

Modeling Strategic Interactions in Counterterrorist Operations

Jonathan P. Caulkins

Carnegie Mellon University

*H. John Heinz III School of Public Policy and
Management & Qatar Campus*

RAND, Drug Policy Research Center

Lots of co-authors from TU Wien including
Doris Behrens, Gustav Feichtinger, Dieter Grass, and
Gernot Tragler

Personal Introduction

- ◆ Time at RAND and in Qatar
 - *Occasional* insights beyond those available in the NY Times, but no deep domain expertise
- ◆ OR & Drug policy expertise
 - Several papers on “What terror policy should and should not learn from drug policy”
 - Partnership with optimal dynamic control theorists to study epidemic models

Lessons from Drug Modeling that Might Apply to Modeling Counter-Terror

- ◆ Think of there being a population or “stock” of terrorists

Modeling a “Stock” of Terrorists is not Common but Has Precedent

- ◆ Keohane and Zeckhauser, 2003: „The ecology of terror defense”
- ◆ Castillo-Chavez & Song, 2003: „Models for the transmission dynamics of fanatical behaviors“
- ◆ Greiner, 2004: „How much to spend on the fight against terrorism? An optimal control approach“
- ◆ Faria, 2004: „Terror cycles“
- ◆ Kaplan et al., 2005: „What happened to suicide bombings in Israel? Insights from a terror stock model”
- ◆ Udwadia et al., 2006: „A dynamical model of terrorism“

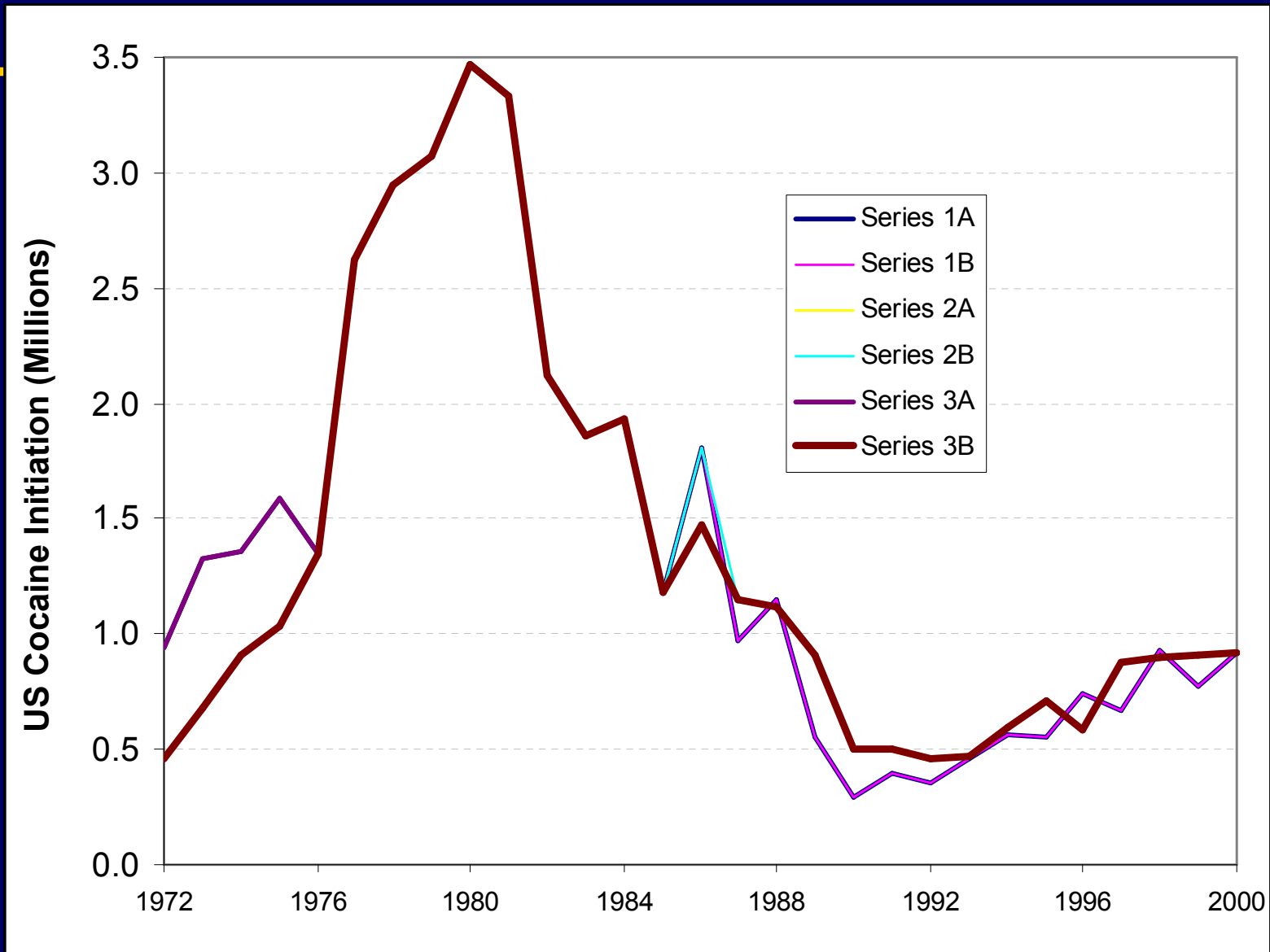
Lessons from Drug Modeling that Might Apply to Modeling Counter-Terror

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- ◆ Focus on “flows” in and out of that stock
 - Pay attention to the possibility that some interventions that increase an *outflow* might simultaneously increase *inflow*
 - Levels of associated “reputation” or “perception” stocks can affect those flows

