sustainability of the conversation. However, if agent A does not hold a secret, the conversation breaks down, and this breakdown gives rise to an inefficient outcome. We can quantify this effect by comparing the expected value of the conversation in the benchmark case without a secret, W, in equation (7) to the payoffs under the separating equilibrium (SE), W^{SE}, in equation (25). We obtain

$$
\begin{aligned}
W - W^{SE} &= p^{\tau^*} \left[2\left(1 - \theta\right) \sum_{k=0}^{\infty} p^k \left(1 - \theta\right) v(\tau^* + k) - \left[v(\tau^*) - \theta v(\tau^* - 1)\right] \right] \\
&= p^{\tau^*} \left[2\left(1 - \theta\right) V(\tau^*) - \left[v(\tau^*) - \theta v(\tau^* - 1)\right]\right] > 0. \quad (26)
\end{aligned}
$$

This expression is strictly positive because $(1 - \theta) V(\tau^*) \geq v(\tau^*) - \theta v(\tau^* - 1)$ by condition (6) and $V(\tau^*) > 0$. Such an inefficiency is standard in models with asymmetric information and is due to the fact that the non-secret holder A_0 cannot credibly communicate the existence of the secret (i.e., its type).

The absence of competition reduces the likelihood for the breakdown of conversation because in the ensuing hybrid equilibrium (HE) the non-secret holder A_0 continues even though agent B threatens to stop with strictly positive probability after observing A continue. The reason for this is that in the absence of competition the non-secret holder A_0 is not concerned about stopping the conversation in t and obtaining a product-market advantage when it anticipates B to stop in $t + 1$. However, agent B will in equilibrium preemptively terminate the conversation with strictly positive probability equal to $(1 - \beta^*)\left[1 - (1 - \alpha_1^*)\pi\right] \in (0, 1)$. The expected joint payoffs from the hybrid equilibrium, W^{HE}, lie between the payoffs from the pooling equilibrium, W^{PE}, and the separating equilibrium, W^{SE}.

This discussion gives rise to normative implications concerning the design of public policy. Clearly, agent A benefits from the presence of an institution that certifies that it is not a secret holder. We will discuss this question in greater detail in Section 5 when we apply our model to specific environments of conversations with secrets.

In Proposition 5 we present comparative statics for the critical threshold $\bar{\pi}_{t+1}(\tau^a)$ in condition (21) that determines the type of equilibrium outcome.

Proposition 5. *Condition* (21) *is less restrictive and the pooling equilibrium* (PE) *more likely supported for more effective conversation processes (higher p) and for a lower degree of competition (lower θ).*

A pooling equilibrium with a sustainable conversation is more likely to arise when the process of conversation is effective with higher values of p. As the effectiveness of the conversation increases, the gains from continuing are higher and the payoffs from stopping are unaffected. More effective conversations are thus more likely to be sustainable although they leave more room for opportunistic *ex-post* disclosure (which is a feature of the pooling equilibrium).

Furthermore, a pooling equilibrium with a sustainable conversation is more likely to arise with low degrees of competition. In this environment agent B is less concerned about the consequences of a secret and condition (21) is satisfied for a larger range of prior beliefs π. This illustrates that competition has a monotonic effect on conversation. For very high degrees of product-market competition the conversational equilibrium can never be sustained as condition (6) is always violated when $\theta = 1$. As competition softens enough to render condition (6) satisfied, conversation can be initiated and is more likely to be sustainable in a pooling equilibrium. However, even though less competition reduces the chance of a breakdown of conversation, the absence of competition with $\theta = 0$ does not necessarily eliminate it. If the critical value $\bar{\pi}_{t+1}(\tau^a)$ in Lemma 2 is strictly less than one for some $t + 1$, then there is a range of prior beliefs π that violate condition (21) and induce agent B to stop with strictly positive probability in the hybrid equilibrium (HE). In Proposition 1, without competition the conversational equilibrium is always sustainable when there is no secret, a result that now fails to hold when secrets introduce an additional source of asymmetric information as agent B may preemptively terminate the process.

Conversation Before Equilibrium Disclosure

In Propositions 3 and 4 we provide the equilibria of the signaling game played by A and B in any given t and $t+1$. It remains to be shown under which conditions this period t is reached in the conversation. An immediate implication from the pooling equilibrium (PE) is that if π is low enough, the conversational equilibrium can be sustained and disclosure is always *ex post*. However, if π is above the critical threshold $\bar{\pi}_{t+1}(\tau^a)$ for some $t+1$, i.e., if condition (21) is violated at $t+1$ then the equilibrium behavior of A_1 and A_0 in t is as in the separating equilibrium (SE) or hybrid equilibrium (HE). Can we conclude that *ex-ante* disclosure is in $t = \tau^*$ or later at equilibrium of the entire game? Could disclosure happen before? To answer this question, we need to study the game played by A and B in all t' preceding t.

In $t-2$ and $t-1$ the decisions of A and B will depend on the continuation payoffs under the equilibrium played in t. In particular, agent B in $t-1$ compares the payoffs from continuing with the payoffs from stopping in $t-1$ where in the former case it faces a secret holder that discloses in t with probability π_{t-1}. When B's beliefs fall below a critical threshold, it will not stop the conversation and the signaling game in period t is reached. Otherwise, B threatens to stop the conversation if it observes continuation in $t-2$ and a signaling game is played between A and B in stages $t-2$. If as an outcome of this latter signaling game a separating equilibrium analogous to (SE) arises, then A_1 discloses and A_0 stops in $t-2$, implying that the timing of *ex-ante* disclosure is no later than $t-2$.

Consider an environment with competition, $\theta > 0$. A sufficient condition for agent B to continue in all $t' \le \tau^* - 1$ is that it is more inclined to continue when it anticipates (SE) be played in $t = \tau^*$ than when it anticipates the pooling equilibrium (PE) be played in all periods. This condition is

$$\pi \left[P(t'|\tau^a) - P(t'|\tau^*) \right] \ge (1 - \pi) \, p^{\tau^* - t' - 1} \left[V(\tau^* - 1) - v(\tau^* - 1) \right]. \tag{27}$$

Intuitively, agent B's gains when A_1 discloses in τ^* (as in (SE)) instead of τ^a (as in (PE)), discounted by the probability π that $A = A_1$, must be at least as large as the costs that B

incurs when the conversation stops in τ^* instead of continuing in all future periods (under (PE)), discounted by the probability $(1-\pi)\,p^{\tau^*-t'-1}$ that $A = A_0$ and stage $\tau^* - 1$ is reached.

Now consider an environment without competition. In the resulting hybrid equilibrium the secret holder discloses and continues with strictly positive probabilities, and agent B will expect a secret holder to disclose in some period $\tau^e \in (\tau^*, \tau^a)$. A sufficient condition for agent B to continue in all $t' \leq \tau^* - 1$ is that it is more inclined to continue when it anticipates (HE) be played in $t = \tau^*$ than when it anticipates the pooling equilibrium (PE) be played in all periods. This condition is

$$\pi\left[P(t'|\tau^a) - P(t'|\tau^e)\right] \geq 0 \tag{28}$$

and holds true because $\tau^e < \tau^a$.

The following Proposition 6 summarizes the results for the sustainability of the conversational equilibrium and the timing of equilibrium disclosure.

Proposition 6. *Define $\pi^{\inf} \equiv \inf \bar{\pi}_{t+1}(\tau^a)$. Let condition (6) be satisfied for all t.*

1. *For $\pi \leq \pi^{\inf}$, the conversational equilibrium with ex-post disclosure is sustainable.*

2. *For $\pi > \pi^{\inf}$, there is some $\pi > \bar{\pi}_{t+1}(\tau^a)$. Let $t = \tau^*$ be the smallest $t \in T_A$ such that $\pi > \bar{\pi}_{\tau^*+1}(\tau^a)$. If condition (27) is satisfied and $\theta > 0$ sufficiently small, then the signaling game with the separating equilibrium (SE) is reachable and ex-ante disclosure is in τ^*.*

3. *For $\pi > \pi^{\inf}$, the signaling game with the hybrid equilibrium (HE) when $\theta = 0$ is reachable and ex-ante disclosure is in τ^* or later.*

[Table 1 about here.]

In Table 1 we summarize our equilibrium results. The first implication is that asymmetric information has no effect on the sustainability of the conversational equilibrium when agent B's prior beliefs about the secret are low. In this case, disclosure of the secret is *ex post*. Private information affects only the distribution of the value of conversation. The picture changes when

prior beliefs increase. The nature of the results then depends on product-market competition. With competition and given the conditions in Proposition 6, the conversational equilibrium can be sustained only if agent A is a secret holder, and *ex-ante* disclosure is in τ^*. Otherwise the conversation stops in τ^*. Without competition the conversational equilibrium can be sustained with certainty only if agent A is not a secret holder. If instead it holds a secret, the conversation is terminated with strictly positive probability. Disclosure is *ex ante* in τ^* or later. If $\pi^{\mathrm{inf}} < 1$, then there is always a sufficiently high π such that these two latter cases arise.

Finally, for $\theta > 0$ disclosure is immediate and $\tau^* = 1$ (or immediate with strictly positive probability for $\theta = 0$) if prior beliefs are sufficiently high, $\pi > \bar{\pi}_2(\tau^a) \geq \pi^{\mathrm{inf}}$, with $\tau^a = \infty$. Such a case always exists if this critical threshold $\bar{\pi}_2(\tilde{\tau})$ evaluated at $\tilde{\tau} = \tau^a$ in Lemma 2 is strictly less than one. By condition (22) this holds true if

$$(1 - \sigma(2)) \left[v(2) - \theta v(1)\right] > (1 - \theta) \left[V(2) - P(2|\infty)\right] \tag{29}$$

for $\theta \geq 0$.[14] Immediate disclosure implies that a conversational equilibrium is sustainable only if A is a secret holder because a non-secret holder agent A_0 type does not initiate the conversation.

