The Arab Spring: A simple compartmental model for the dynamics of a revolution

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- ongoing work with my PhD student John Lang
- observation: ‘new types of connectivity’ between people appear to have an important influence on social processes
- can we use mathematics and network theory to try to model and understand some of this?
- our starting point: what is the simplest (ODE) dynamical model that can capture essential aspects of the Arab Spring revolutions? (including the influence of ‘new media’)

1. Introduction

'new types of connectivity' between people appear to have an important influence on social processes

- examples:
  - **protest movements:** Quebec student protests, Idle No More, BC HST referendum, Occupy, Stuttgart 21,. . . (note: both 'progressive' and 'conservative' causes!)
  - **riots:** London, Vancouver Stanley Cup, . . . (note: both rioters and law enforcement use new media!)
  - **how democracies work:** fundraising, elections (Obama 2.0), timescales of public opinion formation and election cycles, . . .

Introduction

‘new types of connectivity’ between people appear to have an important influence on social processes

- more examples:
  - **advertising and e-commerce:** Google, Gmail, Google AdWords, Google News; iTunes; Yelp, TripAdvisor; growth of Facebook versus Google+, . . .
  - **societal norms and morality:** ‘internet morality police’ in China, punishment of plagiarizing professors, internet mobs (influences legal system!)
  - **revolutions:** are the dynamics of revolutions tied to the underlying social network connectivity?; we consider the Arab Spring

- social processes result from a balance between many forces; changes in social network connectivity may change the status quo (sometimes dramatically)

Introduction

- can we use mathematics and network theory to try to model and understand how changing connectivity between people may influence social processes?
  - sure, mathematicians (or social scientists) can always try to come up with models . . .
  - but is there any quantitative data to go by? . . . well . . . online social networks may provide useful dynamic data? stay tuned

- our starting point: what is the simplest (ODE) dynamical model that can capture essential aspects of the Arab Spring revolutions, taking the influence of 'new media' into account (in a rudimentary way)

2. Modelling Arab Spring Revolutions

"After decades of political stagnation... new winds of hope were felt in the Middle East, accompanied by a new catchword making the rounds in the American media, 'Arab Spring'... The age of the old patriarchs, it appeared, was nearing its end. And the new media - satellite television, mobile phones, the Internet - were often regarded as having precipitated this development by undermining governments' hegemonic control over the flow of information."

– Hofheinz (2005)

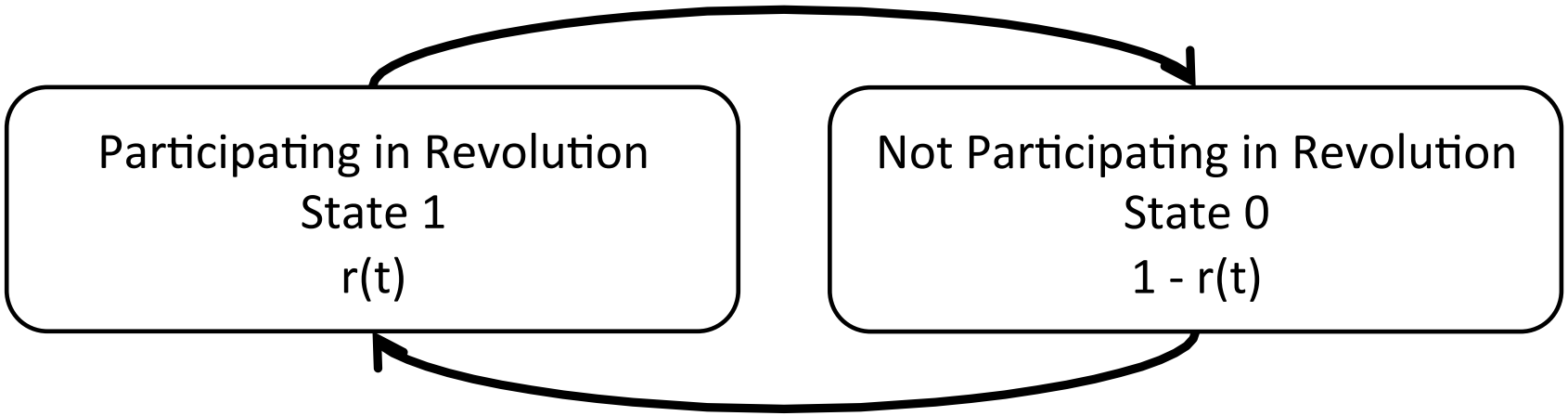
$\Rightarrow$ this was about modest advancements in democracy and political liberalization in a handful of Middle Eastern countries in 2005

but bigger events ensued in January 2011 . . .

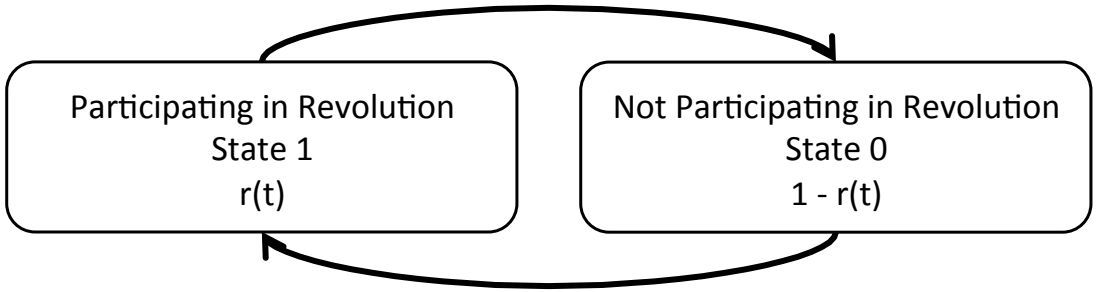
Figure 1: Tahrir Square (Mohammed Abed, AFP/Getty Images.)

2.1 A Conceptual Model for Arab Spring Revolutions

- consider regimes that employ
  - censorship to control the media
  - police repression of political dissent
- assumption: the regime is very unpopular and all individuals would privately like to see the regime changed
- simplest compartmental model:



A Conceptual Model for Arab Spring Revolutions



- consider regimes employing censorship and police repression, and assume the regime is very unpopular
- simple ODE: growth and decay terms

$$\dot{r} = \underbrace{c_1\ v(r;\alpha)\ (1-r)}_{g(r)} - \underbrace{c_2\ p(r;\beta)\ r}_{d(r)}, \tag{1}$$

- growth (with timescale c_1) only when the revolution is large enough to be *visible* to the population despite censorship
- decay (with timescale c_2) only when the revolution is sufficiently small that the police can suppress it

A Conceptual Model for Arab Spring Revolutions

$$\dot{r} = \underbrace{c_1\ v(r;\alpha)\ (1-r)}_{g(r)} - \underbrace{c_2\ p(r;\beta)\ r}_{d(r)}, \tag{1}$$

- most simple conceptual model that captures essential aspects:
  - growth only when the revolution is large enough to be *visible* to the population despite censorship (step function visibility $v(r;\alpha)$)
  - decay only when the revolution is sufficiently small that the police can suppress it (step function policing $p(r;\beta)$)

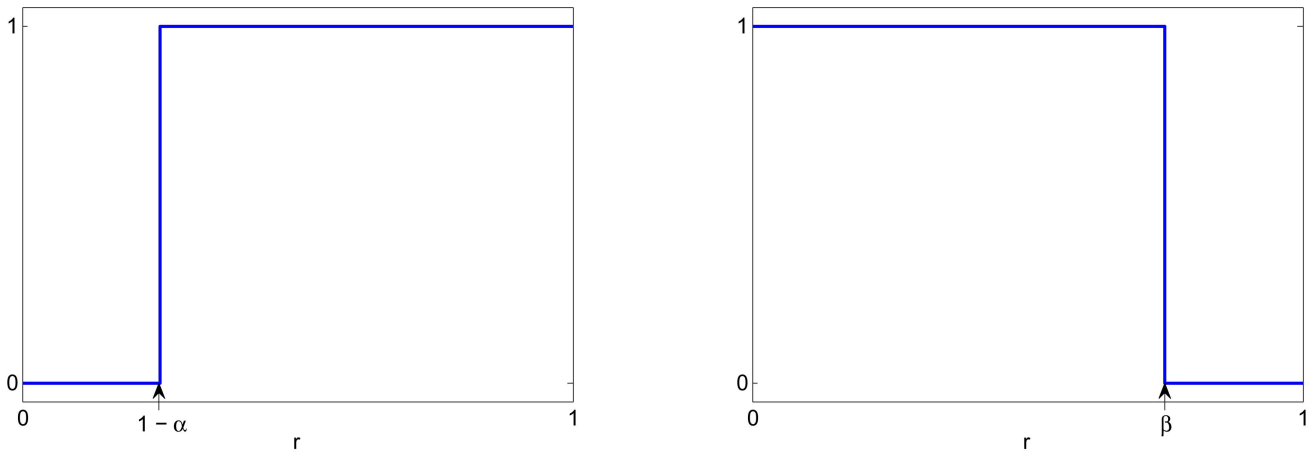


Figure 2: visibility $v(r;\alpha)$ and policing $p(r;\beta)$ functions

Further Justification of Visibility Step Function

Collective action problem: if individuals protest in sufficient numbers then the state loses its ability to punish (Kuran, 1992). Suppose

