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# Building them up, breaking them down: Topology, vendor selection patterns, and a digital drug market's robustness to disruption☆

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ABSTRACT

Drug distributors are increasingly turning to online markets to deliver and procure illegal drugs. Online venues allow drug vendors to span broad audiences, reshape organizational structure, and remain relatively anonymous. Such trends raise fundamental questions regarding the structural robustness, topological characteristics, and tie formation patterns in online drug distribution networks. We examine one online illegal opioid transaction network. We characterize the network's topology, evaluate selection dynamics that sustain and facilitate the growth of the drug market, and investigate network vulnerability. Results support the existence of trust-based preferential attachment and give insight to how the network reacts to disruption.



Drug trade has gone digital. Users and curious individuals have turned to online marketplaces to make drug purchases, both legal and illegal (Aldridge and Decary-Hetu, 2013; Eurobarometer, 2014; UNODC, 2016). Consequently, online drug marketplaces have proliferated on both the surface web—all websites that can be accessed through a mainstream search engine—and the darknet[1]—an encrypted region of the Internet only accessible via anonymous 'Tor' browsers. These 'Tor markets'[2]; engage in trade similar to that of the surface web, incorporating transaction rankings, private messaging, and bidding systems. Unlike surface web markets, however, they use anonymous currency to protect vendors and customers involved in illegal drug exchange from potential identification.

The relative accessibility of drugs through the Internet and the decreased risk associated with drug purchasing (e.g. Barratt et al., 2016a) has contributed to a rapid growth in online drug trade. Recent research estimates a 50% increase in the number of drug users worldwide who have purchased from a Tor drug market over the last two years (Barratt et al., 2014; Van Buskirk et al., 2016).[3] Similarly, roughly one quarter of drug users report using Internet markets for illegal drug purchasing (UNODC, 2016). Many of these markets generate large amounts of revenue. Some larger Tor drug markets generate over $180 million US in revenue per year (Soska and Christin, 2015), with over half of all generated revenue coming from wholesale purchases above $1000 US (Aldridge and Decary-Hetu, 2016), indicating that both mid-level retailers and users have turned to Tor markets to procure drugs (Aldridge and Decary-Hetu, 2016).

Digital drug trade sits at the intersections of two growing networks-related research areas: online commerce (Stephen and Toubia 2009; Diekmann et al., 2014) and criminal networks (DellaPosta 2017; Morselli, 2009; Raab and Milward, 2003; Smith and Papachristos, 2016)—particularly drug distribution networks (Natarajan, 2006; Wood, 2017). Network analysis of digital drug markets provides rare insight to new forms of illicit trade, online offending, and the interactive dynamics of an active drug market (Barratt and Aldridge, 2016). Examination of these dynamics will help elucidate the resilience of digital drug markets and the relational processes that sustain and facilitate the growth of illicit online trade.

Further, online drug markets are an opportunity to evaluate how Internet venues affect the structure and operation of criminal networks. Some research shows that criminal groups use social media

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[1] Technically, the 'Tor network' employs an anonymizing 'darknet.' Most references to darknet activity refer to activity on the Tor network—currently the most popular anonymous web service. We use the term darknet here as it is more recognizable by broad audiences.

[2] Much of the current literature refers to Tor markets as 'cryptomarkets.' We use the term 'Tor market' to avoid confusion with the specific market we study, named *Cryptomarket*.

[3] Van Buskirk et al. (2016) report 9.6% of global drug users interviewed use Tor markets for drug procurement.

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to co-ordinate over a much larger distance, draw on more resources, and engage in more crime than their offline counterparts (Patton et al., 2013, 2016). Similarly, terrorist organizations are increasingly turning to Internet venues to advance political agendas and recruit participants (Chen et al., 2008; Berton and Pawlak, 2015). Just as the Internet raised fundamental questions related to the social structure of everyday friendship networks (e.g. Lewis et al., 2008, 2012; Dunbar et al., 2015), crime groups' usage of the Internet to coordinate offending and recruit participants is now raising important questions regarding the behavior and structure of offending networks. What are the topological characteristics of online drug distribution networks? What actor-level behaviors explain the formation of this topology? And, how do online drug markets fare against disruption?

