Immigration Policy and Counterterrorism

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Abstract

A terrorist group, based in a developing (host) country, draws unskilled and skilled labor from the productive sector to conduct attacks at home and abroad. The host nation chooses proactive countermeasures, while accounting for the terrorist campaign. Moreover, a targeted developed nation decides its optimal mix of immigration quotas and defensive counterterrorism actions. Even though proactive measures in the host country may not curb terrorism at home, it may still be advantageous in terms of national income. Increases in the unskilled immigration quota augment terrorism against the developed country; increases in the skilled immigration quota may or may not raise terrorism against the developed country. When the developed country assumes a leadership role, it strategically augments its terrorism defenses and reduces its unskilled immigration quota to induce more proactive measures in the host country. The influence of leadership on the skilled immigration quota is more nuanced.

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1. Introduction

Ever since the unprecedented terrorist attacks on September 11, 2001 (henceforth 9/11), economists have focused on myriad aspects of terrorism including its impact on growth (Blomberg et al. 2004; Gaibulloev and Sandler 2008, 2011), development (Keefer and Loayza 2008), stock markets (Chen and Siems 2004), and counterterrorism policy (Bandyopadhyay and Sandler 2011). Economists and political scientists applied game-theoretic tools to investigate the practice of counterterrorism against both homegrown domestic terrorism and transnational terrorism (see, e.g., Arce and Sandler 2005; Bapat 2006, 2011; Landes 1978; Sandler et al. 1983). Some contributions investigated the demand side in terms of the number and location of terrorist incidents (e.g., Sandler and Siqueira 2006; Siqueira and Sandler 2007), while other studies examined the supply side in terms of the roots of terrorism (e.g., Abadie 2006; Krueger and Maleckova 2003; Piazza 2006, 2011). Krueger and Laitin (2008) investigated both sides of terrorism by analyzing what determines whether a nation is a source or a target of transnational terrorism (see, also, Blomberg et al. 2009). Another strand of the terrorism literature relates to international trade and foreign direct investment (e.g., Bandyopadhyay et al. 2011a; Enders and Sandler 1996; Nitsch and Schumacher 2004). The findings and methodology of this literature are nicely summarized by Mirza and Verdier (2008). In general, terrorism can curb trade and capital flows owing to heightened costs and risks.

Despite these contributions, there is no paper that formally connects immigration policy to the supply of terrorism in a game-theoretic general equilibrium context. This is an important omission because an exclusive focus on the standard terms-of-trade effects of immigration policy may result in misleading policy recommendations.[1] The purpose of this paper is to fill this void by integrating immigration and counterterrorism policies in a strategic general equilibrium framework. We show that terrorism-related costs and/or benefits, along with terms-of-trade effects, are required when determining an optimal immigration policy. There is a small emerging empirical literature that comes to vastly divergent conclusions about the relationship between immigration and transnational terrorism. In particular, studies that focused on known transnational terrorists showed that many were immigrants (e.g., Leiken and Brooke 2006), while a study that looked at immigrants in general did not find a significant relationship between immigration and terrorism (Dreher and Gassebner 2010). Based on the World Values Survey on attitudes, Fischer (2011) found that immigrants are more likely than natives to support the application of terrorism. These mixed empirical results indicate that a theoretical analysis of the relationship between terrorism and immigration quotas imposed on the potential source country for terrorists may enlighten not only policymakers, but also empirical researchers. This is especially true in our theoretical framework, which has counterterrorism measures as choice variables in the target and source countries.

In our theoretical framework, a transnational terrorist organization, based in a developing country, draws unskilled and skilled labor from the productive sector to attack targets at home and abroad. These two types of laborers join the terrorist group when their anticipated gain exceeds that in the productive sector; this decision is influenced by wages and counterterrorism-induced risks of failure. The ideal factor proportions differ between attacks at home and abroad. Hitting targets abroad in a developed country, such as the United States or France, requires a greater proportion of skilled to unskilled labor, compared with hitting targets at home. This

[1] In this context, terms-of-trade effect refers to the wages of skilled or unskilled immigrants that the developed nation has to pay. A fall in the immigrant's wage is a terms-of-trade gain for the developed nation.

follows because attacks abroad require more complex logistics, language skills, reduced infrastructure, and traversing borders. Given that attacks abroad are more skill-intensive than home attacks, we analyze the effects of counterterrorism policy as well as immigration policy on the supply of terrorism and on the national income of the two countries. The source country applies proactive measures to annihilate the resident terrorists, while the targeted developed country relies on defensive measures to deflect attacks abroad. As such, there are elements of positive and negative international externalities. Our theoretical construct is descriptive of transnational terrorism in the post-Cold War era during which terrorist groups – e.g., al-Qaida, al-Qaida in the Arabian Peninsula, Lashkar-e-Taiba, and Jemaah Islamiyah – take refuge in developing countries (e.g., Pakistan, Yemen, and Indonesia), while attacking host and developed countries' interests at home and abroad.

Given the diverse types of agents in our model (i.e., terrorist recruits, terrorist group, source country, and developed country) and the alternative policy instruments, the tradeoffs are subtle and complex. Among other results, we find that the developed country's defensive efforts deflect attacks back to the source country. Proactive measures against the terrorists in the source or host country may or may not reduce attacks abroad depending on a critical unskilled to skilled labor threshold. When this threshold is high, the terrorist group reduces unskill-intensive terrorism rapidly at home in response to proactive measures, thereby shifting more of its resources to attacks abroad. The opposite is true when this threshold is relatively small. Larger unskilled immigration quotas raise terrorism in the developed country as terrorism is reduced in the source country as unskilled workers emigrate. An increase in skilled immigration quotas need not raise terrorism in the developed country despite skill-intensive terrorism on its soil owing to opposing forces. Even when a proactive campaign in the source country results in more terrorism, it may be advantageous as the productive sector recaptures more labor, thereby raising income. The developed country may gain from assuming a leadership role in choosing its defensive measures and immigration quotas by inducing more proactive countermeasures in the source country. Such measures safeguard the developed country – a positive externality.

The remainder of the paper contains four sections. Section 2 displays the problem of the terrorist group and its volunteers as they respond to the two countries' policy choices. In Section 3, the source or foreign country's proactive choice is analyzed. This is followed in Section 4 by an analysis of the defensive and immigration choices in the developed (home) country under two scenarios: (i) simultaneous policy choices in the two countries, and (ii) a leadership role for the developed country. Concluding remarks are contained in Section 5.

2. The terrorist organization

Terrorism is the premeditated use or threat to use violence by individuals or subnational groups in order to obtain a political or social objective through intimidation of a large audience beyond that of the immediate victims (Enders and Sandler 2011). Terrorism is transnational when an incident in one country involves perpetrators, victims, institutions, governments, or citizens of another country – e.g., 9/11 skyjackings. In recent years, transnational terrorist groups often locate their base in a developing country from which they can attack Western interests at home or abroad. Thus, Yemen, Lebanon, Somalia, Syria, Pakistan, Morocco, Algeria, Afghanistan, and other developing countries have been the base for many notorious terrorist groups (Hoffman 2006; Mickolus 2008).

The underlying game has two to three stages. In the first variant, the two governments choose their counterterrorism and immigration policies in the first stage, and the terrorist group decides its terrorist campaign in the second stage. In the second variant, the developed country decides its counterterrorism and immigration policies in the first stage, followed by the developing country picking its proactive countermeasures in the second stage. Finally, the terrorist group allocates its attacks at home and abroad in the third stage. We solve both games backwards beginning with terrorist group's decision in the final stage.

The terrorist organization derives benefit from attacking targets in both the host developing nation (say, *F*) and the developed nation (say, *H*). Along the lines of Mirza and Verdier (2008) and Bandyopadhyay et al. (2011b), the terrorist group's utility function is

$$V = \phi^H \left(p^H T^{*H} + p^F \tilde{T}^H \right) + \phi^F p^F T^F \,, \tag{1}$$

where ϕ^j is the terrorists' preference for attacking nation *j* (=*H*, *F*); p^j is the probability of success of a planned attack in nation *j*; T^{*H} is terrorism damage in *H*; and T^F is terrorism damage in nation *F*.[2] In (1), $\tilde{T}^H$ is *H*'s terrorism damage from an attack in *F*, so that developed countries' interests can be hit at home or abroad. This accords with reality – e.g., very few attacks on US interests occur on US soil in recent years (Enders and Sandler 2011). As in Bandyopadhyay et al. (2011b), we assume that terror damage for *H* in *F* is[3]

$$\tilde{T}^H = \delta^H T^F \,, \tag{2}$$

where δ^H is a parameter measuring the extent of *H*'s foreign interests in *F*. The probability of success of a planned attack against *H* is lowered by its defensive actions, *e*, although at a diminishing rate, i.e.,

[2] We assume that both economies produce the same single good, which serves as the numeraire in this model. Also, the developed nation is assumed to have superior technology, which contributes to its factor returns being strictly larger than the corresponding factor returns in the developing nation. This international factor price difference is possible (in equilibrium) because factor mobility is controlled by immigration quotas imposed by the developed nation.

