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Distrust, but verify?
Theoretical insights into auditing carbon sequestration in tropical forests

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Distrust, but verify?

Theoretical insights into auditing carbon sequestration in tropical forests

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Abstract

Greenhouse gas emissions abatement costs are of a significant character. Therefore, mitigation activities involving low marginal abatement costs, such as carbon sequestration in tropical forest, are appealing. Challenges related to information, incentives and institutions, however, hinder the implementation of such a scheme. After failing to reach consensus at 2012 climate summit, a decision on the topic of monitoring, reporting and verification is expected to be adopted at the 2013 climate summit.

Generalizing the cost structure of Kofman and Lawarrée (1993), I characterize if and how it is best to audit conservation. In my model, the donor country has to disposal two auditors; An auditor located in the recipient country who is costly and might collude with landholders, and an international and independent auditor who is more expensive but truthful.

When the limited liability constraint of landholders is low and the auditing technology is imperfect, I find that costs of auditing may be so high that one is better-off not doing it. Interestingly, the findings therefore underscore the scope of capacity building. Such activities may facilitate a reduction in costs of auditing. It might become preferable to use an auditor of the recipient country to monitor reports of landholders and then have an independent institution at the international level verifying this information.

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Introduction

Motivation

Reducing emissions of greenhouse gases to mitigate climate change is expected to yield large net benefits (Nordhaus, 2008). However, even lower bound estimates of expected emissions abatement costs are nontrivial (Stern, 2007). For these reasons, economists and policy makers have found it appealing to consider activities to mitigate greenhouse gases involving low marginal abatement costs. Much spurred by Stern (2007), one arrangement that has achieved much attention over the last years is carbon sequestration in tropical forests. Since the 2007 Bali climate summit, it has been negotiated under the heading REDD+, an acronym for Reduced Emissions from Deforestation and forest Degradation in developing countries. The argument is that if deforestation is carried out at the margin and agricultural rent is low, it may potentially reduce costs of mitigation activities (for an investigation, see, e.g., Kindermann et al., 2008).

Despite the prospects of a scheme for conserving rainforest, there are fundamental challenges in implementing it. Angelsen (2010) conceptualizes challenges within three categories: Information, incentives and institutions. Information relates to the fact that the audit technology, to stick to my glossary, is imperfect. The donor country will not be perfectly aware of whether or not money set aside for projects induce conservation that would not have happened anyway. In other words, by only having an imperfect representation of the counterfactual, one leaps into a problem of additionality. This relates to the difficulty creating the right incentives. The fact that the landholders' outside opportunities are not observed open up for adverse selection. A landholder might make use of his private information to grab rents from the donor, pretending that the area conserved would not have been conserved anyway (Mason and Plantinga, 2013). If this is the case, the donor country ends up spending money on conserving forest that would have been conserved nonetheless. Another challenge with landholders' incentives is that the donor country cannot perfectly observe the effort put down to part with practices driving deforestation (for an illustration, see, e.g., MacKenzie et al., 2012). The problem of moral hazard is also central in evaluating the impact of institutions. This relates to monitoring whether or not conservation efforts truly are additional. Romijn et al. (2012) and Herold and Skutsch (2009) state that conflict of interests may be magnified by low levels of institutional capacity. If closely related to the forest sector, bureaucrats of the recipient country can have an incentive to manipulate the monitored information reported to the international community (Angelsen, 2010). In the forest country Indonesia, for example, Palmer (2005) underscores the frequent amounts of bribery in the forest sector.[1]

At the 2012 climate summit in Doha, parties to the United Nation's climate convention were expected to come to an agreement on the topics of monitoring, reporting and verification (UNFCCC, 2012). However, for different reasons the largest donor and recipient countries were not able to compromise and no consensus were made (IISD, 2012). Recipient countries, such as Brazil, have for a long while argued in favor of monitoring conservation themselves (IISD, 2012). One reason is that REDD+ is voluntary in nature. On the other hand, donor countries, including Norway, have raised their voice in favor of relying on internal audits by the recipient country, but with reviews conducted by an international and independent agency (IISD, 2012). One reason for this is that they need to be accountable to their electorate when spending funds on international efforts.

Because of the breakdown, it is up to the 2013 climate summit in Warsaw to adopt decisions on how to audit conservation. The current draft conclusions resemble something looking like the position of donor countries (UNFCCC, 2013). This document will most likely be the basis for the discussions at the climate summit in Warsaw this November.

Acknowledging the challenges of information, incentives and institutions in implementing REDD+, the objective of my dissertation is to inform the decision to be made. The question set forth answering is whether or not it is optimal for the donor country to have landholders' reported conservation audited. Further, if it is efficient to monitor the claims of landholders, which auditors should be utilized? Is it better to rely on auditing effort conducted by the government of the recipient country, by an international and independent institution, or a combination of these?

Contribution and literature

In answering the above question, I generalize the framework by Kofman and Lawarrée (1993) for studying collusion in hierarchies. Kofman and Lawarrée (1993) combine the models of Baron and Besanko (1984) and Tirole (1986). In the model, they analyze whether or not it is optimal for the shareholders of a firm to rely on the firm auditing itself or if an external auditor should be employed in assessing its economic performance. The aim is to reduce the rents and increase

[1] Suggestive evidence for this being a challenge is the letter of intent defining the agreement on forest conservation between Norway and Indonesia. As a prerequisite, Norway claimed the auditing authority to be located outside ministries regulating the forest sector (Norway, 2010).

the effort of the manager. The internal auditor is free, contrary to Tirole (1986), but requires a compensation not to collude with the manager and thereby manipulate its report. The external auditor, on the other hand, is truthful but costly, and closely follows the set-up of Baron and Besanko (1984). The analysis by Kofman and Lawarrée (1993) serves as a motivation for shareholders relying on both auditors, contrary to previous arguments by Williamson (1985) on the limits to organizations.[2] Since the opportunity cost of relying on the internal auditor is small, Williamson (1985) argues for using the internal auditor. The external auditor is therefore seen as a substitute and not a compliment to the internal auditor. Kofman and Lawarrée (1993) find that for an imperfect quality of the audit technology and a high enough upper bound on the limited liability constraint on the manager, meaning the maximum level for which he could be punished if detected cheating, the internal auditor should be utilized all of the times. However, relying on the external auditor should be randomized with the aim of eliminating the compensation made to the internal auditor to avoid him colluding. This challenges Williamson (1985).

Inspired by the theoretical model of the seminal contribution of Tirole (1986) and stylized facts from the case of conservation in the tropics, I generalize the set-up of Kofman and Lawarrée (1993). In Kofman and Lawarrée (1993) there is no cost in using the internal auditor, except paying him not to collude with the agent. However, as argued later, costs for an agency of the recipient country to monitor the amount of forest conserved by landholders are significant (Böttcher et al., 2009; Hardcastle et al., 2008). Therefore, I incorporate this aspect into Kofman and Lawarrée (1993). This alters some of the general applicability of their results. Under some conditions, it may be efficient for the principal to rely only on the external auditor. In such a case I distance from the findings of Kofman and Lawarrée (1993) and more closely follow Williamson (1985). But more relevant for the case of conservation in the tropics, in which, as argued later, the limited liability constraint of landholders is low (see, e.g., Sands and Peel, 2012) and the auditing technology is imperfect (see, e.g., Asner, 2011), the costs of auditing may be so high that the donor country would be better-off not auditing. Interestingly, my findings therefore underscore the importance of combining monitoring with capacity building. Capacity building may facilitate a reduction in the costs of utilizing internal auditing (Wertz-Kanounnikoff and Verchot, 2008). Within the relevant domain of the limited liability constraint of the landholder and the quality of the audit technology, it might therefore be preferable for the donor country to utilize an auditor in the recipient country to monitor reports of landholders and then have an independent institution at the international level verifying this information.

[2] Some other seminal contributions on the limits of organizations include Coase (1937), Arrow (1974), and Stiglitz (1975).

My contribution to the body of academic and technical literature is two-fold. First, my dissertation contributes to theories on collusion in hierarchies. This is because some previous findings no longer are true on a general basis. Second, my dissertation is, to my knowledge, the first application of a model like this to conservation in the tropics. Therefore, it may hopefully inform the decision to be agreed upon at the 2013 climate summit in Warsaw.

The dissertation proceeds as follows. The next section presents the theoretical model. In this section literature is pointed towards for supporting my claims. Then, the model is solved. In addition to presenting reference cases, it is illustrated how the efficient audit regime depends on the limited liability constraint on the landholder and the quality of the audit regime. I also show that my results converge to the results of Kofman and Lawarrée (1993) when it is costless to use the government of the recipient country to audit landholders. Subsequently, for the relevant domain of parameter values, I discuss how the choice of audit regime is affected by conducting capacity building, general attempts to reduce auditing costs, and effort to increase the quality of the audit technology. I close the dissertation by presenting policy implications, discussing some limitations, and highlighting areas of future research. Proofs are delegated to the appendix.

The model

Some characterizations

In order to better structure the question I am endeavoring to answer, namely if and how to monitor and verify that landholders in developing countries truly are conserving as much forest as they are being paid for, I have modeled a three-level hierarchy with four players. The players are the government of the donor country (principal), an auditor based in the recipient country (internal auditor), an international and independent auditor (external auditor), and a representative landholder in the recipient country (agent). All players are assumed to be risk-neutral, although — as formalized later — the internal auditor and the agent are protected by a specified limit to liability. In the model, the principal contracts with the agent to conserve forest, and the agent executes the assignment being privately informed about its baseline and effort.[3] The auditors are called in to monitor the efficiency of the agent if the principal request so. The model presented is a generalization of the set-up by Kofman and Lawarrée (1993). In Kofman and Lawarrée (1993), only sending the external auditor involves a cost. Sending the internal auditor therefore comes at no cost, except compensating the internal auditor for not colluding with the agent. As argued later in this section, recognizing that monitoring carbon sequestration is costly implies that the assumption of the internal auditor being free should be relaxed.

I assume the hierarchy to be the optimal structure of the relationship between the principal, auditors and the agent. This has the implication that it will never be optimal for the principal to take the actions of conserving forest of the recipient country himself. For a justification of such a claim, consult Harstad (2013). Harstad argues that leasing forest would be more efficient than buying it, provided that the forest is outside the boundaries of the country interested in conserving it. One narrative supporting this claim is that protection costs would be higher if bought by a foreign country. Another implication of the above statement is that it is not effective for the principal to audit whether or not the agent is conserving. Theoretical reasons might be that costs of information processing are lower for auditors given that they specialize in such tasks (Tirole, 1986). I also assume that the principal is able to commit to his audit strategy (Khalil, 1997). According to Khalil and Lawarrée (1995, p. 443), this assumption might be problematic if "the relationship is long-term in nature, the principal is dealing with many small

[3] Throughout the dissertation, I assume that property rights are well-defined. Articles discussing conservation and property rights include Palmer (2011) and Araujo et al. (2009).

agents, and audits are observable." Recognizing this limitation, I stick to this assumption to keep my model tractable.