- $\bar{\rho}$ is the average degree
- θ is the min. fraction of neighbours necessary to consider joining

$$\dot{r} = (1 - r) \times \underbrace{\text{prob. consider joining}}_{v(r;\alpha)} \times c_1 \tag{2}$$

$$v(r;\alpha) = \sum_{k=\lceil \theta\bar{\rho} \rceil}^{\lfloor \bar{\rho} \rfloor} \binom{\lfloor \bar{\rho} \rfloor}{k} r^k (1-r)^{\lfloor \bar{\rho} \rfloor - k} = \text{Binom}(\lfloor \bar{\rho} \rfloor - \lceil \theta\bar{\rho} \rceil; \lfloor \bar{\rho} \rfloor, 1 - r)$$

Further Justification of Visibility Step Function

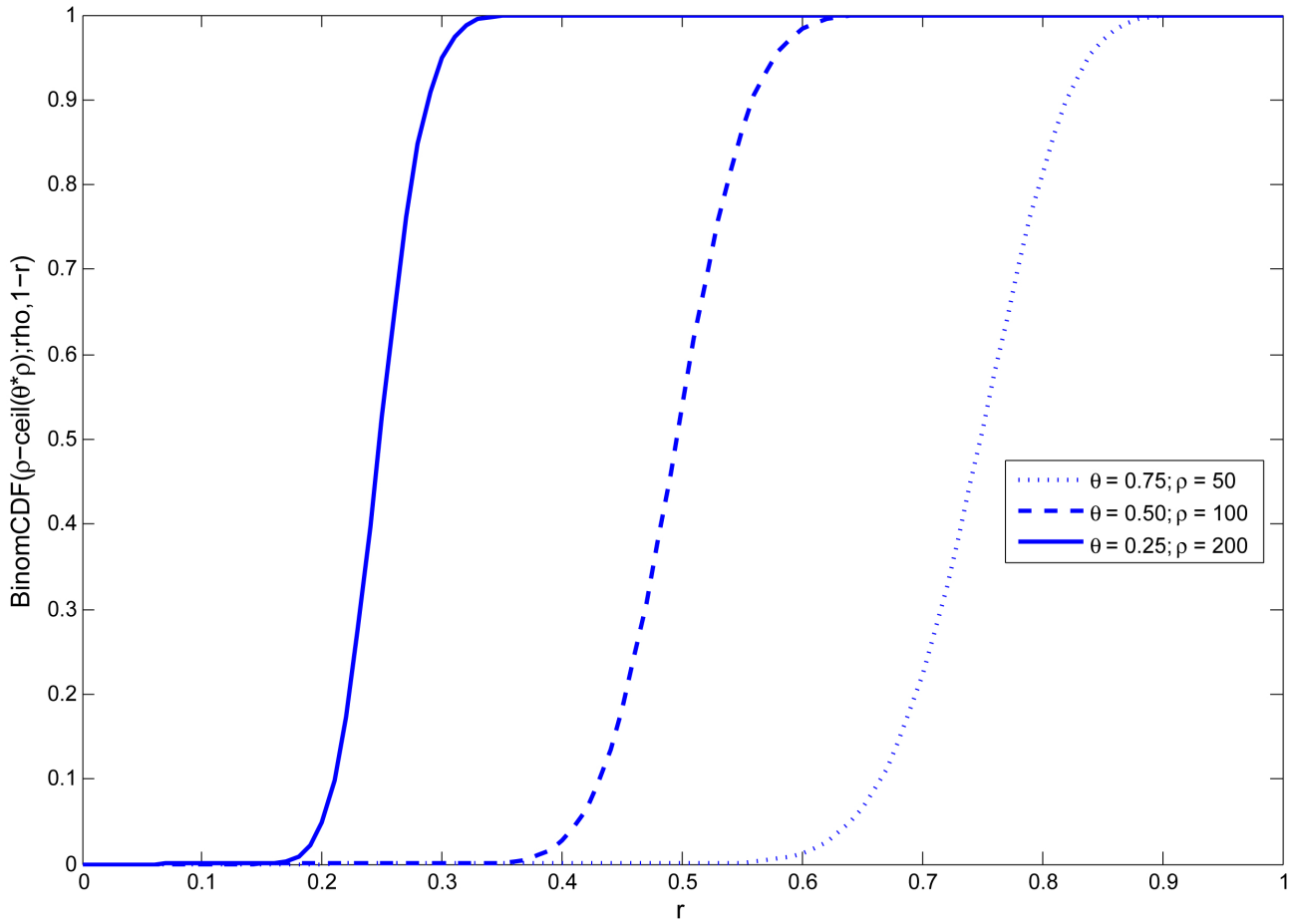
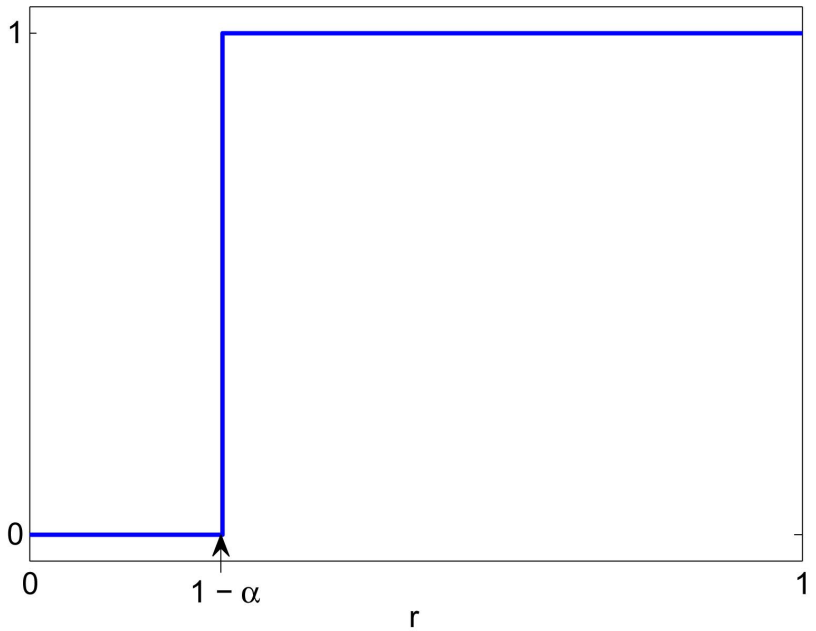
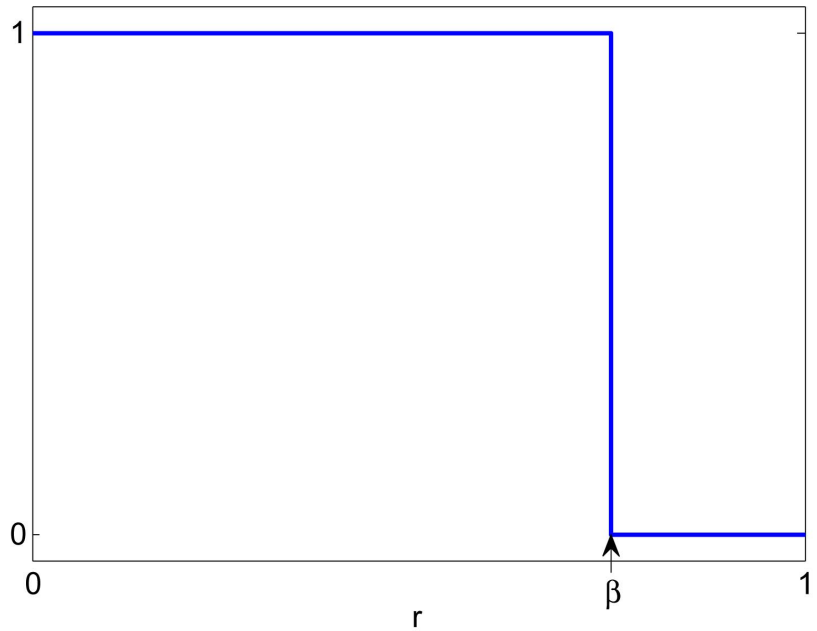


Figure 3: Dependence on negatively correlated θ and $\bar{\rho}$.