[3] We note a few things. First, we assume that *F* has no foreign interests in *H*, so that attacks in *H* are attacks against *H* alone. However, *H* has foreign interests in *F* that may be subject to terrorism attacks. In principle, attacks in *F* against *H*'s or *F*'s interests may be separate. Also, these attack technologies may be distinct, with different skill intensities. If this is the case, then there are three skill intensities, a high skill intensity for attacks in *H*, an intermediate skill intensity for attacks against *H* in *F*, and a low skill intensity for attacks against *F*. Although this structure is reasonable, it is analytically intractable in this general equilibrium setup. The compromise that we use is that an attack against *F* has a collateral damage component for *H*, which is weighted by its foreign interests in *F*. For example, if the United States has extensive foreign interests in Pakistan, then US interests are more likely to be targeted in Pakistan than in the United States by Pakistan-based groups.

$$p^H = p^H(e),\ p^{H\prime}(e) < 0, \text{ and } p^{H\prime\prime}(e) > 0. \tag{3}$$

Terrorist attacks targeted in a developed nation from foreign bases require a higher degree of sophistication and are produced using a more skill-intensive technology. However, both types of terrorism require a mix of unskilled and skilled labor and exhibit constant returns to scale (CRS). The terrorism production functions in *H* and *F* are:[4]

$$T^H = T^H\left(L^{tH}, S^{tH}\right) \text{ and} \tag{4a}$$

$$T^F = T^F\left(L^{tF}, S^{tF}\right), \tag{4b}$$

respectively, where L^{tj} (S^{tj}) is unskilled (skilled) labor used by the terrorists to attack targets in nation *j*. A natural question is how is the terrorism that is produced by a developing nation's resources delivered in the developed nation? Although cyber-attacks can be delivered remotely, more traditional terrorist attacks necessitate some physical presence in the target nation. This may require participation by immigrants and/or tourists in the developed nation. For tourist perpetrators, someone may acquire a temporary visa, visit the country, and carry out the attack without any local help, so that immigrants are not involved. If, in contrast, the terrorist group's attack is facilitated by an existing immigrant pool, then the effective terrorism (i.e., T^{*H}) in the developed nation depends on a sympathetic pool of skilled and unskilled immigrants. A simple way to model this is as follows:

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[4] These are standard CRS production functions with positive marginal products T_i^j, negative second-order partials ($T_{ii}^J < 0$), and positive cross partials ($T_{ix}^j > 0$, $i \neq x$). We also assume without loss of generality that producing terrorism directed against *H* is more skill-intensive (i.e., $l^{tH} < l^{tF}$, where $l^{tj} = \dfrac{L^{tj}}{S^{tj}}$, $j = H, F$). Unless specified otherwise, we will use the convention that for any function $f\left(x_1, x_2, ..x_n\right)$, f_i is the partial derivative of f with respect to its *i*th argument, and f_{ij} the partial derivative of f_i with respect to the *j*th argument.

$$T^{*H} = A(\alpha,\rho)T^{H}\left(L^{tH}, S^{tH}\right),\ A_{\alpha} = \frac{\partial A}{\partial \alpha} \geq 0,\ A_{\rho} = \frac{\partial A}{\partial \rho} \geq 0, \text{ and } A > 0, \tag{5}$$

where α and ρ are unskilled and skilled immigrant pools, respectively, in the developed nation. The partials of A are non-negative because the presence of more skilled or unskilled immigrants potentially improves the delivery capability for terrorism in *H*. Using Eqs. (1)-(5), we express the terrorist group's expected utility as:

$$V = \gamma^{H}T^{H} + \gamma^{F}T^{F},\ \gamma^{H} = \phi^{H}A(\alpha,\rho)\,p^{H}(e), \text{ and } \gamma^{F} = p^{F}\left(\phi^{H}\delta^{H} + \phi^{F}\right). \tag{6}$$

Let the unskilled (skilled) labor supply be inelastically given for *F* at $\bar{L}^{F}$ ($\bar{S}^{F}$). We assume that *H*'s skilled and unskilled wages are sufficiently large relative to their counterparts in *F*, such that given an option to emigrate to *H*, a labor unit (skilled or unskilled) will choose to do so. Thus, the immigration levels α and ρ equal the immigration quotas for unskilled and skilled immigration chosen by *H*. The unskilled and skilled labor force in *F* net of emigrants are $\bar{L}^{F} - \alpha$, and $\bar{S}^{F} - \rho$, respectively.

Each unit of unskilled labor has a certain level of radical beliefs, parameterized by θ^{u}, which means that if they succeed in working for the terrorist organization they get a utility equivalent to θ^{u} units of the numeraire good. Even though units of unskilled labor are homogeneous as inputs in terrorism or in producing goods, they differ in their radical beliefs. The distribution of such beliefs is given by the following probability density and cumulative distribution functions, respectively:

$$\theta^{u} \sim x\left(\theta^{u}\right),\ X\left(\bar{\theta}\right) = \int_{-\infty}^{\bar{\theta}} x\left(\theta^{u}\right)d\theta^{u}. \tag{7}$$

All unskilled labor units in *F* earn w^{uF} from the productive sector, which equals the marginal product of unskilled labor in producing goods. When they volunteer for the terrorist organization, they know that there is a chance that they may not be able to serve effectively. For example, they may be killed or incarcerated before being able to take part in an attack. They are assumed to succeed in providing their services to the terrorist organization with a probability β, which is a declining function of proactive effort m undertaken by the host government. Assuming diminishing returns in the use of such offensive action, we have

$$\beta = \beta(m),\ \beta'(m) < 0, \text{ and } \beta''(m) > 0. \tag{8}$$

An unskilled labor unit stays in the productive sector if its wage exceeds it expected marginal return from being a terrorist:

$$\theta^u \beta(m) < w^{uF} \Rightarrow \theta^u < \frac{w^{uF}}{\beta(m)}. \tag{9}$$

Eq. (9) describes a margin that is similar to ones used in models of equilibrium migration, where a migrant equates the expected return from migrating to that of the *status quo*.[5] Consider the decision faced by an illegal immigrant (e.g., Ethier 1986). If, say, someone stays home in Mexico, s/he earns a Mexican wage with certainty. When, however, s/he attempts to migrate illegally to the United States, s/he may be caught and returned home after some penalties are imposed; or s/he may cross successfully and earn a higher wage. The higher the probability of detection at the border and the greater the penalty, the less likely is the individual to migrate. The analogy here is that higher proactive effort reduces the anticipated probability of success for a laborer contemplating a move to the terrorist sector. The associated deterrence effect of proaction provides a more favorable allocation of labor for the productive sector, thereby bolstering national income. Thus, the margin, described in (9), is critical and endogenous to

[5] The legal immigration quotas discussed in this paper are not based on an internal equilibrium relationship. They arise from a corner solution where the migrant's *ex ante* return from emigrating exceeds the return that can be obtained from staying back. However, because immigration is controlled by quotas, this wedge in the returns is sustained in equilibrium.

policy choices.

Based on Eq. (7) and (9), the fraction of unskilled labor force that stays in the productive sector is $X\left(\frac{w^{uF}}{\beta(m)}\right)$. Thus, $(1-X)\left(\overline{L}^{F}-\alpha\right)$ labor units volunteer for the terrorist organization, of which a fraction β succeeds in providing their services in terrorist attacks. Thus, the unskilled labor pool L^T for the terrorist organization is

$$L^{T}=\beta(m)\left[1-X\left(\frac{w^{uF}}{\beta(m)}\right)\right]\left(\overline{L}^{F}-\alpha\right)=L^{T}\left(\alpha,w^{uF},m,\overline{L}^{F}\right). \tag{10}$$

Similarly, let θ^{s}, $g\left(\theta^{s}\right)$, and $G\left(\theta^{s}\right)$, be the radicalization parameter, the probability density function, and the cumulative distribution function for skilled labor, respectively. Therefore, the skilled-labor pool for the terrorist organization is

$$S^{T}=\beta(m)\left[1-G\left(\frac{w^{sF}}{\beta(m)}\right)\right]\left(\overline{S}^{F}-\rho\right)=S^{T}\left(\rho,w^{sF},m,\overline{S}^{F}\right). \tag{11}$$

The terrorist organization maximizes its utility [Eq. (6)], given its supply of skilled and unskilled labor [Eqs. (10) and (11)]. The constrained optimization problem for the terrorist organization is

$$\begin{aligned} Max\; V=\gamma^{H}T^{H}\left(L^{tH},S^{tH}\right)+\gamma^{F}T^{F}\left(L^{tF},S^{tF}\right)+\lambda_{L}\left[L^{T}\left(\alpha,w^{uF},m,\overline{L}^{F}\right)-L^{tH}-L^{tF}\right] \\ +\lambda_{S}\left[S^{T}\left(\rho,w^{sF},m,\overline{S}^{F}\right)-S^{tH}-S^{tF}\right], \end{aligned} \tag{12}$$

where λ_L and λ_S are the Lagrangian multipliers associated with the unskilled and skilled labor constraints, respectively. The first-order conditions (FOCs) yield the unskilled and skilled labor used by the terrorist organization in attacks at home and abroad and also the shadow prices (i.e., the optimal values of λ_L and λ_S) of these resources for the terrorist organization. Denoting the vector of parameters faced by the terrorist organization by μ, we have

$$L^{tj} = L^{tj}\left(\mu\right),\ S^{tj} = S^{tj}\left(\mu\right),\ j = H, F\ ;\ \lambda_i = \lambda_i\left(\mu\right),\ i = L, S \text{ , where}$$

$$\mu = \mu\left(\gamma^H, \gamma^F, \alpha, \rho, w^{uF}, w^{sF}, m, \overline{L}^F, \overline{S}^F\right). \tag{13}$$

Substituting (13) into (12), we have the envelope function V^*:

$$V^* = V^*\left(\gamma^H, \gamma^F; \alpha, \rho, w^{uF}, w^{sF}, m, \overline{L}^F, \overline{S}^F\right). \tag{14}$$

Using the envelope theorem, we obtain the supply of terrorism aimed at *H*'s and *F*'s interests:

$$T^H = V_1^*\left(\gamma^H, \gamma^F; \alpha, \rho, w^{uF}, w^{sF}, m, \overline{L}^F, \overline{S}^F\right) \text{ and} \tag{15a}$$

$$T^F = V_2^*\left(\gamma^H, \gamma^F; \alpha, \rho, w^{uF}, w^{sF}, m, \overline{L}^F, \overline{S}^F\right). \tag{15b}$$

It is easy to show that V^* is convex and homogeneous of degree one in γ^H and γ^F.[6]

Proposition 1: A rise in *H*'s counterterrorism defense effort (e) reduces terrorism against it while raising the terrorism directed at *F*.