Examples of Feedback from Perceptions/Reputation to Inflow

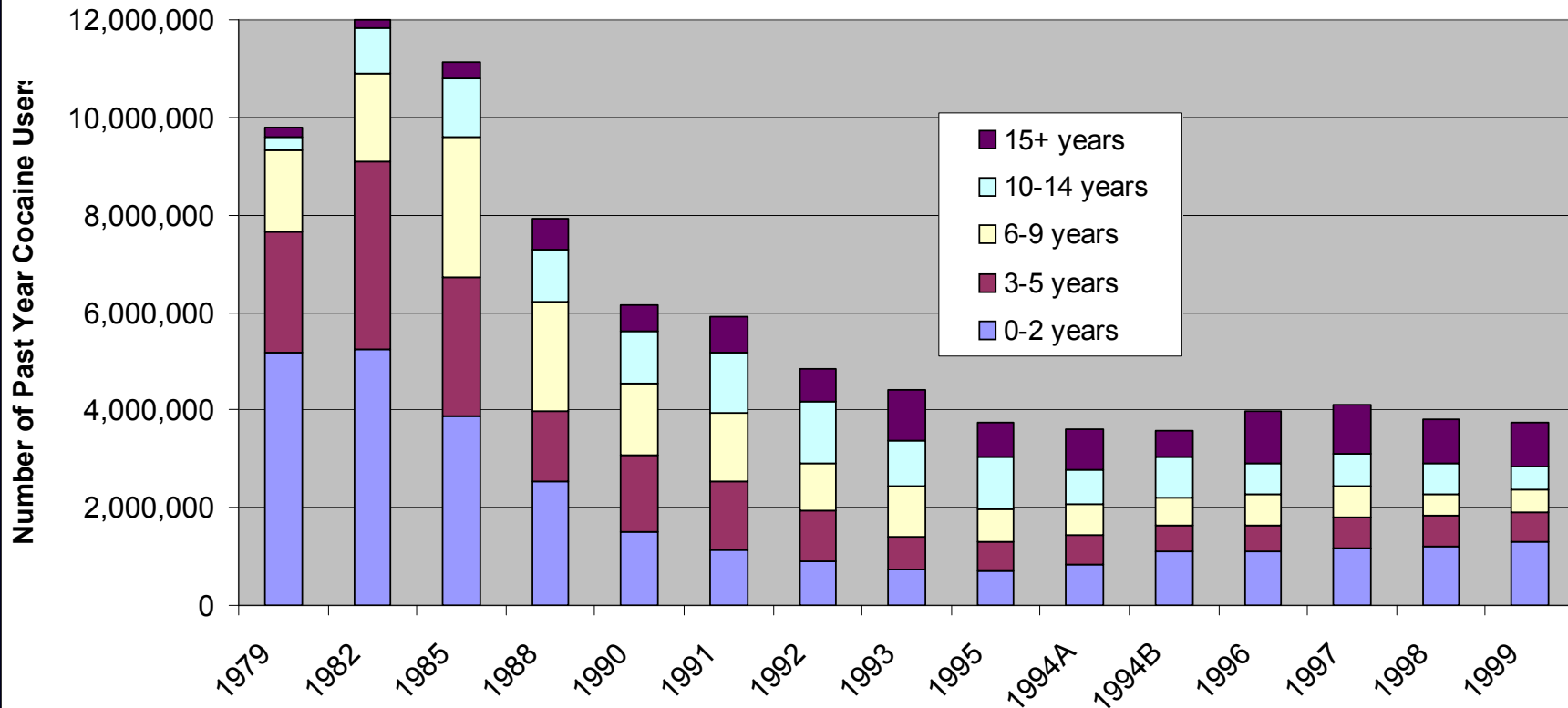
- ◆ Mountain climbing is safer, so now there are more deaths from mountain climbing (MacCoun)
- ◆ Prevalence of HIV affects sexual behavior and hence inflow into stock of ...
 - Susceptibles and/or
 - » Blower, Doyle, & Lewis (2000), Greenhalgh et al. (2001)
 - Infecteds
 - » Zeiler (2007)
- ◆ Drug epidemics end when enough people have progressed to states of use that manifest the drugs' potential ill effects (Musto, 1987; Kleiman, 1992; Behrens et al. 1999, 2000)

Cocaine Initiation in the US Over Time



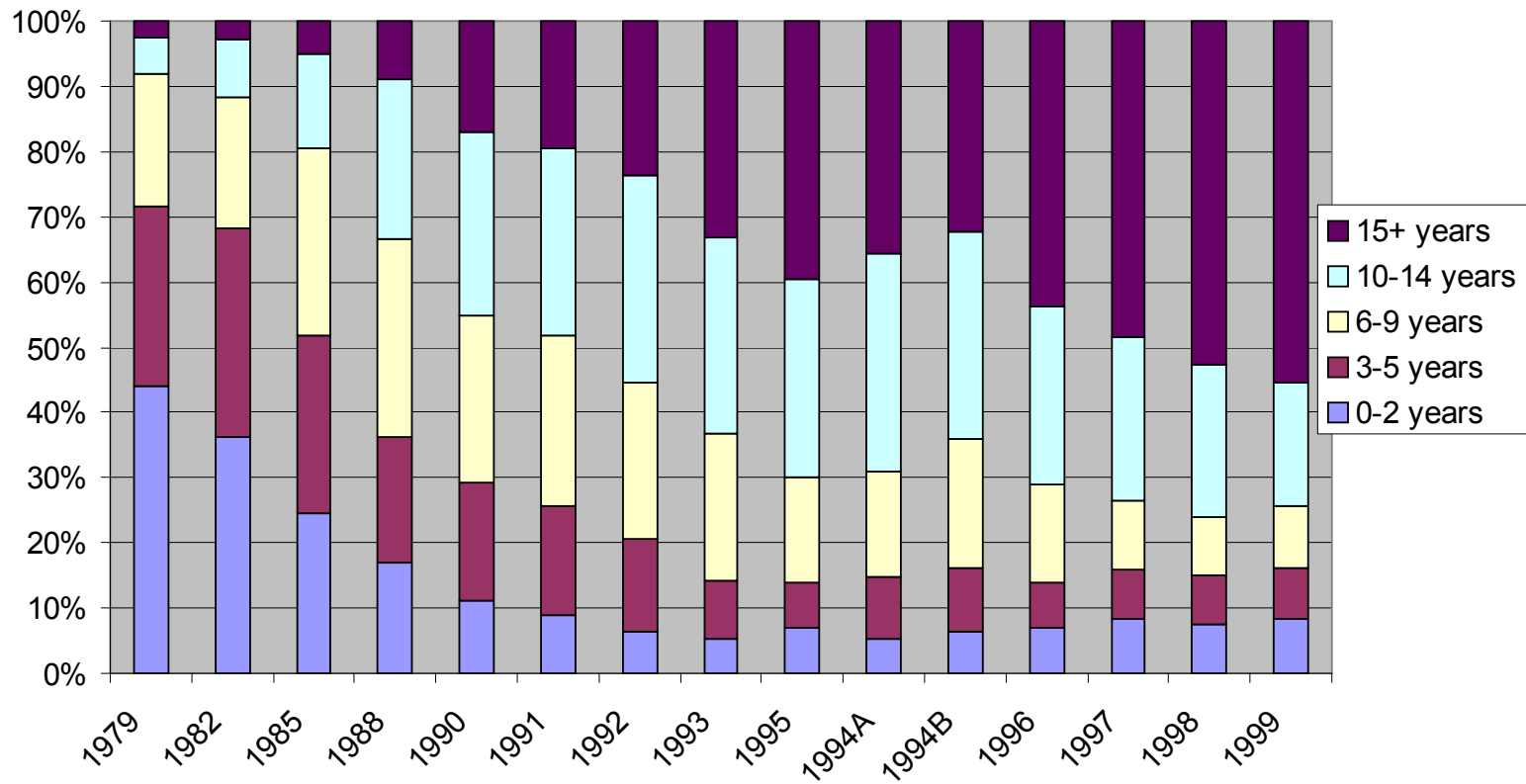
Knowledge Base About Cocaine Changed Dramatically Over Time

Changing Composition of Current Cocaine Users: Number of Years Since Starting Cocaine Use, by NHSDA Survey Year

