The Terrorist Endgame

A MODEL WITH MORAL HAZARD AND LEARNING

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The author models the relationship between a government and former terrorists as a game with both moral hazard and learning. The government is uncertain about both the former terrorists' ability and skill at providing counterterrorism aid. The government has the option—after observing the success or failure of counterterrorism—of replacing the former terrorist leadership with a new negotiating partner. This study demonstrates that the threat of replacement, in addition to promised concessions, provides incentives for former terrorists to exert counterterrorism effort, particularly when the potential replacements are of moderate ability. Furthermore, the author identifies conditions under which governments are likely to replace the former-terrorist leadership with which it has been negotiating. The model also has implications for the effect of counterterrorism successes on future concessions and the impact of the government's ability to consider replacing the former terrorists on concessions and counterterrorism.

Keywords: *terrorism; counterterrorism; moral hazard; learning; concessions; negotiation*

On June 24, 2002, President Bush announced, "I call on the Palestinian people to elect new leaders, leaders not compromised by terror." The president went on to justify this demand for regime change, arguing that "the United States will not support the establishment of a Palestinian state until its leaders engage in a sustained fight against the terrorists and dismantle their infrastructure."[1]

This speech was consistent with the Israeli government's policy that there would be no negotiations until the Palestinian leadership provided a sustained peace. Indeed, in December of the same year, the Israeli cabinet officially declared Yasser Arafat "irrelevant."

Pressure from the United States and Israel seemed to have a short-run effect. Shortly after the president's speech, the Palestinian Authority placed Sheikh Ahmed Yassin—the spiritual leader of Hamas—and other militant leaders under arrest. How-

1. President George W. Bush, Rose Garden Speech, June 24, 2002. Transcript available at http://www.whitehouse.gov/news/releases/2002/06/20020624-3.html.

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ever, not long after, attacks against Israel resumed, and by September 2003, the Israeli government made Arafat's removal official policy.

This policy eventually led to the ascendance of a new Palestinian prime minister, Abu Mazen. Asked to respond to the new leadership, the spokesman for Israeli Prime Minister Ariel Sharon stated, "What counts is the extent to which the prime minister [Abu Mazen] and the new government will execute the necessary reforms and perform the necessary steps to fight terrorism and fight incitement" (CNN 2003). Israel responded similarly when another new prime minister, Ahmed Qorei, ascended to head the Palestinian government.

Similarly, on October 17, 2002, British Prime Minister Tony Blair called on the Irish Republican leadership to put an end to violence, stating,

> The fork in the road has finally come . . . we cannot carry on with the IRA [Irish Republican Army] half in, half out of this process . . . the continuing existence of the IRA as an active paramilitary organisation . . . makes it harder for us to respond to nationalist concerns.

Blair went on to make his demands explicit:

> It's time for acts of completion . . . should real change occur, we can implement the rest of the Agreement, including on normalisation, in its entirety and not in stages but together. . . . But that means also commitment from others . . . Nationalists to act if violence returns. Republicans to make the commitment to exclusively peaceful means, real, total and permanent.[2]

Blair's speech was a response to the tension, existent since the signing of the Good Friday Accords and the bombing of Omagh, between the desire for a lasting peace and the unwillingness of Republicans to fully disarm or renounce violence. The speech implicitly threatened that the British government would cease negotiations if Sinn Fein were unable or unwilling to reign in Republican militants. The alternative, Blair intimated, was that the British would not "implement the rest of the Agreement, including on normalisation" in full until a Republican leadership emerged that would commit "to exclusively peaceful means." Indeed, following the speech, some British politicians called on Blair to expel Sinn Fein members of Parliament from their Westminster offices (Settle 2002).

The Republicans responded angrily to the Blair speech, refusing to consider disbanding the IRA (Brown 2002). The conflict continued in a series of speeches by British, Loyalist, and Republican leaders, with the Republicans claiming to have responded to the British concerns and the British continuing to maintain that Sinn Fein has failed to fully renounce paramilitarism (McGinn 2003). This back and forth continues unto today.

The events that have taken place both between the Israelis and Palestinians and the British and Irish Republicans highlight an important dynamic in negotiations between governments and former insurgent leaders who are seeking concessions. Frequently, a

2. Prime Minister Tony Blair, speech at the Harbour Commissioners' Offices in Belfast, Ireland, October 17, 2002.

precondition for government concessions is that the former insurgents provide aid in ending future acts of terrorism. Other examples of such collusive relationships between governments and their former enemies include the combined British and Hagannah efforts to prevent terrorism by Zionist organizations such as the Irgun and LEHI in 1940s British-Mandate Palestine (Bell 1977) and the Italian use of former-terrorist informants to infiltrate left-wing terrorist organizations (della Porta 1995). Moreover, as both cases discussed above indicate, governments frequently hold moderate leaders responsible when violence continues—threatening to withhold concessions and even to end negotiations until new, more productive negotiating partners can be found.

Recent scholarship has begun to address this link between government concessions and counterterrorism. Kydd and Walter (2002) develop a model in which extremists attempt to undermine peace negotiations between moderate terrorists and a government by convincing the government that the moderates are weak. The government is assumed to prefer to strike a deal with strong moderates because in future (unmodeled) periods of the game, strong moderates will be able to suppress extremist violence. Bueno de Mesquita (2005) also models the link between concessions and the suppression of extremist violence. In that model, governments and former terrorists ensure the credibility of government concessions and former terrorists' promises of counterterrorism aid through punishment strategies in a repeated game.

In this article, I model the relationship between a government and former terrorists as a game with both moral hazard and learning. The government is uncertain both about how hard the former terrorists are working to prevent terror and how skillful the former terrorists are at counterterrorism. That is, the government has to deduce whether to blame counterterrorism failures on the former terrorists being unable (learning) or unwilling (moral hazard) to prevent attacks. By observing outcomes, the government learns about the former terrorists' ability and effort. Furthermore, the government has the option—after observing the success or failure of counterterrorism in the first round and updating its assessment of the former terrorists' ability—of replacing the former terrorist leadership with a new negotiating partner (whose counterterrorism ability is also uncertain).