A Conceptual Model for Arab Spring Revolutions

$$\dot{r} = \underbrace{c_1\ v(r;\alpha)\ (1-r)}_{g(r)} - \underbrace{c_2\ p(r;\beta)\ r}_{d(r)}, \tag{1}$$





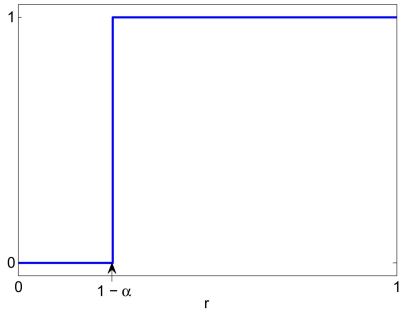
Open Questions:

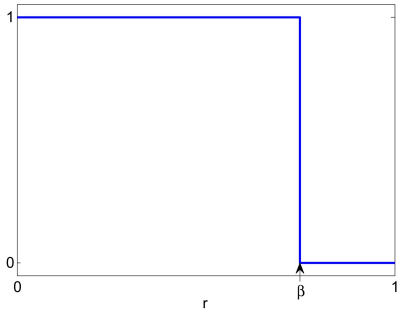
1. How can a small number of active social media users and relatively low Internet penetration[1] have a dramatic effect on the stability of a regime?,
2. How is it that regimes manage to seem so stable until the revolution is underway?,
3. Why did the January 28 - February 1, 2011, Internet shutdown in Egypt not have a greater inhibitory effect on protests?, and
4. Why is it that some regimes fall in a matter of weeks, others fight to a stalemate, and still others survive relatively unscathed?

[1] According to Howard et al. (2011) approximately 25% of Tunisians and 10% of Egyptians had used the Internet at least once prior to the Arab Spring.

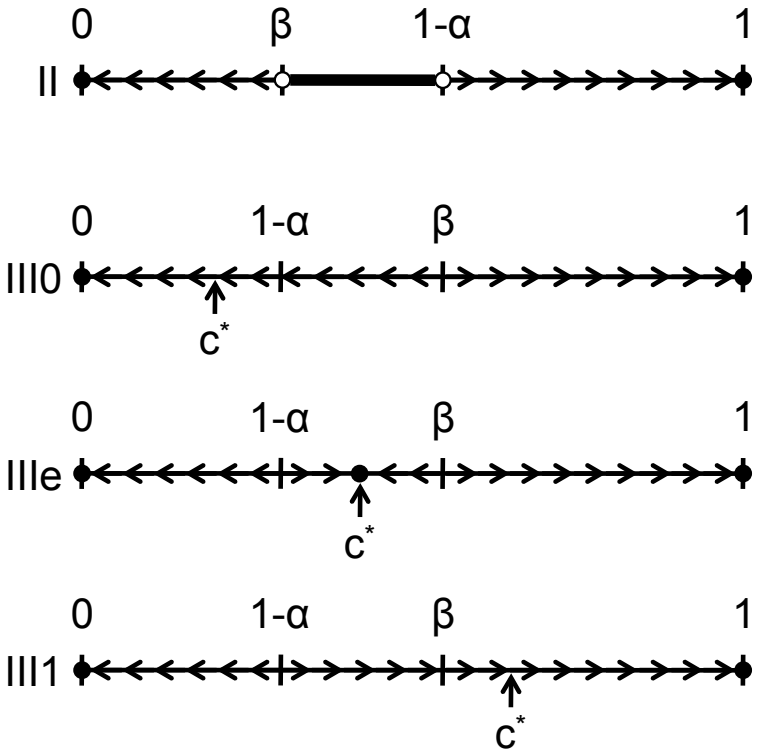
2.2 Elementary Model Analysis

Dynamics of Parameter Space





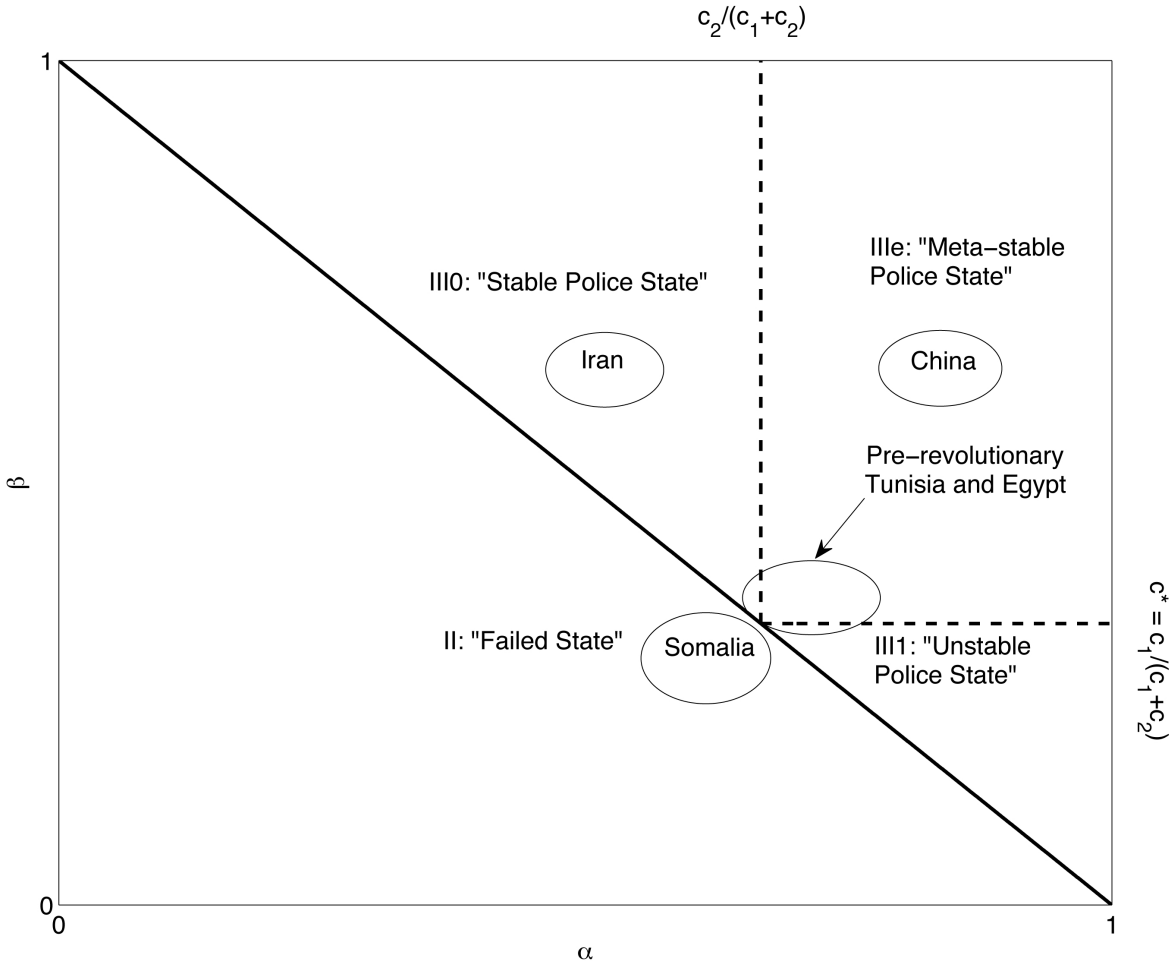
$$\dot{r} = c_1\ v(r;\alpha)\ (1-r) - c_2\ p(r;\beta)\ r$$

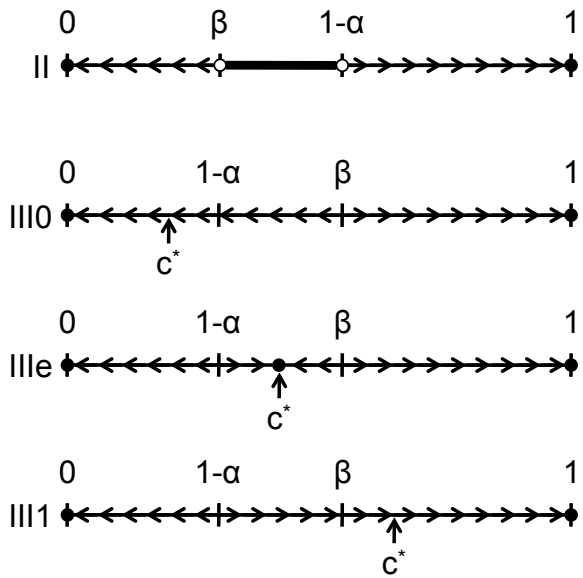


$(c^* = c_1/(c_1 + c_2))$

Elementary Model Analysis

Summary of Parameter Space





Interpretation

Effect of Technology on Parameters

$$\dot{r} = \underbrace{c_1\ v(r;\alpha)\ (1-r)}_{g(r)} - \underbrace{c_2\ p(r;\beta)\ r}_{d(r)},$$

Internet, social media, satellite TV, and cell phone communications technologies may empower protesters by enhancing their[2]

1. capacity for organization and coordination (c_1),
2. ability to assess the current public support for the revolution (α), and
3. awareness of the nature and severity of government repression (α and c_1).