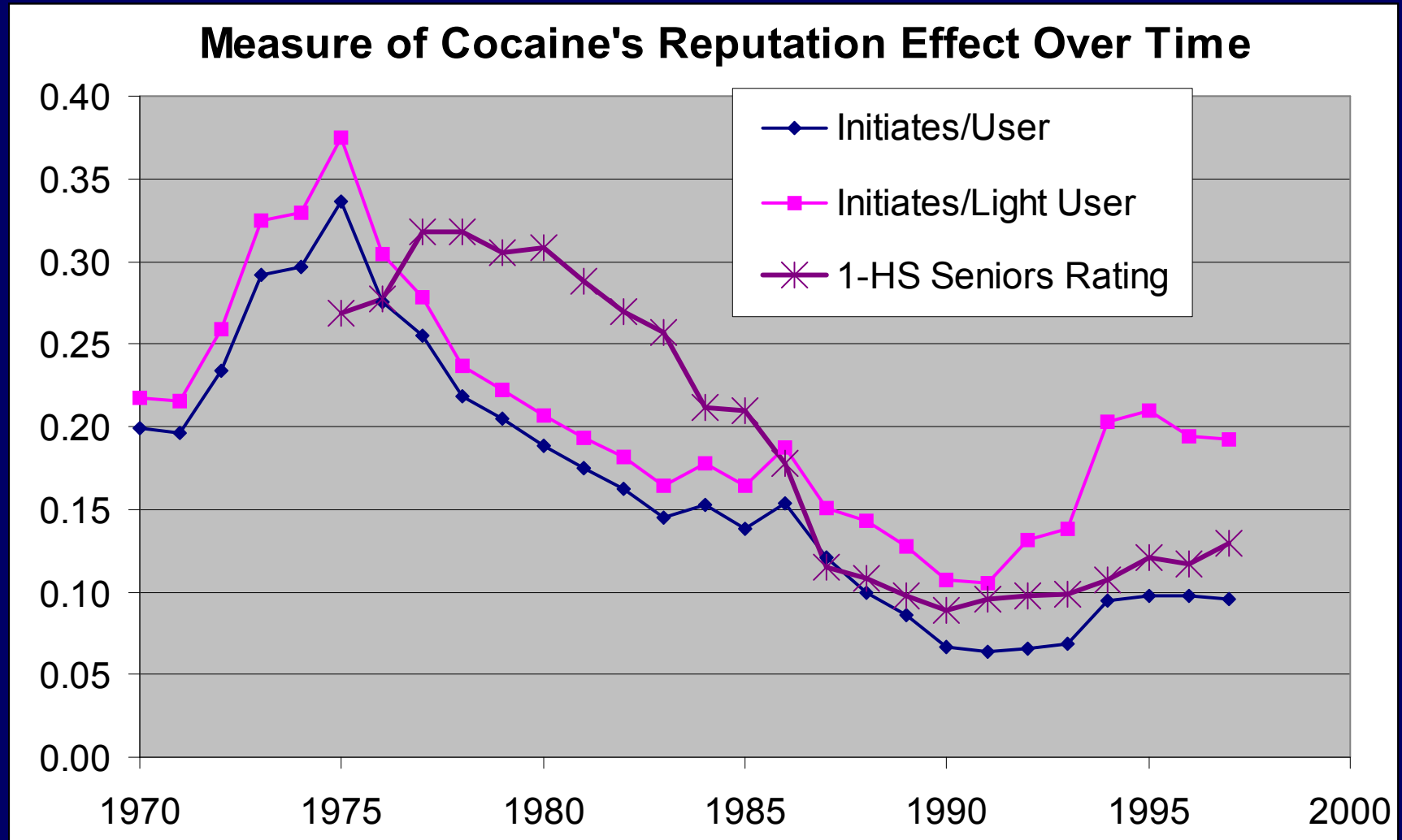


Parallel Graph for Ever Users

Changing Composition of Ever Cocaine Users: Years Since Trying Cocaine, by NHSDA Survey Year



Measures of Reputation and Infectivity Correlated Over Time



Data Limitations

- ◆ Drug data are poor
- ◆ Terror stock data are worse
 - So models are stylized and not validated
 - Value stems from articulating ideas in a language as precise as mathematics
 - » Not from hypothesis testing or
 - » Providing specific, quantitative guidance

Four Types of Counter-Terror: We Focus on the Last

- ◆ **Reactive**
 - Target hardening
 - Emergency response
- ◆ **Investigative**
 - Pre-incident: Data mining CTRs and telecommunications
 - Post incident: Conventional law enforcement tactics
- ◆ **Active defense**
 - Airport screening
 - Facial image recognition
- ◆ **Proactive (offense)**
 - **Attacking terrorists (asymmetric warfare)**

Stylized Facts

- ◆ Basic idea (after Keohane and Zeckhauser, 2003) is that terror attacks are produced by a stock of terrorists
- ◆ Counter-terror seeks to reduce the terror stock
- ◆ Targeted hits, arrests, interceptions, and suicide bombings themselves all reduce the stock
- ◆ Terror stock is replenished via recruitment, which might depend on counter-terror tactics (such as targeted killings that generate collateral casualties)

Basic Model: “Should One Fight Fire with Fire or Water” (*Computers & OR*)

- ◆ One state (x = strength of terrorists)
 - Uncontrolled dynamics $dx/dt = \tau + kx^\alpha - \mu x$
- ◆ Two controls
 - Induce outflow proportional to $\ln(1 + \text{control}) x^\theta$
 - Intelligence driven/targeted “Water” (u)
 - » Expensive (smaller coefficient) and limited ($\theta < 1$)
 - More aggressive screening/sweeps “Fire” (v)
 - » Larger coefficient and $\theta = 1$, but
 - » Increases recruitment by factor $(1 + \rho v)$
- ◆ Objective: minimize discounted integral of $x + u^2 + v^2$