Existence of a Secret is Common Knowledge

To deepen our understanding of how asymmetric information affects the sustainability of the conversation, we now isolate the effect of uncertainty about the secret from the effect of the secret itself (with the bargaining leverage it provides). We assume agent B knows for sure that it will be held up by a secret holder A (so that $\pi = 1$) but does not know what its secret entails. As a result it cannot protect itself against A's *ex-post* opportunism and the secret holder extracts $\sigma(\tau)$. We refer to this scenario as one in which existence of a secret is *common knowledge*. By comparing the expected joint payoffs from the equilibria for the full model (W^{PE}, W^{SE}, and W^{HE}) with the expected joint payoffs from the equilibrium in this intermediate case

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[14]In the Online Appendix we present a parameterized version of the model that illustrates our equilibrium results. We provide a range of parameters for which condition (29) is satisfied.

in which secrets are common knowledge (denoted by W^{CK}), we can quantify the inefficiency that arises from asymmetric information in a model of conversation with secrets. The results in Proposition 7 follow from Propositions 3 and 4 for $\pi = 1$.

Proposition 7. *Let conditions* (6) *and* (23) *be satisfied. When the existence of the secret is common knowledge, equilibrium disclosure is immediate, $\tau^* = 1$, if condition* (29) *holds and delayed otherwise. Conversation is sustainable in all $t \geq 1$.*

The expected joint payoffs from the equilibrium in Proposition 7 equal $W^{CK} = W^{SE}|_{\pi=1} = W$; for both the case of immediate disclosure $(\bar{\pi}_2(\tau^a) < 1)$ and delayed disclosure $(\bar{\pi}_2(\tau^a) \geq 1)$. Observe that these payoffs are the same as the payoffs from conversation without a secret (Section 3). *Ex-post* opportunism by the secret holder has an effect on welfare only if it is accompanied by B's uncertainty about agent A's type. When player B knows for sure the type of player A then the secret has a distributive effect only.

We can quantify the welfare losses arising from asymmetric information about agent A's type by comparing the expected payoffs from the baseline model with the expected payoffs from the scenario with common knowledge on secret's existence. First observe that asymmetric information has no effect on welfare when agent B's prior beliefs are sufficiently small $(\pi < \pi^{\mathrm{inf}})$ and the equilibrium is the pooling equilibrium (PE) in which conversation is sustainable for both agent A types. In this case, $W^{PE} = W = W^{CK}$. However, when agent B's beliefs are higher and the equilibrium is not pooling, implying that the conversation is terminated with strictly positive probability, then the welfare losses caused by asymmetric information are equal to $W^{CK} - W^{SE} = W - W^{SE} > 0$ for $\theta > 0$ and $W^{CK} - W^{HE} = W - W^{HE} > 0$ for $\theta = 0$. This is the extra milage due to asymmetric information in a model of conversation.

5 Applications

Industry Standard Development

As Farrell and Saloner (1988) point out, "[standard-setting] committees often identify and promote compromises." Moreover, "participants are often engineers who share information and view the committee as a design process, and pursue an 'ideal technology'." We provide a theory that addresses these functions of SSOs and captures an environment that is characterized by a genuine need to develop a standardized technology. This is the case in SSOs such as ETSI or JEDEC, where firms repeatedly meet to develop a standard by exchanging ideas in a cooperative environment.[15] Our results provide novel insights into the functioning of standard setting (as an exchange of *ideas*) and the decision to disclose standard-essential patents (*secrets*).

Strategic tensions often undermine the work of standard-setting committees, particularly when firms are competitors and patent-protected technologies are involved. Committee members can at best form beliefs about the existence of an essential patent. This is for at least two reasons: First, identifying a patent that is essential to the development of a specific standard imposes significant search costs (DOJ/FTC, 2007; Bessen and Meurer, 2008; Chiao, Lerner, and Tirole, 2007). Second, patent applications are frequently pending while the underlying technologies are considered for inclusion, and the applications are not published for at least 18 months after the filing (Johnson and Popp, 2003; Aoki and Spiegel, 2009).

When the patent holder manages to get its patented technology included, it can hope for a future stream of licensing revenue. This might induce patent holders to conceal the existence of standard-essential patents to other members of the standard-setting committee (Chiao, Lerner, and Tirole, 2007). Late disclosure may equip the patent holder with bargaining leverage over prospective users. Such leverage is the result of the technology users' *lock-in* (Shapiro and Varian, 1998; Farrell and Klemperer, 2007) and arises when firms rely on the standard (yet to be published and adopted), make irreversible or standard-specific investments, and manufacture

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[15]Also, Simcoe (2012b) describes the early IETF as an SSO that "creates and maintains" standards, with early members being academic and government researchers.

final products based on the present state of the standard proposal. Empirical findings in Layne-Farrar (2011) suggest that—in absence of a clear rule—firms postpone the disclosure of patents until the end of the standard-setting process, i.e., *ex post*, after the publication of a standard version. Such conduct by means of *ex-post* disclosure is often referred to as patent ambush, a form of patent holdup at the core of many high profile legal disputes.[16]

Patent Disclosure in Standard Development

In our model, a patent holder can decide to disclose the patent *(i) ex ante*, before the process ends, or *(ii) ex post*. We assume that *ex-post* disclosure comes without direct costs and in Propositions 3 and 4 provide conditions under which the patent holder will decide to disclose *ex ante* even in the absence of such costs. If the prior beliefs about facing a patent holder are sufficiently low, then in the resulting pooling equilibrium (PE) the standard-setting process ends only when a new idea fails to arrive and the patent is disclosed *ex post*. When prior beliefs are sufficiently high, the patent holder will disclose *ex ante* with strictly positive probability.[17]

In Proposition 5 we show that *ex-post* disclosure is more likely to arise (because the condition supporting the pooling equilibrium is more likely to be satisfied) for lower degrees of competition (lower values of θ) and for more effective conversation processes (higher values of p). Soft product-market competition reduces the incentives to stop the conversation, thus lowering the patent holder's risk of a premature termination of the process by its rival. At the same time, for more lively standard-setting committees, those in which the flow of ideas for improvement is more prolific, rival participants are less likely to stop the process in order not to forego the increased benefits of standardization. Consequently, more effective committees and those with lower product-market competition of its participants are more likely to experience *ex-post*

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[16]In the FTC matters against Dell Computer Corp. (*Dell Computer Corp., FTC Docket No. C-3658, 121 F.T.C. 616 (1996)*) and Rambus Inc. (*FTC v. Rambus Inc., 522 F.3d 456 (D.C. Cir. 2008)*), or *Broadcom Corp. v. Qualcomm Inc., 501 F.3d 297 (3d Cir. 2007)*, plaintiffs contended that patentees failed to comply with the SSO's disclosure rules.

[17]With product-market competition, the patent is disclosed *ex ante* with certainty in the resulting separating equilibrium (SE), without product-market competition the patent holder discloses *ex ante* with positive probability in the resulting hybrid equilibrium (HE).

disclosure and are in this way more vulnerable to *ex-post* rent extraction by strategic patent holders.

Policy Implications for Standard Development

The normative implications of our analysis are concerned with institutions that avoid the inefficiency caused by "early" termination of the process that arises in the separating equilibrium when a rival participant faces a non-patent holder. We discuss three possible solutions.

License Commitments. Under licensing commitments the patent holder promises to license a standard-essential patent at a pre-defined or maximum license fee or royalty rate,[18]

irrespective of the timing of disclosure. The most common policy is to require licensing on *Reasonable and Non-Discriminatory (RAND)* terms.[19] We argue that such RAND commitments (or license commitments) can solve the inefficiency associated with the separating equilibrium (SE).

Suppose an SSO adopts a license commitment policy and suppose the royalty rate under such a commitment is σ^R so that $\sigma(\tau) \leq \sigma^R$. Let the conditions in Proposition 6 be satisfied and the standard-setting process reach the signaling game in τ^*. Then, an optimal pre-committed royalty rate cap is $\sigma^R \leq \sigma(\tau^*)$. To see this, recall that, as we showed in Lemma 2, a rival's "threat" to stop the process absent disclosure arises when later disclosure results in higher license fees or royalty rates. If $\sigma^R \leq \sigma(\tau^*)$, the maximum royalty rate is not higher than the rate that would induce the rival participant to stop in $\tau^* + 1$ absent disclosure in τ^*. Therefore, for all $t > \tau^*$, the rival participant firm B has no incentive to stop the process in case the patent has not been disclosed, and a non-patent holder A_0 will not stop the process in τ^*. As for the patent holder, it is indifferent between disclosing in τ^* and disclosing later, because it cannot

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[18]Two examples of a pre-defined license fee are the World Wide Web Consortium (W3C) that requires royalty-free licensing and the HDMI Consortium that sets royalties at \$0.15 per unit sold. Alternatively, a maximum-license-fee policy is followed by VITA. See Simcoe (2012a) for a detailed discussion.

[19]Swanson and Baumol (2005), Farrell, Hayes, Shapiro, and Sullivan (2007), or Layne-Farrar, Padilla, and Schmalensee (2007), among others. See Contreras (2013a) for evidence of the use of RAND commitments.

increase the royalty rate by disclosing later. To summarize, a license commitment $\sigma^R \leq \sigma(\tau^*)$ solves the inefficiency from early process termination in the separating equilibrium.

Our model implies an upper bound for the royalty rates under RAND commitments. Of course, the positive effect of a lower *reasonable* (or maximum) royalty σ^R on the sustainability of the process must be balanced with the possibly negative effect that lower royalty payments have on patent holders' incentives to participate in standardization (Layne-Farrar, Llobet, and Padilla, 2012) and their incentives to innovate (Ganglmair, Froeb, and Werden, 2012).

Implied Waiver. A court stipulated *implied waiver*[20] renders one's patents waived if the SSO has disclosure rules in place that require all participants to disclose all standard-essential patents but a patent has not been disclosed by the time the standard-setting process comes to an end.[21] We provide a simple rationale for its introduction in the context of our model.[22]

With an *implied waiver* rule in place, the patent holder runs the risk of not being able to disclose in time before the process ends, rendering its patent unenforceable. The waiver thus introduces a cost of *ex-post* disclosure. As a result, even when the standard-setting process is not constrained by a rival's "threat" to stop, the patent holder is more inclined to disclose *ex ante*. This effect of the waiver is consistent with the findings in Layne-Farrar (2011).

In a standard-setting environment in which, without the waiver, the equilibrium is a pooling equilibrium, the introduction of a waiver will result in earlier disclosure (and lower license fees) but will not affect the sustainability and duration of the standard-setting process. The process continues until a new idea fails to arrive, independent of the waiver. In an environment in which the equilibrium is a separating equilibrium, whether the waiver affects the duration of the standard-setting process depends on when the patent holder would otherwise disclose.