I show that the threat of replacement, in addition to promised concessions, provides incentives for former terrorists to exert counterterrorism effort. This is particularly true when the potential replacements are perceived to be of moderate ability. If they are clearly better or clearly worse than the current leadership, the current leadership believes that its actions have no affect on the government's retention decisions. Furthermore, I identify conditions under which governments are likely to bear the costs of searching for new negotiating partners and when, given that they have searched, the government is likely to replace the former-terrorist leadership with which it has been negotiating. In particular, I demonstrate that the intuition that governments are more likely to replace former-terrorist leaders who have failed at counterterrorism is true only if counterterrorism effort and ability are strategic complements. The model also has implications for the effect of counterterrorism successes on future concessions and the impact of the government's option to replace the former terrorists on concessions and counterterrorism.

THE MODEL

Consider the following two-period model. In period 1, the government (G) makes an offer of concessions, contingent on the former-terrorist leadership (FT) aiding with counterterrorism. The former terrorists then decide how much effort to exert toward counterterrorism. The success of counterterrorism is a function both of the former-terrorist leaders' effort and ability, neither of which is observed directly by the government. If the former terrorists succeed in counterterrorism, the government grants the concessions due, but if the former terrorists fail, then the government does not grant concessions. Following the counterterrorism outcome, the government has the option to search for a new leadership within the terrorist organization with whom to negotiate. Undertaking such a search is costly. Moreover, even if it searches, the government still observes the potential replacement leaders' ability imperfectly and must choose whether to retain the original leadership for the next round with only this limited information. In the second round, the government makes a new offer of concessions to its negotiating partner, the former terrorists, who decide how much effort to exert, and the government makes concessions only if counterterrorism is successful. The game ends at the end of the second period.

Label the government's offer of concessions in period t, w_t. In each round, the former terrorists choose to exert a level of effort ($a_t \in (0, 1)$). The former terrorists' ability is known neither by the government nor by the former terrorists themselves. The idea is that there is uncertainty on both actors' parts as to how effective the former terrorists will be in combating violence. Label the former terrorists' true ability $\theta \in (0, 1)$. There is a common prior distribution of θ with probability density function (pdf) $f(\bullet)$ and cumulative distribution function (cdf) $F(\bullet)$, where $F(\bullet)$ is strictly increasing on its support, (0, 1). The expected value of θ, in round 1, is given by $\overline{\theta}_0 = \int_0^1 \theta f(\theta) d\theta$.

The probability of successful counterterrorism is a function of the former terrorists' effort and ability, given by $pr(\text{success}|a, \theta) = a\theta$. Effort and ability both increase the probability of success and act as complements. The more able a former terrorist, the more productive are his or her counterterrorism efforts. This assumption is consistent with the notion that ability represents the former terrorists' knowledge of the inner workings of the terrorist organization, which makes counterterrorism more efficient. This assumption is explored in more depth later.

The former terrorists also bear costs $c(a)$ for effort expended on counterterrorism, where $c'(\bullet) > 0$, $c''(\bullet) > 0$, and $c'''(\bullet) \geq 0$.[3] These costs should be thought of as the opportunity costs of expending scarce effort and resources on counterterrorism and any potential retribution or political costs for "betraying" former comrades-in-arms.[4]

The true ability of the potential replacement leadership is θ_R, which is a random variable drawn from a density $g(\bullet)$ with cdf $G(\bullet)$, which is increasing on its support, (0, 1). The mean of this distribution is $\overline{\theta}_R$. Initially, the government and former terrorists do not know this mean, although they have common priors that $\overline{\theta}_R$ is distributed

3. These assumptions are satisfied, for example, by $c(a) = a^2$.
4. For a detailed discussion of the internal relations among terrorist factions, see Siqueira (2005).

according to $h(\bullet)$ with cdf $H(\bullet)$. If the government searches for a replacement, it observes the mean of this distribution, although it does not observe the true ability. The intuition is that the government gains information through the process of searching.

I also assume that the government is not certain of the costs of searching. These costs, k, are a random variable distributed according to $i(\bullet)$ with cdf $I(\bullet)$. The government discovers the costs of searching just before deciding whether to search. The idea is that, at the beginning of the game, the government may be uncertain of a host of political or other factors that make pursuing a replacement more or less feasible. For instance, even if the identity of a potential replacement is clear, prior to deciding to replace a negotiating partner, a government might publicize the possibility to learn whether the potential replacements are strong enough to withstand internal challenges. This can create costs for the government. It could, for example, foment a power struggle within the terrorist movement and thereby create an increase in violence (Bloom 2004). Alternatively, going public with the idea of replacing one's negotiating partner may entail public relations costs, such as the international disapproval the Israelis faced following their threat to isolate Yasser Arafat.

The players' payoffs are as follows. In the first period, the former terrorists derive utility w from concessions, only if they succeed at counterterrorism. The former terrorists also consider how their performance in the first period affects second-period expected payoffs. This calculation involves several factors. First-period success affects the probability that the government searches for a replacement, the probability that the government replaces the former-terrorist leaders given that it has searched, and the posterior assessment of the former terrorists' ability, which affects the level of concessions offered and the effort exerted in the second period. Finally, the former terrorists bear costs for effort. Formally, the expected utility is

$$
\begin{aligned}
&EU_1^{FT}(a_1) = E\{pr(\text{success}|a_1, \theta) \\
&[w_1 + pr(\text{search}|\text{success})pr(\text{retain}|\text{search, success})EU_2^{FT}(\bar{\theta}_1|\text{success}) + \\
&(1 - pr(\text{search}|\text{success}))EU_2^{FT}(\bar{\theta}_1|\text{success})] \\
&+ pr(\text{failure}|a_1, \theta)[pr(\text{search}|\text{failure})pr(\text{retain}|\text{search, failure})EU_2^{FT}(\bar{\theta}_1|\text{failure}) + \\
&(1 - pr(\text{search}|\text{failure}))EU_2^{FT}(\bar{\theta}_1|\text{failure})]\} - c(a_1).
\end{aligned}
$$

The former terrorists' expected utility in period 2 is simply the probability of success multiplied by the concessions minus the costs:

$$EU_2^{FT}(a_2|\bar{\theta}_1) = E[pr(\text{success}|a_2, \theta)w_1] - c(a_2).$$