Figure 1: DNS Point

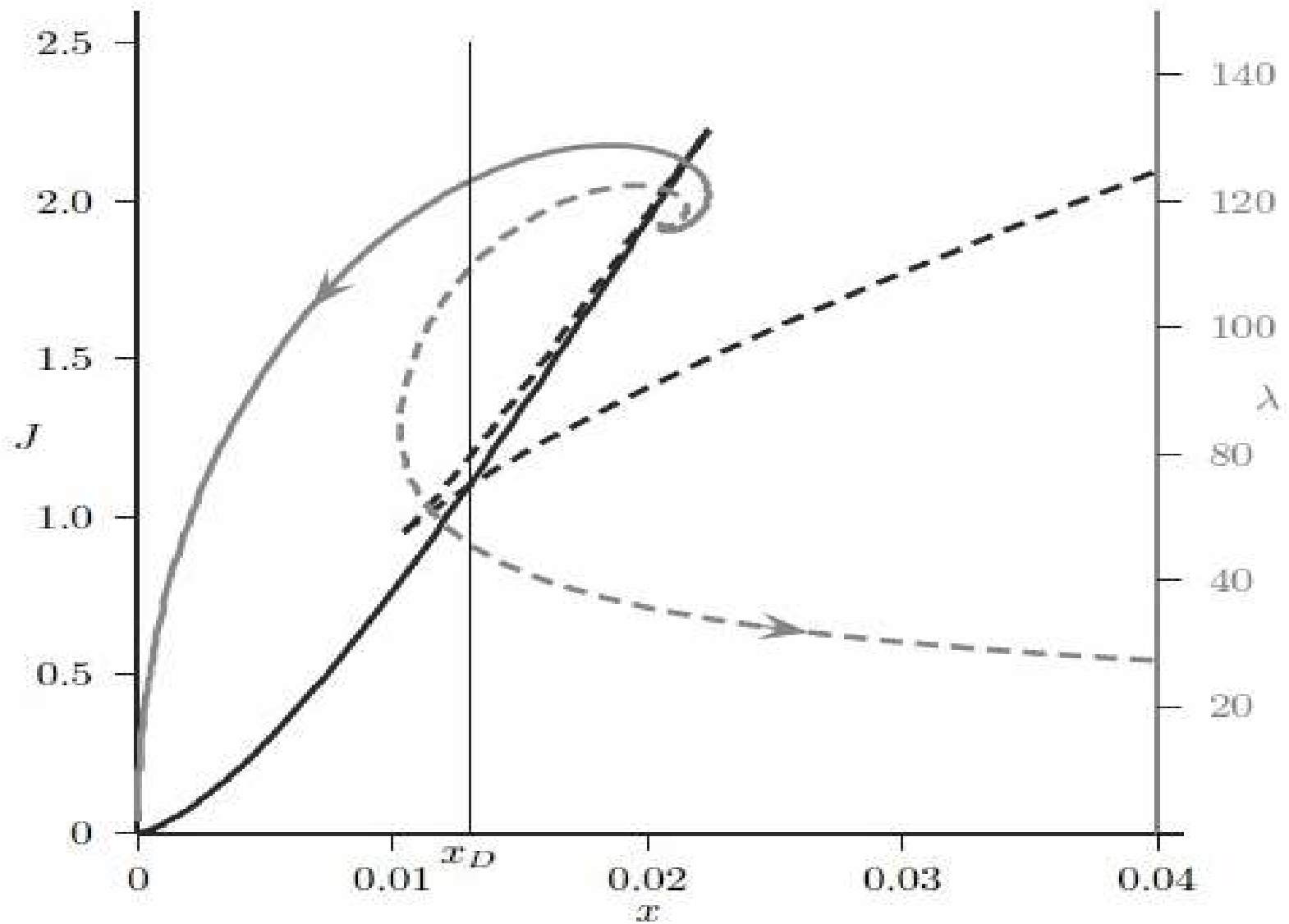


Figure 3a: If x is Small, Use Lots of Water (and