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[20]For instance, the U.S. Court of Appeals for the Federal Circuit found in *Qualcomm Inc. v. Broadcom Corp., 2007-1545, 2008-1162 (Fed. Cir. 12-1-2008)* that "Qualcomm's misconduct falls within the doctrine of waiver." The conclusion was an "un-enforceability remedy limited in scope to any [standard]-compliant products." See Hovenkamp, Janis, Lemley, and Leslie (2010) for a discussion of this and related cases.

[21]For a discussion of disclosure rules as a solution to the problem of patent hold-up see Simcoe (2012a), for a recent survey of *ex-ante* disclosure rules see Contreras (2013). For a more general discussion of the effect of disclosure laws see Grossman and Hart (1980).

[22]Our results under the waiver are a direct implication of the analysis developed above. We provide the formal analysis in the Online Appendix.

Suppose disclosure in the scenario with the waiver is before disclosure in the scenario without. Then the signaling game is never played along the equilibrium path. Therefore, with the implied waiver rule, both firms continue the conversation until a new idea fails to arrive, whereas the conversation stops without waiver when a rival participant faces a non-patent holder. Hence, the introduction of a waiver is desirable insofar as it avoids inefficient termination.

Certificates. The last solution we discuss is borrowed from the literature on asymmetric information that suggests quality certification to overcome the lemons problem (e.g., Viscusi, 1978). In the context of our model, quality certification is implemented by way of the patent office certifying that the firm requesting the certificate has not applied for a patent that might be essential to the standard. Because patent applications are not in the public domain for at least 18 months after initial filing, such a certificate eliminates the uncertainty over the existence of pending patents. If the inefficiency associated with the separating equilibrium arises from a non-patent holder A_0 not being able to credibly communicate that it does not hold a patent application then such a certificate can remedy this problem. In circumstances in which the patent office holds superior information about standard-setting participants—which is the case with patent applications—the provision of the certificate is desirable.

A number of features of standard-setting processes are not captured by our setting. First, the economics literature (e.g., Farrell and Saloner, 1988; Farrell and Simcoe, 2012) has modeled standard setting as a war of attrition and the delay in standard adoption comes as a costly byproduct, whereas in our model a longer conversation allows firms to achieve a better technological outcome.[23] Second, in our setting the delay of disclosure, and the resulting stronger scope for holdup, does not reduce the total value generated by the process, but only implies a different redistribution of the same value. This outcome can be rationalized by the use of a two-part tariff scheme in which the patent holder sets the linear component to achieve bilateral

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[23]The introduction of costly delay would lead to qualitatively analogous results. When late implementation of a technology results in lower market value, there is an optimal finite end date of the conversation, say $\bar{\tau}$. Consequently, under a conversational equilibrium the conversation reaches this optimal end date, whereas a secret compromises sustainability if the equilibrium disclosure date is before $\bar{\tau}$.

efficiency, whereas the value of the fixed component depends on the bargaining power of the patent holder (Tarantino, 2012).

Joint Ventures and Business Ventures

In cooperative agreements to jointly develop a business idea in a competitive environment (Kogut, 1989), or in a joint venture, firms share technological knowledge yet often remain competitors in the product market (e.g., d'Aspremont and Jacquemin, 1988; Hernán, Marín, and Siotis, 2003). Our model applies in this context to answer the question of a joint venture's sustainability in the presence of asymmetric information.

In our model, we capture the basic concept of a joint venture. Often such ventures begin when an entrepreneur A shares with a colleague B an idea for a novel initiative and then develop through the exchange of further *ideas* for improvements. Each partner is interested in maximizing the size of the pie to be shared, while at the same time trying to capture as large a fraction of this pie as possible. Suppose this entrepreneur A has control over some essential input through, e.g., exclusive supply contracts. This means that, if A keeps this contract a *secret*, the two partners design the joint venture under asymmetric information.[24] Moreover, if, as part of the joint venture, B invests in a production facility that requires the use of the essential input that partner A controls, A can *ex post* extract payments from B.

The implication for the equilibrium outcome is an inefficient termination of the venture (for sufficiently high prior beliefs) by the entrepreneur without the exclusive contract. By Proposition 5, the separating equilibrium that gives rise to inefficient termination is more likely to arise with fiercer competition and lower potential of the partnership. This is consistent with theoretical results in the literature. Pérez-Castrillo and Sandonís (1996) conclude that with high spillovers (high value of p) firms in research joint ventures prefer cooperative R&D. They also argue that partners have little incentive to share information when they compete in other

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[24]Just like a patent in the earlier example, an exclusive supply contract is *ex-ante* verifiable. The owner of such a contract can reveal it to its partner. An entrepreneur without such a contract, however, cannot reveal a contract that does not exist.

markets.[25] The management literature provides empirical results consistent with our findings. Park and Ungson (1997) document that the sustainability of joint ventures is negatively affected when partners' product markets overlap (as proxy for θ),[26] and Li (1995) and Hennart, Kim, and Zeng (1998) show that the sustainability of joint ventures is positively affected by industry growth and higher value of cooperation (as proxies for p).

6 Concluding Remarks

We study how the sustainability of a conversation between competing agents is affected by the existence of a secret. We present a dynamic model of conversation as exchange of *ideas* (Stein, 2008) in which one agent is endowed with a piece of private information that provides for *ex-post* bargaining leverage and affects the distribution of final payoffs. We study the impact this *secret* has on the sustainability of the conversation and analyze the secret holder's decision to disclose the secret and relinquish its private information.

We find that even if there exist no explicit rules requiring disclosure, a secret holder chooses to disclose during the conversation (*ex-ante* disclosure) in order to preempt early termination by the other agent. Moreover, because a non-secret holder cannot credibly communicate that it does not hold a secret (due to *ex-ante* verifiability), it stops the conversation to obtain a product-market advantage when it anticipates that its rival will terminate the conversation. Private information about the *secret* therefore negatively affects the sustainability of conversation, and this inefficiency is more likely to arise with fiercer competition between the agents and a slower flow of new ideas. We apply our model to two contexts: *industry standard development*, modeled as a process of *ex-ante* cooperation in the design of a new technology, and *joint ventures*.

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[25]For the literature on research joint ventures and the effect of product-market competition and spillovers see also, e.g., Choi (1993) and Combs (1993).

[26]The example discussed in von Hippel (1987) relates to this.

A Proofs

Proof of Proposition 1. Let p and θ be such that (6) holds for all t, then neither agent has an incentive to deviate from the conversation strategy (i.e., they always continue) for any t. If (6) is violated for some t, so that agent i stops in t, then agent $-i$ stops in $t-1$. Agent $-i$ in $t-1$ anticipates that if it continues in $t-1$, with probability $1-p$ agent i will not observe a new idea in t, and $-i$'s payoffs are $(1-\theta)\,v(t-1)$. With probability p, a new idea arrives which i will not share and $-i$'s payoffs are $(1-\theta)\,v(t-1)$. Therefore, $-i$'s expected payoffs from continuing in $t-1$ when i stops in t are $(1-\theta)\,v(t-1)$. Its payoffs from stopping in $t-1$ are instead $(1-\theta)\,v(t-1)+\theta\,[v(t-1)-v(t-2)]=v(t-1)-\theta v(t-2)$. Agent $-i$ therefore stops for any $\theta > 0$. By the same argument, i stops in $t-2$. Continuing in this fashion, A stops in $t=1$. Conversation is thus not initiated if (6) is violated for *some t*.

To show that condition (6) is less restrictive for higher values of p, observe that $V(t)$ increases in p: The derivative for $V(t)$ with respect to p is

$$\frac{\partial V(t)}{\partial p} = \sum_{k=0}^{\infty} p^k \left(\frac{k(1-p)}{p}-1\right) v(t+k) = \sum_{k=0}^{\infty}(1+k)\,p^k\,[v(t+k+1)-v(t+k)] > 0,$$

for all $p \in (0,1)$. As $V(t)$ increases in p, the LHS of (6) is increasing in p and the condition becomes less restrictive. To show that (6) is less restrictive for lower values of θ, note that the RHS in increasing in θ. Finally, to show that (6) always holds for $\theta = 0$, we show that the LHS is strictly larger than unity. For that, $V(t) > v(t)$. Because

$$V(t) - v(t) = \sum_{k=0}^{\infty} p^k\,(1-p)\,[v(t+k)-v(t)] > 0$$

holds for all t and $p \in (0,1)$, condition (6) holds for all t if $\theta = 0$. Q.E.D.

Proof of Proposition 2. Agent B's condition (13) is identical to both agents' condition (6) in the case without secret (or in the case with a secret when $\tau = 1$). Because $\sigma(\tilde{\tau}) \geq 0$ for all $\tilde{\tau} \geq 1$, (13) is at least as restrictive as (10). If (13) holds for all $t \geq \tilde{\tau}$, then (10) holds for all

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$t \geq \tilde{\tau}$. Because of this, if (6) (for the case without a secret) holds, then both (10) and (13) (for the case with a revealed secret) hold as well. Q.E.D.

