Journal of Economic Behavior & Organization 141 (2017) 43–63

Contents lists available at ScienceDirect

Journal of Economic Behavior & Organization

journal homepage: www.elsevier.com/locate/jebo

# Criminal network formation and optimal detection policy: The role of cascade of detection☆

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ARTICLE INFO

*Article history:*
Received 11 January 2017
Received in revised form 18 May 2017
Accepted 9 June 2017
Available online 20 June 2017

*JEL classification:*
A14
C70
D85
K42

*Keywords:*
Criminal network
Cascade of detection
Network formation
Local complementarity
Detection policy

ABSTRACT

This paper investigates the effect of cascade of detection, how detection of a criminal triggers detection of his network neighbors, on criminal network formation. We develop a model in which criminals choose both links and actions. We show that the degree of cascade of detection plays an important role in shaping equilibrium criminal networks. Surprisingly, greater cascade of detection could reduce ex ante social welfare. In particular, we prove that full cascade of detection yields a weakly denser criminal network than that under partial cascade of detection. We further characterize the optimal allocation of the detection resource and demonstrate that it should be highly asymmetric among ex ante identical agents.

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## 1. Introduction

Criminal decision making is often interdependent. Social interaction is both theoretically and empirically identified as an important channel through which neighborhood criminal behavior affects individual criminal behavior. While the structure of social networks plays a key role in facilitating crimes, it can also be utilized by law enforcement agencies to trace linked criminals.[1] In a criminal network, detection of an agent could potentially trigger further detection of his network neighbors. We call this triggering effect *cascade of detection*. In this paper, we study how cascade of detection affects ex ante social welfare in the presence of endogenous network formation among criminals. Interestingly, we find that a *higher degree of cascade of*

☆ We gratefully acknowledge the comments and suggestions of the Editor, Daniel Houser, and two anonymous referees. We thank Ying Chen and M. Ali Khan for several stimulating conversations; John Morris for professional editing and proofreading; Nizar Allouch, Amitabh Basu, Michael Dinitz, Hülya Eraslan, Jean Guillaume Forand, Timo Hiller, Edi Karni, Jiaxiong Yao, Jan Zapal, Yongchao Zhang, and Junjie Zhou for helpful comments. We also thank our discussants, Filippo Pavesi and Benjamin Schwall, along with seminar and conference participants at the Johns Hopkins University, Stony Brook Game Theory Festival, SAET Conference, Econometric Society China Meeting, Econometric Society Asia Meeting, Annual Conference on Network Science in Economics, Eastern Economic Association Annual Conference, and Southern Economic Association Annual Meetings for comments. All errors are ours.

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[1] For recent empirical work, see Lindquist and Zenou (2014), Rostami and Mondani (2015), among others.

http://dx.doi.org/10.1016/j.jebo.2017.06.002
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*detection may backfire*. The relationship between the degree of cascade and ex ante social welfare is nonmonotonic. Although enhancing cascade of detection is ex post efficient, it could be ex ante suboptimal precisely because criminal network formation adjusts based on the degree of cascade. Under a higher degree of cascade, as the additional cost of connecting to an indirect network neighbor becomes lower, criminals become less selective in choosing their linking partners, thus rendering a denser equilibrium network. Our work highlights that the degree of cascade of detection has very nuanced implication on social welfare, thereby shedding light on the nexus between law enforcement and criminal networks.

In our model, the government first announces a detection policy. It consists of two components, the degree of cascade and the allocation of the detection budget. The former is the key innovating feature of our model. After observing the detection policy, agents play a two-stage game. In the first stage, they propose links to each other, which require bilateral consent. Creating a new link does not incur any explicit cost, but a well-connected agent tends to be more likely to be detected. In the second stage, agents play a game with local complementarities in the fashion of Ballester et al. (2006). The payoff of an agent increases with his centrality in the network. Therefore, each agent is faced with the trade-off between increasing of his centrality in the network and being more likely to be detected. Under a given detection policy, we consider two equilibrium notions, pairwise stable Nash equilibrium and its refinement, strongly stable Nash equilibrium. We say an equilibrium is pairwise stable if it is stable against bilateral coordination of link formation (Jackson and Wolinsky, 1996; Hiller, 2014) and an equilibrium is strongly stable if it is stable against multilateral coordination of link formation (Jackson and van den Nouweland, 2005).