The amount of land in forest at the end of the game x is a function of some representation of the agent's effort e and his baseline θ. More specifically, e might be thought of as practices such as foregoing selective logging, preventing forest fires, avoiding over-exploitation of fuel wood and other non-timber products, or keeping the land free from mining activity (GOFC-GOLD, 2010). θ, on the other hand, is the some measure of what would have been conserved if no compensation is made by the principal (Wertz-Kanounnikoff and Verchot, 2008). The higher θ, the more land would have been conserved without compensation. I refer to this as the baseline. Kofman and Lawarrée (1993) is analyzing a function assumed to take the form $x = \theta + e$. For the purpose of conservation in the tropics, however, this is not an adequate representation. Rather, I define the function $x - \theta = e$. Intuitively, the additional amount of conserved forest $x - \theta$ is equal to the effort induced by the agent to conserve it. θ takes values θ_1 or θ_2, in which $\theta_1 < \theta_2$ and $\theta_2 - \theta_1 \equiv \Delta\theta$. θ_1 is drawn with probability q and θ_2 with $(1-q)$. The reason for relying on the simplistic two-type case is that the problem gets less tractable by letting the number of types grow large. This is due to losing the single-crossing condition (Laffont and Martimort, 2002). Hence, I make use of the two-type case to be able to rely on local incentive constraints. While amount of forest conserved by the agent x is observable for all players, effort e and baseline θ are assumed to be known only to the agent.[4] Therefore, there is asymmetric information. Specifically, adverse selection arises because the agent is being privately informed about his baseline. This gives rise to moral hazard because the agent gets privately informed about his effort.

By specifying the function above on the form $x - \theta = e$, the principal is only valuing conservation that is additional. The principal's per unit valuation of additionally conserved rainforest is normalized to unity. If the agent does effort e to conserve, he gets disutility $\frac{e^2}{2}$. Note also that the contract offered by the principal might specify a punishment P^a, which under some conditions — introduced later — can be imposed on the agent. Therefore, the agent objective is to maximize $t - \frac{e^2}{2} - E(P^a)$, where t is the transfer from the principal to the agent in order to induce effort. A further restriction is that $\frac{q}{(1-q)} > \Delta\theta$. This assumption, which is common across

[4] Note that qualitative results need not be very different by not letting x be observed by the principal. Contrary to Tirole (1986), papers by Baliga (1999) and Faure-Grimaud, Laffont and Martimort (2003) find that principal-supervisor-agent models possess some equivalence under the different set of informational assumptions.

the literature, implies that the principal is willing to contract with any agent even without the possibility of applying auditors.

The internal auditor observes a signal $s \in \{s_1, s_2\}$ which is imperfectly correlated with θ, but is not necessarily reporting truthfully. The report of the internal auditor is denoted $\hat{s}^i$. Thus, it is assumed that the auditor rather than monitoring the agent's effort, try to represent additional land in forest by approximating the baseline (Herold and Skutsch, 2009). I therefore stick to the requirements of the early tiers of the IPCC Good Practice Guidelines for reporting at the international level (IPCC, 2003, 2006). Hence, I take into account some institutional and political limits to auditing addressed in the climate negotiations (UNFCCC, 2009).

The external auditor is assumed to observe the same signal s, and if employed, truthfully reports $\hat{s}^e = s$. Since both auditors observe an identical signal, I follow Kofman and Lawarrée (1993) by not taking into account the value of information. For a recent model explicitly taking into account the value of information in auditing collusive behavior, I refer to Banerjee et al. (2012). This alternative approach allows investment in the audit technology rather than choosing between auditors. The rational for letting auditors observe the same exogenous signal is to make the choice between auditors explicit. If any of the auditors are utilized and learns the signal, the agent is assumed to learn the signal, as well. I allow for type-1 and type-2 errors by imposing the following probability distribution: $Prob(s_1|\theta_1) = Prob(s_2|\theta_2) = r$; $Prob(s_1|\theta_2) = Prob(s_2|\theta_1) = (1-r)$. This means that signals are correct with probability r and incorrect with probability $(1-r)$, irrespective of θ. It is assumed that $r > \frac{1}{2}$. This is a fair assumption because it allows the audit technology to be imperfect but still relevant. Later in the dissertation the quality of the audit technology is discussed. The general tendency in the literature is that the audit technology is lacking precision but is serving some purpose in detecting whether or not conservation is additional (Asner, 2011; Haverman, 2009). Therefore, it is key to take into account the audit technology in advising on an audit regime.

In some respects, my model parts significantly from Kofman and Lawarrée (1993). Contrary to their paper, internal auditing comes not necessarily for free. In addition to a reward w to the internal auditor to avoid him colluding with the agent, sending him comes at a cost kz, in which $1 > k \geq 0$.[5] Let z be the cost of sending the truthful external auditor. In Kofman and Lawarrée (1993) $k = 0$, meaning that the act of sending the internal auditor is costless. As I show formally, this assumption is crucial for driving their results. Relaxing this restriction makes the picture more complex. It becomes less obvious which, if any, auditor to rely on. The reason for relaxing this assumption, besides general theoretical interest, is that it brings us closer to the

[5] Argument for $k < 1$ are provided later.

case of conservation in the tropics. A growing stock of academic and technical literature highlights that sending the internal auditor will come at a cost (see, e.g., Romijn et al., 2012; Böttcher et al., 2009; Hardcastle et al., 2008; UNFCCC, 2009; Wertz-Kanounnikoff and Verchot, 2008). One reason is because a cost-effective approach to monitoring requires both remote sensing and ground measurements. These activities are not costless. The interesting theoretical case would be the one where the cost of sending the internal auditor alone is strictly smaller than the costs of sending the external auditor alone. If not, we would choose to only utilize the external auditor. Therefore, I have set $k < 1$. This is a plausible assumption because the internal auditor would have contextual knowledge and expertise that the external auditor does not possess. Also, sending the external auditor would be more costly since it is further away from the relevant sites. A counter-argument is, however, that the external auditor can rely on economics of scale (Böttcher et al., 2009). Therefore, this paper relies on the assumption that economics of scale does not offset the cost-savings of relying on an auditor located closer to the relevant landholders. By including k in the model, I also allow the benefits of capacity building bringing k down to be investigated.

Note that the principal, through the design of the contract, can introduce the possibility of punishing the agent. We assume that this punishment P^a is bounded above by an exogenously given P^{a*}, which can be interpreted as a limit on liability. Therefore, if the internal or external auditor reports a signal different from what the agent reported to the principal, the agent can be punished up to the level of P^{a*} by the principal. Note further that this payment is not depending on the transfer t between the principal and agent. Therefore, we are relying on an exogenous punishment rather than an endogenous punishment where the fine is imposed to be larger or equal to the agent's benefit from cheating (Laffont and Martimort, 2002). The rationale for specifying the punishment in such a way is to enable me to look into how the choice of auditing regime depends on the constraint on liability of the agent. International environmental law is known for having low limits to liability (Sands and Peel, 2012).[6]

There is scope for collusion between the agent and the internal auditor. Even though monitoring activities may reduce rent seeking because of increased transparency (Tacconi et al., 2009), there are good reasons for claiming the reverse to be true. Many countries where rainforest conservation activities are occurring or are planned to take place, lack the capacity to confront collusive behavior (Romjin et al., 2012). If the internal auditor is sent alone, the agent is willing to pay a bribe up to P^{a*} for the internal auditor to manipulate the signal to the principal.

[6] An alternative, however, is to look into contract breach. For a contribution on termination, consult Stiglitz and Weiss (1983). Within the domain of conservation, Palmer et al. (2009) offer an interesting perspective. This is to be discussed later.

A paper explicitly modeling the design and enforcement of side-contracts between the auditor and agent is Martimort (1999) looking into dynamics. This opens for the role of differing time preferences. Another article is Laffont and Meleu (1997) conceptualizing it as exchange of favors. Mutual information between auditors and the agent may hurt the principal. Since the internal auditor knows the agent best, this is an argument for relying on the external auditor. In this dissertation, however, the bargaining process is not modeled. It is assumed that the side-contract between the agent and the internal auditor is enforceable and non-renegotiable. If collusion is detected, meaning that the external auditor when policing the internal auditor reports a different signal to the principal, a punishment P^i bounded above by P^{i*} is imposed by the principal on the internal auditor. The agent is punished at P^a.

Finally, the principal designs and offers the contract to the agent and the auditors with the aim of maximizing his expected profits $E(\pi) = [x - \theta - t - w - kz - z + P^a + P^i]$. The timing of the game is according to Figure 1.

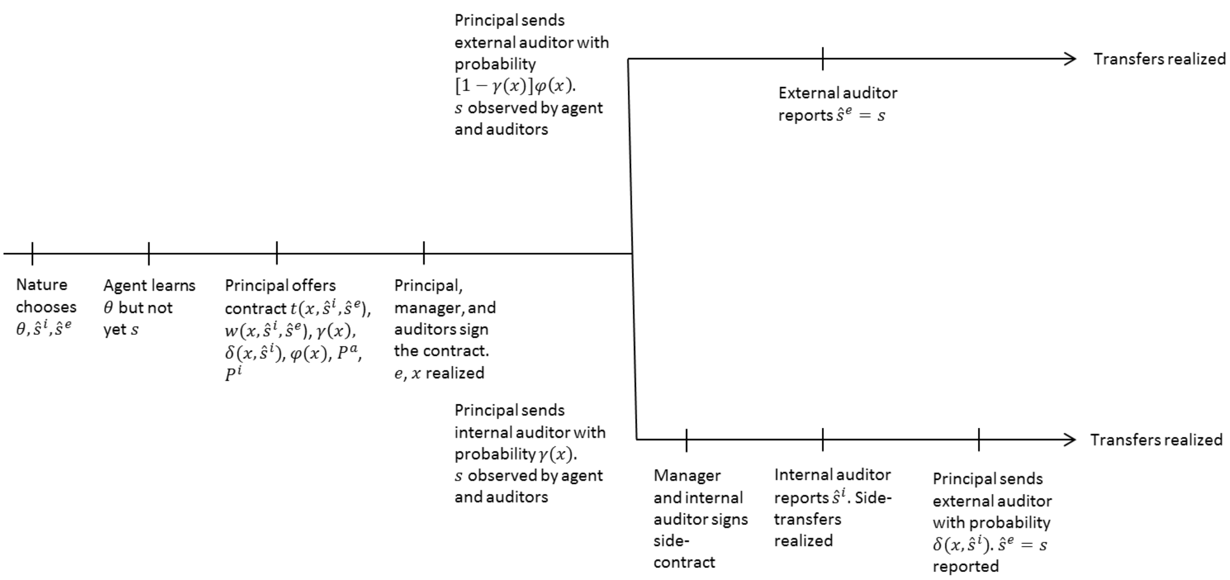

Figure 1: Timing of the game.