[2][Beckett C. (2011), Husain M. and Pollack R. (2011), Pollock J. (2011), Schneider C.L. (2011)]

Interpretation

Effect of Technology on Parameter α

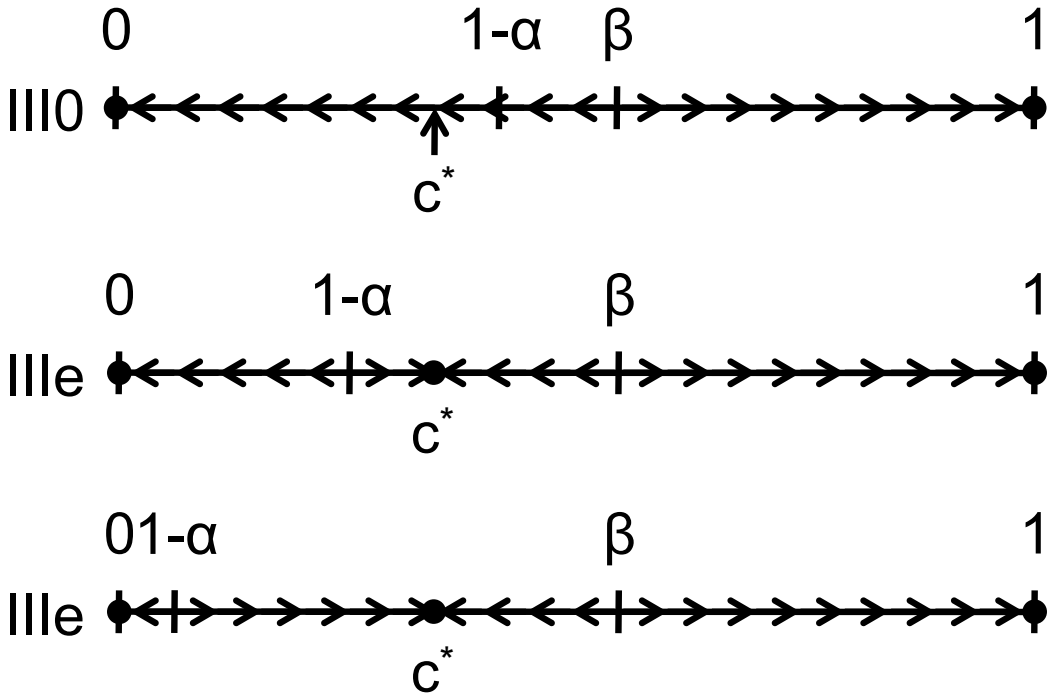


Figure 4: Increasing α (protesters become more visible).

Interpretation

Effect of Technology on Parameter c_1

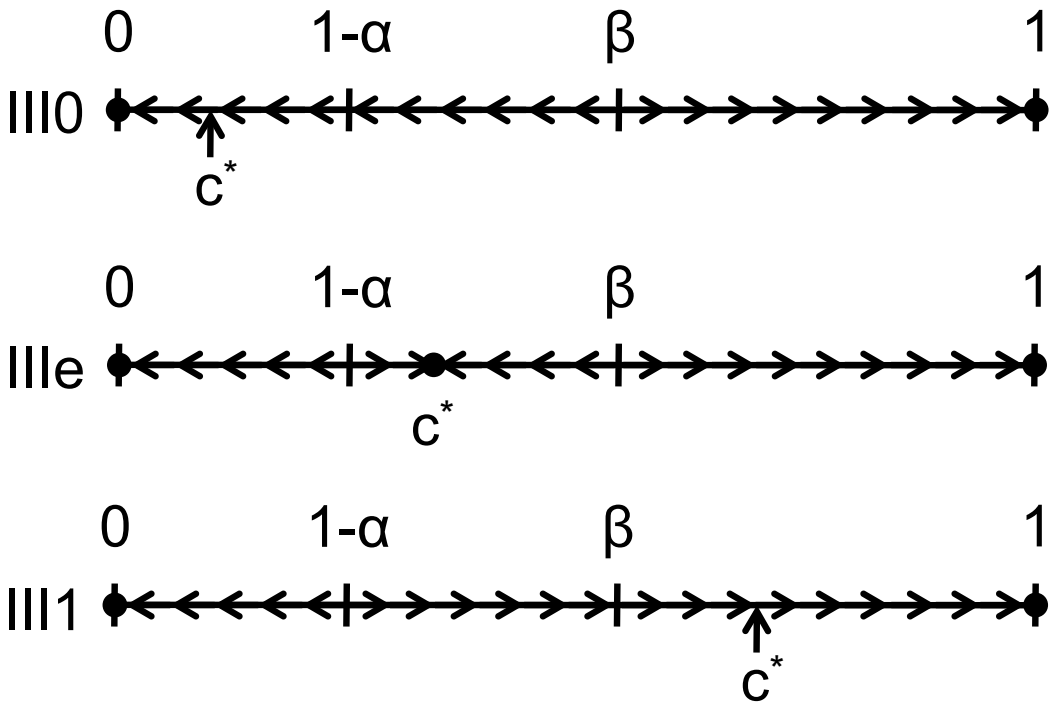
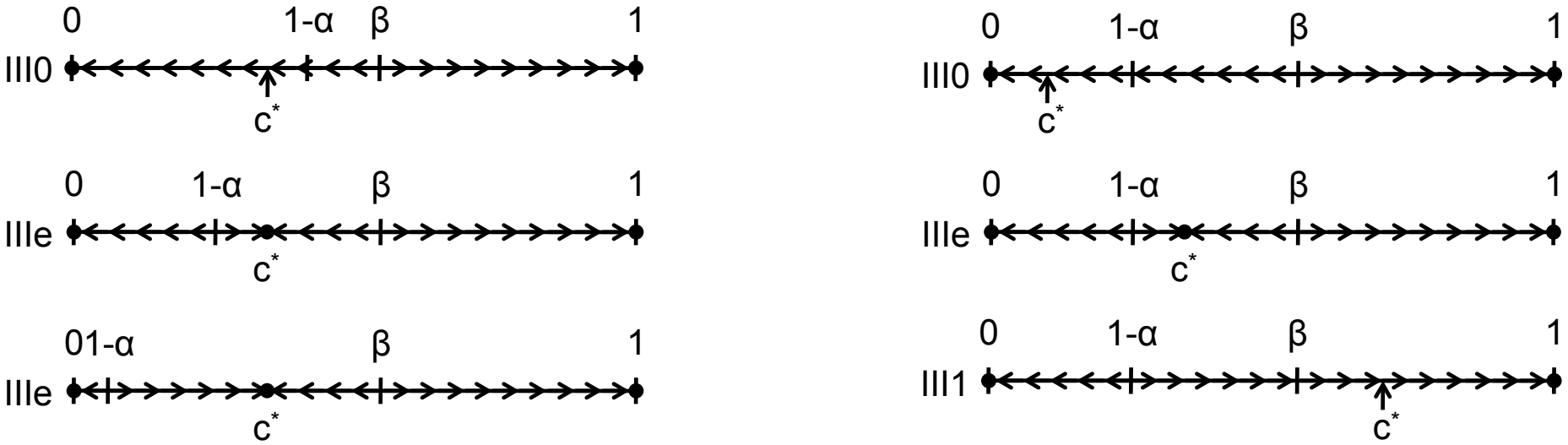


Figure 5: Increasing c_1 (protesters become more motivated).

2.3 Case Study: Tunisia

Question 1

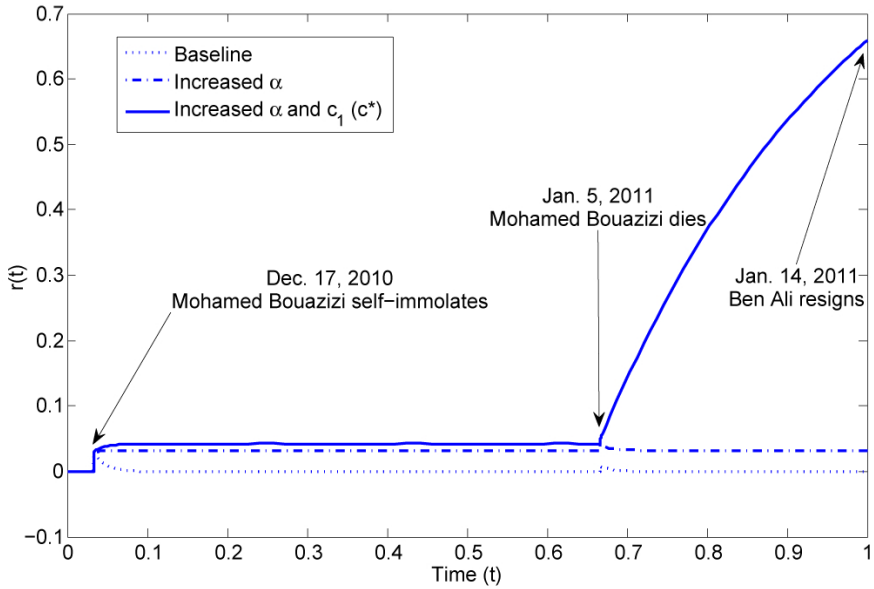
1. How can a small number of active social media users and relatively low Internet penetration have a dramatic effect on the stability of a regime?



small changes in α and c_1 may move parameters from III0 to IIIe; two small 'shocks' (much more likely!) may then suffice