Proof

Based on the FOCs of the optimization problem, it is easy to show that[7]

$$\frac{\partial T^H}{\partial \gamma^H} > 0 \Rightarrow V_{11}^* > 0. \tag{16}$$

Given that $\gamma^H = \phi^H A p^H\left(e\right)$, we have

$$\frac{\partial T^H}{\partial e} = \left(\frac{\partial T^H}{\partial \gamma^H}\right)\phi^H A p^{H\prime} < 0 \Rightarrow \frac{\partial T^{*H}}{\partial e} = A\frac{\partial T^H}{\partial e} < 0. \tag{17}$$

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[6] V^* is similar to the revenue function used in dual models of trade (see Dixit and Norman 1980). The proofs of convexity and homogeneity are standard and are available from the authors on request.

[7] Proof is in the Appendix.

Because V^* is homogeneous to degree one, the first-order partial V_1^* is homogeneous of degree zero in γ^H and γ^F. Using Euler's theorem and (16), we get

$$0 = V_{11}^*\gamma^H + V_{12}^*\gamma^F \Rightarrow V_{12}^* = -V_{11}^*\frac{\gamma^H}{\gamma^F} < 0 \Rightarrow V_{12}^* = V_{21}^* = \frac{\partial T^F}{\partial \gamma^H} < 0\,. \tag{18a}$$

Eq. (18a) implies that

$$\frac{\partial T^F}{\partial e} = \left(\frac{\partial T^F}{\partial \gamma^H}\right)\phi^H A p^{H\prime} > 0\,. \tag{18b}$$

Eqs. (17) and (18b) establish the proposition. ■

Proposition 1 confirms the terrorism reduction versus terrorism deflection consequence of defensive measures that dates back to Lapan and Sandler (1988) (see also Bandyopadhyay and Sandler 2011; Bier et al. 2007; Intriligator 2010; Sandler and Siqueira 2006). This proposition shows that a general equilibrium framework preserves this result. *H*'s defensive actions reduce the likelihood of successful terrorist incidents in *H*, thereby deflecting them back to the source country *F*. Although *H*'s homeland is now safer for its actions, its interest can still be hit abroad – e.g., attacks against US people or property in Pakistan. Thus, country *H* must weigh these losses against the gains from reduced attacks on its homeland when coming up with an optimal defense policy (see Section 4). Homeland attacks are typically more damaging than foreign attacks on its interests. Recent empirical studies showed a marked shift in terrorist attacks from developed to developing countries following 9/11-motivated security increases (Enders and Sandler 2006, 2011). Developed countries' interests were more frequently targeted abroad.

We now turn our attention to the effects of proactive policies in the country hosting the terrorists. The effect of a rise in proactive measures m on T^H is

$$\frac{\partial T^H}{\partial m} = \frac{\partial V_1^*}{\partial m} = \frac{\partial V_m^*}{\partial \gamma^H}. \tag{19}$$

Using the envelope property of V^* and (12), we obtain

$$V_m^* = \lambda_L \frac{\partial L^T}{\partial m} + \lambda_S \frac{\partial S^T}{\partial m}. \tag{20}$$

Differentiating (10) and (11), respectively, yields

$$\frac{\partial L^T}{\partial m} = L_m^T = \left(\overline{L}^F - \alpha\right)\beta'(m)\left(1 - X + \frac{xw^{uF}}{\beta}\right) < 0 \text{ and}$$

$$\frac{\partial S^T}{\partial m} = S_m^T = \left(\overline{S}^F - \rho\right)\beta'(m)\left(1 - G + \frac{gw^{sF}}{\beta}\right) < 0. \tag{21}$$

Eq. (21) shows that proactive effort must reduce both the unskilled and the skilled labor resources of the terrorist group for two reasons. First, a rise in proactive effort depletes the group's labor resources for a given labor allocation between the productive and terrorist sectors. Second, as proaction rises, the *ex ante* return from joining the terrorist organization must fall [Eq. (9) above], so that fewer laborers become terrorists. This effect complements the direct effect of proaction, leading to fewer terrorists.

Substituting (21) into (20) and differentiating (20), we obtain

$$\frac{\partial V_m^*}{\partial \gamma^H} = L_m^T\left(\frac{\partial \lambda_L}{\partial \gamma^H}\right) + S_m^T\left(\frac{\partial \lambda_S}{\partial \gamma^H}\right). \tag{22}$$

In the Appendix, we show that

$$\frac{\partial \lambda_L}{\partial \gamma^H} = \gamma^F T_{11}^F\left(\frac{\partial l^{tF}}{\partial \gamma^H}\right) < 0 \text{ and } \frac{\partial \lambda_S}{\partial \gamma^H} = \gamma^F T_{21}^F\left(\frac{\partial l^{tF}}{\partial \gamma^H}\right) > 0. \tag{23}$$

From Eq. (12), γ^H is the marginal return of T^H for the terrorist organization. A rise in this return makes the terrorists produce relatively more of this type of terrorism, so that T^H expands, thus requiring more skilled relative to unskilled labor. To supply these additional resources, terrorists must contract unskill-intensive T^F , which releases relatively more unskilled labor. The result is an excess supply of unskilled labor and an excess demand of skilled labor, which leads to a fall in the shadow price of unskilled labor (i.e., λ_L) and a rise in the shadow price of skilled labor (i.e., λ_S).

Using (19)-(23), we find that the sign of $\frac{\partial T^H}{\partial m}$ is ambiguous. Proposition 2 throws light on this ambiguity.

Proposition 2: A small rise in *F*'s proactive effort will reduce terrorism in *H* if and only if l^{tF} exceeds a critical level l^0. This critical level depends on the initial proactive level, *H*'s immigration quotas, *F*'s factor endowments and factor prices, and the probability density functions *x* and *g*. Terrorism in *F* will fall if and only if l^{tH} is less than the critical value l^0. It is not, however, possible for terrorism to rise in both nations.

Proof

Using (19)-(23), we show in the Appendix that

$$\frac{\partial T^H}{\partial m} < 0 \Rightarrow \frac{\partial T^{*H}}{\partial m} = A\frac{\partial T^H}{\partial m} < 0 \text{ if and only if } l^{tF} > l^0,$$

$$\text{where } l^0 = \frac{L_m^T}{S_m^T} = \left(\frac{\bar{L}^F - \alpha}{\bar{S}^F - \rho}\right)\left[\frac{(1-X)\beta + xw^{uF}}{(1-G)\beta + gw^{sF}}\right] = l^0\left(\alpha, \rho, w^{uF}, w^{sF}, m, \bar{L}^F, \bar{S}^F\right). \tag{24}$$

Analogously, we can show that

$$\frac{\partial T^F}{\partial m} < 0 \text{ if and only if } l^{tH} < l^0. \tag{25}$$

From the terrorist organization's FOCs, terrorism labor intensities are entirely determined by γ^H and γ^F. Depending on the values of γ^H and γ^F, we can have different possibilities. We can rule out the possibility that both $\frac{\partial T^{*H}}{\partial m}$ and $\frac{\partial T^{F}}{\partial m}$ are positive, because it requires that $l^{tF} < l^{0}$ and $l^{tH} > l^{0}$ in violation of the assumed factor intensity ranking $l^{tH} < l^{tF}$. Based on (24) and (25), three cases are possible:

Case 1: $\frac{\partial T^{*H}}{\partial m} > 0$, $\frac{\partial T^{F}}{\partial m} < 0$, if $l^{tF} < l^{0}$, $l^{tH} < l^{0}$.

Case 2: $\frac{\partial T^{*H}}{\partial m} < 0$, $\frac{\partial T^{F}}{\partial m} > 0$, if $l^{tF} > l^{0}$, $l^{tH} > l^{0}$.

Case 3: $\frac{\partial T^{*H}}{\partial m} < 0$, $\frac{\partial T^{F}}{\partial m} < 0$, if $l^{tF} > l^{0} > l^{tH}$.

Cases 1 through 3 establish the proposition. ■

From (21), we know that a rise in proactive effort reduces both the skilled and unskilled labor resources of the terrorist group; however, this does not imply that terrorism must fall in both nations. To explain why, we focus on Case 1. Eq. (24) indicates that l^{0} is the relative rate at which proaction reduces the terrorist group's unskilled compared with its skilled labor resources. Consider a situation where S_m^T tends to zero, while L_m^T is nonzero and finite. Therefore, l^{0} is arbitrarily large and must exceed both l^{tH} and l^{tF}. Now, consider a rise in proactive effort. This rise reduces the terrorist organization's unskilled resources, but has a negligible effect on its skilled resources (because $S_m^T \to 0$). This relative scarcity of unskilled labor makes the terrorist group scale back unskill-intensive T^{F}, which sheds some skilled labor in the process. If this excess supply of skilled labor is exactly offset by the reduction in skilled resources due to proaction, then there is no unemployment of skilled resources. However, given that the magnitude of S_m^T is arbitrarily small, the excess supply of skilled labor cannot be neutralized. The only way for these resources to be fully utilized is to transfer them to the production of T^H. Consequently, at an optimum, the terrorist organization must scale up its production of T^H, which then raises the volume of terror T^{*H} experienced by *H*. The opposite redistribution of labor happens in Case 2.