The program

Suppose for now that the principal has to disposal both auditors. If desirable for to audit, he could make use of three different regimes.

First, the principal could rely only on the internal auditor. Sending the internal auditor comes at a cost kz. In addition, for the internal auditor to report truthfully he requires a reward w which is at least as high as P^a. Receiving this wage makes the internal auditor indifferent between colluding and truthfully revealing his signal $\hat{s}^i$. Let γ denote the probability of using the internal auditor when the agent's reported baseline is low.

Second, to eliminate collusion between the internal auditor and the agent, the principal could rely on an additional auditor. Now, rather than paying the internal auditor w to refuse the bribe, the principal uses the external auditor to verify the report of the internal auditor. If the signal reported by the internal auditor is different from the truthful signal of the external auditor, this is evidence of collusion between the agent and the internal auditor. Let δ denote the probability of relying on the external auditor in addition to the internal auditor when the internal auditor has reported a low signal.

Third, the principal could send the external auditor alone. Thus, he is willing to pay the cost z for a truthful signal of the agent's baseline. When Kofman and Lawarree (1993) postulated that the internal auditor was free, this regime remained unused. However, when the internal auditor is no longer assumed to be free, meaning $k > 0$, it is plausible that the principal, under some conditions, may rely on the external auditor alone. Let φ denote the probability of using the external auditor alone when the agent's reported baseline is low.

Formally, the program of the principal is the following. He is choosing e_1, e_2, t_1, t_2, w, γ, δ, φ, P^a, and P^i in order to:

$$\max q \begin{Bmatrix} e_1 - t_1 + \gamma[(1-r)(P^a - w) - kz - r\delta z] \\ +(1-\gamma)\big[\varphi\big((1-r)P^a - z\big)\big] \end{Bmatrix} + (1-q)\{e_2 - t_2\} \qquad (P1)$$

such that

$$t_1 \geq \frac{e_1^2}{2} + P^a(1-r)[\gamma + \varphi(1-\gamma)] \qquad \text{AIR 1}$$

$t_2 \geq \frac{e_2^2}{2}$ AIR 2

$t_2 - \frac{e_2^2}{2} \geq t_1 - \frac{(e_1 - \Delta\theta)^2}{2} - rP^a[\gamma + \varphi(1 - \gamma)]$ AIC

$\gamma\left[w - P^a + \delta(P^a + P^i)\right] \geq 0$ CIC

Compared to a standard principal-agent model without auditing, $\gamma = \varphi = 0$, introducing the possibility of auditing requires some more general constraints:

Agent 1's incentive rationality constraint (AIR 1) states that the low baseline agent requires a relatively higher transfer than only covering its costs of effort in order to take part. This is to take into account the probability of mistakenly being punished P^a. If the agent has a low baseline and the auditing technology is imperfect $r < 1$, the agent runs the risk of being punished if the signal received by the auditors wrongly indicates that he is a high baseline type faking to have a low baseline.

Since the high baseline type claiming to be of high baseline will never be audited, agent 2's incentive rationality constraint (AIR 2) follows the standard structure. It is never efficient for a low baseline agent to claim to be of high baseline. Therefore, the transfer simply needs to be at least as large as the cost of effort for him to be willing to participate.

In order to make the different types of agents reveal their type, one needs to take into account the incentives for the high baseline agent. This is the agent's incentive compatibility constraint (AIC). The constraint ensures that that the amount of output produced corresponds to the desires of the principal. In order for the high baseline agent to reveal its type, his net gain acting as the high baseline type must be at least as large as his expected net gain by pretending to be of low baseline. The net gain by pretending to be of low baseline is a function of the transfer the low baseline agent receive from the principal, the lower cost of effort by pretending to be of low baseline, and the probability of getting punished P^a for faking his type.

To motivate the internal auditor not to collude with the agent, one needs the coalition incentive compatibility constraint (CIC) to hold. Intuitively, for the internal auditor to reveal his signal, the reward w must be structured in a specific way. The wage must be larger or equal to the punishment P^a of the agent, and taking into account the fines for the agent P^a and the internal auditor P^i if the external auditor is utilized to verify the signal. The last term is reducing the scope of collusion.

Results

Reference cases

First-best outcome

Suppose that in addition to the agent's output x being publicly observable, effort e and baseline θ are now observable to the principal. This has implications for $(P1)$. Since all information is observable to the principal, there is no gain in auditing. Therefore, $\gamma = \varphi = 0$. This has the consequence of simplifying the objective and affects several constraints. For example, since internal auditing is not relied upon, the coalition incentive compatibility constraint (CIC) disappears. Further, since the agent's baseline θ is publicly observable, it is impossible to fake type and the high baseline agent's incentive constraint (AIC) disappears. The principal's program simplifies to choosing e_1, e_2, t_1, t_2 to:

$$\max q\{e_1 - t_1\} + (1-q)\{e_2 - t_2\} \qquad (P2)$$

such that

$$t_1 \geq \frac{e_1^2}{2} \qquad \text{AIR 1}$$

$$t_2 \geq \frac{e_2^2}{2} \qquad \text{AIR 2}$$

This standard program has the well-known solution $e_1 = e_2 = 1$. Transfers are $t_1 = t_2 = \frac{1}{2}$ (Laffont and Martimort, 2002). Because the principal observes everything, he offers the agent exactly the transfer that makes him produce the amount of output desired by the principal.

Second-best outcome

Suppose that the agent's effort e and baseline θ are no longer observable to the principal. Another restriction is that the principal is not allowed to audit. The difference from the first-best case is therefore that it is possible for a high baseline agent to fake to have a lower baseline. To avoid this, the principal introduces the high baseline agent's incentive compatibility constraint (AIC). The principal is now choosing e_1, e_2, t_1, t_2 to:

$$\max q\{e_1 - t_1\} + (1-q)\{e_2 - t_2\} \qquad (P3)$$

such that

$t_1 \geq \frac{e_1^2}{2}$ AIR 1

$t_2 - \frac{e_2^2}{2} \geq t_1 - \frac{(e_1 - \Delta\theta)^2}{2}$ AIC

This standard model of asymmetric information has the well-known solution $e_1 = 1 - \frac{1-q}{q}\Delta\theta, e_2 = 1$. Transfers are $t_1 = \frac{e_1^2}{2}, t_2 = \frac{1}{2} - \frac{e_1^2}{2} + \frac{(e_1-\Delta\theta)^2}{2}$. A simple proof is sketched in Kofman and Lawarrée (1993). Observe that the high baseline type exerts the optimal level of effort, but that the transfer received is larger than in the first-best case. This is because of paying him an informational rent to reveal his type. The low laseline type exerts a lower level of effort than optimal but receives the same transfer as in the first-best case.

Solving the program

Suppose that the agent's output x, but not his effort e or baseline θ is observable to the principal. Compared to the reference cases, I do no longer restrict $\gamma = \varphi = 0$. We are back in the richer model of $(P1)$ and the timeline of Figure 1. In the last subsection, I showed that the second-best outcome is obtained if no auditors are utilized. Therefore, for the principal to be willing to employ any of the auditors or a combination of these, he should expect auditing to improve upon the second-best solution.

The objective of the paper is not to come up with the explicit solutions for how to engage the different auditors The focus is rather to identify conditions for one auditing regime being preferred over another. Before solving the program of the principal, a number of simplifications can be made to $(P1)$. I present some below. These lemmas are generalizations of Kofman and Lawarrée (1993).

LEMMA 1: Without loss of generality, one may assume that $w = max\{0, P^a - \delta(P^a - P^i)\}$.

Proof: See appendix.

This is the lowest value of the reward w to the internal auditor that ensures the coalition incentive compatibility constraint (CIC) not to be violated. Since the reward w is a deterministic function of other variables, the principal does not need to explicitly choose w. This simplifies the program of the principal.

LEMMA 2: Without loss of generality, one may assume that

$$\delta = \begin{cases} 0 & \text{if } (1-r)(P^a + P^i) < rz \\ \dfrac{P^a}{P^a + P^i} & \text{if } (1-r)(P^a + P^i) \geq rz \end{cases}$$

Proof: See appendix.

This is the core messages of Kofman and Lawaarée (1993). Intuitively, if the principal suspects that the internal auditor is colluding and wishes to send the external auditor to verify the signal, the external auditor will be sent with a probability smaller than unity. There will be random auditing of the internal auditor if the fines raised are at least as high as the costs of sending the external auditor. Note that the cost of sending the internal auditor kz is not included in the above expressions. Since the internal auditor is sent, this cost is sunk.

LEMMA 3: Without loss of generality, one may assume that $P^i = P^{i*}$, $P^a = P^{a*}$.

Proof: See appendix.

If the sanction set in the contract is lower than the feasible level of punishment for either the internal auditor or the agent, the principal will not be performing worse by increasing the punishment to its upper bound. This simplification serves the purpose of helping us to pin down which auditors to use and how best to use them when the agent and the internal auditor are protected by limited liability. Earlier, we stated that P^{i*} and P^{a*} are exogenous. As a result, the principal has two fewer variables to decide on.[7]

Making use of LEMMAS 1-3, $(P1)$ can be simplified. The principal now chooses e_1, e_2, t_1, $t_2, \gamma,\ and\ \varphi$ in order to:

$$\max q \begin{Bmatrix} e_1 - t_1 + \gamma[(1-r)P^{a*} - kz - r\delta z] \\ +(1-\gamma)\big[\varphi\big((1-r)P^{a*} - z\big)\big] \end{Bmatrix} + (1-q)\{e_2 - t_2\} \qquad (P4)$$

such that

$t_1 \geq \frac{e_1^2}{2} + P^{a*}(1-r)[\gamma + \varphi(1-\gamma)]$ AIR 1

$t_2 \geq \frac{e_2^2}{2}$ AIR 2

$t_2 - \frac{e_2^2}{2} \geq t_1 - \frac{(e_1-\Delta\theta)^2}{2} - rP^{a*}[\gamma + \varphi(1-\gamma)]$ AIC

The objective of the principal and remaining constraints are comparable $(P1)$. Observe that in addition to the four decision variables of the reference cases, the principal need to decide on the probability of using the internal auditor γ and the probability of relying on the external auditor only φ, when the agent reports to be of low baseline.