In the first period, the government bears direct costs T if counterterrorism fails and bears costs w for concessions made. The government must also decide whether to search for new negotiating partners, which imposes costs k, and, if it does search for a new negotiating partner, whether to replace the former terrorists. These decisions will, of course, be affected by the posterior assessment of the former terrorists' ability. Formally, the government's expected utility in round 1 is

$$
\begin{aligned}
&EU_1^G(w_1) = E\{pr(\text{success}|a_1(w_1),\theta)\\
&[-w_1 + pr(\text{search}|\text{success})pr(\text{retain}|\text{search, success})EU_2^G(\bar{\theta}_1|\text{success}) +\\
&(1 - pr(\text{retain}|\text{search, success}))EU_2^G(\bar{\theta}_R|\text{success, no retain}) - k)] +\\
&(1 - pr(\text{success}|a_1(w_1),\theta))[-T +\\
&pr(\text{search}|\text{failure})(pr(\text{retain}|\text{search, failure})EU_2^G(\bar{\theta}_1|\text{failure}) +\\
&(1 - pr(\text{failure}|\text{search, failure}))EU_2^G(\bar{\theta}_R|\text{failure, no retain}) - k)]\}.
\end{aligned}
$$

The government's expected utility in period 2 is simply a function of the probability of successful counterterrorism and the expected costs of concessions:

$$EU_2^G(w_2|\bar{\theta}_1) = E[pr(\text{success}|a_2(w_2),\theta)(-w_2) + (1 - pr(\text{success}|a_2(w_2),\theta))(-T)].$$

LEARNING

There is symmetric uncertainty over the former terrorists' ability at the beginning of the game. In equilibrium, the former terrorists choose a level of effort, a^*, and the government anticipates this level of effort, despite the fact that the actual action is unobserved (there is moral hazard). There are two possible posterior distributions depending on whether counterterrorism was successful. Label the posterior $\hat{f}$. Then, we have

$$\hat{f}(\theta|\text{success}, a^*) = \frac{a^*\theta f(\theta)}{a^*\int_0^1 \theta f(\theta)d\theta} = \frac{\theta f(\theta)}{\bar{\theta}_0},$$

$$\hat{f}(\theta|\text{failure}, a^*) = \frac{(1-a^*\theta)f(\theta)}{\int_0^1 (1-a^*\theta)f(\theta)d\theta} = \frac{(1-\theta)f(\theta)}{1-\bar{\theta}_0}.$$

I will label the posterior ability following success

$$\bar{\theta}_s = \int_0^1 \theta \frac{\theta f(\theta)}{\bar{\theta}_0} d\theta$$

and following failure

$$\bar{\theta}_f = \int_0^1 \theta \frac{(1-\theta)f(\theta)}{1-\bar{\theta}_0}.$$

Importantly, $\bar{\theta}_s > \bar{\theta}_f$, which is proven below.

Remark 1: The expected ability of the former terrorists is higher following success than following failure.

The proof is in the appendix. When not specifying whether there was success or failure, I will call this posterior expected ability $\bar{\theta}_1$.

EQUILIBRIUM

As is standard, I solve starting at the end of the game.

PERIOD 2 WITH RETENTION

I begin by focusing on the period 2 subgame in which the government retained the former terrorists in period 1. I analyze this subgame and then return to the period 2 subgame in which the government replaced the former terrorists.

Level of Effort

In period 2, the former terrorists do not have to worry about whether they will be retained. Their effort level is chosen only with regard to the concessions offered, the probability of success, and the opportunity costs of effort. The probability of successful counterterrorism is $\int_0^1 a\theta\hat{f}(\theta)d\theta = a\bar{\theta}_1$. The optimal level of effort will solve the following:

$$a_2^* = \arg\max_a a\bar{\theta}_1 w_2 - c(a).$$

The first-order condition characterizes the optimum:

$$\bar{\theta}_1 w_2 = c'(a_2^*). \tag{1}$$

The level of effort chosen by the former terrorists is increasing in the concessions offered. When the proposed concessions are particularly valuable, effort is particularly attractive. This further implies that an increase in concession increases the probability of successful counterterrorism.

Remark 2: The level of counterterrorism effort and, consequently, the probability of successful counterterrorism are increasing in the level of concessions offered.

The proof is in the appendix. Intuitively, concessions act as an incentivizing device. The government can encourage effort by promising rewards. Later in the analysis, I also examine how the level of effort is affected by the posterior beliefs about ability.

Concessions

The government will offer concessions that maximize its expected utility:

$$w_2^* = \arg\max_w a_2^*(w)\bar{\theta}_1(T - w) - T.$$

The first-order condition defines the optimal level of concessions at an interior solution:

$$\frac{\partial a_2^*}{\partial w_2}(T - w_2^*) = a_2^*.$$

The left-hand side represents the marginal benefit associated with increasing the level of effort the former terrorists exert, which increases the probability of successful counterterrorism. The right-hand side represents the marginal cost associated with increasing the amount of concessions that must be granted when success is achieved. Applying the implicit function theorem to equation (1) shows that

$$\frac{\partial a_2^*}{\partial w_2} = \frac{\bar{\theta}_1}{c''(a_2^*)}.$$

Substituting and rearranging yield

$$w_2^* = T - \frac{a_2^* c''(a_2^*)}{\bar{\theta}_1}. \tag{2}$$

It follows from equation (2) that the level of concessions is increasing in the costliness of the terrorist campaign. The more devastating terrorist attacks are, the more willing the government is to make concessions to encourage counterterrorism aid. Furthermore, the government's expected utility is improved by an increase in the expected ability of the former terrorists. This is because such an improvement increases the probability that the former terrorists succeed at counterterrorism. This intuition is formalized in the following remark.

Remark 3: The government's expected utility in the second round is increasing in the expected ability of the former terrorists.

The proof is in the appendix. This will be important for the development of the equilibrium because it implies that, in the first round, the government will be more likely to retain former terrorists who succeeded at counterterrorism.

The Impact of Expected Ability

The final comparative-static questions for the second period are how changes in the beliefs about the former terrorists' ability affect concessions and counterterrorism effort. This will reveal whether, when the government decides to retain the former terrorists, it offers greater concessions to former terrorists who succeeded or failed in counterterrorism in the first round. Recall that the choice of a level of concessions is driven by two factors: (1) the marginal benefit of increasing the level of effort the former terrorists exert and (2) the marginal cost of having to pay a greater level of concessions when counterterrorism succeeds. On one hand, as the expected ability of the former terrorists improves, the level of effort that any given level of concessions induces increases because effort and ability are complements. That is, an increase in ability increases the marginal effect of concessions on effort, putting upward pressure on the

optimal level of concessions. On the other hand, as the expected ability of the former terrorists improves, the probability of successful counterterrorism increases, which increases the probability that the concessions will actually have to be made, which increases the marginal cost of concessions, putting downward pressure on the optimal concessions. Thus, both the marginal benefits and the marginal costs of concessions increase when expected ability increases, which complicates the comparative-static analysis.