Terrorism must fall in both nations only in the intermediate case (Case 3), where l^0 lies between the two labor intensities l^{tH} and l^{tF}. In this case, proaction's damaging effects on skilled and unskilled labor resources of the terrorist organization are more balanced relative to either Case 1 (where unskilled labor suffers more) or Case 2 (where skilled labor suffers more). In Case 3, as unskilled labor resources decline, the terrorist group scales back T^F, releasing some skilled labor. This excess supply of skilled labor is more than offset by the decline in skilled labor due to proaction (i.e., S_m^T is sufficiently large). The result is a shortage of skilled labor, which is resolved by scaling down T^H. Thus, the terrorist group's ability to circumvent *F*'s countermeasures through a change in the mix of terrorism is more limited.

Proposition 3: A rise in the terrorist group's target preference for *H* raises T^{*H} and lowers T^F. An increase in the unskilled immigration quota α raises T^{*H} and reduces T^F. A rise in the skilled immigration quota ρ may or may not raise T^{*H} and T^F.

Proof

The proof is in the Appendix. ■

A greater target preference for *H* makes the terrorists devote more of their resources to attacking *H*, which leaves fewer resources for attacks on *F*. Thus, when terrorists fixate on *H*, T^{*H} rises and T^F falls. The effect of immigration quotas is more complicated. When

α increases, it raises *A* and makes it easier to deliver terrorism in *H*. This creates a greater incentive for the terrorist group to perpetrate terrorism in *H*. The net supply of unskilled labor in *F* (i.e., $\overline{L}^F - \alpha$) is also reduced, which decreases the relative supply of unskilled labor for the terrorist group [see Eq. (10)]. This then results in a rise in the supply of skill-intensive terror T^{*H} and a reduction in the supply of unskill-intensive terrorism T^F . Both the terrorism-delivery facilitation and the factor-intensity effect suggest that a rise in unskilled immigration must augment terrorism in *H* and reduce it in *F*. When, however, we consider the skilled immigration quota, we encounter two opposing effects. On the one hand, a greater pool of skilled immigrants facilitates terrorism delivery in *H*, which tends to raise T^{*H} and reduce T^F . On the other hand, a reduction in the relative availability of skilled laborers due to emigration in *F* reduces S^T [see Eq. (11)], which limits skill-intensive T^{*H} and augments unskill-intensive T^F . Thus, the net effect of an increase in the skilled immigration quota on both T^{*H} and T^F is ambiguous.

3. The foreign (source) government

In stage 2, *F*'s government decides its proactive measures against the resident terrorist group. We assume that *F* produces a single good, Q^F , using the following CRS production function:

$$Q^F = \eta^F \left(L^F, S^F \right), \tag{26}$$

where L^F and S^F are unskilled and skilled labor used in the production of this good. Recalling that *X* is the share of unskilled labor engaged in productive activity in *F*, we have[8]

$$L^F = \left(\overline{L}^F - \alpha \right) X , \tag{27a}$$

and, similarly,

[8] We assume that emigration is neutral in terms of affecting the probability distributions of radicalization in *F*'s population of skilled and unskilled labor. Thus a reduction of the unskilled (skilled) labor pool through emigration does not affect the fraction *X (G)*.

$$S^F = \left(\bar{S}^F - \rho\right)G. \tag{27b}$$

F's national income, including the earnings of its emigrants and net of terrorism damage, T^F, and counterterrorism spending, is

$$Y^F = \eta^F\left[\left(\bar{L}^F - \alpha\right)X, \left(\bar{S}^F - \rho\right)G\right] + w^{uH}\alpha + w^{sH}\rho - T^F - m, \tag{28}$$

where w^{uH} and w^{sH} are the unskilled and skilled wage rates, respectively, in H. In (28), the price of proactive measures is normalized to be 1.

We assume that H's CRS production function is:

$$Q^H = \eta^H\left(L^H, S^H\right). \tag{29}$$

Accounting for the immigrants in H's labor pool, we obtain

$$L^H = \bar{L}^H + \alpha \text{ and } S^H = \bar{S}^H + \rho. \tag{30}$$

The wage rates in the two nations reflect their respective marginal products. Suppressing the factor endowments in the functional forms, we have:

$w^{uH} = \eta_1^H\left(i^H, 1\right) \equiv w^{uH}\left(i^H\right)$, $w^{sH} = \eta_2^H\left(i^H, 1\right) \equiv w^{sH}\left(i^H\right)$, $w^{uF} = \eta_1^F\left(i^F, 1\right) \equiv w^{uF}\left(i^F\right)$, and

$w^{sF} = \eta_2^F\left(i^F, 1\right) \equiv w^{sF}\left(i^F\right)$, where

$$i^H = \frac{\bar{L}^H + \alpha}{\bar{S}^H + \rho} = i^H\left(\alpha, \rho\right) \text{ and}$$

$$i^F = \frac{\left(\bar{L}^F - \alpha\right)X\left(\dfrac{w^{uF}}{\beta(m)}\right)}{\left(\bar{S}^F - \rho\right)G\left(\dfrac{w^{sF}}{\beta(m)}\right)} = i^F\left(m, \alpha, \rho\right). \tag{31}$$

Eq. (31) reflects that homogeneity of degree one of the production functions in both nations makes the marginal products and, hence, the factor returns determined entirely by the unskilled labor intensity $i^j\left(j = H, F\right)$. In equilibrium, the unskilled labor intensities reflect the relative abundance of the unskilled labor available in the two nations for productive activities. Clearly, immigration affects this abundance by making more labor available to *H* at the expense of country *F*. For example, a rise in unskilled immigration raises the unskilled labor intensity in *H* and reduces it in *F*. This then reduces the marginal product of unskilled labor and its wage in *H*. In contrast, a rise in *H*'s unskilled labor intensity raises its marginal product of skilled labor and, hence, its skilled wage. For the same reasons, emigration from *F* must move its wages in exactly the opposite direction. Finally, proactive effort can affect the wages in *F* but not in *H*. Wages in *H* are unaffected because i^H is entirely determined by the immigration quotas and *H*'s existing labor stocks, so that proaction has no direct effect on it. In contrast, increased proactive measures deplete both types of labor in *F* [see Eq. (21)], possibly changing i^F and wages in *F*. When, however, proaction reduces the availability of skilled and unskilled labor in the same proportion, their relative abundance in *F* is unchanged, so that *F*'s wages are unaffected. This issue is addressed below.

Country *F* takes *H*'s immigration quotas (α and ρ) as given when choosing its national-income-maximizing proactive effort.[9] In light of (31), this fixes i^H and, hence, the skilled and unskilled wages in *H* in terms of *F*'s decision making. Differentiating (28), we obtain the FOC for *F*'s income-maximizing proactive effort:

$$\frac{\partial Y^F}{\partial m} = Y_m^F\left(m; e, \alpha, \rho\right) = \eta_1^F\left(\bar{L}^F - \alpha\right)\left(\frac{\partial X}{\partial m}\right) + \eta_2^F\left(\bar{S}^F - \rho\right)\left(\frac{\partial G}{\partial m}\right) - \frac{\partial T^F}{\partial m} - 1 = 0\,. \tag{32a}$$

Eq. (32a) implicitly defines *F*'s Nash reaction function as

$$m = m\left(e, \alpha, \rho\right). \tag{32b}$$

Differentiating the distribution function X yields:

[9] This is consistent with two scenarios: *H* and *F* simultaneously choosing their income-maximizing policies; and *H* choosing its policy at an earlier stage compared to *F*. We analyze both scenarios.

$$\frac{\partial X}{\partial m}=\frac{x}{\beta^2}\left[\beta\left(\frac{\partial w^{uF}}{\partial i^F}\right)\left(\frac{\partial i^F}{\partial m}\right)-w^{uF}\beta'\right]. \tag{33}$$

In the Appendix, we show that

$$\frac{\partial i^F}{\partial m}\geq 0 \text{ if and only if } \varepsilon^X\geq\varepsilon^G,\ \ \varepsilon^X=\frac{d\ln X\left(\theta^u\right)}{d\ln\theta^u},\varepsilon^G=\frac{d\ln G\left(\theta^s\right)}{d\ln\theta^s}, \tag{34}$$

where ε^X and ε^G are the elasticity of the distribution functions X and G with respect to the respective radicalization parameters θ^u and θ^s, respectively. The intuition behind (34) is straightforward. Proactive measures reduce the returns from joining the terrorist group for both skilled and unskilled volunteers [see Eqs. (9)-(11)]. Thus, the proportions of skilled and unskilled labor (i.e., G and X, respectively) that join the productive sector must both rise. If ε^X exceeds ε^G, the proportion X rises faster than the proportion G. In the light of (31) this suggests that i^F must rise. If the elasticities are equal (as in the specific functional forms for the probability distributions we use below), X and G rise at the same rate, and i^F does not change. Consequently, wages in F do not change. For simplicity, we henceforth assume that the probability density functions x and g are independently, identically, and uniformly distributed with supports zero and $\overline{\theta}$, such that[10]

$$x(\theta)=g(\theta)=\frac{1}{\overline{\theta}} \text{ and } X(\theta)=G(\theta)=\frac{\theta}{\overline{\theta}}. \tag{35}$$

Using (35) and the definitions of ε^X and ε^G from (34), we get

$$\varepsilon^X=\varepsilon^G=1\Rightarrow\frac{\partial i^F}{\partial m}=0. \tag{36}$$

Using (36) in (33), we have:

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[10] We show in (36) below that this assumption allows us to focus on the simplest of the three possible cases in (34), which is $\varepsilon^X=\varepsilon^G$. Most of the tradeoffs faced by the governments then come out cleanly. While it is possible to analyze the other two cases (i.e., $\varepsilon^X>\varepsilon^G$, and $\varepsilon^X<\varepsilon^G$), we choose not to do so in this paper, both for clarity of exposition and space considerations.

$$\frac{\partial X}{\partial m} = -\frac{\beta' w^{uF} x}{\beta^2} > 0\,. \tag{37a}$$

Similarly, we get:

$$\frac{\partial G}{\partial m} = -\frac{\beta' w^{sF} g}{\beta^2} > 0\,. \tag{37b}$$

Proposition 4: Nation *F* chooses its proactive response to reduce its terrorism damages and also to benefit from bringing more of its resources from the terrorist sector into the productive sector. Even when proactive efforts raise terrorism in *F*, the government may still choose to employ it.