Solving relevant parts of the program is delegated to the appendix. In this section, focus will be on intuition and interpretation. I start with the contribution of this dissertation; Solving the model in which sending the internal auditor involves a cost kz, with $k > 0$. Results of this examination are presented in PROPOSITION 1 and illustrated in Figure 2. After, I show that as $k \to 0$, we approximate the findings of Kofman and Lawarrée (1993). Their results are presented in PROPOSITION 2 and illustrated in Figure 3.

Let $P^{i*} = nP^{a*}, n \geq 0$, then $\frac{P^{a*}}{P^{a*}+P^{i*}} = \frac{1}{1+n}$. Define $\varepsilon(r)$ as the minimum value of P^{a*} making the principal willing to send in the internal auditor alone with probability $\gamma = 1$. Let $\vartheta(r)$ be the minimum value of P^{a*} making the principal willing to send in the internal auditor with probability $\gamma = 1$ and having the internal auditor policed by the external auditor with

[7] This dates to Becker's (1968) economic analysis of crime. Kofman and Lawaarrée (1993) show conditions for this principle to be invalid. Constant punishment might be optimal if increasing punishment only leads to the agent becoming more willing to bribe the internal auditor. This will not constrain me since I am interested in which auditors to use rather than how to use them.

probability $\delta > 0$. $\rho(r)$ is defined as the value of P^{a*} that make the principal wanting to rely on the internal auditor alone rather than having him policed by the external auditor. Define $\xi(r)$ as the minimum value of P^{a*} where the probability of sending the internal auditor alone is $0 < \gamma < 1$. Likewise, define $\mu(r)$ as the minimum value of P^{a*} where the probability of sending the internal auditor alone is $0 < \gamma < 1$. Consult Box 1 for a presentation of the functions.

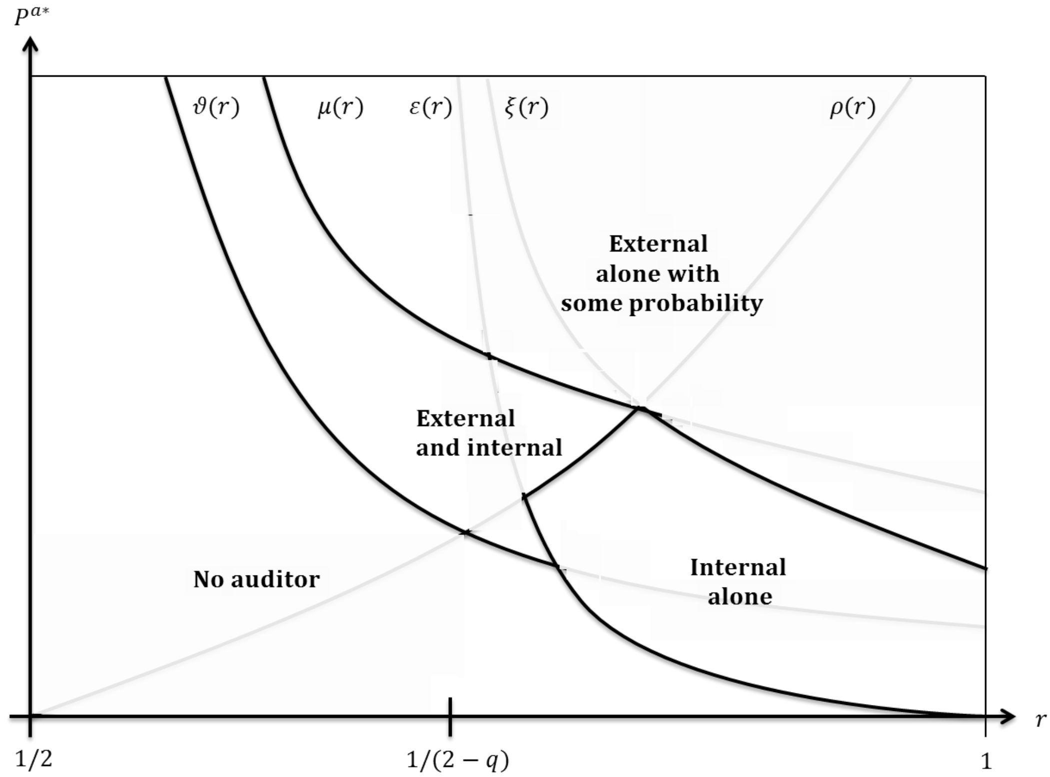

Figure 2: Diagrammatic representation of PROPOSITION 1; $k > 0$.

Regimes are separated by the dark and solid lines.

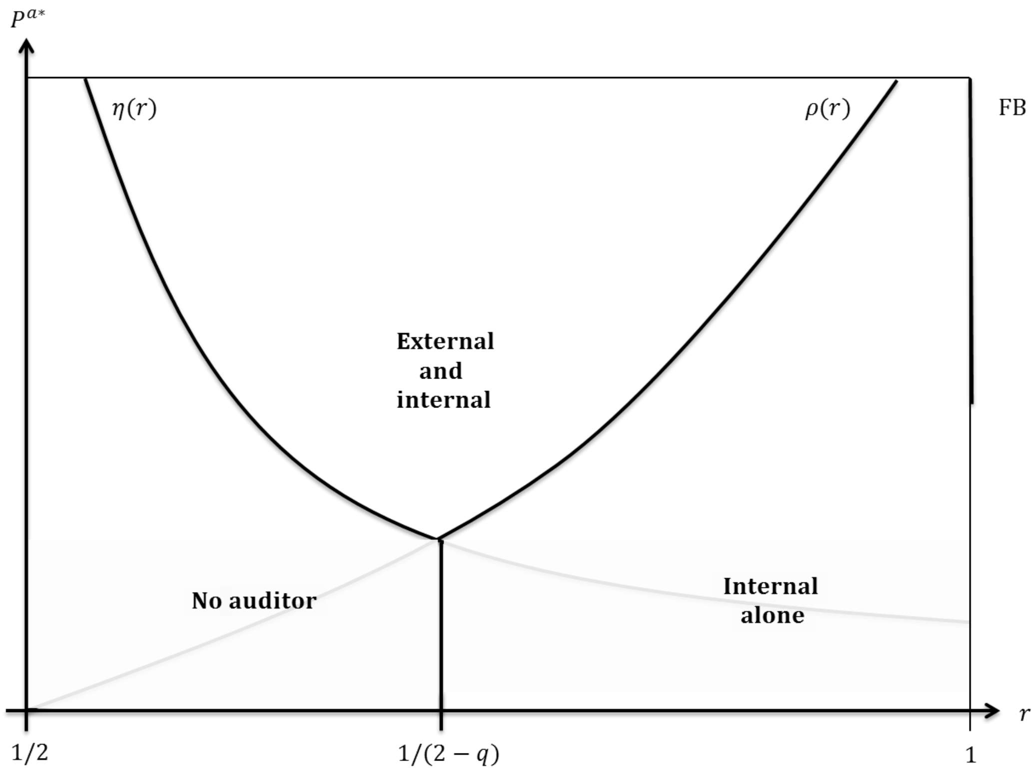

Figure 3: Diagrammatic representation of PROPOSITION 2; $k = 0$.

Regimes are separated by the dark and solid lines.

PROPOSITION 1

$$\varepsilon(r) = \frac{qzk}{r(2-q)-1}$$

$$\vartheta(r) = \frac{qz(k+\frac{1}{1+n}r)}{(1-q)(2r-1)}$$

$$\rho(r) = \frac{z\frac{1}{1+n}r}{(1-r)}$$

$$\xi(r) = \frac{\Delta\theta\left[(2r-1-{}^1/_2\Delta\theta)+\sqrt{(2r-1-{}^1/_2\Delta\theta)^2-4kz(2r-1)}\right]}{2(2r-1)^2}$$

$$\mu(r) = \frac{\Delta\theta\left[(2-\Delta\theta)+\sqrt{(\Delta\theta-2)^2-16z(\frac{1}{1+n}r+k)}\right]}{4(2r-1)}$$

PROPOSITION 2

$$\eta(r) = \vartheta(r, k=0) = \frac{qz\frac{1}{1+n}r}{(1-q)(2r-1)}$$

$$\rho(r) = \frac{z\frac{1}{1+n}r}{(1-r)}$$

Box 1: Explicit representation of formulas proved in the appendix.

PROPOSITION 1:

If $0 < k < 1$, the following must hold:

a) There exist a region where it is optimal for the principal not to audit, i.e. if

$$r < \min\{\, \varepsilon^{-1}(P^{a*});\ \vartheta^{-1}(P^{a*})\,\}$$

b) There exist a region where it is optimal for the principal to rely only on the internal auditor, i.e. if

$$\max\{\, (\varepsilon^{-1}(P^{a*});\ \rho^{-1}(P^{a*})\,\} \leq\ r < \xi^{-1}(P^{a*})$$

c) There exist a region where it is optimal for the principal to rely on both the internal and external auditor, i.e. if

$$\min\{\, \rho^{-1}(P^{a*});\ \mu^{-1}(P^{a*})\,\}\ < r \leq \vartheta^{-1}(P^{a*})$$

If both the internal and external auditors are used, the external auditor is sent with a probability smaller than one and its mission is to police the internal auditor.

d) There exist a region where it might be optimal for the principal to rely on the external auditor alone, i.e. if

$$r \geq\ \min\{\, \xi^{-1}(P^{a*});\ \mu^{-1}(P^{a*})\,\}$$

The external auditor will be sent alone with a probability smaller or equal to one. If the external auditor is not sent alone and it is still optimal to audit, the internal auditor is sent alone or the external auditor is sent along with the internal auditor, depending on if r takes a value larger or smaller than $\rho^{-1}(P^{a*})$.

PROOF: See Appendix.

Result a) identifies the no-auditing regime. If the audit technology r is very imprecise or the agent has a very low level of limited liability P^{a*}, the principal's cost of sending in auditors are not offset by the benefit of auditing. Therefore, sending in auditors will not improve upon the second-best outcome. More specifically, both functions $\varepsilon(r)$ and $\vartheta(r)$ are decreasing in the quality of the audit technology r. If the quality of the audit technology is low, the limited liability constraint on the agent P^{a*} needs to be high in order for auditing to improve upon the outcome. The costs of reducing informational rents of the agent and adjusting effort, is too high.