Similarly, it is not immediately obvious whether the level of effort will increase or decrease. Effort and ability are complements, so the direct effect of an increase in expected ability is to increase effort. However, effort and concessions are also strategic complements. Thus, if an increase in expected ability decreases the concessions offered, this indirect effect could offset the direct positive effect on effort.

Despite these complications, it turns out that increasing expected ability increases both concessions and effort. This result is given in the following remark.

Remark 4: An increase in the expected ability of the former terrorists increases the level of concessions offered by the government and the level of effort exerted by the former terrorists.

The proof is in the appendix.

PERIOD 2 WITHOUT RETENTION

So far, I have analyzed how the government and former terrorists behave if the government retains the former terrorists in the first round. I now turn to the scenario in which the government replaces the former terrorists. In the previous section, the actors' decisions did not depend on the full posterior distributions of ability but only on the means of the distributions. As such, the only relevant piece of information for behavior in the second round is the new leadership's expected ability. Given this, the analysis is the same as above, substituting $g(\bullet)$ for $\hat{f}(\bullet)$.

PERIOD 1

Retention

The last decision made in the first period is whether to retain the former-terrorist leaders. The government only has this option if it first chose to search for a replacement. When the government decides whether to retain the former-terrorist leadership, it has already had the opportunity to update its beliefs about the first-period former-terrorist leaders' ability, depending on whether they succeeded or failed in their counterterrorism. The government will adopt a simple cutoff rule.

Call the government's expected utility in round 2, $EU_2^G(\overline{\theta}_1)$. Remark (1) shows that $\overline{\theta}_f < \overline{\theta}_s$, which, by remark (3), implies that $EU_2^G(\overline{\theta}_f) < EU_2^G(\overline{\theta}_s)$—the government's second-period expected utility is higher if it retains former terrorists who succeeded in

round 1 than if it retains former terrorists who failed in round 1. The government's expected utility in round 2, if it replaces the former terrorists, is $EU_2^G(\bar{\theta}_R)$. The government replaces the former terrorists only if $EU_2^G(\bar{\theta}_R) > EU_2^G(\bar{\theta}_1)$, which is true if $\bar{\theta}_R > \bar{\theta}_1$.

To Search or Not to Search

Prior to deciding whether to retain the former-terrorist leadership, the government must choose whether to bear the costs of searching for replacements. If the government searches, it has the opportunity to find out whether a more desirable trading partner is likely to exist. However, it also has to bear the costs of searching. The government's expected utility from searching is

$$EU_G\ (\text{search}) = \int_0^{\bar{\theta}_1} EU_2^G(\bar{\theta}_1)h(\bar{\theta}_R)d\bar{\theta}_R + \int_{\bar{\theta}_1}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - k.$$

The government's expected utility if it does not search is simply

$$EU_G(\text{no search}) = EU_2^G(\bar{\theta}_1).$$

The government will search if and only if

$$k < \int_{\bar{\theta}_1}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1 - H(\theta_1))EU_2^G(\bar{\theta}_1).$$

This means that the probability of the government searching is

$$pr\ (\text{search}) = I\left(\int_{\bar{\theta}_1}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1 - H(\theta_1))EU_2^G(\bar{\theta}_1)\right). \tag{3}$$

A key comparative static is that the probability of the government searching for a new negotiating partner is decreasing in the government's assessment of the ability of the current leadership. This can be seen by differentiating equation (3):

$$\frac{\partial pr(\text{search})}{\partial \bar{\theta}_1} = -(1 - H(\theta_1))\frac{\partial EU_2^G(\bar{\theta}_1)}{\partial \bar{\theta}_1} i\left(\int_{\bar{\theta}_1}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1 - H(\theta_1))EU_2^G(\bar{\theta}_1)\right) < 0.$$

Thus, the government is more likely to search for a new negotiating partner following a failure by the former terrorists (since $\bar{\theta}_s > \bar{\theta}_f$).

Level of Effort

In the first period, the former terrorists consider four factors when deciding how much effort to exert: the concessions they will obtain if they succeed in counterterrorism, the probability that the government will search for a replacement, the probability of being retained even if the government searches for a replacement, and their expected payoffs in the second period contingent on performance in the first period.

With regard to the probability of being retained, given that the government searches for a replacement, there are three potential cases:

1. $EU_2^G(\bar{\theta}_R) < EU_2^G(\bar{\theta}_f)$, which occurs if $\bar{\theta}_R < \bar{\theta}_f$.
2. $EU_2^G(\bar{\theta}_f) < EU_2^G(\bar{\theta}_R) < EU_2^G(\bar{\theta}_s)$, which occurs if $\bar{\theta}_f < \bar{\theta}_R < \bar{\theta}_s$.
3. $EU_2^G(\bar{\theta}_R) > EU_2^G(\bar{\theta}_s)$, which occurs if $\bar{\theta}_R > \bar{\theta}_s$.

In cases 1 and 3, performance in the first period has no effect on the probability of retention (except through its effect on the decision of whether to search). In case 1, whether or not the former terrorists succeed, they will be retained because the outside option is thought to be so bad. In case 3, if the government searches, it finds the outside option so attractive that, even if the former terrorists succeed, they will not be retained. In case 2, the former terrorists are only retained if they succeed.

When the former terrorists choose a level of effort, they do not know what the government's assessment of the alternatives will be, but they do know the probability distribution, $h(\bar{\theta}_R)$. Let p_1 be the probability that they are in case 1, p_2 be the probability they are in case 2, and $p_3 = 1 - p_1 - p_2$ be the probability that they are in case 3.[5] Furthermore, the former terrorists do not know what the realization of the government's cost of searching will be and thus do not know whether the government will search. Let q_s be the probability that the government searches, given success by the former terrorists, and let q_f be the probability that the government searches given failure by the former terrorists.[6] It follows from the discussion above that $q_s < q_f$. The former terrorists solve the following problem:

$$\max_a a\bar{\theta}_0\Big[w_1 + q_s(p_1 EU_2^{FT}(\bar{\theta}_s) + p_2 EU_2^{FT}(\bar{\theta}_s)) + (1-q_s)EU_2^{FT}(\bar{\theta}_s)\Big] + (1-a\bar{\theta}_0)\Big[q_f p_1 EU_2^{FT}(\bar{\theta}_f) + (1-q_f)EU_2^{FT}(\bar{\theta}_f)\Big] - c(a).$$