Proof

Using (31), we can write (32a) as

$$w^{uF}\left(\overline{L}^F - \alpha\right)\left(\frac{\partial X}{\partial m}\right) + w^{sF}\left(\overline{S}^F - \rho\right)\left(\frac{\partial G}{\partial m}\right) - \frac{\partial T^F}{\partial m} = 1\,. \tag{38}$$

The proposition is established from (38) in light of (37a), (37b), and Proposition 2. ■

A positive $\frac{\partial X}{\partial m}$ in (37a) reflects the rise in the proportion of productive unskilled labor in *F* as greater proactive measures dissuade some potential terrorist volunteers. The ensuing rise in output in *F* is captured by the first term of (38). Similarly, the second term in (38) reflects the corresponding rise in output from the return of skilled labor to productive activities. Based on Proposition 2, proactive effort may, however, increase T^F . Even then, national income may increase as long as the first two terms in (38) dominate (starting from $m = 0$). This is a general equilibrium result, novel to this literature. This finding indicates that the deterrence effect, which keeps more of the population away from terrorism, may be an important determinant of national-income-maximizing counterterrorism policy. It can rationalize the apparently counterintuitive behavior of governments that continue to engage in proactive counterterrorism policies, despite a rise in terrorist attacks due to such policies. Such attacks are known as backlash stemming from counterterrorism-induced grievances (Bloom 2005; Rosendorff and Sandler 2004; Siqueira and Sandler 2007).

4. The developed country's government policy choices

Based on (29)-(31) , *H*'s national income, net of immigrant earnings, terrorism damages, and counterterrorism expenditure, is[11]

$$Y^H = \eta^H\left[\bar{L}^H + \alpha, \bar{S}^H + \rho\right] - w^{uH}\alpha - w^{sH}\rho - p^H(e)T^{*H} - \tilde{T}^H - e, \tag{39a}$$

where the price of defensive effort is normalized at 1. Using (2) and (5), we have

$$Y^H = \eta^H\left[\bar{L}^H + \alpha, \bar{S}^H + \rho\right] - w^{uH}\alpha - w^{sH}\rho - p^H(e)A(\alpha,\rho)T^H - \delta^H T^F - e. \tag{39b}$$

We consider two scenarios for *H*'s choice of its national-income-maximizing combination of defense and immigration policies. First, we analyze the (Nash) case where *H* moves simultaneously with *F* in the first stage. Second, we analyze a Stackelberg game where *H* chooses its policy one stage earlier compared with *F*, so that we have a three-stage game.

4.1 Nash equilibrium

We have already described the policy choice rule for *F* where it assumes *H*'s policies to be given when choosing its income-maximizing proactive level. Under the Nash assumption, *H* takes *m* as given while choosing its income-maximizing policy variables. The resulting equilibrium is a Nash policy equilibrium. Using (31), we can differentiate (39b) to obtain *H*'s FOCs for defense

[11] Omitting immigrant incomes from the host nation's objective function is a debatable issue. However, for lack of an unambiguously superior alternative, this approach is standard and is used widely in the trade-immigration literature (e.g., see Ethier 1986).

and immigration quota choices as:

$$\left(\frac{\partial Y^H}{\partial e}\right)_{|m} = -AT^H p^{H\prime} - Ap^H\left(\frac{\partial T^H}{\partial e}\right) - \delta^H\left(\frac{\partial T^F}{\partial e}\right) - 1 = 0\,, \tag{40a}$$

$$\left(\frac{\partial Y^H}{\partial \alpha}\right)_{|m} = \left(i^H\rho - \alpha\right)\frac{\partial w^{uH}}{\partial \alpha} - p^H\left[A_\alpha T^H + A\left(\frac{\partial T^H}{\partial \alpha}\right)\right] - \delta^H\left(\frac{\partial T^F}{\partial \alpha}\right) = 0\,, \text{ and} \tag{40b}$$

$$\left(\frac{\partial Y^H}{\partial \rho}\right)_{|m} = \left(i^H\rho - \alpha\right)\frac{\partial w^{uH}}{\partial \rho} - p^H\left[A_\rho T^H + A\left(\frac{\partial T^H}{\partial \rho}\right)\right] - \delta^H\left(\frac{\partial T^F}{\partial \rho}\right) = 0\,. \tag{40c}$$

Proposition 5: Defensive countermeasures are chosen to balance terrorism-reducing benefits in *H* with terrorism-deflecting costs and defense costs. If the unskilled labor intensity of the immigrant pool (i.e., α/ρ) is larger than the corresponding intensity in production i^H, then unskilled immigration confers terms-of-trade benefits that must be weighed against costs from increased terrorism. If α/ρ exceeds i^H, skilled immigration confers terms-of-trade losses that must be weighed against potential gains from terrorism reduction for *H*.

Proof

The proof is provided in the Appendix. ■

Here we discuss the intuition behind Proposition 5 by focusing on each of the three policy choices separately.

For given levels of the immigration quotas, we see that i^H, w^{uH}, and w^{sH} are all fixed – see (31). Thus, defense cannot affect the first three terms on the right-hand side of (39b). Its effect on *H*'s national income is through the expected terrorism damages in *H* and *F* and from its budgetary cost. Using Proposition 1, we know that defense reduces terrorism in *H* and raises terrorism in *F*. Thus, at an optimum, the benefit from terrorism reduction at home has to be balanced against the damages on *H*'s foreign interests in *F*, as well as against the direct budgetary cost of defense. Eq. (40a) provides this optimal choice rule. The influences on *H*'s decision regarding the unskilled labor quota is captured in (40b). Using Eq. (31), we can see that $\frac{\partial w^{uH}}{\partial \alpha} = \eta_{11}^{H}\left(\frac{\partial i^{H}}{\partial \alpha}\right) < 0$. This fall in unskilled wage benefits (hurts) *H* depending on whether $\left(i^{H}\rho - \alpha\right)$ is negative (positive). This is best understood by first considering the case where there are no skilled immigrants in *H* (i.e., $\rho = 0$). In this case, the first term on the right-hand side of (40b) equals $-\alpha\left(\frac{\partial w^{uH}}{\partial \alpha}\right) > 0$. This is simply the gain in *H*'s national income from having to pay less to the inframarginal units of unskilled immigrants when the marginal immigrant reduces the wages for the existing unskilled laborers. Now, consider the presence of an existing pool of skilled immigrants (i.e., $\rho > 0$). The fall in the unskilled wage due to unskilled immigration drives up the skilled wage $\left[\textit{i.e.,} \frac{\partial w^{sH}}{\partial \alpha} = -i^{H}\left(\frac{\partial w^{uH}}{\partial \alpha}\right) > 0\right]$. Thus, more has to be paid to the skilled immigrant pool – i.e., $\rho\frac{\partial w^{sH}}{\partial \alpha} = -i^{H}\rho\left(\frac{\partial w^{uH}}{\partial \alpha}\right)$. This loss for *H* and the gain from having to pay less to the unskilled immigrant pool are summarized by the first right-hand side term in Eq. (40b). If the unskilled labor intensity of the immigrant pool (i.e., α/ρ) is larger than the corresponding intensity in production i^{H}, then these influences raise *H*'s national income.

The effect of unskilled immigration on terrorism in *H* is captured by the second term on the right-hand side of Eq. (40b). Analyzing this term, we can show that a rise in α must raise the effective terrorism T^{*H} in *H*. There are several reasons for this, of which the ones related to terrorism facilitation in *H* and resource reallocation for the terrorist organization had been discussed in Proposition 3. An additional effect derives from changes in *F*'s wage rates. From (31), a rise in α must reduce the unskilled labor intensity in *F*'s productive sector and, consequently, raise w^{uF} and lower w^{sF}. This draws more unskilled labor out of terrorism and more skilled labor into terrorism. The decline in the relative supply of unskilled labor for the terrorist group makes it produce more of the skill-intensive terrorism T^{*H}.

We know from Proposition 3 that the factor allocation effects lead to a fall in the unskill-intensive T^{F}. In addition, the wage changes discussed above also draws more skilled labor into terrorism. This tends to reduce T^{F}, which benefits *H* if it has extensive foreign interests. Eq. (40b) suggests that in the presence of terrorism, the term-of-trade effects as well as the terrorism-related costs (or benefits) must be appropriately evaluated to design unskilled immigration policy. The general equilibrium analysis highlights that there is a complex interplay of margins.

Finally, we turn to an analysis of the skilled immigration quota on *H*'s income. In light of the preceding discussion, it is easy to see that a rise in the skilled immigration quota reduces w^{sH} and raises w^{uH}. However, unlike the case discussed above, if α / ρ exceeds i^{H}, then *H*'s national income falls due to the terms-of-trade effect. This follows because *H* loses more from paying higher wages to unskilled immigrants than it gains from reduced payments to the relatively small group of skilled immigrants.