Note that the scope of the no-auditing regime is increasing in the cost of relying on the internal auditor relative to the cost of relying on the external auditor. Increasing k shifts both $\varepsilon(r)$ and $\vartheta(r)$ upwards. The more costly it is to employ the internal auditor, everything else constant, the larger the limited liability constraint on the agent P^{a*} must be in order to make it profitable for the principal to utilize the internal auditor. The same is true for increasing the costs of both the internal and external auditors, but without changing the relative costs. If z increases, both $\varepsilon(r)$ and $\vartheta(r)$ shift upwards. The cost of using the internal auditor alone or using some combination of the internal and external auditors increases, and therefore the area of the no-auditor regime will grow larger. If the limited liability constraint on the internal auditor relative to the agent n grows larger, however, $\vartheta(r)$ shifts downwards and the area of the no-auditing regime will shrink.

Result b) identifies the internal auditor regime. If for a given quality of the audit technology r, the limited liability constraint of the agent $P^{a*}$is lower than than $\rho(r)$ and in-between $\varepsilon(r)$ and $\xi(r)$, the internal auditor should be used alone and should be relied on every time the agent reports to be of low type. Formally, $\gamma = 1$ and $\delta = 0$. The rationale for it being smaller or equal to $\rho(r)$ is that this function tells us the size of P^{a*} to equalize the cost of sending in the external auditor to police the internal auditor — with the purpose of eliminating his reward w — to the reward being paid to the internal auditor if he is not policed by the external auditor. Mathematically, I choose P^{a*} such that $z\frac{1}{1+n}r = (1-r)P^{a*}$. This is independent of k. $\rho(r)$ is increasing in the cost of relying on the external auditor and decreasing in the limited liability constraint on the internal auditor relative to the agent n.

The function $\varepsilon(r)$ behaves as described in a) and describes for which value of P^{a*} it gets preferable for the principal to use the internal auditor rather than not auditing. The function is increasing in cost of internal auditing kz. $\xi(r)$ is discussed in-depth later, but deserves some attention. Within the relevant domain of r, it defines for what values of P^{a*} it is no longer optimal to utilize the internal auditor with probability $\gamma = 1$. In other words, where there is a chance of relying on the external auditor alone or to mix between regimes. The more costly it is to rely on the internal auditor kz, the lower is $\xi(r)$. Note that in b) the focus of the principal is to use the internal auditor to reduced the informational rents of the high baseline type and after to increase the effort of the low baseline type.

Result c) describes the region where it is optimal to rely on the internal auditor monitoring the agent but having the external auditor policing him. Thus, rather than to pay the internal auditor a reward w in order to avoid him colluding, the internal auditor will not need be compensated. If the external auditor receives a signal s different from what the internal auditor reported $\hat{s}^i$, the internal auditor will be fined at the level P^{i*}. The higher the level of the fine, the lower the probability of policing δ need to in order to disincentive collusive activity. Within the relevant domain of r, $\vartheta(r)$ defines the minimum value of punishment P^{a*} making it optimal for the principal to rely on the internal auditor with probability $\gamma = 1$ and the external auditor with probability $\delta > 0$. The larger the cost of relying on the external auditor z, the larger this threshold P^{a*} must be. The same is true for increasing the proportional cost of relying on the internal auditor k. Increasing the costs of auditing will make it less profitable for the principal to engage in such activities. The reverse is true for increasing in the limited liability constraint on the internal auditor relative to the agent n. This makes auditing cheaper because δ is reduced. The borderline between using the internal auditor along with the external auditor and using the internal auditor alone is still defined by $\rho(r)$. Hence, what was stated under b) still applies.

The upper bound to the area where the internal auditor is used with probability $\gamma = 1$ and policed by the external auditor with probability $\delta > 0$ is $\mu(r)$. Within the relevant domain of r, if the liability constraint on the agent P^{a*} is at least as large as $\mu(r)$, the internal auditor will be utilized together with the external auditor with probability $\gamma < 1$. This means that it would be optimal, under some conditions, to send in the external auditor alone. More on this is discussed under d). Note, however, that this upper bound is decreasing in k and increasing in n. In c), the focus of the principal is to use the internal and external auditors to reduce the informational rents of the high baseline type and then to increase the effort of the low baseline type.

Result d) identifies the area where it with some probability might be optimal to rely on the external auditor alone. The lower bound of this regime is defined by the functions $\xi(r)$ and $\mu(r)$ from the point where they intersect. These functions define the lowest value of P^{a*}making it efficient to send in the external agent alone with probability $(1-\gamma)\varphi$. This choice is depending on whether the value of P^{a*} is at least large enough to satisfy the relevant first order constraint. More specifically, if $P^{a*} \geq \frac{qz}{\lambda_3(2r-1)}$.[8] In other words, it needs to be profitable for the principal to rely on the external auditor alone. Note that it with probability $\gamma < 1$ still is desirable for the principal to stick to the regimes described in b) and c), depending on $\rho(r)$. This follows the same intuition as described earlier. Inspecting $\xi(r)$ and $\mu(r)$, the area of relying on the external auditor alone is getting larger the higher the relative cost of relying on the internal auditor k. This facilitates a substitution of auditing activity into the hands of the external auditor. Further, the area of the audit regime gets smaller the higher the limited liability constraint on the internal auditor relative to the agent n. Relying on the external auditor along with the internal auditor gets relatively cheaper compared with sending the external auditor alone. The

[8] λ_3 is defined in the appendix as the shadow price on AIC.

first-best outcome will only be reached with the quality of the audit technology $r = 1$ and the limited liability constraint on the agent $P^{a*} \to \infty$.

For completeness, I now illustrate that PROPOSITION 1 converges to the results of Kofman and Lawarrée (1993) when $k = 0$. Let $\eta(r)$ be defined as $\vartheta(r)$ with $k = 0$. Note that $\rho(r)$ is independent of k. $\varepsilon(r) = 0$ when $k = 0$, but can be reformulated to $r = \frac{1}{2-q}$. This defines the minimum value of r making the principal willing to send in the internal auditor alone with probability $\gamma = 1$. Further, $\xi(r)$ and $\mu(r)$ with $k = 0$ still define the minimum value of P^{a*} where the probability of sending the internal auditor either alone or policed by the external auditor is $0 < \gamma < 1$. Note, however, that it can be proved that it is never optimal to set $\varphi > 0$. Consult Box 1 for a presentation of the functions.

PROPOSITION 2 (adopted from Kofman and Lawarrée, 1993):

If $k = 0$, the following must hold:

a) There exist a region where it is optimal for the principal not to audit, i.e. if

$$r < \min\{\frac{1}{2-q};\ \eta^{-1}(P^{a*})\}$$

b) There exist a region where it is optimal for the principal to use the internal auditor, i.e. if

$$r \geq \max\{\frac{1}{2-q};\ \rho^{-1}(P^{a*})\}$$

c) If used at all, the external auditor is used as a second option and sent with a probability less than one. The reward for the internal auditor is zero.

PROOF: See Appendix for a proof of the convergence. Kofman and Lawarrée (1993) offer an explicit solution.

Result a) identifies the region where it is optimal not to audit. $\varepsilon(r)$ gets transformed into $r = \frac{1}{2-q}$ when $k = 0$. Intuitively, when the cost of sending the internal auditor gets 0, the no-audit region gets smaller. Note further that $\eta(r)$ is closer to the origin than $\vartheta(r)$. This is another effect reducing the space of the no-audit regime. When the cost of relying on the internal auditor is 0, the cost of using the internal auditor along with the external auditor decreases.

Result b) defines the area where it is optimal to send the internal auditor with probability $\gamma > 0$. Because of the breakdown of the function $\varepsilon(r)$, the area where the internal auditor is used alone increases. The function $\xi(r)$, which defines where the internal auditor is used with probability $\gamma < 1$, is still valid. Although, with $k = 0$ shifts away from the origin. Formally, Kofman and Lawarrée (1993) show that in the area below this new function $\xi(r)$, the principal use the internal auditor to reduce the rents of the high type agent and increase the effort of the low type. With $k = 0$, $P^{a*} > \xi(r = 1)$ defines the first best outcome. Because $k = 0$, there is no cost in sending the internal auditor. Since $r = 1$ the internal auditor is motivated to reveal the truth and the agents are never punished by mistake. It will never be optimal to send in the external auditor when P^{a*} is higher than $\xi(r)$ (Kofman and Lawarrée, 1993). As I have argued, this statement is no longer true when $k > 0$.

Result c) describes the area where it is optimal to rely on the internal auditor with probability $\gamma > 0$ and having the external auditor police him with probability $\delta > 0$. $\rho(r)$ is as defined earlier. If the limited liability constraint on the internal auditor relative to the agent $n = 0$, we would rather rely on another auditing regime. Therefore, $\delta < 1$(Kofman and Lawarrée, 1993).

$\eta(r)$ is closer to the origin than $\vartheta(r)$. Thus, the area of the regime where both the internal and external auditors are used is larger for $k = 0$. Kofman and Lawarrée (1993) show that in the area below this new function $\mu(r)$, the principal use the internal auditor to reduce the rents of the high type agent and increase the effort of the low type agent. However, it will never be optimal to send it the external auditor alone when P^{a*} is higher than $\mu(r)$. As shown in PROPOSITION 1, this statement is no longer true when $k > 0$.

Discussion

At the 2012 climate summit in Doha, parties to the United Nation's climate convention were expected to come to an agreement on the topic of monitoring, reporting and verification (UNFCCC, 2012). However, for different reasons the largest donor and recipient countries were not able to compromise and no consensus were reached. Countries advocated for different auditing regimes. Recipient countries, such as Brazil, have for a long time argued in favor of relying on an internal auditor only (IISD, 2012). One reason is that REDD+ is voluntary in nature. On the other hand, donor countries, including Norway, have raised their voice in favor of relying on internal audits by the recipient country, but with reviews conducted by external auditors (IISD, 2012). One reason for this is that they need to be accountable to their electorate when spending funds on international efforts.

It is now up to the 2013 climate summit in Warsaw to adopt decisions on how to audit conservation in the tropics. The current draft conclusions proposed by the chair of the relevant subsidiary body of the climate convention resembles something looking like the position of donor countries (UNFCCC, 2013). More specifically, one should rely on an internal auditor to monitor reports of landholders and then an external auditor can be sent in to review and verify the signal of the internal auditor. If the current draft conclusions are not changed at the next round of intersessional climate talks, this document will be the basis for the discussions at the climate summit in Warsaw this November.