Proof of Lemma 1. We first construct $P(t|\tilde{\tau})$. This payment from B to A is equal to B's product market profits times σ. Suppose firm B continues in t, and let $\tilde{\tau} = t + 1$. We obtain

$$
\begin{aligned}
P(t|t+1) &= (1-p)\,\sigma(t+1)v(t) + p\,(1-p)\,\sigma(t+1)v(t+1) + \\
&\quad p^2\,(1-p)\,\sigma(t+1)v(t+2) + \ldots \quad = \sigma(t+1)V(t). \quad \text{(A1)}
\end{aligned}
$$

Now, suppose that A does not disclose before $\tilde{\tau} = t+3$, i.e., it will disclose whenever the process comes to end before $t + 3$, or in $t + 3$ when this stage is reached. Then,

$$
P(t|t+3) = \sum_{k=0}^{2} p^k\,(1-p)\,\sigma(t+1+k)v(t+k) + p^3\sigma(t+3)V(t+3).
$$

We derive the expression in (15) analogously for general $\tilde{\tau}$. To show that $P(t|\tilde{\tau})$ is increasing in $\tilde{\tau}$, we compare $P(t|\tilde{\tau})$ with $P(t|\tilde{\tau} + \omega)$ and show that $P(t|\tilde{\tau} + \omega) > P(t|\tilde{\tau})$ for all $\omega \geq 1$. From equation (15),

$$
P(t|\tilde{\tau}+\omega) = \sum_{k=0}^{\tilde{\tau}+\omega-t-1} p^k\,(1-p)\,v(t+k)\sigma(t+1+k) + p^{\tilde{\tau}+\omega-t}\sigma(\tilde{\tau}+\omega)V(\tilde{\tau}+\omega). \quad \text{(A2)}
$$

After some manipulation we obtain

$$
\begin{aligned}
P(t|\tilde{\tau}+\omega) - P(t|\tilde{\tau}) &= p^{\tilde{\tau}-t}\sum_{k=0}^{\omega-1} p^k(1-p)v(\tilde{\tau}+k)\left[\sigma(\tilde{\tau}+1+k) - \sigma(\tilde{\tau})\right] + \\
&\quad p^{\tilde{\tau}+\omega-t}\left[\sigma(\tilde{\tau}+\omega) - \sigma(\tilde{\tau})\right]V(\tilde{\tau}+\omega) > 0,
\end{aligned}
$$

which is positive because $\sigma(\tilde{\tau})$ is increasing in $\tilde{\tau}$. Later disclosure being always better than immediate disclosure, $U_{A_1}(C|t+2) > U_{A_1}(C|t)$, follows from $P(t|\tilde{\tau})$ increasing in $\tilde{\tau}$. Because of this, the aspired disclosure date is $\tau^a = \infty$ and A_1's payoffs are $U_{A_1}(C|\infty) = (1-\theta)\,[V(t) +$

$P(t|\infty)]$. Moreover,

$$U_{A_1}(C|\infty) = (1-\theta)\left[V(t) + P(t|\infty)\right] > v(t) + \theta v(t-1) + (1-\theta)\,\sigma(t)v(t-1) = U_{A_1}(S|t)$$

because condition (6) and

$$P(t|\infty) - \sigma(t)v(t-1) \;=\; \sum_{k=0}^{\infty} p^k\,(1-p)\left[\sigma(t+k+1)v(t+k) - \sigma(t)v(t-1)\right] > 0$$

ensure that $(1-\theta)\,V(t) \geq v(t) + \theta v(t-1)$. It is never optimal for A_1 to stop in t.   Q.E.D.

Proof of Lemma 2. Condition (21) follows directly from the comparison of (19) and (20). For *claim (1)*, the cutoff value $\bar{\pi}_t(\tilde{\tau})$ is strictly decreasing in $\tilde{\tau}$ because $P(t|\tilde{\tau})$ is strictly increasing in $\tilde{\tau}$ (Lemma 1). For *claim (2)* we first note that if (6) holds with strict equality, then the numerator in (21) is equal to zero. Moreover, the denominator is strictly positive if

$$\frac{P(t|\tilde{\tau}) - \sigma(t)v(t-1)}{\sigma(t)\left[v(t) - v(t-1)\right]} > \frac{1}{1-\theta}. \tag{A3}$$

Because by equation (A1)

$$\frac{P(t|\tilde{\tau}) - \sigma(t)v(t-1)}{\sigma(t)\left[v(t) - v(t-1)\right]} > \frac{V(t) - v(t-1)}{v(t) - v(t-1)} \iff P(t|\tilde{\tau}) > \sigma(t)V(t) = P(t|t), \tag{A4}$$

condition (6) is more constraining than (A3), i.e., if (6) holds with strict equality, (A3) is slack and the denominator in (21) is strictly positive so that $\bar{\pi}_t(\tilde{\tau}) = 0$. If (6) is slack and the numerator in (21) strictly positive, (A3) holds and the denominator in (21) is positive so that $\bar{\pi}_t(\tilde{\tau}) > 0$. Finally, the cutoff value $\bar{\pi}_t(\tilde{\tau})$ is strictly less than one if the denominator in (21) is larger than the numerator. After some manipulation, condition (22) is obtained.   Q.E.D.

Proof of Lemma 3. For t to be reached without disclosure, all agents must have continued in all $t' < t$. For *claim (1)*, as shown in the proof of Proposition 1, A_0's payoffs from continuing in t when B stops in $t+1$ are $(1-\theta)\,v(t)$. Its payoffs from stopping in t are as in equation (5).

When $\theta > 0$, A_0 strictly prefers stop to continue; when $\theta = 0$, A_0 is indifferent. For *claim (2)* we first note that for A_1, the payoffs from stopping in t, $U_{A_1}(S|t)$, are in equation (18). By Proposition 2, and (6) satisfied, B continues in $t+1$ if A_1 discloses in t. Moreover, both agents then continue in all $t' > t+1$ until a new idea fails to arrive. The secret holder's payoffs from disclosing in t equal $U_{A_1}(D|t)$ in equation (16). Observe that stopping is dominated by disclosing if $U_{A_1}(D|t) \geq U_{A_1}(S|t)$ or, using $P(t|t) = \sigma(t)V(t)$,

$$(1 + \sigma(t)) \frac{V(t) - v(t - t)}{v(t) - v(t - 1)} \geq \frac{1}{1 - \theta}. \tag{A5}$$

Because (6) holds and $\sigma(t) > 0$ unless for $t = 1$ when $\sigma(1) = 0$ (so that (6) and (A5) are equivalent), this condition always holds. We therefore focus on A_1's decision to either disclose in t or continue in t. If A_1 continues in t, then by (21) in Lemma 2 being violated in $t+1$, agent B will stop in $t+1$ and the conversation ends. Secret holder A_1 then discloses the secret after the conversation ends in $t+1$. Its payoffs from continuing in t when B stops in $t+1$, $\bar{U}_{A_1}(C|t+1)$, are

$$\bar{U}_{A_1}(C|t+1) = (1 - \theta)v(t) + \sigma(t+1)[p(v(t+1) - \theta v(t)) + (1 - p)(1 - \theta)v(t)]. \tag{A6}$$

The secret holder discloses in t if $U_{A_1}(D|t) \geq \bar{U}_{A_1}(C|t+1)$ which after some manipulation gives condition (23). Q.E.D.

Proof of Proposition 3. We derive perfect Bayesian equilibria (PBE) in pure strategies of the continuation game played in t and $t+1$ by agent A_h types $h = 1, 0$ and agent B. Note that the secret has not yet been disclosed. In order for t to be reached without disclosure both agent A types must have continued in all $t' < t$, and B has not had a chance to update its beliefs, so that $\pi_{t'} = \pi$ for all $t' < t$. More specifically, $\pi_{t-1}^C = \pi$.

Pooling equilibrium (PE) in *claim (1)*: If agent B continues in $t+1$, then by Propositions 1 and 2, both agent A types continue in t for all θ and $s_t^1 = s_t^0 = C$. In $t+1$, B cannot update its beliefs and $\pi_{t+1}^C = \pi_{t-1}^C = \pi$. We can rewrite condition (21) as $\pi \leq \bar{\pi}_{t+1}(\tilde{\tau})$ for some $\tilde{\tau} \in T_A$.

If (21) holds for $\tilde{\tau} = \tau^a = \infty$, $\pi \leq \bar{\pi}_{t+1}(\infty)$, then, by Lemma 1, A_1 will delay disclosure until after the conversation ends, $\tau^a = \infty$, and both agents continue in all t and $t+1$ because (21) holds for $\tilde{\tau} = \tau^a$. Neither agent A type has an incentive to deviate: If, out-of-equilibrium, A_1 chooses D instead of C, then $\pi_{t+1}^D = 1$ (by virtue of credible disclosure of its type). Because (6) is satisfied, by Proposition 2 agent B continues once the secret has been disclosed, $s_t^D = C$. Then, A_1 prefers C to D. If either agent chooses S instead of C then the conversation stops. Because on the equilibrium path B continues, both agent A types prefer C to S, by (6) satisfied.

To show that (PE) is the unique pure-strategy PBE, we consider the alternative strategy profiles (s_t^1, s_t^0) with $s_t^1, s_t^0 \in \mathscr{A}_t$: (D, S), (D, C), (C, S), (S, S), and (S, C). Given profiles (D, S), (D, C), and (S, C), A_1 deviates by playing $s_t^1 = C$ which, by (21) satisfied, implies $s_{t+1}^C = C$ and disclosure as in Lemma 1. Likewise, given profile (S, S), A_1 deviates, e.g., by playing $s_t^1 = D$ to induce B to continue. Finally, given profile (C, S), A_0 deviates by playing $s_t^0 = C$ to induce $s_{t+1}^C = C$. Hence, if (21) is satisfied, (PE) is the unique pure-strategy PBE.

Separating equilibrium (SE) in *claim (2)*: Suppose (21) with $\tilde{\tau} = \tau^a$ is violated for some $t+1$, B stops in $t+1$ if A continues in t so that $s_{t+1}^C = S$. If (23) is satisfied, A_1, who anticipates B to stop in $t+1$ when $s_t = C$, strictly prefers disclose to continue, $s_t^1 = D$. In this case, B continues by Proposition 2 so that $s_{t+1}^D = C$. A non-secret holder A_0 who anticipates $s_{t+1}^C = S$ weakly prefers stop to continue in t so that $s_t^0 = S$ for $\theta \geq 0$ (strict for $\theta > 0$). After $s_t^0 = S$ the game ends and no information set for B is reached in $t+1$. For both agent A types, agent B does not need to update its beliefs on the equilibrium path using Bayes' rule because its information set is a singleton (A_1 discloses), or the game has ended (A_0 stops). The equilibrium action profile for A in period t is $(s_t^{1*}, s_t^{0*}) = (D, S)$. If, out-of-equilibrium, B observes A to continue, then at least one of the types must have deviated. The out-of-equilibrium beliefs that support (SE) are $\pi_{t+1}^C > \bar{\pi}_{t+1}(\tau^a)$. Given these posterior beliefs, by (21) in Lemma 2, B stops in $t+1$ if A continues in t. Because A_1 then prefers disclose to continue and A_0 prefers stop to continue, no agent A type will deviate from $(s_t^{1*}, s_t^{0*}) = (D, S)$.