Case Study: Tunisia

Question 1



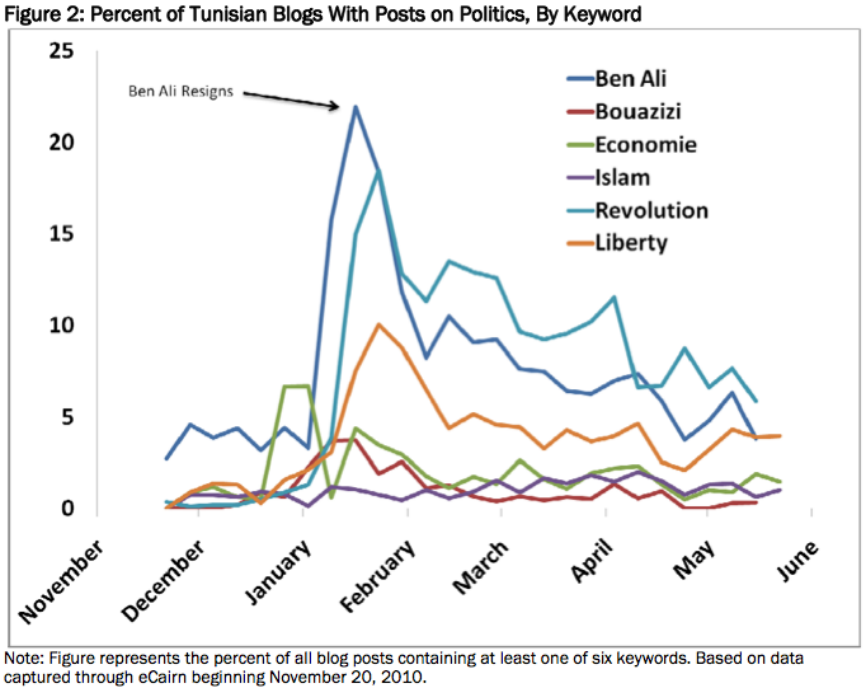


Figure 6: (Left) A possible scenario for the Tunisian Revolution. (Right) Blog data from Howard et al. (2011).

$\dot{r} = c_1\ v(r;\alpha)\ (1-r) - c_2\ p(r;\beta)\ r$

(baseline in III0, others in IIIe)

(small increase in α (2%) and moderate increase in c_1 (33%))

Case Study: Tunisia

Question 2

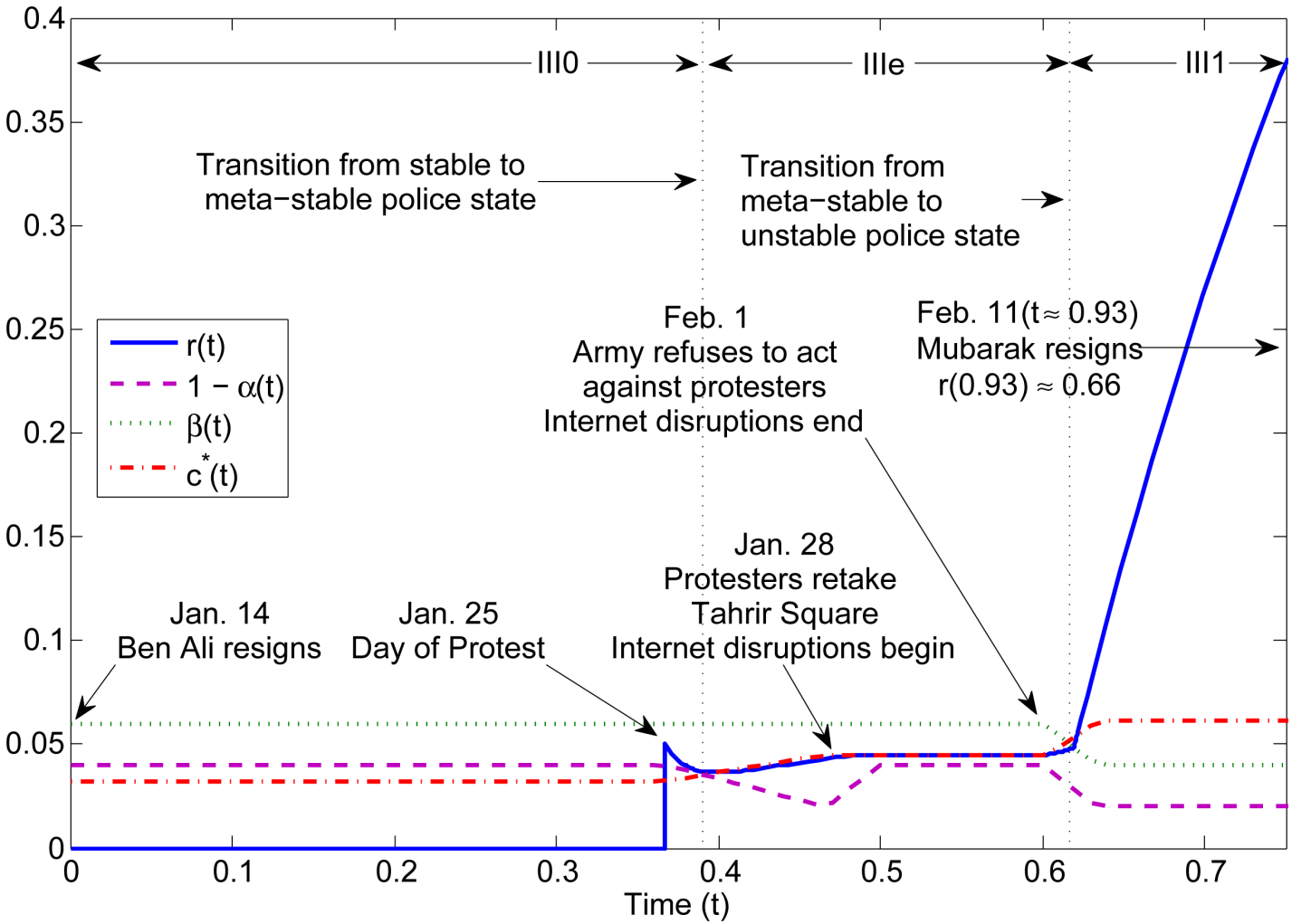
2. How is it that regimes manage to seem so stable until the revolution is underway?
    1. $r = 0$ always locally asymptotically stable,
    2. Large shocks are exceedingly rare, and
    3. Determining the values of the parameters/state of the regime is difficult.

2.4 Case Study: Egypt

Timeline

- Dec. 17, 2010: MB self-immolates in Tunisia
- Jan. 14-15, 2011: Tunisian revolution succeeds
- Jan. 25, 2011: Day of Protest in Tahrir Square
- Jan. 26, 2011: Police clear Tahrir Square
- Jan. 28, 2011: Protesters occupy Tahrir Square, Mubarak addresses nation, major Internet disruptions begin
- Feb. 1, 2011: US President Obama withdraws support for Mubarak regime, army refuses to act against protesters, major Internet disruptions end
- Feb. 2, 2011: State thugs attack protesters in Tahrir Square, army officers intervene on behalf of protesters
- Feb. 11, 2011: Mubarak resigns

Case Study: Egypt (Possible Scenario)