There are many reasons, however, for not auditing. Specifically, given relevant parameter values, the principal cannot improve upon the second-best outcome by sending in auditors to observe the landholder. I now present some arguments supporting such a view. Due to the nature of international relations, the limited liability constraint on the agent P^{a*} is expected to be low. The international community cannot punish a landholder in the recipient country heavily for not sticking to the agreed terms of a contract (Sands and Peel, 2012). Denote this upper value $\widetilde{P^{a*}}$. The same can be claimed about the limited liability constraint on the internal auditor P^{i*}, implying low n and δ close to one. Further, academic and technical literature argues that the quality of the audit technology r is imperfect (Wertz-Kanounnikoff and Verchot, 2008; Goetz et al., 2009; Haverman et al., 2009). It need not be straight forward to identify additional conservation because of limits to technical capacity. Forests in countries such as Ecuador and Peru are in areas with differing topography, making the usage of satellite data inadequate to detect changes in land cover (Wen et al., 2008). In addition, areas in the tropics are covered by clouds larger parts of the year, making it hard to get comparable images for the same area over time (Wen et al., 2008). A complicating factor is that by relying on satellite data what is measured is change in forest cover. Still, what the principal is interested in is stored carbon. Large uncertainties are involved in estimating the change in stock of carbon by changing land cover (Grassi et al., 2008). In this process, biased estimates could occur because of an inadequate sampling procedure (FAO, 2006, 2010; Maniatis and Mollicone, 2010). Suppose $\tilde{r}$ is the current quality of the audit technology.

Finally, the costs of monitoring conservation are not insignificant. Costs of employing a given audit technology are high for the external auditor z because it is located far from the relative sites and have costly employees (Hardcastle et al., 2008). This cost is significant, but, as assumed earlier, lower for the internal auditor because it is located closer to the relevant projects and landholders, as well as having contextual knowledge and thus lower cost in information processing.

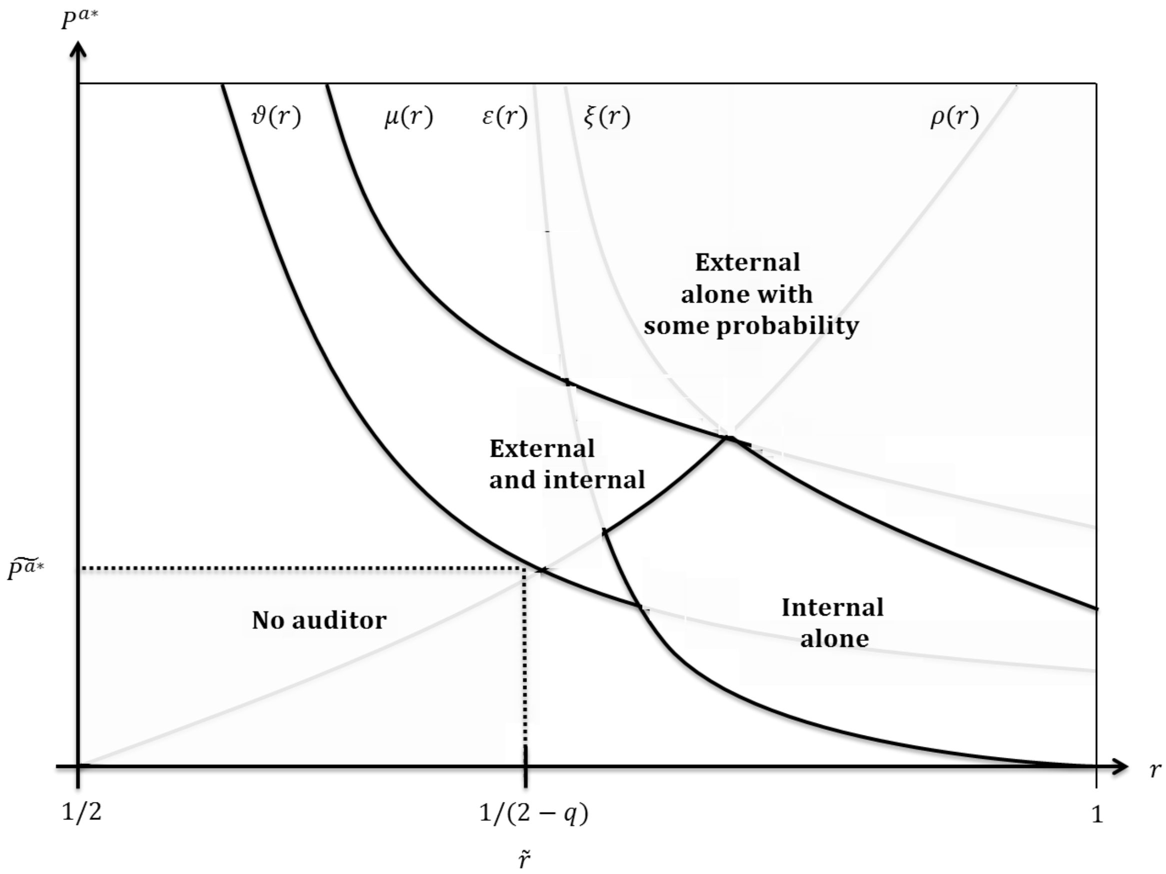

Figure 4: Choosing regime when k large.

The above facts point in the direction of the space of the no-auditing regime getting large, see Figure 4. Further, the constraints on the quality of the audit technology r and the limited liability constraint on the landholder P^{a*} might be sufficiently small to recommend the principal sticking to this regime. Yet, the choice of auditing regime should not be done in isolation. There is a large set of complementary efforts and policies that could be undertaken by the players of the game. For example, capacity building can be done in the recipient country with the aim of reducing the cost of auditing relative to the cost of relying on an external auditor. This change manifests through a smaller k. Another alternative is more general attempts to bring down the cost of monitoring and verification. This will reduce z, making both auditors cheaper. Yet another example is increasing the quality of the auditing technology. This will lead to a larger value on r.

Although I have chosen to not model these investment decisions, it is important to take them into account. For instance, the draft conclusions presented by the chair at this year's second intersessional meeting in Bonn, the importance of readiness activities was highlighted (UNFCCCC, 2013). If implemented, we can expect k to become smaller in the foreseeable future. This reduces the area of no-auditing. Recognizing that auditing rainforest conservation is a process of learning-by-doing, prospects for reducing costs in general z and increasing the quality of the audit technology r, at least within some domain, should not be underestimated (Wertz-Kanounnikoff and Verchot, 2008). Therefore, when deciding which audit regime to go for, we should take these aspects into account. Notice that smaller values of z reduces the area of no-auditing. Increasing r makes the principal more likely to employ auditors even when the limited liability constraint of the landholder P^{a*} is not large.

Based on my findings, the value of the quality of the audit technology r needs to grow larger than at least $\frac{1}{(2-q)}$, and even higher for large values of k, for it to be preferable for the principal to use the internal auditor alone. Given that there is scope in increasing the quality of the audit technology r, but that there is a bound to how precise auditing will be (see, e.g., Asner, 2011), this is relevant for the decision necessary to be made. Another reason for r being bound at a low level is that auditors should rely on conservative estimates when data is uncertain and incomplete (Grassi et al., 2008). Formally, let $\tilde{r}$ be the upper bound on r. If $\tilde{r} < \frac{1}{(2-q)}$, it would never be efficient to rely on the internal auditor alone even if the he comes at $k = 0$. This is because of the reward w paid to avoid him colluding. Therefore, for low values of P^{a*}, there is effectively a choice to be made between not auditing or relying on both auditors. The more effort put in doing capacity building to bring down k or general attempts to reduce costs z, the more willing the principal would be to audit. An illustration of such an outcome is presented in Figure 5. Compared to Figure 4, the costs of relying on the internal auditor relative to the external auditor k are marginally reduced. This suggests that doing capacity building may increase the prospects for auditing conservation in the tropics. And by this activity improve upon the second-best outcome. If expenditures on capacity building with the aim of reducing the costs of employing the internal auditor are smaller than the gain in terms of reducing the rents and increasing the effort of landholders, it is preferable to invest.

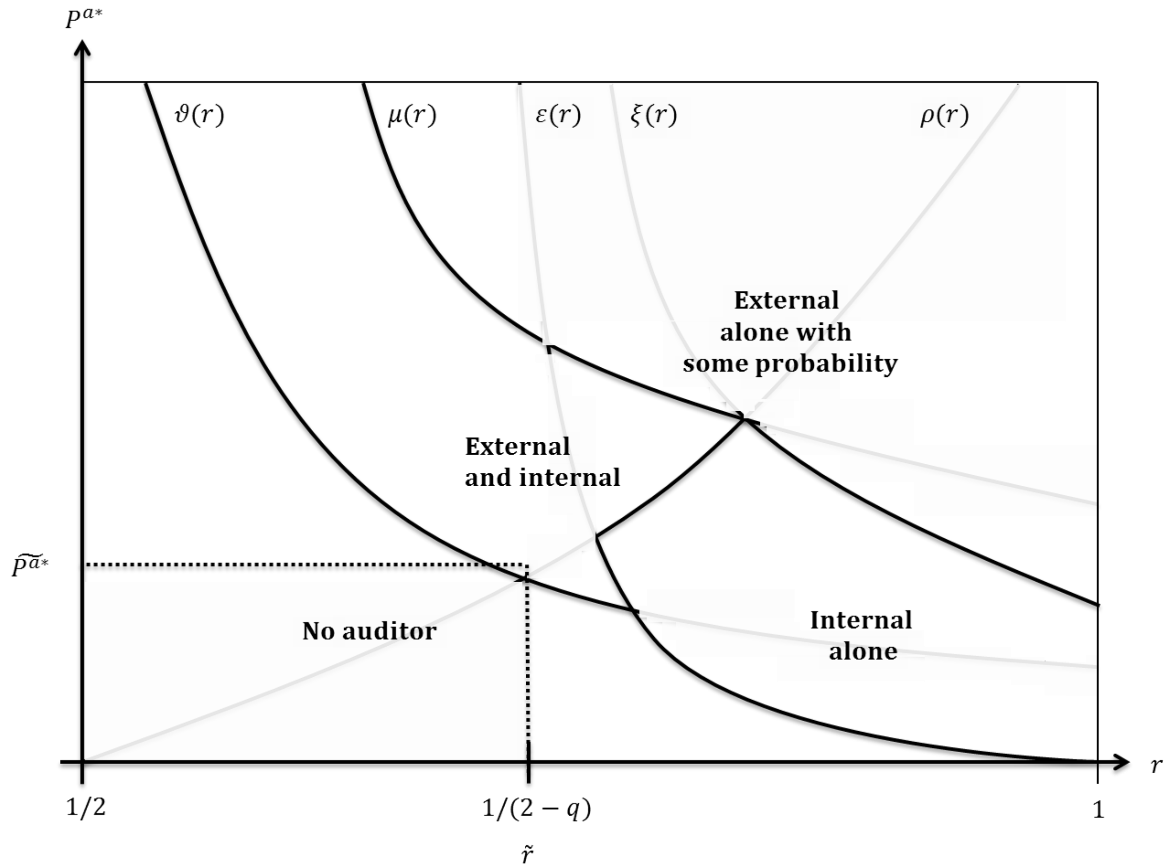

Figure 5: Choosing regime when *k* marginally smaller than Figure 4.