At an interior solution, the optimum is implicitly defined by the first-order conditions:

$$\bar{\theta}_0\begin{bmatrix} w_1 + p_1(q_s EU_2^{FT}(\bar{\theta}_s) - q_f EU_2^{FT}(\bar{\theta}_f)) + p_2 q_s EU_2^{FT}(\bar{\theta}_s) + \\ (1-q_s)EU_2^{FT}(\bar{\theta}_s) - (1-q_f)EU_2^{FT}(\bar{\theta}_f) \end{bmatrix} = c'(a). \tag{4}$$

There are several factors that enter into the former terrorists' decision. The first term in equation (4) ($\bar{\theta}_0 w_1$) represents the marginal effect of effort on the probability of succeeding at counterterrorism and, thereby, gaining concessions. The second term

5. Formally,
$$p_1 = \int_0^{\bar{\theta}_f} h(\bar{\theta}_R)d\bar{\theta}_R,\ p_2 = \int_{\bar{\theta}_f}^{\bar{\theta}_s} h(\bar{\theta}_R)d\bar{\theta}_R \text{ and } p_3 = \int_{\bar{\theta}_s}^{1} h(\bar{\theta}_R)d\bar{\theta}_R.$$

6. Formally,
$$q_s = I\left(\int_{\bar{\theta}_s}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1-H(\theta_s))EU_2^G(\bar{\theta}_s)\right) \text{ and}$$
$$q_f = I\left(\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1-H(\theta_f))EU_2^G(\bar{\theta}_f)\right).$$

$(\overline{\theta}_0 p_1 (q_s EU_2^{FT}(\overline{\theta}_s) - q_f EU_2^{FT}(\overline{\theta}_f)))$ represents the marginal effect of effort on the probability of success and, thereby, future payoffs, conditional on the government intending to retain the former terrorists regardless of counterterrorism outcomes (case 1 above). In this case, the effect of successful counterterrorism is to change the post-erior assessment of the former terrorists' ability and to decrease the likelihood that the government searches for a replacement in the first place. The third term $(\overline{\theta}_0 p_2 q_s EU_2^{FT}(\overline{\theta}_s))$ represents the marginal benefit of effort associated with improving the probability of being retained in the scenario in which the former terrorists are only retained if they succeed in counterterrorism. The fourth term $((1-q_s)EU_2^{FT}(\overline{\theta}_s) - (1-q_f)EU_2^{FT}(\overline{\theta}_f))$ represents the increased payoff in future rounds associated with success, if the government does not search. The final term $(-c'(a))$ is the marginal cost of effort.

It is possible to determine from equation (4) how various parameters affect the level of effort the former terrorists exert. Clearly, the level of effort is increasing in w_1 and in $\overline{\theta}_0$. That is, the higher the concessions offered and the better the prior beliefs about the effectiveness of the former-terrorists' counterterrorism efforts, the greater the level of effort.

The left-hand side of equation (4) is also increasing in p_2. The more likely it is that counterterrorism success affects the government's retention decision, the greater the level of effort. This is because in the scenarios in which either the former terrorists will be maintained for sure or replaced for sure (given that the government searches), the only motivations the former terrorists have to exert effort are concessions and the possibility of convincing the government not to search for replacements. However, when retention is dependent on counterterrorism success, the former terrorists have an added incentive. This argument implies that governments have an interest in cultivating rival factions within a terrorist organization that are, more or less, equally powerful. An alternative negotiating partner who is either too strong or too weak will undermine the credibility of long-term payoffs as an incentive for actions that are costly in the short term. These results are summarized in the following remark:

Remark 5: The terrorists exert greater effort the greater their expected ability ($\overline{\theta}_0$), the higher the level of concessions (w_1), and when there is a credible challenger who is neither clearly better nor clearly worse than the incumbents.

Proof. The first two results are clear from inspection of equation (4).

When p_2 increases, the left-hand side of equation (4) increases more so than if p_1 increases since $q_s EU_2^{FT}(\overline{\theta}_s) > q_s EU_2^{FT}(\overline{\theta}_s) - q_f EU_2^{FT}(\overline{\theta}_f)$ or than if p_3 increases since $q_s EU_2^{FT}(\overline{\theta}_s) > 0$. Thus, increasing p_2, at the expense of either p_1 or p_3, increases the probability of effort. Q.E.D.

It is also worth noting the effects that the government's ability to search for a new negotiating partner has on the effort expended. On one hand, it increases the cost associated with failure by creating the possibility that failure will lead to replacement. On the other hand, it also allows for states of the world where there is no hope of being

retained, which diminishes the marginal benefit of effort. However, this latter state of affairs (case 3 above) seems rather unlikely empirically. If there were an alternative terrorist leadership that clearly dominated the current leadership, regardless of the current leaderships' performance, one would think the government would already have identified these new partners. Thus, it seems likely that p_3 is quite small. If this probability is sufficiently small, then the second effect is relatively small, and so the government's ability to search for a new negotiating partner increases the incentive for the former terrorists to exert effort. This result is summarized in the following remark:

Remark 6: If p_3 is sufficiently small, then the level of effort by the former terrorists is greater when the government has the option of searching for a replacement.

The proof is in the appendix.

Level of Concessions

The government chooses a level of concessions to maximize its expected utility, taking into account both first- and second-round payoffs. The offer of concessions will solve

$$\begin{aligned}
&\max_a a^*(w)\bar{\theta}_0 \\
&\left[-w + q_s\left((1-H(\bar{\theta}_s))EU_2^G(\bar{\theta}_s) + \int_{\bar{\theta}_s}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_s\right) + (1-q_s)EU_2^G(\bar{\theta}_s)\right] \\
&+ (1-a^*(w))\bar{\theta}_0 \\
&\left[-T + q_f\left((1-H(\bar{\theta}_f))EU_2^G(\bar{\theta}_f) + \int_{\bar{\theta}_f}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_f\right) + (1-q_f)EU_2^G(\bar{\theta}_s)\right],
\end{aligned}$$

where $\bar{k}_f$ is the expected cost of searching given that the government searched following failure, and $\bar{k}_s$ is the expected cost of searching given that the government searched following success.[7] It is clear that $\bar{k}_s > \bar{k}_f$.