$$\dot{r} = c_1\ v(r;\alpha)\ (1-r) - c_2\ p(r;\beta)\ r$$

Summary of Parameter Space

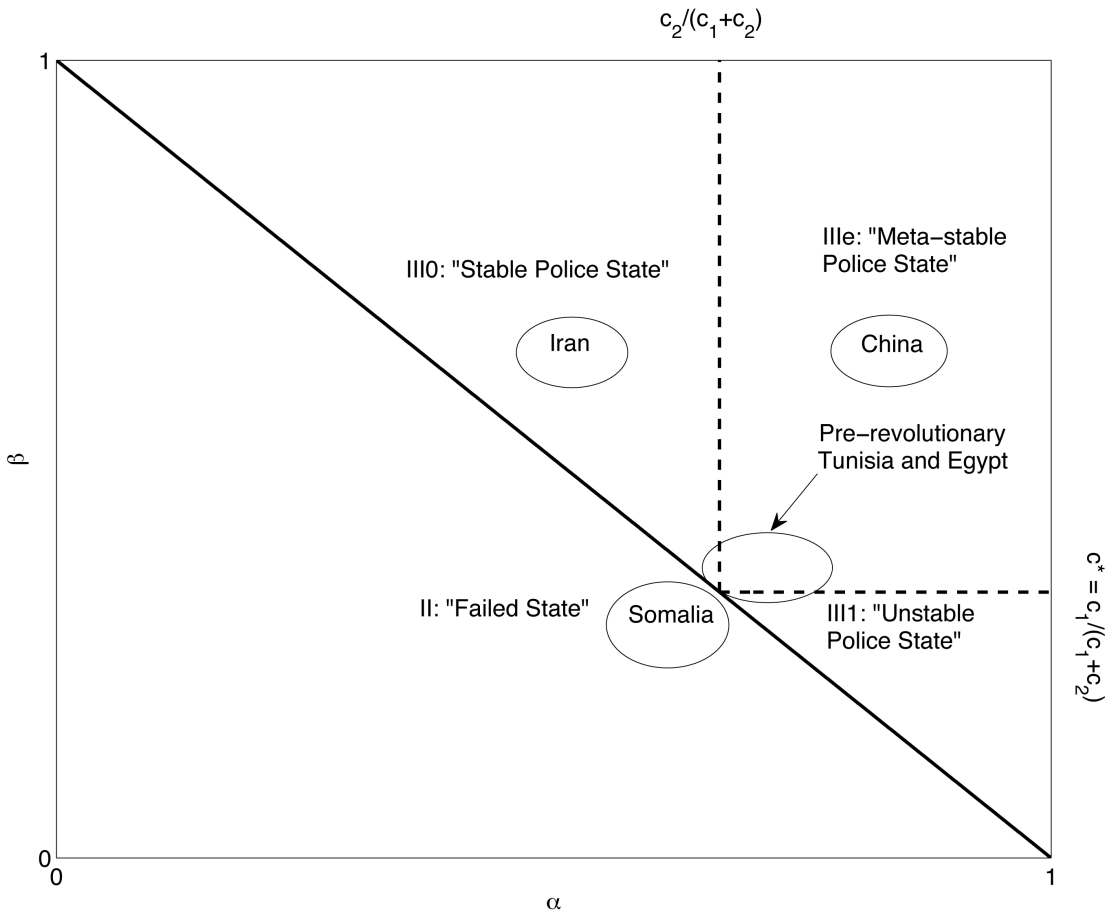
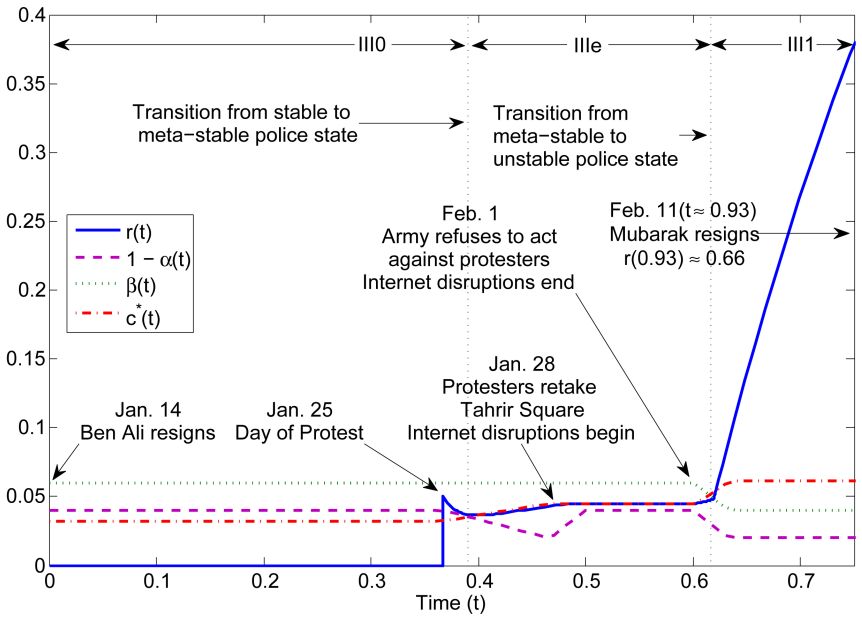


Figure 7: Regions II, III0, IIIe, and III1 in $\alpha - \beta$ parameter space.

Case Study: Egypt

Question 3



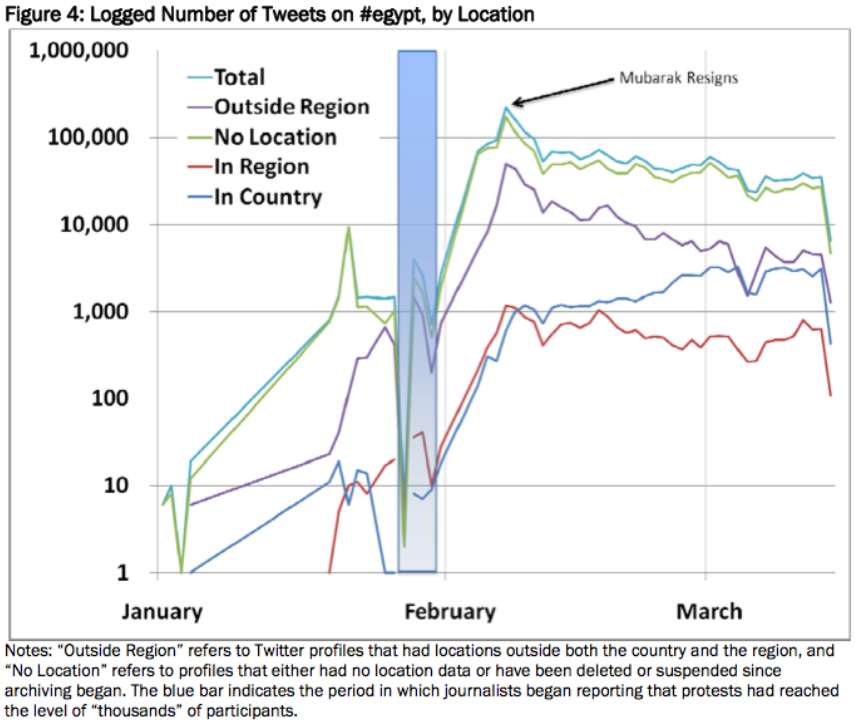


Figure 8: (Left) A possible scenario for the Egyptian Revolution. (Right) Twitter data from Howard et al. (2011)

Case Study: Egypt

Question 3

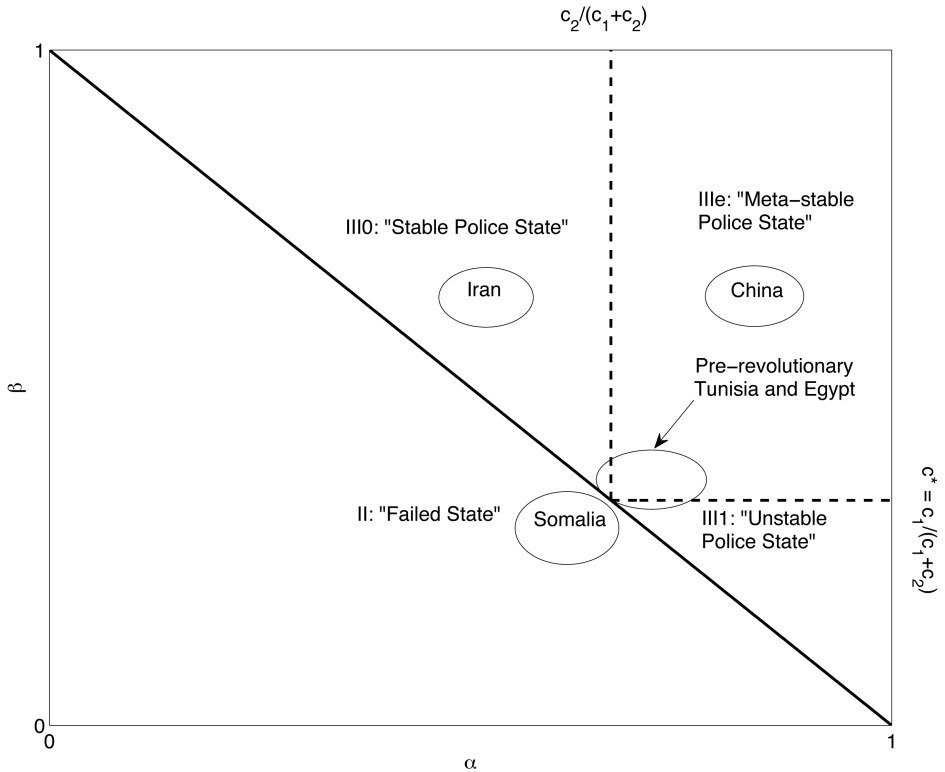
3. Why did the Jan. 28 - Feb. 1, 2011, Internet shutdown in Egypt not have a greater inhibitory effect on protests?