As a starting point, we consider three scenarios[2]: (1) no cascade of detection, detection of an agent does not trigger any further detection; (2) partial cascade of detection, detection of an agent only triggers detection of his direct network neighbors; (3) full cascade of detection, detection of an agent triggers detection of every agent who is directly or indirectly connected with him. We show that the equilibrium network in any pairwise stable Nash equilibrium, including the strongly stable Nash equilibrium, if any, under partial cascade of detection is weakly sparser than the equilibrium network in the unique strongly stable Nash equilibrium under full cascade of detection. This result holds for any allocation of the detection budget.

Using the unique strongly stable Nash equilibrium under full cascade of detection as a benchmark, we also fully characterize the optimal allocation of detection budget. We show that the optimal budget allocation is highly asymmetric among ex ante identical agents. Intuitively, when the government is unable to prevent agents from linking to each other, the best strategy is to minimize the number of linked agents. To achieve this, the government needs to create a certain gradient in terms of scrutiny among agents such that a subset of agents will be excluded from link formation.[3]

From a substantive point of view, our work shares with Garoupa (2007) the insights that stricter law enforcement could have unintended consequences, albeit through very different channels. Garoupa (2007) argues that more severe punishment tends to change the internal organization of criminal networks and consequently reduces effectiveness of the policy.[4] Using a very different framework, our work explicitly accounts for the network structure among criminals and its formation. With a network grounding, our model captures how aggregate criminal activity reacts to the cascade of detection and explains why ex ante social welfare could be dampened under stricter law enforcement.

Our paper is closely related to the literature on organized crimes and punishment. By allowing agents to choose between individual crime and organized crime, Chang et al. (2005) propose a natural way to endogenize the size of a criminal organization. Tractability of the model enables them to examine in detail the interaction between individual crime decision, aggregate crime behavior, and optimal law enforcement. In a subsequent study, Chang et al. (2013) embed potential criminals' occupation choices into a search-theoretic framework, further opening up the black box of crime organizations. Kugler et al. (2005) take crime organizations as given and study the criminal competition among themselves in the presence of bribery and its implication on the relationship between crime rates and punishment. Beyond optimal law enforcement, Piccolo and Immordino (2016) offer a novel theory to study optimal judicial leniency. Their analysis highlights the distinction between ex ante and ex post efficiency in considering leniency policy.

Our model is built upon the framework of Baccara and Bar-Isaac (2008). Using terrorist networks as a motivating example, they investigate the optimal information structure in a criminal organization and its implication on the optimal detection policy. Our work complements two aspects of theirs. First, we focus on individual incentive to form networks, while the notion of the optimal information structure in Baccara and Bar-Isaac (2008) is from a group perspective. Different from their centralized view of organized crime, we take a decentralized approach to tackle criminal networks. Second, this paper examines in detail the cascade of detection. With very few exceptions,[5] most of the existing work in the literature on detection policy of criminal networks assumes either no cascade of detection or full cascade of detection. Our work offers insights on how the degree of cascade of detection could affect ex ante social welfare in a surprising direction.

[2] Results concerning more general cascade of detection are presented in Section 5.1.

[3] In a recent study, Galiani (2016) provides a comprehensive theoretical analysis of a trade-off between concentrated protection and social segregation, a policy dilemma that has been largely neglected by the existing literature.

[4] In his earlier work, Garoupa (2000) takes a market structure view of organized crime and models it as a vertical structure. He demonstrates that less severe enforcement could be welfare-enhancing in the presence of organized crime.

[5] A notable exception is the follow-up work by Baccara and Bar-Isaac (2009), but again they focus on the efficient network from a group perspective, which is more applicable to highly organized criminal networks like terrorist networks.

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