a Bit of Fire) to “Eradicate”

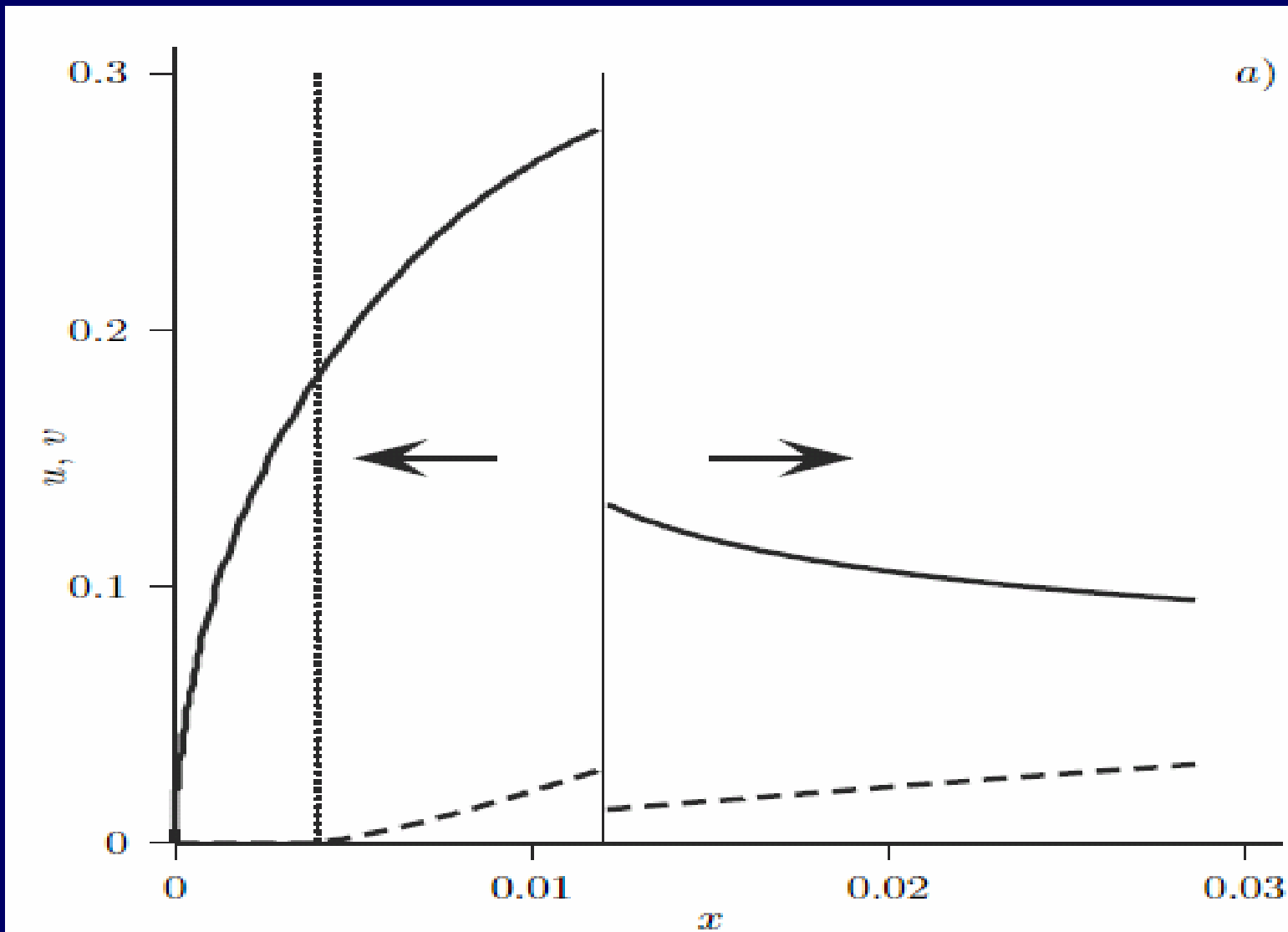
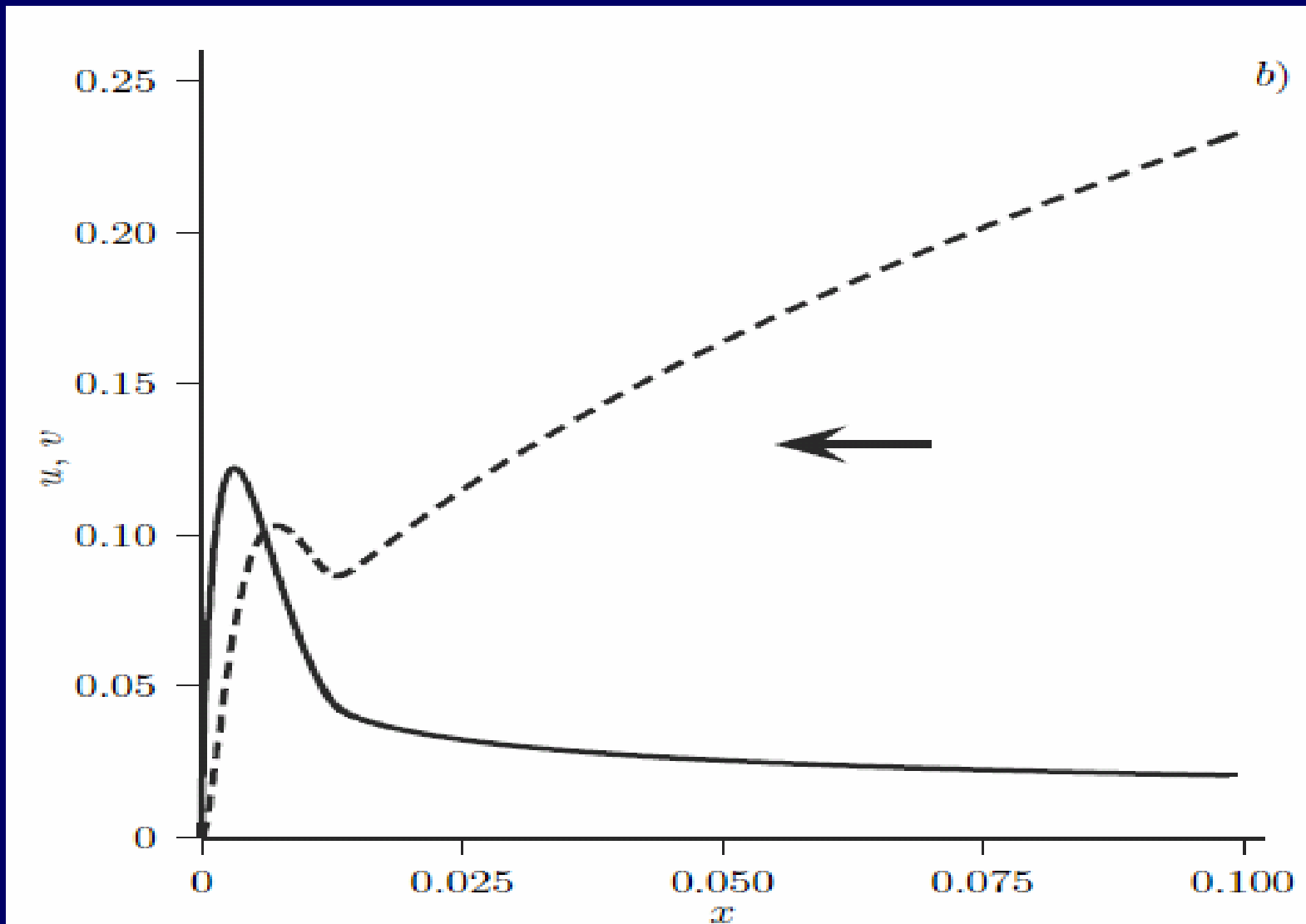