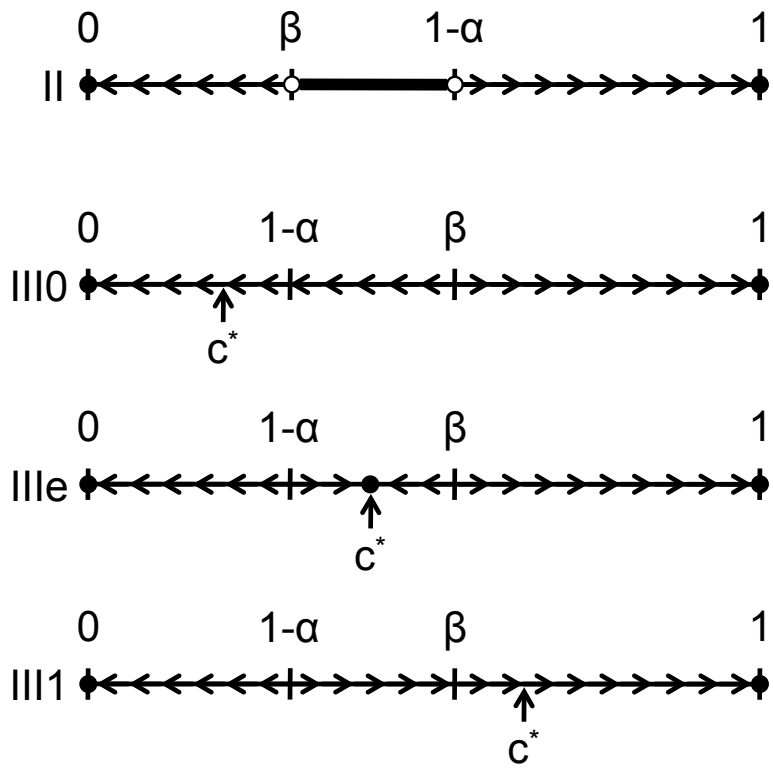
   - For censorship to succeed: $1 - \alpha > r$,

   - *Internet shutdown may have increased α, c_1 (Husain and Pollack, 2011)*

Question 4

4. Why is it that some regimes fall in a matter of weeks, others fight to a stalemate, and still others survive relatively unscathed?

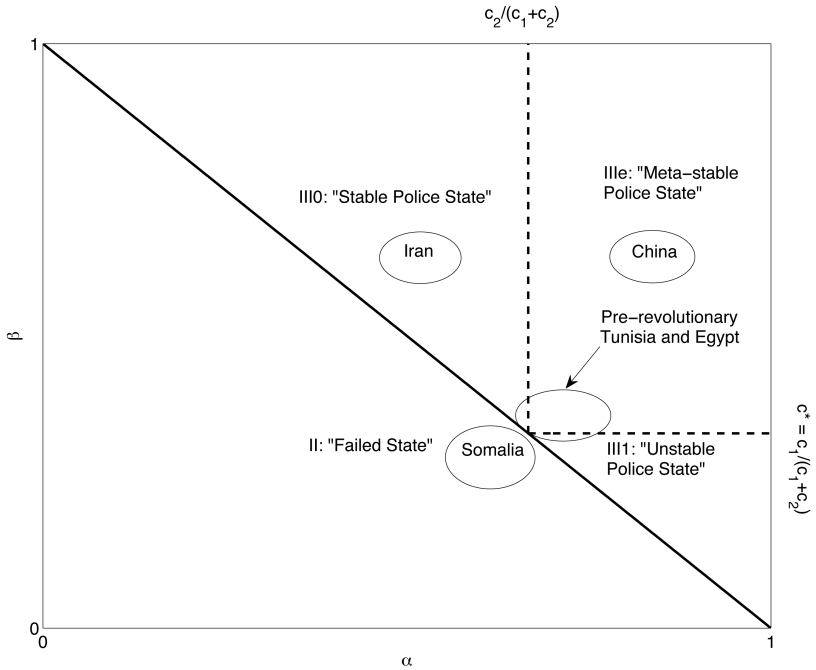




- Somalia:
  - weak media (low α) and weak central government (low β): region II

Question 4

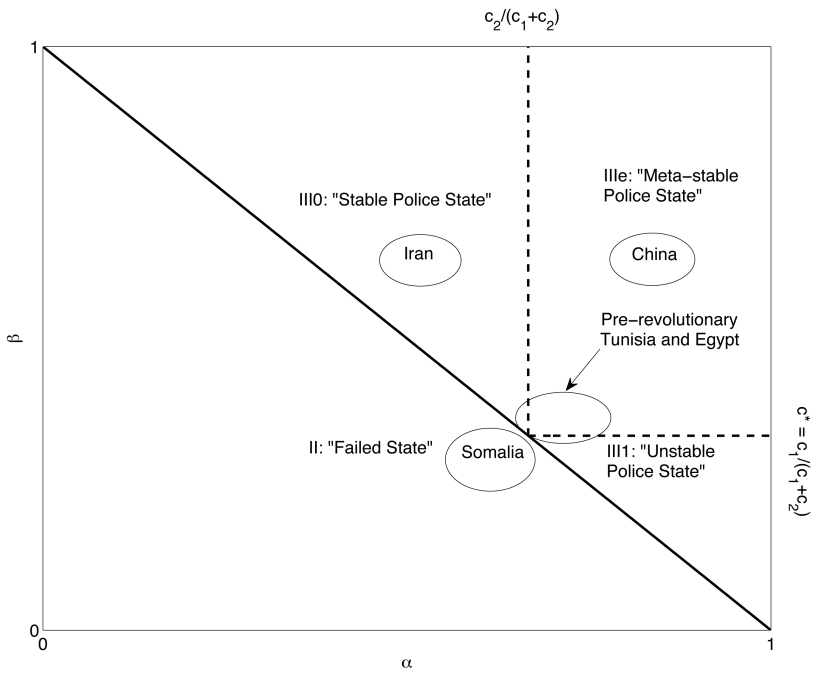
4. Why is it that some regimes fall in a matter of weeks, others fight to a stalemate, and still others survive relatively unscathed?



- Iran's 2009 'Green Revolution':
  - large β and c_2 (extensive government resources)
  - small α and c_1 (social media in infancy)
  - region III0, but more social networking, economic sanctions, 'outside examples' may change the balance

Question 4

4. Why is it that some regimes fall in a matter of weeks, others fight to a stalemate, and still others survive relatively unscathed?



- present-day China:
  - censorship to control the media/Internet, police repression of political dissent
  - 'The number of "mass group incidents" reported annually in China has been rising consistently for at least two decades' (Wedeman, 2009) (Region IIIe with rising c^*)

Twitter Data as a Window on Revolutionary Events

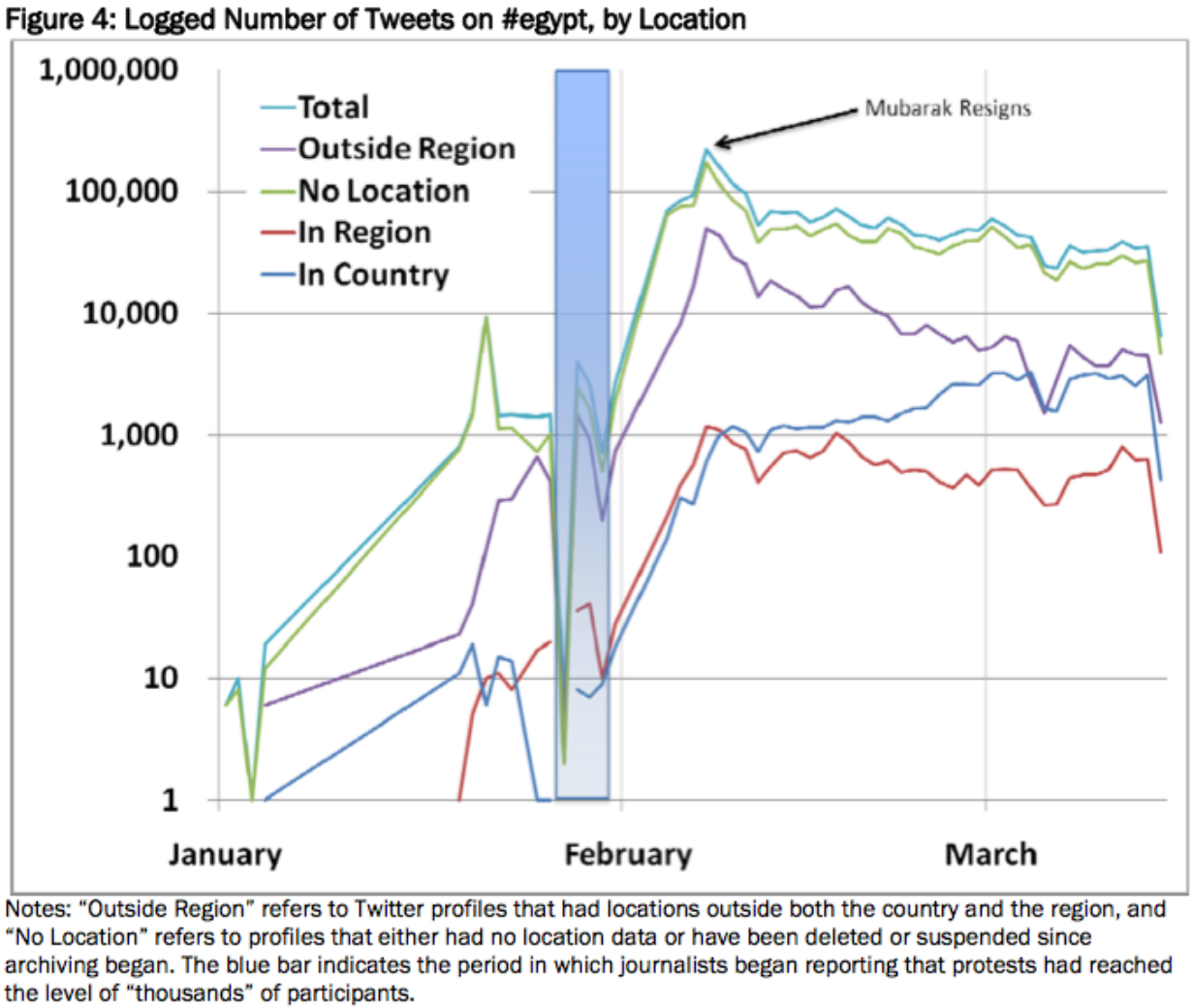


Figure 9: Twitter data from Howard et al. (2011)

Twitter Data as a Window on Revolutionary Events

- data from online social networks (Twitter, Facebook, Youtube, . . .) have the potential to provide a wealth of quantitative information on human social behaviour
- perhaps for the first time in history, this allows researchers to quantify human social behaviour ‘at scale’ and in real-time
- compare: it has taken only a few decades for biology to become a quantitative and data-driven science
- if this data becomes increasingly available, will parts of the social sciences also become quantitative and data-driven?