Conclusion and limitations

Since even the lower bound estimates of expected emissions abatement costs are nontrivial (Stern, 2007), economists and policy makers have found it appealing to consider activities to mitigate greenhouse gases involving low marginal abatement costs. In this dissertation, I have looked closer into one of these activities, namely carbon sequestration in tropical forest. The argument being that if deforestation is carried out at the margin and agricultural rent is low, it has the prospects of reducing costs of mitigation activities (Kindermann et al., 2008). There are, however, many challenges in implementing such a scheme. One related topic involving challenges, such as information, incentives and institutions (Angelsen, 2010), is monitoring, reporting and verification of conservation.

Generalizing the framework of Kofman and Lawarrée (1993), these challenges are taken into account in an attempt to characterize optimal audit regimes for such efforts. The previous UN climate summit failed in reaching agreement on this agenda item (IISD, 2012). A new decision is drafted for the upcoming summit (UNFCCC, 2013). In the model set-up, the role of institutions is particularly taken into account. An agency monitoring conservation within the recipient country might collude with landholders. Therefore, an international and independent institution can be utilized to verify the signal of the audit agency of the recipient country. This alternative is, however, more expensive.

Acknowledging that audit activities are indeed costly (Hardcastle et al., 2008; Böttcher et al., 2008), I incorporate this into aspect into the model. From a theoretical point of view these findings challenge Kofman and Lawarrée (1993). It becomes more attractive not to rely on any auditors at all, and under some conditions, it may be optimal to send the independent auditor alone. This provides a new motivation for relying on an external auditor. Its purpose is not necessarily only to verify the signal of the internal auditor. This has implications for actors in systems where the legally specified limit to liability is high. An example is regulation of domestic firms. Yet, this finding does not apply to the case of conservation. Under international environmental law, the constraint on limited liability is generally low (Sands and Peel, 2012). Further, the quality of the audit technology is imperfect (Asner, 2011). Ironically, a policy implication, I have argued, is then not to audit conservation at all. Auditing cannot improve upon the second-best outcome when it is too costly. Realizing this, there might still be some scope for auditing. If expenditures on capacity building with the aim of reducing the costs of employing the internal auditor are smaller than the gain in terms of reducing the rents and increasing the effort of landholders, it is preferable to invest. It should be stated that I have not modeled this investment decision. Though, I have showed that if optimal to audit, the recipient country should monitor landholders, while an international agency, on a random basis, should verify these reports. This provides a rationale for adopting the current draft proposal to be discussed at the Warsaw climate summit, but emphasizing the necessity of capacity building.

My model has a set of limitations that point in the direction of areas of future research. First, to further inform how to utilize the auditors my model should be solved explicitly. This will involve a series of straight forward, although time-consuming, derivations. Second, in modeling, I have most specifically taken into account the preferences of the donor country and not the recipient country. To conduct a complete welfare analysis, my model should therefore be extended. Third, to provide a more robust advice on whether or not to audit carbon sequestration in forests, one should model capacity building as an investment decision. If this is done, one could more clearly identify the trade-off discussed earlier. Finally, an alternative narrative to that presented here is that of contract breach. More specifically, if the external auditor reveals that the landholder is cheating or that the internal auditor is manipulating the signal, the donor country may terminate the contract. Future research should consider how this impacts the choice of auditors.

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Appendix

PROOF OF LEMMA 1:

Similarly to Kofman and Lawarrée (1993), this is the lowest value of w that satisfies the coalition incentive compatibility constraint (CIC). If $\gamma = 0$, the value of w is not relevant.

Q. E. D.

Thus, the principals objective becomes

$$q\begin{Bmatrix} e_1 - t_1 + \gamma\big[(1-r)min\{0, P^a - \delta(P^a - P^i)\} - kz - r\delta z\big] \\ +(1-\gamma)\big[\varphi\big((1-r)P^a - z\big)\big] \end{Bmatrix} + (1-q)\{e_2 - t_2\}$$

PROOF OF LEMMA 2:

If the internal auditor is already sent, implying $\gamma > 0$, the cost of sending him is sunk. Therefore, this cost should not be taken into account when choosing whether or not to send the external auditor to police the internal auditor. I am back in the case of Kofman and Lawarrée (1993).

Q. E. D.

PROOF OF LEMMA 3:

Given a contract specifying γ, φ, P^a, and P^i, suppose that γ is replaced by $\hat{\gamma} = \gamma \frac{P^a}{P^{a*}}$, φ by $\hat{\varphi} = \frac{P^a - P^a\gamma}{P^{a*} - P^a\gamma}$, P^a by P^{a*}, P^i by P^{i*}, and δ by $\hat{\delta} = \frac{P^{a*}}{P^{a*}+P^{i*}}$. Notice that AIR 1 and AIC are satisfied.

The objective of the principal has difference

$$\hat{\gamma}\,\hat{\delta}\left((1-r)\big(P^{a*} + P^{i*}\big) - rz\right) - \gamma\delta\left((1-r)\big(P^a + P^i\big) - rz\right) + (\gamma - \hat{\gamma})kz$$
$$+ (1-\hat{\gamma})\hat{\varphi}\big((1-r)P^{a*} - z\big) - (1-\gamma)\varphi\big((1-r)P^a - z\big) \geq 0$$

Beacause this difference is non-negative, the principal cannot be worse-off by setting P^a and P^i as specified by LEMMA 3.

Q. E. D.

Note that by LEMMAS 1-3, we now have two cases.

1. If $(1-r)\left(P^{a*}+P^{i*}\right)<rz, \delta=0$.

$$\max q\begin{Bmatrix} e_1-t_1+\gamma[(1-r)P^{a*}-kz] \\ +(1-\gamma)\left[\varphi\left((1-r)P^{a*}-z\right)\right]\end{Bmatrix}+(1-q)\{e_2-t_2\}$$

such that

$$t_1 \geq \frac{e_1^2}{2}+P^{a*}(1-r)[\gamma+\varphi(1-\gamma)] \qquad \text{AIR 1}$$

$$t_2 \geq \frac{e_2^2}{2} \qquad \text{AIR 2}$$

$$t_2-\frac{e_2^2}{2} \geq t_1-\frac{(e_1-\Delta\theta)^2}{2}-rP^{a*}[\gamma+\varphi(1-\gamma)] \qquad \text{AIC}$$

The Lagrangian for the problem is

$$L=q\begin{Bmatrix} e_1-t_1-\gamma kz \\ +(1-\gamma)\left[\varphi\left((1-r)P^{a*}-z\right)\right]\end{Bmatrix}+(1-q)\{e_2-t_2\}$$
$$+\lambda_1\left\{t_1-\frac{e_1^2}{2}-P^{a*}(1-r)[\gamma+\varphi(1-\gamma)]\right\}+\lambda_2\left\{t_2-\frac{e_2^2}{2}\right\}$$
$$+\lambda_3\left\{t_2-\frac{e_2^2}{2}-t_1-\frac{(e_1-\Delta\theta)^2}{2}+rP^{a*}[\gamma+\varphi(1-\gamma)]\right\}+\lambda_4\{1-\gamma\}+\lambda_5\{1-\varphi\}$$

with additional non-negativity constraints.

The Kuhn-Tucker conditions are

$$\frac{\partial L}{\partial e_1}=q-\lambda_1 e_1+\lambda_3(e_1-\Delta\theta) \leq 0, \qquad e_1\frac{\partial L}{\partial e_1}=0$$

$$\frac{\partial L}{\partial e_2}=1-q-\lambda_2 e_2-\lambda_3 e_2 \leq 0, \qquad e_2\frac{\partial L}{\partial e_2}=0$$

$$\frac{\partial L}{\partial t_1}=-q+\lambda_1-\lambda_3 \leq 0, \qquad t_1\frac{\partial L}{\partial t_1}=0$$

$\frac{\partial L}{\partial t_2} = q - 1 + \lambda_1 + \lambda_3 \leq 0,$ $\qquad t_2 \frac{\partial L}{\partial t_2} = 0$

$\frac{\partial L}{\partial \gamma} = q\{-kz - \varphi\big((1-r)P^{a*} - z\big)\}$

$+\lambda_1\{(\varphi - 1)P^{a*}(1-r)\} + \lambda_3\{(1-\varphi)rP^{a*}\} - \lambda_4 \leq 0,$ $\qquad \gamma \frac{\partial L}{\partial \gamma} = 0$

$\frac{\partial L}{\partial \varphi} = q\{(1-\gamma)\big((1-r)P^{a*} - z\big)\}$

$+\lambda_1\{P^{a*}(1-r)(\gamma - 1)\} + \lambda_3\{rP^{a*}(1-\gamma)\} - \lambda_5 \leq 0,$ $\qquad \varphi \frac{\partial L}{\partial \varphi} = 0$

plus constraints and complementary slackness conditions.

2. If $(1-r)(P^{a*} + P^{i*}) \geq rz, \delta = \frac{P^{a*}}{P^{a*}+P^{i*}}$.

$$\max q \begin{Bmatrix} e_1 - t_1 + \gamma\left[(1-r)P^{a*} - kz - r\frac{P^{a*}}{P^{a*}+P^{i*}}z\right] \\ +(1-\gamma)\big[\varphi\big((1-r)P^{a*} - z\big)\big] \end{Bmatrix} + (1-q)\{e_2 - t_2\}$$

such that

$t_1 \geq \frac{e_1^2}{2} + P^{a*}(1-r)[\gamma + \varphi(1-\gamma)]$ AIR 1

$t_2 \geq \frac{e_2^2}{2}$ AIR 2

$t_2 - \frac{e_2^2}{2} \geq t_1 - \frac{(e_1 - \Delta\theta)^2}{2} - rP^{a*}[\gamma + \varphi(1-\gamma)]$ AIC

The Lagrangian for the problem is

$$L = q \begin{Bmatrix} e_1 - t_1 - \gamma\left[(1-r)P^{a*} - kz - r\frac{P^{a*}}{P^{a*}+P^{i*}}z\right] \\ +(1-\gamma)\big[\varphi\big((1-r)P^{a*} - z\big)\big] \end{Bmatrix} + (1-q)\{e_2 - t_2\}$$
$$+\lambda_1\left\{t_1 - \frac{e_1^2}{2} - P^{a*}(1-r)[\gamma + \varphi(1-\gamma)]\right\} + \lambda_2\left\{t_2 - \frac{e_2^2}{2}\right\}$$
$$+\lambda_3\left\{t_2 - \frac{e_2^2}{2} - t_1 - \frac{(e_1-\Delta\theta)^2}{2} + rP^{a*}[\gamma + \varphi(1-\gamma)]\right\} + \lambda_4\{1-\gamma\} + \lambda_5\{1-\varphi\}$$

with additional non-negativity constraints.