Fig 3b: If x is Large (& larger γ), Use Lots of Fire to Stabilize (At High Levels)



Elaborated Model: OC of Terrorism and Global Reputation

- ◆ Just one control (u)
- ◆ But add a 2nd state (y)
 - y represents sympathy *for* counter-terror forces
 - Control-induced outflow is increasing in y
 - » Outflow = $\eta u x^\beta y^\gamma$
 - y tends to baseline (b), but is increased by terror attacks and diminished by counter terror
 - » $dy/dt = \delta x - \rho u^2 + \kappa (b - y)$
- ◆ Objective: min discounted integral of $x + u^2$
 - y does not enter objective directly

Fig 1a: 2D DNS Threshold with Sensible Interpretation

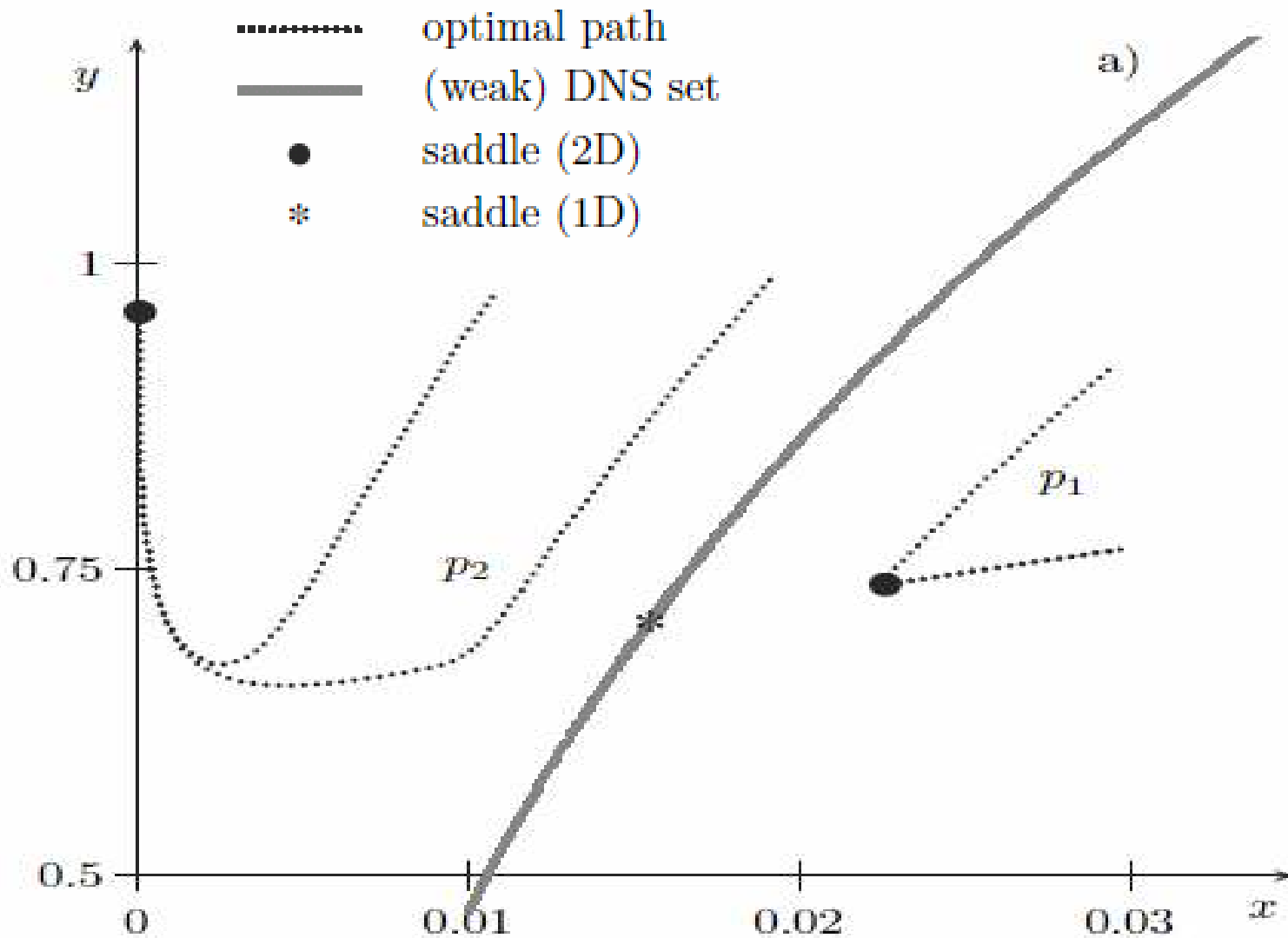
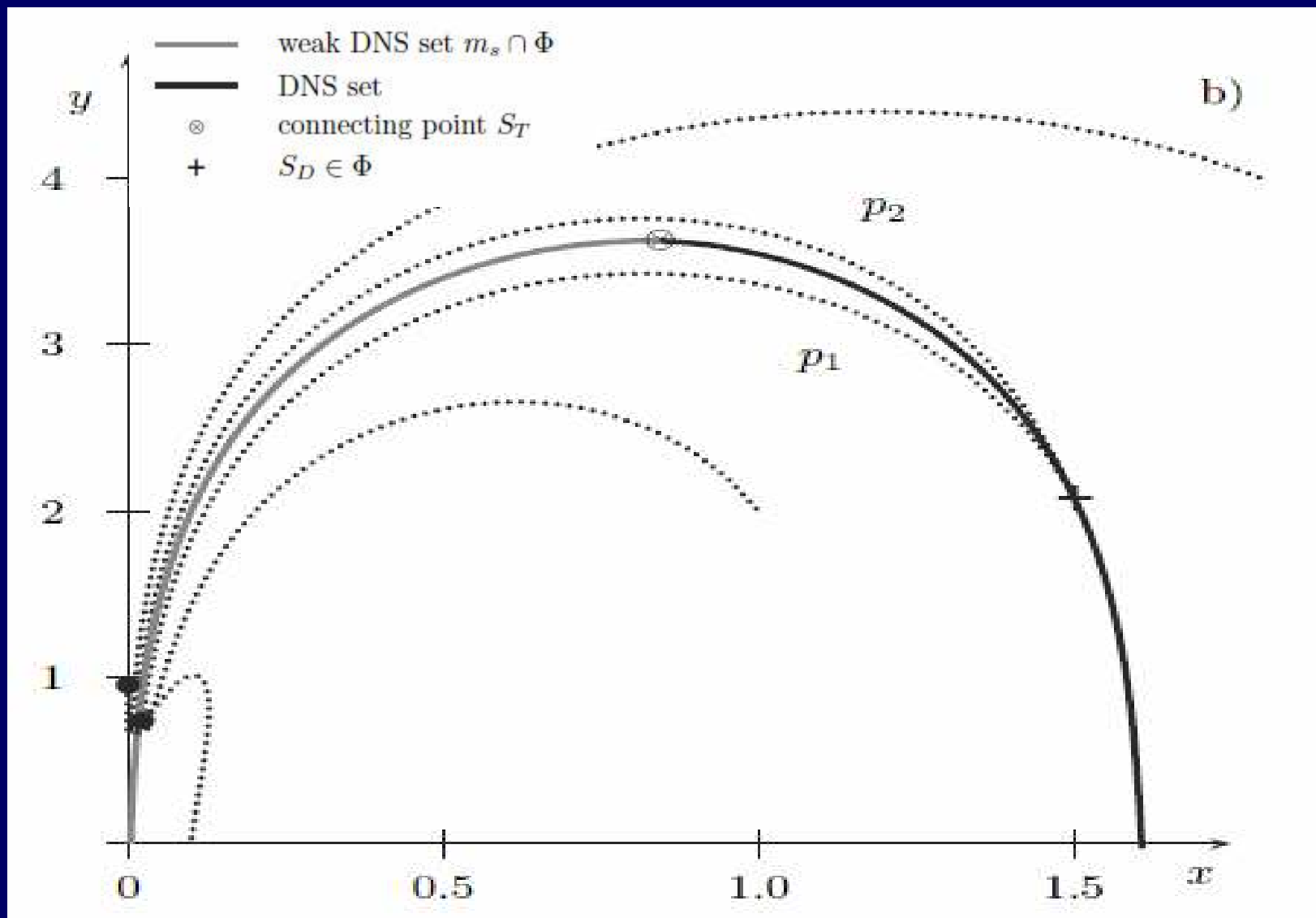


Fig 1b: 2D DNS Threshold Arcs Back, Complicating Interpretation



Work in Progress

- ◆ For modestly different parameter values the arcs lift off axis, becoming a bubble
 - Properties still being investigated

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 - Pay attention to the possibility that some interventions that increase an *outflow* might simultaneously increase *inflow*
 - Levels of associated “reputation” or “perception” stocks can affect those flows
- ◆ **Goals matter**

Goals Matter in Drug Policy

- ◆ To reduce # of users
 - Use prevention, user sanctions
- ◆ To reduce quantity consumed
 - Use treatment
- ◆ To reduce spending on drugs
 - Cut enforcement against suppliers (let price fall)
- ◆ To reduce drug-related consequences
 - Use harm reduction (e.g., NSP, SIF, etc.)

Goals Matter in Counter-Terror: What Are Al-Qaeda's Goals?

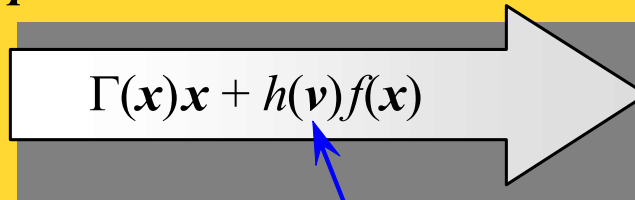
- ◆ Story #1: “Clash of civilizations”
 - Al-Qaeda simply hates the West, and their only objective is to kill as many Westerners as possible
 - Islamacists want to restore or even expand classical Ummah
- ◆ Story #2: von Clausewitz Realpolitik
 - Terrorism is continuation of politics with other means
 - Al-Qaeda hates the (relatively secular) al-Saud dynasty, but has failed in its efforts to challenge House of Saud directly
 - Al-Qaeda attacks NYC, London, Madrid, etc. to induce a reaction that makes the pro-West royal family unpopular

Crucial Distinction

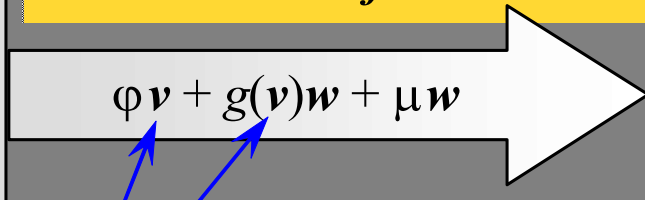
- ◆ Presumably al-Qaeda's objective function is increasing in its own stock (x)
- ◆ But how do controls affect its utility?
 - Story #1: Utility is increasing in its own control (w)
 - Story #2: Utility is increasing in West's control (v)
- ◆ How does this play out in a (one state dynamic game) game theoretic analysis?