However . . . Online Social Network Data is Hard to Get!

- 'Twitter changed its terms of service on March 20, 2011, to disallow public sharing of tweets. . . . All tracking ends March 20, 2011 due to Twitter's terms of service change.' (Howard, 2011.)

- 'As you understand, there is a cost to the data. Our one-time historical projects start at a minimum $500 which covers up to 10 consecutive historical days of data.' (email from gnip.com)

- 'The Library of Congress is trying something slightly more ambitious than that: storing and indexing every tweet ever posted.' 'Nearly half a billion tweets each day as of October 2012.' 'They are starting to address the significant technology challenges in making the archive accessible to researchers in a comprehensive, useful way.' (You may need Google's infrastructure and engineers for this. . .)

Online Social Network Data is Hard to Get!

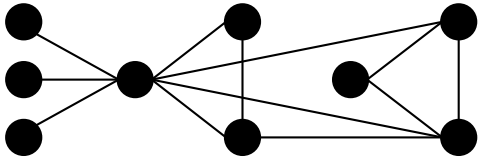
- my take on this: there is enormous potential in online social media data to do good (and bad!) things
- social network data is way too powerful/valuable to leave it in the hands of a few dominant (American) commercial companies
- it's perhaps not so surprising that China is adamant on having its own versions of Facebook, Twitter, Youtube, Google, . . . (good policy?)
- some people have brought up the idea of 'nationalizing' online social networks (as public-interest infrastructure, like roads and bridges and market squares, operated by tax revenues, rather than by selling personal data) (this may at least solve some issues like privacy and social media policing...)
- I hope we can at least get access to data for research!

2.5 Summary of Arab Spring Compartmental Model

- Established a simple two-compartment model for a revolution (in regimes that employ censorship and police repression)
- Visibility and police capacity terms with step function form, for which we provided conceptual and network-based justifications
- Identified four realistic parameter regions
  - Considered case-studies of Egypt and Tunisia, compared with Howard et al (2011)
  - Consider case studies of Iran, China, and Somalia
- Provided a unified framework for answering four revolution-related questions
- But our goal was: the simplest (ODE) dynamical model that can capture essential aspects of the Arab Spring revolutions; so this is only a start . . .

3. Future Directions

Moving up the Ladder



Agent-based

↓ Trpevski, Tang, and Kocarev (2010)
↓ Macal and North (2010)

Effective Degree

↓ Lindquist et al. (2011)
↓ Hadjichrysanthou, Broom, and Kiss (2012)

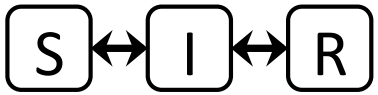
Nekovee

↓ Moreno, Nekovee, and Pacheco (2004)
↓ Nekovee et al. (2007)

Moment Closure

↓ Bauch (2002)
↓ Demirel et al. (2011)

Compartmental



Khelil (2002)
Zhao et al. (2011)

Probability Generating Function (Bond Percolation)

Watts (2002)
Meyers (2006)

Partial Differential Equation

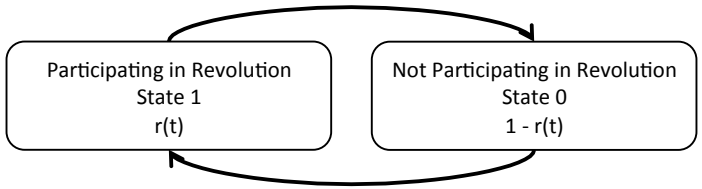
Short et al. (2008)

Stochastic Processes

Nasell (2002)

Future Directions

- extend and apply model to
  - Bahrain
  - Lybia
  - Syria



- 'the regime is very unpopular and all individuals would privately like to see the regime changed' $\longrightarrow$ religious/ethnic/tribal/elite allegiances (stalemate more likely) ('$0.7 - r(t)$')

- outside influences appear more important

- extend and apply model to the collapse of Eastern Europe's communist regimes (censorship and police repression)

Future Directions

Understanding the Influence of Network Properties on Social Dynamics

- Study the differences in network properties for
  - social connections via ‘new media’ (online networks)
  - traditional social connections
- What are the differences that matter? (statistically, connectivity, . . .) (inspiration from infectious disease modelling)
- How much do these differences influence social events? (like revolutions)
- There is ample ‘online networks’ data (in principle), but is there any ‘traditional networks’ data (at scale?)

Future Directions

Understanding the Influence of Network Properties on Social Dynamics

- Consider using network models
- Use real network data (Twitter, Facebook, Youtube, etc.) and person-person networks
- Develop models on these networks (opinion formation, collective action, agents/DEs/degree approximations/...)
- We have lots of work to do, and the time may be ripe (because the technology for gathering quantitative data is there ...)

Thank you!

References

Bauch C.T. (2002). A versatile ODE approximation to a network model for the spread of sexually transmitted diseases. *J Math Biol*, **45**: 375-395.

Beckett C. (2011). After Tunisia and Egypt: towards a new typology of media and networked political change. *Blog*, Accessed August 27, 2012: http://blogs.lse.ac.uk/polis/2011/02/11/after-tunisia-and-egypt-towards-a-new-typology-of-media-and-networked-political-change/

Demirel G. et al. (2011). Cyclic dominance in adaptive networks. *Eur Phys J B*, **84**: 541-548.

Hadjichrysanthou C., M. Broom, and I.Z. Kiss. (2012). Approximating evolutionary dynamics on networks using a Neighbourhood Configuration model. *J Theor Biol*, **312**: 13-21.

Hofheinz A. (2005). The Internet in the Arab World: Playground for Political Liberalization. *International Politics and Society*, 3: 78–96.

Howard P.N. et al. (2011). Opening Closed Regimes: What was the Role of Social Media During the Arab Spring? *PITPI*, Research Memo. Seattle, University of Washington.

Husain M. and R. Pollack (2011). How Facebook Changed the World: The Arab Spring. *BBC*, Accessed May 25, 2012: http://www.bbc.co.uk/programmes/b014grsr.

Khelil A. C. et al. (2002).An Epidemic Model for Information Diffusion in MANETs. *Proceedings of the 5th ACM*: 1-7.

Lindquist J. et al. (2011). Effective degree network disease models. *J Math Biol*, **62**: 143-164.

Macal C.M. and M.J. North. (2010). Tutorial on agent-based modelling and simulation. *Journal of Simulation*, **4**: 151-162.

Meyers L.A. (2007). Contact network epidemiology: Bond percolation applied to infectious disease prediction and control. *B M Math Soc*, **44**(1): 63-86.

Moreno Y., M. Nekovee, and A.F. Pacheco. (2004). Dynamics of rumour spreading in complex networks. *Phys Rev E*, **69**: 066130.

Nasell I. (2002). Stochastic models of some endemic infections. *Math Biosci*, **179**(1): 1-19.

Nekovee M., Y. Moreno, G. Bianconi, M. Marsili. (2007). Theory of rumour spreading in complex social networks. *Physica A*, **274**: 457-470.

Pollock J. (2011). Streetbook: How Egyptian and Tunisian youth hacked the Arab Spring. *Technology Review*, Accessed August 24, 2012: http://www.technologyreview.com/featured-story/425137/streetbook/.

Schneider C.L. (2011). Violence and State Repression. *Swiss Political Science Review*, **17**(4):480-484.

Short M.B. et al. (2008). A statistical model of crimilar behavior. *Math Models Methods Appl Sci*, **18S**:1249-1267.

Trpevski D., W.K.S. Tang, and L. Kocarev. (2010). Model for rumour spreading over networks. *Phys Rev E*, **81**: 056102.

Watts D.J. (2002). A simple model of global cascades on random networks. *PNAS*, **99**(9): 5766-5771.

Zhao L. et al. (2011). Rumour spreading model with consideration of forgetting mechanism: A case of online blogging LiveJournal. *Physica A*, **390**: 2619-2625.