The optimal choice at an interior solution is characterized by the following first-order condition:

$$\begin{aligned}
&\bar{\theta}_0 \frac{\partial a^*}{\partial w}[T - w + EU_2^G(\bar{\theta}_s)(1 - q_s H(\bar{\theta}_s)) \\
&\quad - EU_2^G(\bar{\theta}_f)(1 - q_f H(\bar{\theta}_f)) + q_s\left(\int_{\bar{\theta}_s}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_s\right) \\
&\quad - q_f\left(\int_{\bar{\theta}_f}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_f\right)] = \bar{\theta}_0 a_1^*.
\end{aligned} \tag{5}$$

7. Formally,

$$\bar{k}_f = \int_0^{\int_{\bar{\theta}_f}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1-H(\theta_f))EU_2^G(\bar{\theta}_f)} ki(k)dk \text{ and}$$

$$\bar{k}_s = \int_0^{\int_{\bar{\theta}_s}^1 EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - (1-H(\theta_s))EU_2^G(\bar{\theta}_s)} ki(k)dk.$$

Concessions are increasing in the size of the terrorist campaign (T). Furthermore, it is possible to determine how the government's ability to search for a new negotiating partner (under the same assumption about p_3 as before) affects concessions. If the government could not search for a new negotiating partner, its expected utility would be

$$\overline{\theta}_0 a_2^*(-w + EU_2^G(\overline{\theta})) + (1 - \overline{\theta}_0 a_2^*)(-T + EU_2^G(\overline{\theta}_f)).$$

The optimal choice is characterized by

$$\overline{\theta}_0 \frac{\partial a_1^*}{\partial w}(T - w + Eu_2^G(\overline{\theta}_s) - EU_2^G(\overline{\theta}_f)) = \overline{\theta}_0 a_2^*. \tag{6}$$

Comparing this with equation (5) yields the following result:

Remark 7: If p_3 is sufficiently small, then the level of concessions offered is smaller when the government has the option to search for an alternative leadership.

The proof is in the appendix.

EVALUATING THE CRITICAL ASSUMPTIONS

Although I include both learning and moral hazard, the analysis does not focus on standard moral hazard questions. This is, in part, because the complementarity of effort, ability, and concessions attenuates the problem of suboptimal provision of effort. There are agency costs, such as the costs of searching for a new negotiating partner incurred to provide incentives for effort. However, this article is primarily concerned with the substantive question of the strategic interaction of effort, ability, and concessions in the relationship between governments and former terrorist leaders. The assumed complementarity of effort and ability plays a key role.

Several of the central results of the analysis may seem, at first glance, sufficiently intuitive that the contribution of the modeling exercise is unclear. These include the findings that the government is strictly better off with higher expected ability former terrorists, that the government is more likely to replace former terrorist leaders if they fail at counterterrorism, and that the government is more likely to search for a new negotiating partner when the former terrorists failed in the first round. Yet each of these seemingly intuitive conclusions is only straightforwardly true when ability and effort are complements.

The intuition for why complementarity is so important is as follows. If effort and ability are substitutes, then the improved posterior beliefs about the former terrorists' ability following successful counterterrorism put downward pressure on the former terrorists' second-period level of effort. If this diminution in effort is greater than the benefit of higher ability, then higher ability can make the government worse off. Moreover, since the government is no longer unambiguously better off with high-ability types, it is not clear that the government is less likely to search for replacements or actually replace the former terrorists following success.

To see this more formally, suppose that the probability of successful counterterrorism is a function $p(a, \theta)$, where $p_a > 0, p_\theta > 0, p_{aa} < 0$, and $p_{a\theta} < 0$. The probability of success is increasing and concave in effort and increasing in ability, but the marginal impact of effort is decreasing in ability (they are substitutes). The former terrorists' second-period problem is

$$\max_a p(a,\theta)w_2 - c(a),$$

and the optimal choice is characterized by

$$p_a(a^*, \theta)w_2 = c'(a^*).$$

The government's second-round expected utility, then, is given by

$$EU_G = p(a^*)(T - w^*) - T.$$

The envelope theorem implies that

$$\frac{\partial EU_G}{\partial \theta} = \left(p_a \frac{\partial a^*}{\partial \theta} + p_\theta \right)(T - w^*).$$

The question is whether this is positive or negative, that is, whether the government's expected utility is increasing or decreasing in the ability of the former terrorists. The sign of this derivative is the same as the sign of $p_a \, \partial a^*/\partial\theta + p_\theta$ since $T - w^* > 0$. By assumption, both p_θ and p_a are positive. Furthermore, $\partial a^*/\partial\theta$ can be calculated by applying the implicit function theorem to the former terrorists' optimization problem above. Doing so demonstrates that $\partial a^*/\partial\theta$ has the same sign as $p_a \, \partial w_2^*/\partial\theta + p_{a\theta} w_2^*$.

Now the distinction between complementarity and substitutability is clear. The effect of increased ability on government welfare cannot be signed because $p_{a\theta} < 0$, which means that $\partial a^*/\partial\theta$ is not clearly positive (effort may decrease in ability). When effort and ability are assumed to be substitutes, there are two effects of an increase in ability. First, it changes the level of concessions offered (which will increase effort if concessions increase). Second, it decreases the incentive for effort because high ability can take the place of high effort (this effect is unambiguously negative). One cannot determine the relative size of these effects without making significant assumptions about functional forms. Thus, it is not true that the government always wants to maintain high-ability former terrorists.

This discussion indicates that some of the more "obvious" results in this model are, perhaps, not as obvious as it first seemed. In particular, the analysis demonstrates that governments unambiguously prefer high-ability former terrorists *only if* counterterrorism effort and ability are complements. The benefit of this finding is that the robustness and empirical validity of the claims of the model hinge on a *substantive*, rather than a technical, assumption. The question of whether effort and ability are substitutes or complements can be evaluated empirically by terrorism experts.

Briefly, it seems to me that complementarity, rather than substitutability, is typically the appropriate assumption. Consider some of the cases of governments negoti-

ating with former insurgents in exchange for counterterrorism aid. As mentioned earlier, examples include the Israelis and Palestinians, British and Zionists, and British and Irish Republicans. In each of these cases, the former terrorists possessed greater "ability" to fight counterterrorism primarily because of their insider knowledge of the still-active terror groups. They knew better than the government who the extremists were, where they were located, how they were funded and organized, and what types of attacks they were likely to pursue. For instance, the Hagannah's anti-Irgun program, known as "the Season," exploited intelligence the Hagannah gained during its alliance with the Irgun to hunt down and arrest virtually the entire Irgun leadership (Bell 1977). This knowledge is not a *substitute* for counterterrorism effort. Indeed, such knowledge is only valuable if it is used to pursue counterterrorism actions. Knowledge of the inner workings of a terror organization complements counterterrorism efforts by making them more effective.