The Kuhn-Tucker conditions are

$$\frac{\partial L}{\partial e_1} = q - \lambda_1 e_1 + \lambda_3(e_1 - \Delta\theta) \leq 0, \qquad e_1 \frac{\partial L}{\partial e_1} = 0$$

$$\frac{\partial L}{\partial e_2} = 1 - q - \lambda_2 e_2 - \lambda_3 e_2 \leq 0, \qquad e_2 \frac{\partial L}{\partial e_2} = 0$$

$$\frac{\partial L}{\partial t_1} = -q + \lambda_1 - \lambda_3 \leq 0, \qquad t_1 \frac{\partial L}{\partial t_1} = 0$$

$$\frac{\partial L}{\partial t_2} = q - 1 + \lambda_1 + \lambda_3 \leq 0, \qquad t_2 \frac{\partial L}{\partial t_2} = 0$$

$$\frac{\partial L}{\partial \gamma} = q\left\{(1-r)P^{a*} - kz - r\frac{P^{a*}}{P^{a*}+P^{i*}}z - \varphi\big((1-r)P^{a*} - z\big)\right\}$$

$$+\lambda_1\{(\varphi - 1)P^{a*}(1-r)\} + \lambda_3\{(1-\varphi)rP^{a*}\} - \lambda_4 \leq 0, \qquad \gamma\frac{\partial L}{\partial \gamma} = 0$$

$$\frac{\partial L}{\partial \varphi} = q\{(1-\gamma)\big((1-r)P^{a*} - z\big)\}$$

$$+\lambda_1\{P^{a*}(1-r)(\gamma - 1)\} + \lambda_3\{rP^{a*}(1-\gamma)\} - \lambda_5 \leq 0, \qquad \varphi\frac{\partial L}{\partial \varphi} = 0$$

plus constraints and complementary slackness conditions.

Note that the first four Kuhn-Tucker constraints are similar across the cases.

By AIR 2 of $(P4)$,

$$\lambda_2 + \lambda_3 = 1 - q > 0$$

$$e_2 = 1$$

Further, note that $e_1 - \Delta\theta > 0$. Inspecting AIR 1, we then observe

$$t_1 \geq \frac{e_1^2}{2} + [\text{something } \geq 0]$$

Therefore, if $e_1 > 0$, $t_1 > 0$. $e_1 > 0$ by assumption $\frac{q}{1-q} > \Delta\theta$.

Also,

$$e_1 = 1 - \frac{\lambda_3}{q}\Delta\theta$$

$$\lambda_1 = q - \lambda_3$$

Therefore, AIR 1 is binding. Observe that this must be true across the two cases

$$\lambda_1 = 1 - \lambda_2$$

$$\lambda_3 \leq 1 - q$$

The above six equations are in line with Kofman and Lawarrée (1993). However, now my approach differs.

Using $\lambda_1 = q - \lambda_3$, for both cases $\frac{\partial L}{\partial \varphi}$ becomes

$$\frac{\partial L}{\partial \varphi} = qz(\gamma - 1) + \lambda_3 P^{a*}(2r - 1)(1 - \gamma) - \lambda_5 \leq 0, \qquad \varphi\frac{\partial L}{\partial \varphi} = 0$$

For case 1, $\frac{\partial L}{\partial \gamma}$ simplifies to

$$\frac{\partial L}{\partial \gamma} = qz(\varphi - k) + qP^{a*}(r - 1) + \lambda_3 P^{a*}(2r - 1)(1 - \varphi) - \lambda_4 \leq 0, \qquad \gamma\frac{\partial L}{\partial \gamma} = 0$$

For case 2, $\frac{\partial L}{\partial \gamma}$ simplifies to

$$\frac{\partial L}{\partial \gamma} = qz\left(\varphi - k - \frac{P^{a*}}{P^{a*}+P^{i*}}r\right) + \lambda_3 P^{a*}(2r - 1)(1 - \varphi) - \lambda_4 \leq 0, \qquad \gamma\frac{\partial L}{\partial \gamma} = 0$$

Before continuing, let $P^{i*} = nP^{a*}, n \geq 0$, then $\frac{P^{a*}}{P^{a*}+P^{i*}} = \frac{1}{1+n}$.

PROOF OF PROPOSITION 1:

The size of P^{a*} making the principal indifferent between sending the internal auditor alone and not sending any auditor at all is defined where $\frac{\partial L}{\partial \gamma}$ for case 1 gets binding. Putting P^{a*} on the left-hand side, I obtain $\varepsilon(r) = \frac{qzk}{r(2-q)-1}$. Note that the optimal choice is $\gamma = 1$.

The size of P^{a*} making the principal indifferent between sending the internal auditor and the external auditor together and not sending any auditor at all is defined where $\frac{\partial L}{\partial \gamma}$ for case 2 gets binding. Putting P^{a*} on the left-hand side, I obtain $\vartheta(r) = \frac{qz(k+\frac{1}{1+n}r)}{(1-q)(2r-1)}$. Note that the optimal choice is $\gamma = 1$. Generally, $\delta < 1$.

The size of P^{a*} making the principal indifferent between sending the internal auditor and the external auditor together and sending the internal auditor alone is defined by setting $\frac{\partial L}{\partial \gamma}$ for case 1 equal to $\frac{\partial L}{\partial \gamma}$ for case 2. Putting P^{a*} on the left-hand side, I obtain $\rho(r) = \frac{z\frac{1}{1+n}r}{(1-r)}$. Mathematically, I choose P^{a*} such that $z\frac{1}{1+n}r + kz = (1-r)P^{a*} + kz$.

The size of P^{a*} making the principal indifferent between sending the internal auditor alone with probability $\gamma < 1$ and relying on another regime with probability $(1-\gamma) < 1$ is defined where $\frac{2r-1}{\Delta\theta}P^{a*} + \frac{\Delta\theta}{2} = 1 - \frac{\Delta\theta(1-r)+\frac{kz}{P^{a*}}}{2r-1}$. In words, how the objective differs between the regimes. Putting P^{a*} on the left-hand side and solving the quadratic equation, I obtain $\xi(r) = \frac{\Delta\theta\left[(2r-1-{}^1/_2\Delta\theta)+\sqrt{(2r-1-{}^1/_2\Delta\theta)^2-4kz(2r-1)}\right]}{2(2r-1)^2}$. Note that, even though it by first glance looks incorrect, it is the accurate solution. I have just rewritten it to make convergence in the next proposition tractable. If $\varphi > 0$ depends on whether P^{a*} is larger than the largest value of $\xi(r)$ and $\frac{qz}{\lambda_3(2r-1)}$, which is the value of P^{a*} making $\frac{\partial L}{\partial \varphi} = 0$. As showed earlier, $\lambda_3 \leq 1-q$.

The size of P^{a*} making the principal indifferent between sending the internal and external auditors with probability $\gamma < 1$ and relying on another regime with probability $(1-\gamma) < 1$ is defined where $\frac{2r-1}{\Delta\theta}P^{a*} + \frac{\Delta\theta}{2} = 1 - \frac{z(\frac{1}{1+n}r+k)}{P^{a*}(2r-1)}$. In words, how the objective differs between the regimes. Putting P^{a*} on the left-hand side and solving the quadratic equation, I obtain $\mu(r) = \frac{\Delta\theta\left[(2-\Delta\theta)+\sqrt{(\Delta\theta-2)^2-16z(\frac{1}{1+n}r+k)}\right]}{4(2r-1)}$. If $\varphi > 0$ depends on whether P^{a*} is larger than the largest value of $\mu(r)$ and $\frac{qz}{\lambda_3(2r-1)}$, which is the value of P^{a*} making $\frac{\partial L}{\partial \varphi} = 0$. As showed earlier, $\lambda_3 \leq 1-q$.

The objective is weakly concave and the constraints convex. Therefore, the Kuhn-Tucker constraints are sufficient for identifying an optimum.

Q. E. D.

PROOF OF CONVERGENCE IN PROPOSITION 2:

$\varepsilon(r) = \frac{qzk}{r(2-q)-1}$ gets transformed to $r = \frac{1}{2-q}$ when $k = 0$. $\vartheta(r) = \frac{qz(k+\frac{1}{1+n}r)}{(1-q)(2r-1)}$ with $k = 0$ is equal to $\eta(r) = \frac{qz\frac{1}{1+n}r}{(1-q)(2r-1)}$. Under PROPOSITION 1, I proved that $\rho(r) = \frac{z\frac{1}{1+n}r}{(1-r)}$ is independent of k. $\rho(r)$ is therefore similar across the propositions.

$\xi(r) = \frac{\Delta\theta\left[(2r-1-{}^{1}/_{2}\Delta\theta)+\sqrt{(2r-1-{}^{1}/_{2}\Delta\theta)^2-4kz(2r-1)}\right]}{2(2r-1)^2}$ turns into $\frac{\Delta\theta(4r-\Delta\theta-2)}{2(2r-1)^2}$ when $k = 0$. This formulation is similar to $\beta(r)$ in Kofman and Lawarrée (1993). Even though $\gamma < 1$, they prove $\varphi = 0$ is optimal. Consult LEMMA 2.3 in Kofman and Lawarrée (1993).

$\mu(r) = \frac{\Delta\theta\left[(2-\Delta\theta)+\sqrt{(\Delta\theta-2)^2-16z(\frac{1}{1+n}r+k)}\right]}{4(2r-1)}$ turns into $\frac{\Delta\theta\left[(2-\Delta\theta)+\sqrt{(\Delta\theta-2)^2-16z\frac{1}{1+n}r}\right]}{4(2r-1)}$ when $k = 0$. This formulation is comparable to $\omega(r)$ in Kofman and Lawarrée (1993), but changing z with $z\frac{1}{1+n}r$. Even though $\gamma < 1$, they prove $\varphi = 0$ is optimal. Consult LEMMA 2.3 in Kofman and Lawarrée (1993).

The objective is weakly concave and the constraints convex. Therefore, the Kuhn-Tucker constraints are sufficient for identifying an optimum.

Q. E. D.