We know from Proposition 3 that a rise in ρ may or may not reduce T^{*H} because of opposing terrorism-facilitation and resource-reallocation effects. An additional effect not contained in Proposition 3 is at work here. The unskilled labor intensity i^{F} must be larger when ρ is raised, which tends to raise w^{sF} and reduce w^{uF}. Following the same logic as in the case of unskilled immigration, this causes resource reallocation in *F* which tends to reduce T^{*H} and raise T^{F}. Because terrorism facilitation in *H* tends to raise T^{*H} and reduce T^{F}, there are opposing effects. The final impact on T^{*H} and T^{F} is ambiguous without further information on the parameters determining the relative strength of these opposing effects.

4.2 Stackelberg equilibrium

This subsection describes the Stackelberg equilibrium in which *H* chooses its policy one stage ahead of *F*, so that the underlying game has three stages. To compare the Stackelberg equilibrium with the Nash equilibrium, we need the slope of *F*'s Nash policy reaction function at the Nash equilibrium. Analysis of this slope is intractable for the general formulation. Therefore, we analyze the special case of $A(\alpha,\rho)\equiv 1$ (i.e., where immigrants have no role in facilitating terrorism) to throw more light on this issue.

Lemma: For $A(\alpha,\rho)\equiv 1$ and $l^{tF} > l^{0} > l^{tH}$, *F*'s income-maximizing proactive level is increasing in *H*'s defense choice.[12] This proactive response is negatively related to *H*'s choice of unskilled immigration quota. The proactive level may either rise or fall in response to an increase in the skilled immigration quota. The direction of this response critically depends on the relative strength of the quota's effects on productive resource allocation and terrorism in *F*.

Proof:

We show in the Appendix that:

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[12] The range $l^{tF} > l^{0} > l^{tH}$ corresponds to Case 3 in Proposition 2. If l^{0} lies outside this range, one of the two types of terrorism must be scaled up. As we explain below, the strategic complementarity of defense and proactive measures depends on how factor intensities change due to defense, and also on how proaction affects the level of terrorism. When both types of terrorism are reduced by proaction, these two effects complement each other. When proaction raises one kind of terrorism, while reducing the other, we have opposing effects and the pattern of strategic complementarity (or substitutability) is not clear.

$$\left(\frac{\partial m}{\partial e}\right)_{|N} > 0\,;\ \left(\frac{\partial m}{\partial \alpha}\right)_{|N} < 0\,.\ \text{Also,}\ \left(\frac{\partial m}{\partial \rho}\right)_{|N} \le 0\ \text{ if and only if }\left|\frac{\partial Z}{\partial \rho}\right| \ge \left|\frac{\partial T_m^F}{\partial \rho}\right|,$$

where Z is the sum of the first two terms in (38), and $T_m^F = \dfrac{\partial T^F}{\partial m}$. ■

Consider the effect of defense on the net marginal benefit of *F*'s proactive response, where the latter is defined in (38). For given *m* and immigration quotas (α and ρ), Eq. (31) indicates that skill intensities and skilled and unskilled wages in both nations are fixed. Thus, the first two terms in (38) cannot be affected by defensive measures in *H*. However, the third term in (38), which measures the marginal reduction in terrorism in T^F coming from *F*'s proactive measures, is amplified by *H*'s actions to deflect more attacks to *F*. *H*'s increased defense creates an incentive for *F* to engage in greater proactive measures. This happens because a rise in defense reduces γ^H as *H* is fortified. The labor intensity of T^H must fall because $\dfrac{\partial l^{tH}}{\partial \gamma^H} > 0$. Next consider the effect of *F*'s proactive measures. If it reduces T^H (see Proposition 2), unskilled labor is released by T^H that can be redeployed for T^F. Because *H*'s defense reduces l^{tH}, a unit decline in T^H due to *F*'s proactive effort releases less unskilled labor, which limits the expansion of unskill-intensive T^F. The net effect is a sharper decline in T^F due to its proactive effort. This positive effect of *H*'s defense on the effectiveness of *F*'s proactive response induces *F*'s government to choose a higher proactive response (i.e., $\dfrac{\partial m}{\partial e} > 0$).

Unskilled emigration reduces the size of the unskilled labor pool in *F* [i.e., $\left(\overline{L}^F - \alpha\right)$]. As a result, proaction's marginal benefit from raising the fraction of laborers entering the productive pool (in *F*) is reduced [see the first term in (38)]. There are other effects working through changes in wages. These cancel out under the assumed uniform probability distributions. Finally, we have another effect working through terrorism-related damages. When $\left(\bar{L}^F - \alpha\right)$ is smaller, the unskilled labor pool for the terrorist organization is also smaller [see (10)]. As a result, proaction's damaging effect on this labor pool is reduced [i.e., $\left|L_m^T\right|$ is smaller], so that proaction is not very effective in reducing unskilled-labor intensive T^F. The lower effectiveness of proaction for a larger level of α tends to reduce the income-maximizing level of proaction – i.e., $\partial m/\partial\alpha < 0$.

Skilled immigration has two opposing effects on the marginal benefit of *F*'s proactive measures. First, a larger ρ reduces the skilled labor pool in *F*, thereby reducing the marginal benefit of proaction captured by the second term in (38). Second, as in the case of α in the preceding paragraph, a larger skilled immigration quota reduces the absolute value of proaction's effect on the skilled labor pool [see $\left|S_m^T\right|$ in (21)]. A smaller reduction in the skilled labor pool implies a smaller rise in T^F, which increases the net marginal benefit of *F*'s counterterrorism measures. Without further information, we cannot say which of these two aforementioned effects dominate. Therefore, the effect of ρ on *F*'s income-maximizing proactive level is ambiguous.

To analyze the Stackelberg equilibrium, we write (39b) as

$$Y^H = Y^H\left(e,\alpha,\rho,m\right). \qquad (41a)$$

Using (32b), we can rewrite (41a) to represent the payoff of *H* from being a Stackelberg leader, as

$$Y^{HL} = Y^H\left[e,\alpha,\rho,m\left(e,\alpha,\rho\right)\right], \qquad (41b)$$

where Y^{HL} is *H*'s payoff function. The FOCs for the choice of defense and the immigration quotas are

$$\frac{\partial Y^{HL}}{\partial e} = \left(\frac{\partial Y^{H}}{\partial e}\right)_{|m} + \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial e}\right) = 0\,, \tag{42a}$$

$$\frac{\partial Y^{HL}}{\partial \alpha} = \left(\frac{\partial Y^{H}}{\partial \alpha}\right)_{|m} + \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial \alpha}\right) = 0\,, \text{ and} \tag{42b}$$

$$\frac{\partial Y^{HL}}{\partial \rho} = \left(\frac{\partial Y^{H}}{\partial \rho}\right)_{|m} + \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial \rho}\right) = 0\,. \tag{42c}$$

Eq. (31) indicates that, for given e, α and ρ, i^H is given and is not affected by *m*; hence, w^{uH} and w^{sH} cannot be directly affected by m. By differentiating (39b) (for given e, α and ρ) with respect to m, we obtain

$$\frac{\partial Y^{H}}{\partial m} = -p^{H}\left(\frac{\partial T^{H}}{\partial m}\right) - \delta^{H}\left(\frac{\partial T^{F}}{\partial m}\right) > 0\,, \tag{43}$$

owing to Case 3 in Proposition 2 where $l^H < l^0 < l^F$, so that both T^H and T^F decline with proactive measures. Eq. (43) suggests that increased proactive effort of *F* leads to an unambiguous income gain for *H*, because it reduces *H*'s damages both at home and abroad.

If we evaluate the marginal leadership payoffs at the Nash equilibrium, then the first term on the right-hand side of (42a) through (42c) , respectively, is zero. Using the Lemma above, we have $\left(\frac{\partial m}{\partial e}\right)_{|N} > 0$, $\left(\frac{\partial m}{\partial \alpha}\right)_{|N} < 0$, while the sign of $\left(\frac{\partial m}{\partial \rho}\right)_{|N}$ is ambiguous. Thus, assuming that $l^H < l^0 < l^F$, we have

$$\left(\frac{\partial Y^{HL}}{\partial e}\right)_{|N} = \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial e}\right)_{|N} > 0\,, \tag{44a}$$

$$\left(\frac{\partial Y^{HL}}{\partial \alpha}\right)_{|N} = \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial \alpha}\right)_{|N} < 0\,, \text{ and} \tag{44b}$$

$$\left(\frac{\partial Y^{HL}}{\partial \rho}\right)_{|N} = \left(\frac{\partial Y^{H}}{\partial m}\right)\left(\frac{\partial m}{\partial \rho}\right)_{|N} \leq 0 \text{ if and only if } \left(\frac{\partial m}{\partial \rho}\right)_{|N} \leq 0\,. \tag{44c}$$

In the light of Eq. (43), it is clear that *H* gains from a policy that can spur *F*'s proactive effort. Given that the Lemma establishes that *H*'s defense and *F*'s proaction are strategic complements, a small rise in *H*'s defensive effort must raise *F*'s proactive effort. This, in turn, raises *H*'s national income. Eq. (44a) captures this effect; Eqs. (44b) and (44c) follow a similar logic.