The Terror Stock Model I

The stock of terrorists is filled via recruitment, which might depend on anti-terror actions.



Targeted hits, arrests, and suicide bombings themselves reduce the stock of terrorists.



Counter-terror actions are assumed to affect both the recruitment rate and the outflow rate positively

The Terror Stock Model II

$$\dot{x} = \gamma (1 - x) x - \mu w - (\beta w + \phi - \alpha v) v$$

x ... number of terrorists at time t relative to the steady state population of terrorists in “peacetime” (*state*),

w ... proportion of the steady state population of al-Qaeda that commits (suicide) attacks at time t (*control of player 2*),

v ... intensity of counter-terror attacks (*control of player 1*).

player 1 = The West / U.S.

player 2 = al-Qaeda

U.S.-Objectives

- ◆ The U.S. wants to minimize the number of attacks and, hence, people killed by al-Qaeda (by minimizing w).
- ◆ The U.S. also would like to minimize the number of terrorists (by minimizing x) because that represents future killing capability and power.

Assumption about U.S. Behavior

- ◆ Since 9-11-2001 the cost of US terror control is basically unconstrained. Thus, the number of counter-terror strikes the U.S. makes is not limited.

al-Qaeda's Objectives

- ◆ al-Qaeda wants to become strong (by increasing x).
- ◆ al-Qaeda *may* value deaths of Westerners that are a direct consequence of its performing successful suicide attacks (by increasing w).
- ◆ al-Qaeda *might* want to induce “excessive” counter-attacks by the West (elicit high values of v from the West) as an indirect way of weakening the power of the House of Saud and other “pro-Western” regimes.

The Dynamic Game Concepts

- ◆ **Time $t = 0$** is September 12th, 2001. al-Qaeda gets to decide whether the game is played at all, but if the game will be played, the US moves and al-Qaeda responds
- ◆ **Stackelberg game** since the overall direction of US defense policy is stable and transparent to all. If the US is attacked, it will counter-attack.
- ◆ **Open-loop solution (+ finite planning horizon)** since US interventions are usually announced (or “credible”) for a particular period, e.g. 4 years.
- ◆ **al-Qaeda co-state omitted from US planning** since US is uncertain as to al-Qaeda’s objective, it is also ignorant of the value of x to its opponent

The Objectives

player 1 = US government:

$$\min_{0 \leq v(t)} \int_0^T e^{-rt} (C_1(x(t)) + C_2(w(t))) dt + e^{-rT} S(x(T))$$

player 2 = Al-Qaeda:

$$\max_{0 \leq w(t) \leq 1} \int_0^T e^{-rt} (D_1(x(t)) + D_2(w(t)) + D_3(v(t))) dt + e^{-rT} S(x(T))$$

- x ... number of terrorists at time t relative to their steady state population of terrorists in “peacetime”,
- w ... proportion of the steady state population of Al-Qaeda that commits (suicide) attacks at time t (control of player 2),
- v ... intensity of US counter-terror attacks (control of player 1).

The Hamiltonian Functions

player 1 = US government:

$$H_1 = -(c_1x + c_2w) + \pi_1(\gamma(1-x)x - \mu w - (\beta w + \varphi - \alpha v)v)$$

$$\frac{\partial H_1}{\partial v} = 0 \quad \Rightarrow \quad v^* = \frac{\beta}{2\alpha} w + \frac{\varphi}{2\alpha}$$

player 2 = Al-Qaeda:

$$H_2 = d_1x + \left(d_2 + d_3 \frac{\beta}{2\alpha}\right)w + d_3 \frac{\varphi}{2\alpha} + \\ + \pi_2 \left(\gamma(1-x(t))x(t) - \frac{\beta^2}{4\alpha} w(t)^2 - \left(\mu + \frac{\beta\varphi}{2\alpha}\right)w(t) - \frac{\varphi^2}{4\alpha} \right)$$

$$\frac{\partial H_2}{\partial w} = 0 \quad \Rightarrow \quad w^* = \frac{1}{\beta^2 \pi_2} (2\alpha d_2 + \beta d_3) - 2 \frac{\alpha \mu}{\beta^2} - \frac{\varphi}{\beta}$$

The Canonical System for $S(x(T)) = cx(T)$

$$\dot{x} = \gamma (1 - x) x + \frac{\mu}{\beta^2} (\alpha\mu + \beta\phi) - \frac{1}{4\alpha\beta^2\pi_2^2} (4\alpha^2 d_2^2 + 4\alpha\beta d_2 d_3 + \beta^2 d_3^2),$$