To show that (SE) is the unique pure-strategy PBE, we consider the alternative strategy profiles (C, C), (D, C), (C, S), (S, S), and (S, C). Note that by Lemma 3, $s_t^1 = D$ dominates

$s_t^1 = S$, and $s_t^1 = D$ dominates $s_t^1 = C$ (inducing $s_{t+1}^C = S$) because (23) is satisfied. Hence, A_1 will deviate from profiles (C, C), (C, S), (S, S), and (S, C). Given (D, C), A_0 deviates by playing $s_t^0 = S$, as $s_{t+1}^C = S$ when (21) is violated. The payoffs for A_0 when it plays $s_t^0 = C$ (and B stops in $t + 1$) are $(1 - \theta) v(t)$ which is (weakly) smaller than the payoffs for $s_t^0 = S$, $v(t) - \theta v(t - 1)$, and A_0 is better off playing $s_t^0 = S$. Hence, if (21) is violated and (23) is satisfied, (SE) is the unique pure-strategy PBE. Q.E.D.

Proof of Lemma 4. We show that both equilibria satisfy the *Intuitive Criterion* and *D1* (Cho and Kreps, 1987) for $\theta > 0$, (PE) survives for $\theta = 0$, and (SE) fails to survive for $\theta = 0$. First, note that there is no information set for B following $s_t^h = S$, $h = 1, 0$. We therefore do not need to consider an out-of-equilibrium action S by A. Some further notation will be helpful: Let $\tilde{\alpha}_h(s_t)$ denote the probability agent A_h assigns to action $s_t \in \mathscr{A}_t$ in the candidate equilibrium (s_t^{1*}, s_t^{0*}). Then denote by $\tilde{\mathscr{A}}_t = \{s_t \in \mathscr{A}_t : \tilde{\alpha}_h(s_t) = 0 \text{ for both types } h = 1, 0\} \backslash \{S\}$ the set of out-of-equilibrium actions. Moreover, for the relevant actions $s_t \in \{C, D\}$ (followed by an information set for B), let $\mathscr{P}(s_t)$ the set of agent A types whose action set includes s_t: $\mathscr{P}(C) = \{A_1, A_0\}$ and $\mathscr{P}(D) = \{A_1\}$. Finally, let $BR(\mathscr{P}(s_t), s_t)$ be the set of B's best responses to action s_t by A when agent A types in $\mathscr{P}(s_t)$ can take action s_t.

For the *Intuitive Criterion* we take two steps. *Step 1:* We determine the set of agents for which an out-of-equilibrium action $s_t \in \tilde{\mathscr{A}}_t$ is not equilibrium-dominated:

$$\Theta(s_t) = \big\{ A_h | U_{A_h}^*(s_t^{h*}) \leq \max_{s_{t+1} \in BR(\mathscr{P}(s_t), s_t)} U_{A_h}(s_t) \big\}, \tag{A7}$$

where $U_{A_h}^*(s_t^{h*})$ is agent A_h's payoff from the equilibrium profile $\{(s_t^{1*}, s_t^{0*}), (s_{t+1}^{D*}, s_{t+1}^{C*})\}$ and $\max_{s_{t+1} \in BR(\mathscr{P}(s_t), s_t)} U_{A_h}(s_t)$ represents the highest payoff that A_h can achieve by sending the out-of-equilibrium message $s_t \in \tilde{\mathscr{A}}_t$ in t when B replies with a best response $s_{t+1} \in BR(\mathscr{P}(s_t), s_t)$. *Step 2:* Once beliefs are restricted to $\Theta(s_t)$, the proposed equilibrium with payoff $U_{A_h}^*(s_t^{h*})$ does not survive the *Intuitive Criterion* if there is a type $A_h \in \Theta(s_t)$ and an action $s_t \in \tilde{\mathscr{A}}_t$ that improves upon the type's equilibrium payoff $U_{A_h}^*(s_t^{h*})$, even if action s_t is responded in $t + 1$

with the action providing the lowest possible payoff $\min_{s_{t+1} \in BR(\Theta(s_t), s_t)} U_{A_h}(s_t)$, i.e., if

$$\min_{s_{t+1} \in BR(\Theta(s_t), s_t)} U_{A_h}(s_t) > U^*_{A_h}(s^{h*}_t) \quad \text{for } A_h \in \Theta(s_t). \tag{A8}$$

If both (A7) and (A8) are satisfied, the equilibrium fails to survive the *Intuitive Criterion*.

Intuitive Criterion for (PE): For (PE), $\tilde{\mathscr{A}}_t = \{D\}$ and $\mathscr{P}(D) = \{A_1\}$. Because $\pi^D_{t+1} = 1$, $BR(\mathscr{P}(D), D) = \{C\}$. *Step 1:* The (highest) payoff associated with $s^1_t = D$ and $s_{t+1} = C \in BR(\mathscr{P}(D), D)$ is $U_{A_1}(D|t)$ which by Lemma 1 is lower than the equilibrium payoff, so that action $s^1_t = D$ is equilibrium-dominated and (A7) is violated for A_1. For this reason, no agent A type has an out-of-equilibrium action $s_t \in \tilde{\mathscr{A}}_t$ that could make it better off, $\Theta(D) = \emptyset$. (PE) survives the *Intuitive Criterion* refinement for all θ.

Intuitive Criterion for (SE): For (SE), $\tilde{\mathscr{A}}_t = \{C\}$ and $\mathscr{P}(C) = \{A_1, A_0\}$. When out-of-equilibrium agent B sees $s_t = C$, then $\pi^C_{t+1} = \pi$ and the best response to C is S because (21) is violated for $\pi^C_{t+1} = \pi$, $BR(\mathscr{P}(C), C) = \{S\}$.

For *Step 1*, let $\theta > 0$. The (highest) payoff associated with $s^1_t = C$ and $s_{t+1} = S \in BR(\mathscr{P}(C), C)$ is $\bar{U}_{A_1}(C|t+1)$ which is, by condition (23) satisfied, smaller than the equilibrium payoff $U_{A_1}(D|t)$ so that action $s^1_t = C$ is equilibrium-dominated and condition (A7) is violated for A_1. For A_0, the (highest) payoff associated with $s^0_t = C$ and $s_{t+1} = S \in BR(\mathscr{P}(C), C)$ is $U_{A_0}(C) = (1-\theta)\,v(t)$, which is smaller than the equilibrium payoff, $U_{A_0}(S) = v(t) - \theta v(t-1)$, so that action $s^0_t = C$ is equilibrium-dominated and (A7) is violated for A_0. Hence, $\Theta(C) = \emptyset$. (SE) survives the *Intuitive Criterion* refinement for $\theta > 0$. Now, let $\theta = 0$. Again, condition (A7) is violated for A_1. For A_0, the (highest) payoff associated with $s^0_t = C$ and $s_{t+1} = S \in BR(\mathscr{P}(C), C)$ is $U_{A_0}(C) = v(t)$, which is the same as the equilibrium payoff, $U_{A_0}(S) = v(t)$, so that $s^0_t = C$ is *not* equilibrium dominated and (A7) is satisfied for A_0. Hence, $\Theta(C) = \{A_0\}$.

For *Step 2*, note that because $\Theta(C) = \emptyset$ if $\theta > 0$, this second step applies only to the case when $\theta = 0$. For $\Theta(C) = \{A_0\}$, $\pi^C_{t+1} = 0 < \bar{\pi}_{t+1}(\tau^a)$. This implies that (21) is satisfied. Agent B's best response is $s^C_{t+1} = C$ and $BR(\Theta(C), C) = \{C\}$. The (lowest) payoffs for A_0 when it plays $s^0_t = C$ (and B plays C in $t+1$) are $V(t)$ which are larger than the equilibrium payoffs

$U_{A_0}(S) = v(t)$ because $V(t) > v(t)$. By this, (A8) is satisfied and (SE) does not survive the *Intuitive Criterion* refinement if $\theta = 0$.

For the *D1* criterion we consider a slightly stricter *Step 1*. (Both criteria coincide in *Step 2*). For *D1*, the set $\Theta(s_t)$ of potential deviators contains the one agent A type that is *more likely* to take an out-of-equilibrium action $s_t \in \tilde{\mathscr{A}}_t$. More specifically, an agent A_h, $h = 1, 0$, is *more likely* to take an out-of-equilibrium action $s_t \in \tilde{\mathscr{A}}_t$ than an agent A_{-h} if there are more best responses $s_{t+1} \in BR(\mathscr{P}(s_t), s_t)$ to s_t such that the condition in equation (A7) is satisfied. Let $R_{A_h}(s_t)$ be the set of B's best responses $s_{t+1} \in BR(\mathscr{P}(s_t), s_t)$ that render $A_h \in \Theta(s_t)$,

$$R_{A_h}(s_t) = \left\{ s_{t+1} | U^*_{A_h}(s_t^{h*}) \leq \max_{s_{t+1} \in BR(\mathscr{P}(s_t), s_t)} U_{A_h}(s_t) \right\}. \tag{A9}$$

Let $|R_{A_h}(s_t)|$ be the number of elements in $R_{A_h}(s_t)$. Then, the type h for which $|R_{A_h}(s_t)|$ is largest is *more likely* to take an out-of-equilibrium action and is the single element in $\Theta(s_t)$.

D1 is (weakly) more restrictive than the *Intuitive Criterion*. It refines the set of equilibria only if $\Theta(s_t)$ in (A7) for the *Intuitive Criterion* is not a singleton, i.e., contains both agent A types. If $\Theta(s_t)$ in (A7) for the *Intuitive Criterion* is a singleton (or the empty set) and the candidate equilibrium survives the *Intuitive Criterion*, it also survives *D1*.

D1 for (PE)*:* For (PE), $\tilde{\mathscr{A}}_t = \{D\}$. Because $\Theta(D) = \emptyset$ when defined for the *Intuitive Criterion*, (PE) survives *D1*. *D1 for* (SE)*:* Let $\theta > 0$. For (SE), $\tilde{\mathscr{A}}_t = \{C\}$. Because $\Theta(C) = \emptyset$ when defined for the *Intuitive Criterion*, (SE) survives *D1* for $\theta > 0$. Because for $\theta = 0$, (SE) does not survive the *Intuitive Criterion*, it does not survive *D1*. $\hspace{2cm}$ Q.E.D.