Proposition 6: Assuming that $A(\alpha,\rho)\equiv 1$ and $l^H < l^0 < l^F$, *H*'s leadership choice of defensive action exceed the Nash level, while its choice of the unskilled immigration quota must be lower than the Nash level. *H*'s choice of the skilled immigration quota is lower than the Nash level if and only if $\left|\frac{\partial Z}{\partial \rho}\right| > \left|\frac{\partial T_m^F}{\partial \rho}\right|$.

Proof

Eqs. (44a) and (44b) show that $\left(\frac{\partial Y^{HL}}{\partial e}\right)_{|N} > 0$ and $\left(\frac{\partial Y^{HL}}{\partial \alpha}\right)_{|N} < 0$. This suggests that e should be raised and α should be reduced at the Nash equilibrium to raise the Stackelberg payoff towards its maximum.[13] Using the Lemma, we know that $\left(\frac{\partial m}{\partial \rho}\right)_{|N} < 0$ if and only if $\left|\frac{\partial Z}{\partial \rho}\right| > \left|\frac{\partial T_m^F}{\partial \rho}\right|$. In this case, (44c) establishes that $\left(\frac{\partial Y^{HL}}{\partial \rho}\right)_{|N} < 0$. In turn, this suggests that the leadership skilled immigration quota must be lower than the Nash level if $\left|\frac{\partial Z}{\partial \rho}\right| > \left|\frac{\partial T_m^F}{\partial \rho}\right|$. ■

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[13] We have to assume here that the cross effect of α on the marginal benefit of defense and *vice versa* does not outweigh the first-order effects we highlight here.

At the Nash equilibrium, *H* assumes that *F*'s proaction is not affected by *H*'s policies. However, under leadership, *H* knows that a rise in its homeland defense will induce *F* to engage in greater attacks on its resident terrorists. If $l^H < l^0 < l^F$, greater proaction reduces terrorist attacks against *H* both at home and in *F*. These benefits prompt *H* to behave strategically by raising its defensive measures to spur *F*'s proactive efforts. The argument for reducing the unskilled immigration quota at the Stackelberg equilibrium is similar, since it raises terrorism in *F*. The skilled immigration quota will be raised or lowered depending on whether ρ raises or reduces proaction, respectively. The condition that is critical in determining the direction of change of the skilled immigration quota is outlined in Proposition 6.

5. Concluding remarks

Immigration and counterterrorism policies are both central concerns confronting the United States and many other targeted developed countries. Moreover, consistent with our model, numerous transnational terrorist groups have taken up residency in developing countries with limited capabilities to root out the groups. This paper is the first game-theoretic general equilibrium analysis that investigates the interrelationship between immigration quotas and the choice between defensive countermeasures in the developed country and proactive measures in the (source) developing country.

Even though the analysis is complex and ambiguous in places, there are many important and unambiguous insights. First, developed countries gain from deflecting attacks back to the source country despite their own interests in the latter. Second, proactive measures against a resident terrorist group need not reduce terrorism at home *and* abroad. This is a novel result that hinges on labor-intensity considerations in the productive and terrorist sectors at home and abroad. In contrast, the literature views such proactive measures as necessarily reducing terrorism everywhere (e.g., Sandler and Siqueira 2006). Third, the source country for terrorism may be better off in augmenting proactive measures even if this leads to more attacks at home. This is the case when such measures more than compensate for the additional terrorism by augmenting the labor supply in the productive sector so that national income rises. Fourth, given that terrorist attacks are skill-intensive in the developed country, we show that the developed country can reduce its terrorism at home by limiting quotas on unskilled labor. This follows because the source country must then contend with a larger pool of terrorists at home. A reduction in the skilled immigration quota may not curb terrorism in the developed country despite terrorism being skill-intensive there. From a war-on-terror viewpoint, our findings support the tendency for developed countries to encourage skilled labor migration and discourage unskilled labor migration. This follows even though terrorism is skill-intensive in the developed country. Fifth, we identify the circumstances where the developed country can gain a strategic advantage through policy leadership. In this case, greater defensive countermeasures combined with reduced unskilled immigration quotas shift the burden of the war on terror to the source country. Sixth, we establish that optimal immigration or counterterrorism policies cannot be examined in isolation; thus, there are firm theoretical grounds for including US Immigration and Customs Enforcement (ICE) in the Department of Homeland Security. That is, the margins affecting immigration choices can be greatly influenced by counterterrorism policies at home and abroad.

There are many fruitful directions for extension. For example, Cases 1 and 2 of Proposition 2 can be investigated in the leader-follower framework. Foreign aid can be introduced as a choice variable to bolster the developing country's proactive efforts in their follower role. Additional countries can be added to the analysis.

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Appendix

1. *Derivation of Eq. (16)*

Using the terrorist organization's FOCs, we have

$$\gamma^H T_1^H \left(l^{tH},1\right) - \gamma^F T_1^F \left(l^{tF},1\right) = 0 \text{ and} \tag{M1}$$

$$\gamma^H T_2^H \left(l^{tH},1\right) - \gamma^F T_2^F \left(l^{tF},1\right) = 0\,. \tag{M2}$$

Totally differentiating (M1) and (M2) and solving using Cramer's rule yield:

$$\frac{\partial l^{tH}}{\partial \gamma^H} > 0\,,\ \frac{\partial l^{tF}}{\partial \gamma^H} > 0\,,\ \frac{\partial l^{tH}}{\partial \gamma^F} < 0\,, \text{ and } \frac{\partial l^{tF}}{\partial \gamma^F} < 0\,. \tag{M3}$$

We can write the terrorist group's unskilled labor constraint as:

$$l^{tH} S^{tH} + l^{tF} S^{tF} = L^T \left(\alpha, w^{uH}, m, \overline{L}^H\right). \tag{M4}$$

Totally differentiating (M4) and the skilled labor constraint, and solving using Cramer's rule give:

$$\frac{\partial S^{tH}}{\partial \gamma^H} = \frac{S^{tH} \dfrac{\partial l^{tH}}{\partial \gamma^H} + S^{tF} \dfrac{\partial l^{tF}}{\partial \gamma^H}}{l^{tF} - l^{tH}} > 0\,, \text{ because } \ l^{tF} > l^{tH}\,. \tag{M5}$$

Using (4a), we have

$$T^H = S^{tH} T^H \left(l^{tH},1\right) \Rightarrow \frac{\partial T^H}{\partial \gamma^H} = T^H \left(l^{tH},1\right) \frac{\partial S^{tH}}{\partial \gamma^H} + S^{tH} T_1^H \left(l^{tH},1\right) \frac{\partial l^{tH}}{\partial \gamma^H} > 0\,. \tag{M6}$$

2. *Derivation of Eq. (23):*

Differentiating the Lagrangian multipliers by using the terrorist organization's FOCs, we get (23).

3. *Derivation of Eqs. (24) and (25):*

Using (19) and (22), we have

$$\frac{\partial T^H}{\partial m} < 0 \text{ iff } -\frac{L_m^T}{S_m^T} > \frac{\left(\frac{\partial \lambda_S}{\partial \gamma^H}\right)}{\left(\frac{\partial \lambda_L}{\partial \gamma^H}\right)}. \tag{M7}$$

We first substitute the expressions for L_m^T and S_m^T from (21) and the expressions for $\left(\frac{\partial \lambda_S}{\partial \gamma^H}\right)$ and $\left(\frac{\partial \lambda_L}{\partial \gamma^H}\right)$ from (23) into (M7), and then we use $\frac{L_m^T}{S_m^T} = l^0$ [see (24)]. Next, by using homogeneity of degree zero of the $T_1^F\left(l^{tF},1\right)$ function and Euler's theorem, we can reduce (M7) to show that:

$$\frac{\partial T^H}{\partial m} < 0 \text{ iff } l^{tF} > l^0. \tag{M8}$$

Analogously, we get Eq. (25):

4. *Proof of Proposition 3:*

(a) To show that $\frac{\partial T^{*H}}{\partial \phi^H} > 0$, we proceed as follows. Using (15a) and (6), we have

$$\frac{\partial T^H}{\partial \phi^H} = V_{11}^* A p^H + V_{12}^* \delta^H p^F . \tag{M9}$$

From (18a), we have $V_{12}^* = -\frac{V_{11}^* \gamma^H}{\gamma^F} < 0$. Substituting this in (M9) and simplifying yield:

$$\frac{\partial T^H}{\partial \phi^H} = \frac{V_{11}^* A \phi^F p^H}{\phi^H \delta^H + \phi^F} > 0 \Rightarrow \frac{\partial T^{*H}}{\partial \phi^H} = A\frac{\partial T^H}{\partial \phi^H} > 0 . \tag{M10}$$

(b) Next we establish that $\frac{\partial T^F}{\partial \phi^H} < 0$. Using (15b), and a similar method as above, we have

$$\frac{\partial T^F}{\partial \phi^H} = -\frac{V_{22}^* p^F \phi^F}{\phi^H} < 0 \text{, because } V_{22}^* = -\frac{V_{21}^* \gamma^H}{\gamma^F} > 0 . \tag{M11}$$

(c) To show that $\frac{\partial T^{*H}}{\partial \alpha} > 0$, we proceed as follows. With (5) and (15a), we have

$$\frac{\partial T^{*H}}{\partial \alpha} = A_\alpha V_1^* + A\left(V_{11}^* \frac{\partial \gamma^H}{\partial \alpha} + V_{1\alpha}^* \right). \tag{M12}$$

Differentiating (6), we get $\frac{\partial \gamma^H}{\partial \alpha} > 0$. Using the envelope theorem and (12), we get V_α^*.

Differentiating V_α^* , we can then show that $V_{1\alpha}^* > 0$. Thus, (M12) shows that $\frac{\partial T^{*H}}{\partial \alpha} > 0$.