The argument above notwithstanding, there are counterterrorism situations in which effort and ability could be substitutes. For instance, suppose that the former terrorists can aid the government in two ways: direct intervention to prevent terrorist attacks or providing intelligence to the government. In this context, effort corresponds to direct attempts to prevent attacks, while ability corresponds to the quality of the intelligence provided to the government. If the terrorists can provide high-quality intelligence, then they can cause a decrease in terrorism without exerting much effort. If, however, their intelligence information is not good, they may have to exert significant effort. In this type of situation, effort and ability are substitutes.

In the final analysis, it is likely that some circumstances are best described by complementarity and others by substitutability. This question must be answered on a case-by-case basis by experts. The insight from the model is that replacement decisions during negotiations between governments and terrorist depend on this distinction.

CONCLUSION

I have presented a model of the negotiations between a government and former terrorists in which concessions are contingent on counterterrorism aid. The government has two instruments with which to provide incentives to the former terrorists: the level of concessions offered and the threat of replacement. The decision of whether to replace the former terrorists is complicated by both moral hazard and learning concerns. The government wants to replace low-ability former-terrorist leaders; however, when counterterrorism fails, the government cannot be certain whether this is because the former terrorists are unwilling (low effort) or unable (low ability) to prevent violence. This set of strategic issues seems descriptive of a variety of empirical cases of negotiations between governments and terrorists, including those in Israel, Ireland, British-Mandate Palestine, and Italy.

The threat of replacement provides two types of incentives, beyond concessions, for former terrorists to exert counterterrorism effort. Former terrorists believe that if they succeed at counterterrorism, they may dissuade the government from bearing the costs of searching for a new negotiating partner. Furthermore, former terrorists believe that if they succeed, the government is less likely to replace them, even if it does search for a replacement. This second effect has an important subtlety. In particular, it is only strong when the potential replacements are perceived to be of moderate ability. If the replacements are clearly better or clearly worse than the current leadership, then the latter does not believe that its actions will affect the government's retention decision. However, if it is likely that the potential replacements are of moderate ability, then the former-terrorist leadership may believe that exerting effort to achieve positive counterterrorism outcomes will prevent the government from replacing them.

This suggests that governments have an incentive to encourage relatively equal, rival factions within terrorist movements. The existence of such rivalries increases the government's bargaining leverage. And, indeed, the Israelis followed precisely such a strategy during the first Intifada by supporting the emerging extremist Islamic movement, which gave rise to Hamas and Islamic Jihad (Wilkinson 1993).

The model is also amenable to extension. An important extension would be to endogenize the strategy of the remaining terrorist organization. As Lapan and Sandler (1993) and Kydd and Walter (2002) point out, the level of violence chosen by still-active terrorists may signal information to the government about the strength of various factions within the terrorist organization. Exploring these dynamics within the context of a model with moral hazard and learning would integrate several aspects of the complex relationship between governments and former terrorists and offer a more complete view of the terrorist endgame. Another interesting move would be to put the current model in a more fully dynamic setting. By modeling indefinitely repeated play, one could explore how the moral hazard and learning dynamics considered here interact with the issue of credible commitment and punishment strategies discussed in Bueno de Mesquita (2005). Finally, the current model assumes that still-active terrorist factions are potential substitutes for terrorist factions engaged in negotiations. Siqueira (2005 [this issue]), however, points out that the relationship between the various factions of a terrorist organization is complicated. In some situations, these factions may be in conflict and thus substitutable. In other circumstances, the split into armed and political factions may facilitate the overall interests of the group and thus be advantageous to all factions. An interesting extension, then, would consider when factions would be willing to replace one another and when they would prefer to maintain their particular roles. Such an extension might also lend insight into when still-active factions would engage in violence against former terrorist who are negotiating with the government. Thus, while the current model complements the extant literature, it also suggests a variety of further theoretical steps that would enhance verisimilitude and, ultimately, lead toward a richer and more nuanced theoretical synthesis.

APPENDIX

PROOF OF REMARK 1

It suffices to show that the distribution following success first-order stochastically dominates the distribution following failure. Recall from the definition of first-order stochastic dominance that this is true if for all $x \in [0, 1]$,

$$\int_0^x \frac{\theta f(\theta)}{\theta_0} d\theta \leq \int_0^x \frac{(1-\theta) f(\theta)}{1-\theta_0} d\theta.$$

Rearranging and applying the fundamental theorem of calculus, this reduces to

$$\frac{1}{\theta_0} \int_0^x \theta f(\theta) d\theta \leq F(x).$$

This is true if

$$\Delta = \frac{1}{\theta_0} \int_0^x \theta f(\theta) d\theta - F(x) \leq 0 \text{ for all } x \in [0, 1].$$

Notice that for $x = 1$ and $x = 0$, $\Delta = 0$. Furthermore, taking the derivative shows that

$$\frac{\partial \Delta}{\partial x} = f(x)\left(\frac{x}{\theta_0} - 1\right),$$

which is negative for all $x < \theta_0$ and positive for all $x > \theta_0$. Thus, the function Δ declines monotonically from 0 at $x = 0$ until $x = \theta_0$, and then it increases monotonically from $x = \theta_0$ up to $x = 1$, where it equals 0 again. Thus, $\Delta \leq 0$ for all $x \in [0, 1]$.

PROOF OF REMARK 2

The probability of successful counterterrorism is $a_2^* \theta_1$, where a_2^* is implicitly defined by equation (1). Thus, it suffices to show that a^* is increasing in w_2. The cross partial of the former terrorists' expected utility with respect to a_2 and w_2 is

$$\frac{\partial^2}{\partial a_2 \partial w_2} (a_2 \theta_1 w_2 - c(a_2)) = \theta_1.$$

Thus, the former terrorists' expected utility has strictly increasing marginal returns in a_2 and w_2, which implies that a_2^* is increasing in w_2 (Edlin and Shannon 1998).

PROOF OF REMARK 3

The government's expected utility is given by the value function

$$a_2^* \theta_1 (T - w_2^*) - T.$$

Consider an increase to θ_1 when the government does not change the level of concessions it offers. There are two effects: (1) a direct effect on the expected utility because θ_1 increases and (2) an indirect effect on expected utility through the effect of an increase of θ_1 on a_s^*. Clearly, the first effect increases the government's expected utility. The second effect also increases the government's expected utility because it exerts upward pressure on the optimal level of a. This can be seen by noticing that, holding w constant, an increase in θ_1 increases the left-hand side of the

APPENDIX (continued)

first-order condition of equation (1) while not changing the right-hand side. If, holding the level of concessions fixed, an increase in $\overline{\theta}_1$ improves the government's expected utility, then this must be all the more so when the government reoptimizes its level of concessions, taking into account the new $\overline{\theta}_1$.