Proof of Proposition 4. First, note that by (6), if A_1 discloses in t then B continues in $t + 1$ with certainty, $\beta_D^C = Pr(s_{t+1}^D = C | D) = 1$ and $\beta_D^S = 0$. Let then $\beta_C^C \equiv \beta$ and $\beta_C^S \equiv 1 - \beta$ agent B's response to $s_t = C$. Moreover, for A_1 disclosing dominates stopping (Lemma 3) so that $\alpha_1^S = 0$. Let then $\alpha_1^C \equiv \alpha_1$ and $\alpha_1^D \equiv 1 - \alpha_1$ so that $(\alpha_1, 1 - \alpha_1, 0)$ is A_1's strategy profile. Finally, let $\alpha_0^C \equiv \alpha_0$ and $\alpha_0^S \equiv 1 - \alpha_0$ so that $(\alpha_0, 1 - \alpha_0)$ is A_0's strategy profile.

Suppose (21) with $\tilde{\tau} = \tau^a$ is violated for some $t + 1$, B stops in $t + 1$ if A continues with certainty in t. In this case (PE) with $\alpha_1 = \alpha_0 = 1$ and $\pi_{t+1}^C = \pi$ cannot be sustained because

$\pi_{t+1}^C = \pi > \bar{\pi}_{t+1}(\tau^a)$. Because A_1 prefers disclose to continue ((23) is satisfied), (SE) with $\alpha_1 = \alpha_0 = 0$ can be sustained. In addition, a hybrid equilibrium can be constructed in which A_1 randomizes between continue and disclose (so as to leave B indifferent between continue and stop) and B randomizes between continue and stop (so as to leave A_1 indifferent between continue and disclose). In such a hybrid equilibrium, given α_1, α_0, and $\pi_{t-1} = \pi$, by Bayes' rule, agent B's posterior belief in $t+1$ is

$$\pi_{t+1} = \frac{\pi \alpha_1}{\pi \alpha_1 + (1-\pi)\alpha_0}. \tag{A10}$$

Because for $\alpha_0 = 0$ we have $\pi_{t+1} = 1$ for any α_1, the optimal strategy for A_1 is then to disclose with certainty, as in (SE). For A_1 to play both disclose and continue with strictly positive probabilities, A_0 must continue with strictly positive probability, $\alpha_0 > 0$.

Agent B with posterior beliefs π_{t+1} in (A10) is indifferent between continue and stop in $t+1$ if $U_B(C|\tau^e)$ in equation (20) (for $t+1$) is equal to $U_B(S|t)$ in equation (19) (for $t+1$). This $t = \tau^e$ denotes the expected future disclosure date, which may not be equal to the aspired disclosure date τ^a. Setting (20) equal to (19) and using (A10) we obtain

$$[V(t+1) - v(t)][\alpha_1 \pi + \alpha_0(1-\pi)] = \alpha_1 \pi [P(t+1|\tau^e) - \sigma(t+1)v(t)],$$

This expression holds if, and only if,

$$\alpha_1 = \hat{\alpha}_1(\alpha_0) \equiv \frac{\alpha_0(1-\pi)}{\pi} \frac{V(t+1) - v(t)}{P(t+1|\tau^e) - V(t+1) + (1-\sigma(t+1))v(t)}. \tag{A11}$$

For the sufficient conditions such that $\hat{\alpha}_1 \in (0,1)$ we are as restrictive as possible and set τ^e equal to the the next possible disclosure date in the next round, hence $\tau^e = t+2$. A sufficient condition for $\hat{\alpha}_1(\alpha_0) < 1$ for all $\alpha_0 > 0$ is

$$\pi > \frac{V(t+1) - v(t)}{P(t+1|t+2) - \sigma(t+1)v(t)} = \frac{V(t+1) - v(t)}{\sigma(t+2)V(t+1) - \sigma(t+1)v(t)}.$$

Finally, $\hat{\alpha}_1(\alpha_0) > 0$ for all $\alpha_0 > 0$ if, and only if,

$$\frac{V(t+1) - v(t)}{P(t+1|t+2) - \sigma(t+1)v(t)} = \frac{V(t+1) - v(t)}{\sigma(t+2)V(t+1) - \sigma(t+1)v(t)} < 1. \qquad (A12)$$

Moreover, if (A12) holds, there is a range of values of $\pi < 1$ such that $\hat{\alpha}_1(\alpha_0) < 1$. Observe that (A12) holds if $\sigma(t+2)$ is sufficiently larger than $\sigma(t+1)$ (e.g., when $\sigma(t+2)$ tends to one). If $\alpha_1 = \hat{\alpha}_1(\alpha_0)$, then agent B is indifferent between continue and stop. In order for A_1 to play $0 < \hat{\alpha}_1(\alpha_0) < 1$, B must play β so as to make A_1 indifferent between continue and disclose. A_1 is indifferent in t if the payoffs from disclosing in t are equal to the expected payoffs from continuing in t, i.e., $U_{A_1}(D|t) = \beta U_{A_1}(C|\tau^e) + (1-\beta)\bar{U}_{A_1}(C|t+1)$ with $U_{A_1}(D|t)$ in (16), $U_{A_1}(C|\tau^e)$ in (14), and $\bar{U}_{A_1}(C|t+1)$ in (A6). We obtain:

$$(1 + \sigma(t))V(t) = \beta\left[(V(t) + P(t|\tau^e)] + (1-\beta)[v(t) + \sigma(t+1)(pv(t+1) + (1-p)v(t))\right].$$

This equality holds for

$$\beta = \beta^* \equiv \frac{(1+\sigma(t))V(t) - [v(t) + \sigma(t+1)(pv(t+1) + (1-p)v(t))]}{V(t) + P(t|\tau^e) - [v(t) + \sigma(t+1)(pv(t+1) + (1-p)v(t))]} \qquad (A13)$$

where $\beta^* < 1$ because $P(t|\tau^e) > P(t|t) = \sigma(t)V(t)$ for all $\tau^e \geq t+2$. Because the numerator of (A13) is smaller than the denominator, a sufficient condition for $\beta^* > 0$ is a positive numerator which holds true by (23) being satisfied. At last, A_0 prefers continue to stop for $\beta > 0$ because $\beta U_{A_0}(C) + (1-\beta)\bar{U}_{A_0}(C) = \beta V(t) + (1-\beta)v(t) > v(t) = U_{A_0}(S)$, where $\bar{U}_{A_0}(C)$ denotes A_0 payoffs when B stops in $t+1$, and therefore plays a strategy $\alpha_0 = \alpha_0^* = 1$. In equilibrium, $\alpha_0^* = 1$, $\alpha_1^* = \hat{\alpha}_1(1) \in (0,1)$ in (A11), and $\beta^* \in (0,1)$ in (A13). Both of B's information sets are reached with strictly positive probability. Posterior beliefs π_{t+1}^C are in (A10) and $\pi_{t+1}^D = 1$.   Q.E.D.

Proof of Lemma 5. Intuitive Criterion for (HE)*:* Because α_1^* is strictly between 0 and 1, all actions $s_t \in \mathscr{A}_t$ that are followed by an information set for B are played with strictly positive

probability so that $\tilde{\mathscr{A}}_t = \emptyset$. (HE) survives the *Intuitive Criterion* refinement. Because there is no out-of-equilibrium action in (HE), the hybrid equilibrium survives *D1*. Q.E.D.

Proof of Proposition 5. First, condition (21), evaluated at $t+1$ as in our equilibrium analysis, is less restrictive for lower values of θ if $\bar{\pi}_{t+1}(\tau^a)$ is decreasing in θ. The derivative of $\bar{\pi}_{t+1}(\tau^a)$ with respect to θ is

$$\frac{\partial \bar{\pi}_{t+1}(\tau^a)}{\partial \theta} = -\frac{[P(t+1|\tau^a) - \sigma(t+1)V(t+1)] \cdot [v(t+1) - v(t)]}{\{(1-\theta)\,P(t+1|\tau^a) - \sigma(t+1)\,[v(t+1) - \theta v(t)]\}^2} < 0,$$

and is negative because $P(t+1|\tilde{\tau})$ is increasing in $\tilde{\tau}$ (Lemma 1) and $\tilde{\tau} > t+1$, so that $P(t+1|\tau^a) > \sigma(t+1)V(t+1) = P(t+1|t+1)$. Hence, $\bar{\pi}_{t+1}(\tau^a)$ is decreasing in θ.

Second, condition (21) is less restrictive for higher values of p if $\bar{\pi}_{t+1}(\tau^a)$ is increasing in p. To show this, let $\Delta_V \equiv \partial V(t+1)/\partial p$ denote the change of $V(t+1)$ as a response to a marginal change of p, and let $\Delta_P \equiv \partial P(t+1|\tau^a)/\partial p$ denote the change of $P(t+1|\tau^a)$ as a response to a marginal increase in p. Then

$$\Delta_V = \sum_{k=0}^{\infty} p^k \left(\frac{k(1-p)}{p} - 1\right) v(t+k+1) > 0,$$

$$\Delta_P = \sum_{k=0}^{\infty} p^k \left(\frac{k(1-p)}{p} - 1\right) \sigma(t+k+2)v(t+k+1) > 0.$$

Because $v(t)$ is increasing at a diminishing rate, and $\sigma(t)$ is increasing at a diminishing rate with range $[0,1]$, $\Delta_V > \Delta_P$. To show that $\bar{\pi}_{t+1}(\tau^a)$ is increasing in p, observe that only $V(t+1)$ in the numerator and $P(t+1|\tau^a)$ in the denominator are functions of p. Given an increase from p to p', the value of $V(t+1)$ increases to $V(t+1)|_{p'} = V(t+1)|_p + \Delta_V$; the value of $P(t+1|\tau^a)$ increases to $P(t+1|\tau^a)|_{p'} = P(t+1|\tau^a)|_p + \Delta_P$. For this reason, $\bar{\pi}_{t+1}(\tau^a)$ increases as p increases if

$$\bar{\pi}_{t+1}(\tau^a)|_p < \frac{(1-\theta)\,[V(t+1)|_p + \Delta_V] - [v(t+1) - \theta v(t)]}{(1-\theta)\,[P(t+1|\tau^a)|_p + \Delta_P] - \sigma(t+1)\,[v(t+1) - \theta v(t)]}.$$

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After some manipulation, we can rewrite this condition as

$$\bar{\pi}_{t+1}(\tau^a)|_p = \frac{(1-\theta)\,V(t+1) - [v(t+1) - \theta v(t)]}{(1-\theta)\,P(t+1|\tau^a)|_p - \sigma(t+1)\,[v(t+1) - \theta v(t)]} < \frac{\Delta_V}{\Delta_P}. \tag{A14}$$

In Lemma 2 we show that $\bar{\pi}_{t+1}(\tau^a)$ is strictly less than one. Then, because $\Delta_V > \Delta_P$, $\bar{\pi}_{t+1}(\tau^a)|_p < 1 < \Delta_V/\Delta_P$ and condition (A14) holds. Hence, $\bar{\pi}_{t+1}(\tau^a)$ is increasing in p. Q.E.D.