(d) To show that $\frac{\partial T^F}{\partial \alpha} < 0$, we proceed as follows. Differentiating Eq. (15b) gives:

$$\frac{\partial T^F}{\partial \alpha} = V_{21}^* \frac{\partial \gamma^H}{\partial \alpha} + V_{2\alpha}^* . \tag{M13}$$

Based on (18a), $V_{21}^* < 0 \Rightarrow V_{21}^* \frac{\partial \gamma^H}{\partial \alpha} < 0$. Using a method similar to above, we can show that $V_{2\alpha}^* < 0$. Thus, we get $\frac{\partial T^F}{\partial \alpha} < 0$ by (M13).

(e) Next, we show that the sign of $\frac{\partial T^{*H}}{\partial \rho}$ is ambiguous. Differentiating T^{*H} gives:

$$\frac{\partial T^{*H}}{\partial \rho} = A_\rho V_1^* + A\left(V_{11}^* \frac{\partial \gamma^H}{\partial \rho} + V_{1\rho}^* \right). \tag{M14}$$

Given (6), $\frac{\partial \gamma^H}{\partial \rho} = \phi^H p^H A_\rho > 0$. Using the envelope theorem and (11)-(12), we obtain V_ρ^* and, in turn, $V_{1\rho}^* < 0$. Based on these facts in (M14), we see that the sign of $\frac{\partial T^{*H}}{\partial \rho}$ is ambiguous.

(f) To show that the sign of $\frac{\partial T^F}{\partial \rho}$ is ambiguous, we proceed as follows. Using (15b), we obtain

$$\frac{\partial T^F}{\partial \rho} = V_{21}^* \frac{\partial \gamma^H}{\partial \rho} + V_{2\rho}^* . \tag{M15}$$

Based on methods similar to above, we can show that $V_{2\rho}^* > 0$. Since $V_{21}^* \frac{\partial \gamma^H}{\partial \rho} < 0$, the sign of

$\frac{\partial T^F}{\partial \rho}$ is ambiguous.

5. *Derivation of Eq. (34):*

Given (31) and the implicit function theorem, we have

$\frac{\partial i^F}{\partial m} = \frac{N_i}{D_i}$, where

$N_i = \frac{\beta'}{\beta^2}\left[gw^{sF} i^F \left(\bar{S}^F - \rho\right) - xw^{uF}\left(\bar{L}^F - \alpha\right)\right]$ and

$$D_i = \left(\bar{S}^F - \rho\right) G + \left[\frac{i^F\left(\bar{S}^F - \rho\right) g}{\beta}\right]\left(\frac{\partial w^{sF}}{\partial i^F}\right) - \left[\frac{\left(\bar{L}^F - \alpha\right) x}{\beta}\right]\left(\frac{\partial w^{uF}}{\partial i^F}\right). \tag{M16}$$

Based on (31), $D_i > 0$. Thus,

$$\frac{\partial i^F}{\partial m} \geq 0 \text{ iff } N_i \geq 0, \text{ i.e., iff } gw^{sF} i^F \left(\bar{S}^F - \rho\right) - xw^{uF}\left(\bar{L}^F - \alpha\right) \leq 0 . \tag{M17}$$

Using Eq. (31), we have $i^F\left(\bar{S}^F - \rho\right) = \frac{\left(\bar{L}^F - \alpha\right) X}{G}$. Substituting this last expression in (M17)

and simplifying, we get (34).

6. *Derivations supporting the Lemma:*

We assume that $A(\alpha,\rho)\equiv 1$ for the Lemma, which implies that γ^H and γ^F are independent of α and ρ. From (M1) and (M2), this means that l^{tH} and l^{tF} are also independent of α and ρ. We use this fact in analyzing the effect of α and ρ on $\frac{\partial T^F}{\partial m}$, which makes the analysis tractable. Details of these derivations (available upon request) are omitted here. Instead, we provide a brief outline of the proof. Using the implicit function theorem on (32a), we have

$$\frac{\partial m}{\partial e} = -\frac{Y^F_{me}}{Y^F_{mm}};\ \frac{\partial m}{\partial \alpha} = -\frac{Y^F_{m\alpha}}{Y^F_{mm}};\ \text{and}\ \frac{\partial m}{\partial \rho} = -\frac{Y^F_{m\rho}}{Y^F_{mm}}. \tag{M18}$$

Using F's second-order condition ($Y^F_{mm}<0$), we know that the signs of $\frac{\partial m}{\partial e}$, $\frac{\partial m}{\partial \alpha}$, and $\frac{\partial m}{\partial \rho}$, depend on the signs of Y^F_{me}, $Y^F_{m\alpha}$, and $Y^F_{m\rho}$, respectively.

(a) Analysis of Y^F_{me}:

Substituting (31), (37a), and (37b) in (32a) gives:

$$Y^F_m(m;e,\alpha,\rho) = -\frac{\left(w^{uF}\right)^2\left(\bar{L}^F-\alpha\right)\beta' x}{\beta^2} - \frac{\left(w^{sF}\right)^2\left(\bar{S}^F-\rho\right)\beta' g}{\beta^2} - \frac{\partial T^F}{\partial m} - 1$$

$$= Z - T^F_m - 1, \text{ where}$$

$$T^F_m = \frac{\partial T^F}{\partial m},\ Z = -\frac{\left(w^{uF}\right)^2\left(\bar{L}^F-\alpha\right)\beta' x}{\beta^2} - \frac{\left(w^{sF}\right)^2\left(\bar{S}^F-\rho\right)\beta' g}{\beta^2}. \tag{M19}$$

When m, α, and ρ are given, w^{uF}, w^{sF}, and $\beta(m)$ are all independent of e. Thus, $\frac{\partial Z}{\partial e}=0$.

We can also show that $\frac{\partial T^F_m}{\partial e} = \frac{\partial T^F_e}{\partial m} < 0$. Thus, using (M19), we have

$$Y^F_{me} = -\frac{\partial T^F_m}{\partial e} > 0 \Rightarrow \frac{\partial m}{\partial e} > 0.$$

(b) Analysis of $Y_{m\alpha}^{F}$:

Differentiating (M19) gives:

$$Y_{m\alpha}^{F} = \frac{\partial Z}{\partial \alpha} - \frac{\partial T_{m}^{F}}{\partial \alpha}. \tag{M20}$$

We can show that

$$-\left(\frac{\beta^{2}}{x\beta'}\right)\frac{\partial Z}{\partial \alpha} = -\left(w^{uF}\right)^{2} < 0 \Rightarrow \frac{\partial Z}{\partial \alpha} < 0. \tag{M21}$$

Furthermore, given $T_{m}^{F} = T^{F}\left(l^{tF},1\right)\frac{\partial S_{m}^{tF}}{\partial m}$, it follows that

$$\frac{\partial T_{m}^{F}}{\partial \alpha} = T^{F}\left(l^{tF},1\right)\frac{\partial S_{m}^{tF}}{\partial \alpha} > 0. \tag{M22}$$

(M20)-(M22) establishes that $Y_{m\alpha}^{F} < 0 \Rightarrow \frac{\partial m}{\partial \alpha} < 0$.

(c) Analysis of $Y_{m\rho}^{F}$:

Based on (M19), we have

$$Y_{m\rho}^{F} = \frac{\partial Z}{\partial \rho} - \frac{\partial T_{m}^{F}}{\partial \rho}. \tag{M23}$$

Analogous to the derivation of $\frac{\partial Z}{\partial \alpha}$ above, it follows that $\frac{\partial Z}{\partial \rho} < 0$. Also, we can show that

$\frac{\partial T_{m}^{F}}{\partial \rho} = T^{F}\left(l^{tF},1\right)\frac{\partial S_{m}^{tF}}{\partial \rho} < 0$. Thus, (M23) implies that

$$Y_{m\rho}^{F} \leq 0 \text{ iff } \left|\frac{\partial Z}{\partial \rho}\right| \geq \left|\frac{\partial T_{m}^{F}}{\partial \rho}\right| \Rightarrow \frac{\partial m}{\partial \rho} \leq 0 \text{ iff } \left|\frac{\partial Z}{\partial \rho}\right| \geq \left|\frac{\partial T_{m}^{F}}{\partial \rho}\right|. \tag{M24}$$

7. *Deriving H's policy rules [Eqs. (40a) through (40c)}:*

(a) Derivation of Eq. (40a):

Eq. (31) indicates that $i^H\left(\alpha,\rho\right)$ is independent of e. In turn, $w^{uH}\left(i^H\right)$ and $w^{sH}\left(i^H\right)$ are independent of e. Differentiation of (39b) with respect to e immediately then yields (40a).

(b) Derivation of Eq. (40b):

Differentiating (39b) and using $w^{uH} = \eta_1^H$, we have

$$\frac{\partial Y^H}{\partial \alpha} = -\alpha \frac{\partial w^{uH}}{\partial \alpha} - \rho \frac{\partial w^{sH}}{\partial \alpha} - p^H \left[T^H A_\alpha + A\left(\frac{\partial T^H}{\partial \alpha} \right) \right] - \delta^H \frac{\partial T^F}{\partial \alpha}. \tag{M25}$$

Using Eq. (31) and the homogeneity of degree zero of the $\eta_1^H\left(\bullet\right)$ function, we can show that

$$\frac{\partial w^{sH}}{\partial \alpha} = -i^H \frac{\partial w^{uH}}{\partial \alpha}. \tag{M26}$$

Based on (M26), we substitute for $\frac{\partial w^{sH}}{\partial \alpha}$ in (M25) to get (40b) of the paper.

(c) Derivation of Eq. (40c):

Derivation of (40c) follows the same logic as that (40b).