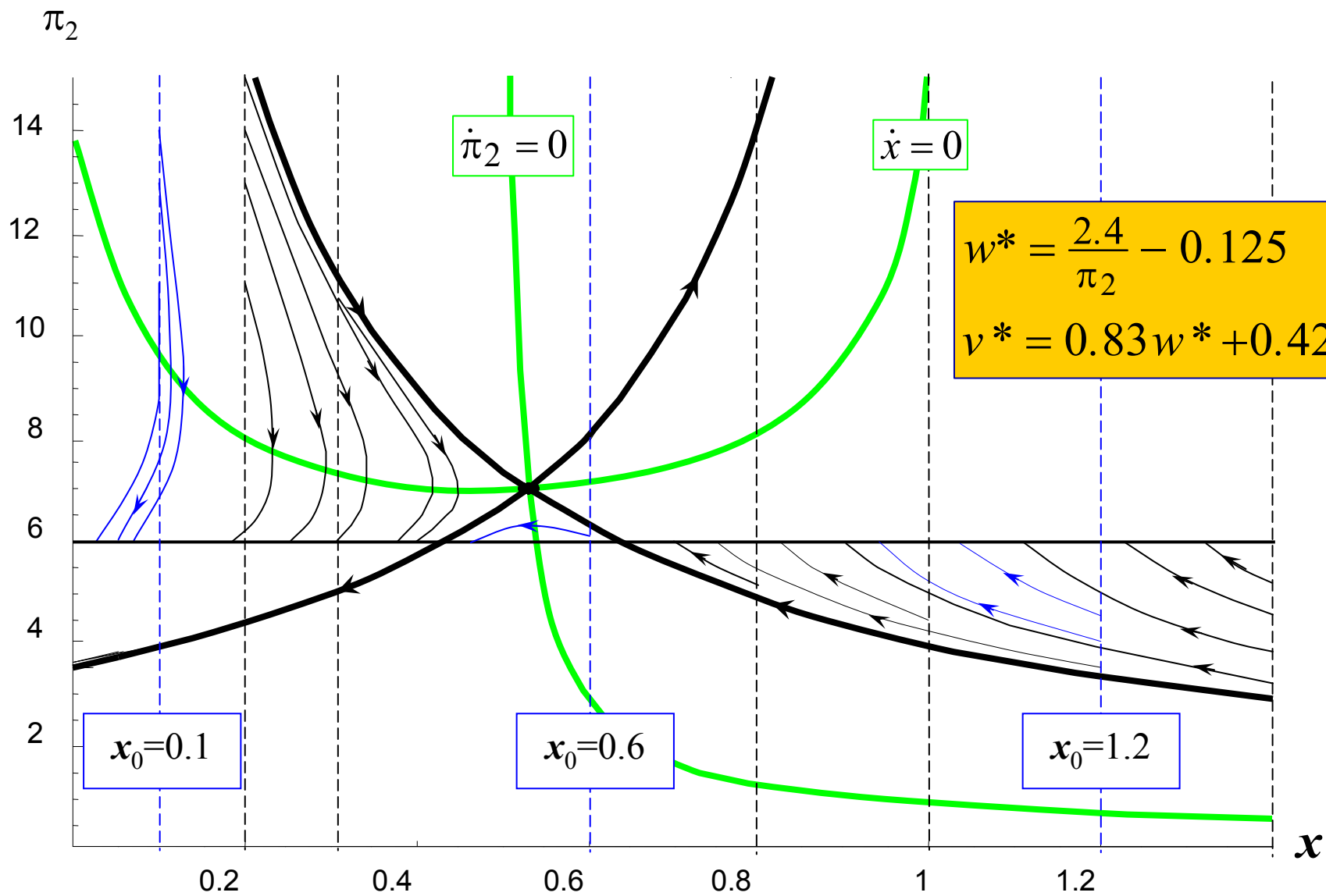
$$x(0) = x_0,$$

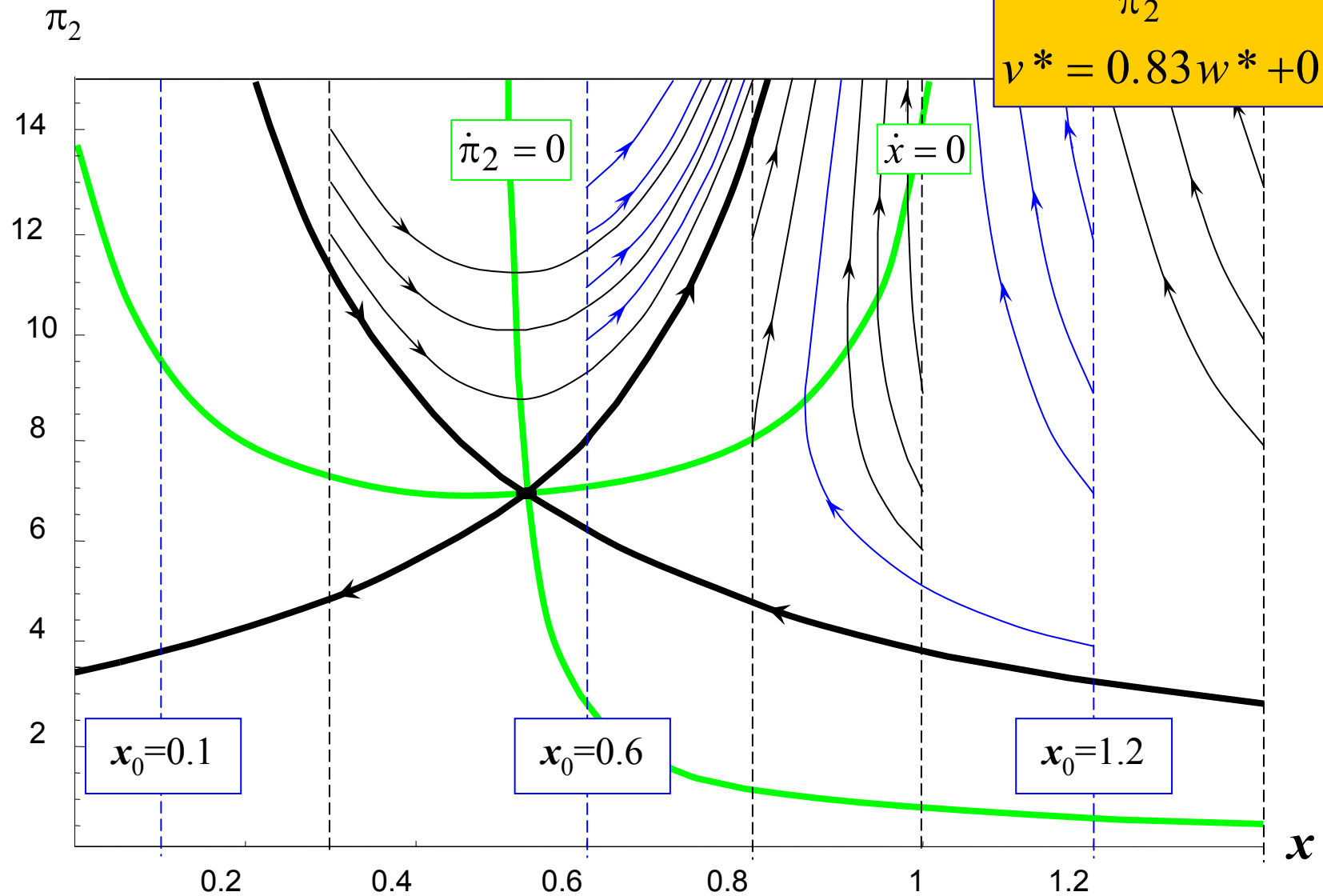
$$\dot{\pi}_2 = (r - \gamma + 2\gamma x) \pi_2 - d_1,$$

$$\pi(T) = c.$$

Base Case Parameter Values

	Interpretation of the Parameter	Value	Interval
γ	Endogenous growth rate of terrorist organization	1.5	1.5-2.0
μ	Average number of terrorists killed or arrested	1	–
α	Growth rate of terrorist organization due to hatred caused by collateral damage induced by US counter-offences	6	3-12
β	Ratio of Al-Qaeda operatives lost per successful attack when the US is on full counter-offensive vs. none at all	10	5-20
ϕ	Rate at which counter-terror operations would deplete Al-Qaeda operatives for $\nu = 1$	0.5	0.25-1.0
r	Discount rate	0.05	0.03-0.05
d_1	Relative importance of the terrorists strength	1	–
d_2	Relative importance of bringing threat to the west	20	1-20
d_3	Relative importance of counter-terror operations	0	0-20





$$w^* = \frac{2.4}{\pi_2} - 0.125$$

$$v^* = 0.83w^* + 0.42$$

Extension to Meta-game

- ◆ Osama bin-Laden has an objective that he knows, but George Bush does not
- ◆ George Bush decides what the US will presume is al-Qaeda's objective
- ◆ Osama bin-Laden decides whether to attack on September 11th
- ◆ If Osama bin-Laden attacks, terror war is played as above but with US presuming al-Qaeda's objective is as guessed by Bush

Punch Line of (Almost Completed) Extension

	Osama wants a “Clash of Civilizations”	For Osama “Terror is politics by other means”
Bush believes it’s a clash of civilizations	Terror war; many deaths	Terror war; Osama gets what he wants
Bush believes Osama wants to overthrow House of Saud	Terror war; US too cautious	???

Punch Line of (Almost Completed) Extension

	Osama wants a “Clash of Civilizations”	For Osama “Terror is politics by other means”
Bush believes it’s a clash of civilizations	Terror war; no one wins	Terror war; Osama gets what he wants
Bush believes Osama wants to overthrow House of Saud	Terror war; US too cautious	September 11 th never happens