Proof of Proposition 6. For *claim (1)*, note that if $\pi \leq \pi^{\text{inf}} = \inf \bar{\pi}_{t+1}(\tau^a)$, then the condition for (PE) in Proposition 3 is satisfied for *all* $t + 1 \geq 2$. This implies that in *any* given t and $t + 1$, both agent A types and B continue and the conversational equilibrium is sustainable.

For claims (2) and (3) we establish the conditions under which neither agent A types nor B have an incentive to deviate from a continuation strategy in any $t' < \tau^*$ preceding the signaling game played in τ^* and $\tau^* + 1$ with (SE) in claim (2) when $\theta > 0$ and (HE) in claim (3) when $\theta = 0$. This means, given B continues in all $t' \leq \tau^* - 1$, we derive conditions under which both agent A types continue in all $t' \leq \tau^* - 2$; and given both agent A types continue in all $t' \leq \tau^* - 2$, we derive conditions under which B continues in all $t' \leq \tau^* - 1$.

Claim (2). Secret holder A_1: If A_1 (disclosing in τ^* in (SE)) continues in t', it obtains payoffs of $(1-\theta)\,[V(t') + P(t'|\tau^*)]$. If it stops in t', its payoffs are $v(t') - \theta v(t'-1) + \sigma(t')\,(1-\theta)\,v(t'-1)$. Hence, if B continues in all $t' \leq \tau^* - 1$, A_1 continues in all $t' \leq \tau^* - 2$ if, and only if,

$$\frac{V(t') + P(t'|\tau^*) - (1 + \sigma(t'))\,v(t'-1)}{v(t') - v(t'-1)} \geq \frac{1}{1-\theta}, \tag{A15}$$

which is always satisfied if (6) holds in t'. To establish this, note that for $t' = \tau^*$, the condition is equivalent to condition (10) (where $\tau^* = \tilde{\tau}$) which is less restrictive than (6) for $\tau^* > 1$ and equivalent to (6) for $\tau^* = 1$. Holding t' constant, as τ^* increases $P(t'|\tau^*)$ increases and the LHS of (A15) increases, rendering (A15) less restrictive.

Non-secret holder A_0: If A_0 (stopping in τ^* in (SE)) continues in t', it obtains payoffs of

$$(1-\theta)\sum_{k=0}^{\tau^*-t'-1} p^k\,(1-p)\,v(t'+k) + p^{\tau^*-t'}\,[v(\tau^*) - \theta v(\tau^* - 1)].$$

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If it stops in t', it obtains payoffs of $v(t') - \theta v(t' - 1)$. Hence, if B continues in all $t' \leq \tau^* - 1$, A_0 continues in all $t' \leq \tau^* - 2$ if, and only if,

$$(1 - \theta) \sum_{k=0}^{\tau^*-t'-1} p^k (1 - p) v(t' + k) + p^{\tau^*-t'} [v(\tau^*) - \theta v(\tau^* - 1)] \geq v(t') - \theta v(t' - 1). \quad \text{(A16)}$$

We first show that $\theta \to 0$ is a sufficient condition for (A16) to hold true in all $t' \leq \tau^* - 2$. To this end, we rewrite condition (A16) for $\theta \to 0$ and obtain

$$\sum_{k=0}^{\tau^*-t'-1} p^k (1 - p) v(t' + k) + p^{\tau^*-t'} v(\tau^*) - v(t') \geq 0. \quad \text{(A17)}$$

After some manipulation, the LHS of (A17) becomes $\sum_{k=1}^{\tau^*-t'} p^k [v(t' + k) - v(t' + k - 1)]$ which is strictly positive because $v(t)$ strictly increases in t. Hence, for $\theta \to 0$, A_0 continues in all $t' \leq \tau^* - 2$. Moreover, by continuity, if θ is positive but sufficiently small, (A16) holds true and A_0 continues in all $t' \leq \tau^* - 2$ when it anticipates B to continue in all $t' \leq \tau^* - 1$.

Agent B: For B we derive a sufficient condition under which it is, in all periods $t' \leq \tau^* - 1$, more inclined to continue when the equilibrium in the continuation game starting at τ^* is (SE) than in the case when the equilibrium in that game is (PE). In other words, the idea is to obtain the condition such that the posterior beliefs' critical threshold below which B continues in all $t' \leq \tau^* - 1$ is larger when (SE) is played in τ^* than when (PE) is played in τ^*.

From Lemma 2, we know that under a conversational equilibrium in which (PE) is played in τ^* agent B continues in t' if

$$V(t') - \pi_{t'} P(t'|\tau^a) \geq \frac{U_B(S|t')}{1 - \theta} \quad \text{(A18)}$$

is satisfied, where $U_B(S|t')$ in (20) are B's payoffs from stopping in t' (and inducing A to disclose in t'). In what follows, we construct the analogous condition when B expects both agent A types to continue between t' and $\tau^* - 2$, A_1 to disclose in τ^*, and A_0 to stop in τ^*. If B continues in t' it obtains expected payoffs of $(1 - \theta) [V(t') - P(t'|\tau^*)]$ with probability $\pi_{t'}$

(when A is expected to be secret holder) and

$$(1 - \theta) \left[\sum_{k=0}^{\tau^* - t' - 1} p^k (1 - p) v(t' + k) + p^{\tau^* - t'} v(\tau^* - 1) \right]$$

with probability $1 - \pi_{t'}$ (when A is expected to be a non-secret holder). By this logic, if both agent A types continue in all $t' \leq \tau^* - 2$, B continues in all $t' \leq \tau^* - 1$ if

$$\pi_{t'} [V(t') - P(t'|\tau^*)] + (1 - \pi_{t'}) \left[\sum_{k=0}^{\tau^* - t' - 1} p^k (1 - p) v(t' + k) + p^{\tau^* - t'} v(\tau^* - 1) \right] \geq \frac{U_B(S|t')}{1 - \theta}. \text{(A19)}$$

Condition (A18) is more restrictive than (A19) if the LHS of (A19) is at least as large as the LHS of (A18). This is the case if

$$\pi_{t'} [P(t'|\tau^a) - P(t'|\tau^*)] - (1 - \pi_{t'}) \left[V(t') - \sum_{k=0}^{\tau^* - t' - 1} p^k (1 - p) v(t' + k) - p^{\tau^* - t'} v(\tau^* - 1) \right] \geq 0.$$

After some manipulation we obtain

$$V(t') - \sum_{k=0}^{\tau^* - t' - 1} p^k (1 - p) v(t' + k) - p^{\tau^* - t'} v(\tau^* - 1) = p^{\tau^* - t' - 1} [V(\tau^* - 1) - v(\tau^* - 1)].$$

Collecting terms, (A18) is more restrictive than (A19) if condition (27) in the text holds. This condition (27) implies the following: If $\pi_{t'} \leq \bar{\pi}_{t'}(\tau^a)$, i.e., if B continues in t' when anticipating that agent A types continue in all t' (Lemma 2), then B continues in t' when it anticipates A_1 to disclose in τ^* and A_0 to stop in τ^*. The LHS of (27) is positive and equal to B's gains when A_1 discloses in $\tau^* < \tau^a$, discounted by the posterior belief $\pi_{t'}$ that $A = A_1$. The RHS of the condition corresponds to the costs that B incurs when the conversation stops in τ^* instead of continuing in all future periods (as it would be under (PE)), discounted by the probability $p^{\tau^* - t' - 1}$ of reaching stage $\tau^* - 1$ and the posterior belief $1 - \pi_{t'}$ that $A = A_0$.

For *claim (3)*, analogously to the proof of claim (2), we derive the conditions under which neither agent A types nor B have an incentive to deviate from a continuation strategy in any $t' < \tau^*$ preceding the signaling game played in τ^* with (HE) when $\theta = 0$.

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Secret holder A_1: Under (HE), A_1 is indifferent between disclosing and continuing in $t = \tau^*$, implying that $U_{A_1}(D|\tau^*) = \beta^* U_{A_1}(C|\tau^e) + (1 - \beta^*)\bar{U}_{A_1}(C|\tau^* + 1)$ with β^* the probability of B choosing to continue and $1 - \beta^*$ the probability of B choosing to stop. Moreover, A_1 is indifferent between disclosing and any mixture of disclosing and continuing, implying that

$$U_{A_1}(D|\tau^*) = \alpha_1^* U_{A_1}(D|\tau^*) + (1 - \alpha_1^*)\left[\beta^* U_{A_1}(C|\tau^e) + (1 - \beta^*)\bar{U}_{A_1}(C|\tau^* + 1)\right].$$

If A_1 continues in t' and plans to disclose in τ^* with probability α_1^* and continue in τ^* with probability $1 - \alpha_1^*$, its expected payoffs are the same as when it discloses in τ^* with a probability of one (as in (SE)). By (16), these expected payoffs are $V(t') + P(t'|\tau^*)$. Suppose B continues in all $t' \leq \tau^* - 1$, A_1 continues in all $t' \leq \tau^* - 2$ if, and only if,

$$\frac{V(t') + P(t'|\tau^*) - (1 + \sigma(t'))\,v(t' - 1)}{v(t') - v(t' - 1)} \geq 1, \tag{A20}$$

which is equivalent to (A15) for $\theta = 0$. Because (A15) always holds when (6) is satisfied, (A20) always holds when (6) is satisfied.