PROOF OF REMARK 4

Substituting equation (2) into equation (1) shows that

$$a_2^* = \frac{\overline{\theta}_1 T - c'(a_2^*)}{c''(a_2^*)}.$$

Resubstituting this into equation (2) yields

$$w_2^* = \frac{c'(a_2^*)}{\overline{\theta}_1}.$$

It is clear from the first of these that

$$\frac{\partial a_2^*}{\partial \overline{\theta}_1} = \frac{T}{c''(a_2^*)} > 0.$$

Similarly, taking the derivative of w_2^* above demonstrates that

$$\frac{\partial w_2^*}{\partial \overline{\theta}_1} = \frac{c''(a_2^*)\dfrac{\partial a_2^*}{\partial \overline{\theta}_1}}{\overline{\theta}_1} - \frac{c'(a_2^*)}{\overline{\theta}_1^2}.$$

Substituting and simplifying yield

$$\frac{\partial w_2^*}{\partial \overline{\theta}_1} = \frac{1}{\overline{\theta}_1}\left(T - \frac{c'(a_2^*)}{\overline{\theta}_1}\right).$$

Notice from equation (1) that $c'(a_2^*) = \overline{\theta}_1 w_2^*$. Thus, substituting in one time shows that

$$\frac{\partial w_2^*}{\partial \overline{\theta}_1} = \frac{T - w_2^*}{\overline{\theta}_1} > 0.$$

PROOF OF REMARK 6

If the government did not have the ability to search for a new negotiating partner, the former terrorists' objective function would be

$$a\overline{\theta}_0(w_1 + EU_{FT}^2(\overline{\theta}_s)) + (1 - a\overline{\theta}_0)EU_{FT}^2(\overline{\theta}_f) - c(a).$$

Thus, the optimal level of effort would be implicitly defined by

$$\overline{\theta}_0(w_1 + EU_{FT}^2(\overline{\theta}_s) - EU_{FT}^2(\overline{\theta}_f)) = c'(a). \tag{7}$$

(continued)

APPENDIX (continued)

Comparing this to equation (4) yields the following result. The right-hand side (marginal costs) of the two first-order conditions is identical. Thus, it suffices to show that the left-hand side of equation (4) is greater than the left-hand side of equation (6). Subtracting one from the other and simplifying show that this is true if

$$u(\bar{\theta}_s)q_s p_3 < u(\bar{\theta}_s)q_f(1-p_1).$$

PROOF OF REMARK 7

Label the optimal choice of effort when the government can search as $\underline{a}_k^*$ and when the government cannot search as $a_{\sim k}^*$. If we divide both first-order conditions by $\bar{\theta}_0 a^*$, then both have the same right-hand side. It is sufficient to show that the left-hand side of equation (5) is less than the left-hand side of equation (6). Assume, for the moment, that

$$\frac{\dfrac{\partial a_k^*}{\partial w}}{a_k^*} = \frac{\dfrac{\partial a_{\sim k}^*}{\partial w}}{a_{\sim k}^*}.$$

Then, the left-hand side of equation (5) is less than the left-hand side of equation (6) if an only if

$$q_s\left(\int_{\bar{\theta}_s}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - H(\bar{\theta}_s)EU_2^G(\bar{\theta}_s) - \bar{k}_s\right)$$
$$-q_f\left(\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R + H(\bar{\theta}_f)EU_2^G(\bar{\theta}_f) - \bar{k}_f\right) < 0.$$

This can be rewritten

$$q_s\left(-\int_{\bar{\theta}_f}^{\bar{\theta}_2} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R + H(\bar{\theta}_f)EU_2^G(\bar{\theta}_f) - H(\bar{\theta}_s)EU_2^G(\bar{\theta}_s) + \bar{k}_f - \bar{k}_s\right)$$
$$-(q_f - q_s)\left(\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - H(\bar{\theta}_f)EU_2^G(\bar{\theta}_f) - \bar{k}_f\right) < 0. \quad (8)$$

The first term is negative since

$$-\int_{\bar{\theta}_f}^{\bar{\theta}_2} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R < 0,\ H(\bar{\theta}_f)EU_2^G(\bar{\theta}_f) < H(\bar{\theta}_s)EU_2^G(\bar{\theta}_s),\ \text{and}\ \bar{k}_f < \bar{k}_s.$$

The second term is also negative. Clearly, $q_f > q_s$. Furthermore, when the government searches, it must be the case that

$$\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - k > EU_2^G(\bar{\theta}_f).$$

Since $\bar{k}_f$ is the expected value of k when the government searches, this implies that

$$\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_f > EU_2^G(\bar{\theta}_f).$$

Last, by the definition of a cdf, $H(\bar{\theta}_f) \leq 1$, which implies that

APPENDIX (continued)

$$\int_{\bar{\theta}_f}^{1} EU_2^G(\bar{\theta}_R)h(\bar{\theta}_R)d\bar{\theta}_R - \bar{k}_f > H(\bar{\theta}_f)EU_2^G(\bar{\theta}_f).$$

Thus, the second term is also negative (due to the negative sign in front of it). This implies that equation (8) is strictly negative.

The proof is not complete because the above analysis assumed that

$$\frac{\frac{\partial a_k^*}{\partial w}}{\frac{a_k^*}{}} = \frac{\frac{\partial a_{\sim k}^*}{\partial w}}{\frac{a_{\sim k}^*}{}},$$

which is not true. It suffices, however, to show that

$$\frac{\frac{\partial a_k^*}{\partial w}}{\frac{a_k^*}{}} \leq \frac{\frac{\partial a_{\sim k}^*}{\partial w}}{\frac{a_{\sim k}^*}{}}.$$

If it is true when they are equal, it will be true, a forteriori, when the first is less than the second. Applying the implicit function theorem to equations (4) and (7) shows that

$$\frac{\partial a_k^*}{\partial w} = \frac{\partial a_{\sim k}^*}{\partial w} = \frac{\bar{\theta}}{c''(a^*)}.$$

This is weakly decreasing in a^* since $c''' \geq 0$. Furthermore, remark (6) demonstrates that $a_k^* > a_{\sim k}^*$. Together, these establish the result.

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