Non-secret holder A_0: Under (HE), A_0 continues with certainty in $t = \tau^*$ and B continues in $t + 1$ with a probability between 0 and 1. A_0's payoffs from continuing in t' are therefore higher than under (SE) when evaluated for $\theta \to 0$. Because A_0 continues under (SE) (because (A17) holds for $\theta \to 0$), it also continues under (HE).

Agent B: Under (HE), in $t + 1 = \tau^* + 1$ agent B is indifferent between continue and stop. Hence, its payoffs from continue given the anticipated (or expected) disclosure by A_1 in $\tau^e \in (\tau^*, \tau^a)$ are equal to its expected equilibrium payoffs in $\tau^* + 1$. When $A = A_1$, these payoffs are $V(t') - P(t'|\tau^e)$ with probability $\pi_{t'}$ and expected payoffs of $V(t')$ with probability $1 - \pi_{t'}$ (recall, A_0 continues with certainty). Its expected payoffs from continuing under (HE) are then $V(t') - \pi_{t'}P(t'|\tau^e)$. Hence, if both agent A types continue in all $t' \leq \tau^* - 2$, agent B continues in all $t' \leq \tau^* - 1$ if $V(t') - \pi_{t'}P(t'|\tau^e) \geq U_B(S|t')$. This condition is less restrictive than (A18) under (PE) because $V(t') - \pi_{t'}P(t'|\tau^e) \geq V(t') - \pi_{t'}P(t'|\tau^a)$ (yielding (28)) because $\tau^e < \tau^a$.

To establish claims (2) and (3) in the proposition, we recapitulate. Let (6) be satisfied and suppose $\tau^* > 1$. When anticipating that B continues in all $t' \leq \tau^* - 1$, both agent A types continue in all $t' \leq \tau^* - 2$ if $\theta > 0$ is small (for (SE)) or $\theta = 0$ (for (HE)). Agent B, when anticipating that both agent A types continue in all $t' \leq \tau^* - 2$, continues in all $t' \leq \tau^* - 1$ if $\pi_{t'} \leq \bar{\pi}_{t'}(\tau^a)$ (i.e., (21) holds) and (27) holds. We have defined $t = \tau^*$ as the lowest $t \in T_A$ such that $\pi > \bar{\pi}_{\tau^*+1}(\tau^a)$. Because $\tau^* > 1$, it must be that $\pi \leq \bar{\pi}_{t'}(\tau^a)$ for all $t' < \tau^*$. Suppose $\pi > \bar{\pi}_{t'}(\tau^a)$ for $t' < \tau^*$, then by definition of τ^* it must be that $t' = \tau^*$, contradicting $t' < \tau^*$. Recall that B anticipates that both agent A types continue in all $t' \leq \tau^* - 2$. If both agent A types continue, then B cannot update its prior beliefs, and $\pi_{t'} = \pi$ for all $t' \leq \tau^* - 1$. Then, $\pi \leq \bar{\pi}_{t'}(\tau^a)$ for all $t' < \tau^*$ implies that $\pi_{t'} \leq \bar{\pi}_{t'}(\tau^a)$ for all $t' < \tau^*$. Because of this, a sufficient condition for B to continue in all $t' \leq \tau^* - 1$ is (27). Finally, if both agent A types continue and agent B continues in all $t' \leq \tau^* - 1$, then the signaling game in τ^* and $\tau^* + 1$ is reached. Alternatively, let $\tau^* = 1$, then the signaling game is played at the outset and the question of reaching τ^* does not arise.

[Figure 2 about here.]

In Figure 2 we depict two examples for $\bar{\pi}_{t+1}(\tau^a)$, varying $t + 1$. In panel (a), $\bar{\pi}_{t+1}(\tau^a)$ is strictly decreasing in $t+1$. This implies that the smallest $t \in T_A$ such that $\pi > \bar{\pi}_{\tau^*-1}(\tau^a)$ is the unique τ^*. In panel (b), $\bar{\pi}_{t+1}(\tau^a)$ is hump-shaped. This means there are values of $\pi = \pi'$ such that $\pi' > \bar{\pi}_{t+1}(\tau^a)$ for low $t+1$, $\pi' < \bar{\pi}_{t+1}(\tau^a)$ for intermediate $t+1$, and $\pi' > \bar{\pi}_{t+1}(\tau^a)$ for high $t + 1$. For these priors π', the signaling game is played in $t = 1$ and $t = 2$ and $\tau^* = 1$.   Q.E.D.

Proof of Proposition 7. Condition (29) for $\theta \geq 0$ is (22) when evaluated in B's first period, $t = 2$. If at $t = 2$, the critical value $\bar{\pi}_t(\tilde{\tau})$ in Lemma 2 (for $\tilde{\tau} = \tau^a = \infty$) is strictly less than unity, then for $\pi = 1$ condition (21) is violated and B stops in $t = 2$. Because (23) is satisfied, A_1 discloses in $t = \tau^* = 1$ with certainty (Proposition 3 for $\theta > 0$) or strictly positive probability (Proposition 4 for $\theta = 0$). The conditions in Proposition 6 for the conversation to reach τ^* do not apply because $\tau^* = 1$.   Q.E.D.

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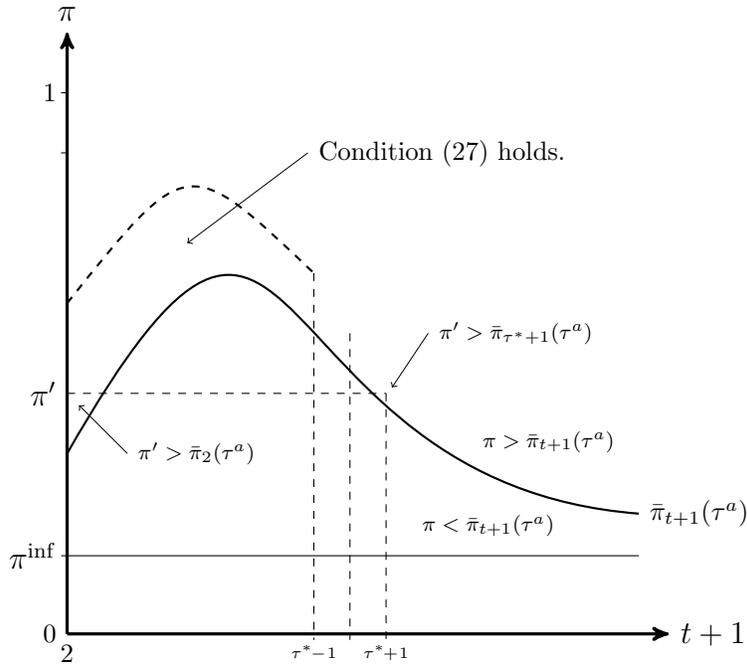
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Figure 1: CONVERSATION GAME WITH SECRETS

Figure 2: SHAPES OF $\bar{\pi}_{t+1}(\tau^a)$
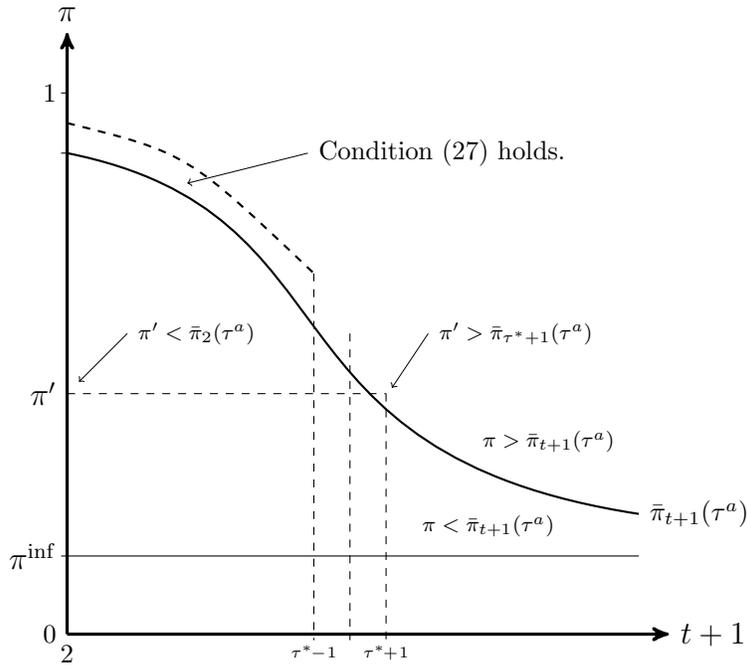
(a) DECREASING $\bar{\pi}_{t+1}(\tau^a)$

(b) HUMP-SHAPED $\bar{\pi}_{t+1}(\tau^a)$

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Table 1: OVERVIEW OF EQUILIBRIUM RESULTS

	No competition: $\theta = 0$	Competition: $\theta > 0$
Low prior beliefs: $\pi \leq \pi^{\inf}$	**Pooling Equilibrium** (PE) *1)* Conversation is sustainable for both agent A types. *2) Ex-post* disclosure.	
High prior beliefs: $\pi > \pi^{\inf}$	**Hybrid Equilibrium** (HE) *1)* Conversation is sustainable in $t < \tau^*$ and sustainable with positive probability in $t \geq \tau^*$. *2) Ex-ante* disclosure in τ^* or later.	**Separating Equilibrium** (SE) *If condition* (27) *holds and θ small:* *1)* Conversation is sustainable in $t < \tau^*$ but sustainable in $t \geq \tau^*$ only for the secret holder. *2) Ex-ante* disclosure in τ^*.
$\pi > \bar{\pi}_2(\tau^a)$	**Hybrid Equilibrium** (HE) *1)* Conversation is sustainable with positive probability in $t \geq \tau^* = 1$. *2) Ex-ante* disclosure in $\tau^* = 1$ or later.	**Separating Equilibrium** (SE) *Immediate disclosure* *1)* Conversation is sustainable in $t \geq \tau^* = 1$ only for the secret holder. *2) Ex-ante* disclosure in $\tau^* = 1$.
$\bar{\pi}_2(\tau^a) < 1$ and $\pi = 1$	*Immediate disclosure* *1)* Conversation is sustainable in all $t \geq \tau^* = 1$ *2) Ex-ante* disclosure in $\tau^* = 1$.	