In this article, we evaluate hypotheses drawn from research on criminal networks and online commerce. We analyze one bipartite Tor opioid exchange network consisting of 1132 illegal drug transactions.[4] We characterize the topology of the network, utilize exponential random graph models (ERGM) to identify vendor selection patterns in the network, and evaluate the network's robustness to disruption. Results have implications for drug market disruption, co-offending, illegal commerce, criminal networks, and the growing body of literature on online drug trade (see Barratt and Aldridge, 2016 for a review).

## Hypotheses

### *Topology*

Network topology gives insight to network resilience and network behavior. Prior research on criminal networks suggests that security concerns and constraints on efficient mobilization generate unique network structures among criminal groups (Baker and Faulkner 1993; Raab and Milward 2003; Morselli et al., 2007). Many drug distribution networks rely on a hierarchical network structure, where high profile distributors insulate themselves from the brunt of the network activity by connecting to only a few actors (Natarajan 2006; Morselli et al., 2007; Breiger et al., 2014). This network structure constrains the behaviors of participants by reducing the efficiency of criminal activities while simultaneously limiting the risk of network disruption by protecting key actors.

Alternatively, social commerce networks often form through preferential attachment, where highly desirable vendors attract a broad base of customers (Diekmann et al., 2014; Stephen and Toubia, 2009). Networks that form through preferential attachment exhibit a degree scaling property, where the probability of degree $k$ is $p(k) \propto k^{-\gamma}$ and $\gamma \geq 1$ is the distribution parameter (Barabasi and Albert, 1999). In these cases, the degree distribution of the network follows a power-law and is said to be scale-free. This network structure is somewhat unintuitive for a criminal network, as hubs in a scale-free network are easy to identify and their removal tends to yield a pronounced disruptive effect on the entire network (Albert et al., 2004).

Still, there is some rationale for anticipating that *online* black markets may exhibit a scale-free network structure. First, research into online commerce finds that legitimate social commerce networks often exhibit a degree scaling property (Stephen and Toubia, 2009). This is because certain vendors span broad audiences (Stephen and Toubia, 2009) while others are perceived to be particularly reputable (Diekmann et al., 2014), both attracting a wide array of buyers. Second, some case studies show that illicit commerce networks may exhibit higher centralization than one would expect in a criminal network. Decary-Hetu and Laferriere (2015) use descriptive network analysis on a stolen credit card market, finding that a few key vendors have particularly high degree centrality. This is suggestive of preferential attachment in online illicit materials markets. Since relative anonymity reduces the risk of detection for online offending (Aldridge and Decary-Hetu 2013; Tzanetakis et al., 2016), we expect that the Tor opioid network topology will exhibit degree scaling.

**Hypothesis 1.** The drug distribution network on the Tor network will be scale-free.

### *Preferential attachment*

Barabasi and Albert's (1999) seminal paper on scale-free networks presents preferential attachment as the mechanism that forms scale-free networks. However, research since then has determined that power-law degree distributions may arise even when preferential attachment is not present (Newman et al., 2001; Vazquez, 2003). In the case of online commerce networks, Stephen and Toubia (2009) demonstrate that selling diverse products may drive the development of a power-law distribution in an online commerce network because it opens the vendor up to a wide audience of buyers. In such cases, a scale-free network topology does not necessarily reflect preferential attachment in the market, but rather is a product of certain vendors spanning broad consumer bases.

Alternatively, trust often plays an important role in establishing trade on online markets (Diekmann et al., 2014). Similarly, much tie formation in criminal and covert networks is driven by trust (Charette and Papachristos, 2017; Morselli et al., 2007; Smith and Papachristos, 2016; Tremblay, 1993; Weerman, 2003). In the case of drug trade, Weerman (2003) suggests that trust between dealers and users facilitates future transactions and that dealers are more likely to repeat transactions with buyers whom they trust. Drawing from this line of reasoning, a scale-free network topology may reflect preferential attachment towards trustworthy vendors in a clandestine commerce network.

We expect trust to dwarf product differentiation in this instance. Even though the Internet reduces the risk associated with real world drug exchange (Barratt et al., 2016a), buyers are often concerned with the purity of their product (Bancroft and Reid, 2016), dealing with an undercover law enforcement officer (Aldridge and Askew, 2017), or being scammed (Van Hout and Bingham, 2013), and thus they may disproportionately select vendors whom they perceive to be credible (e.g. Cox, 2016).

**Hypothesis 2.** As vendors' trustworthiness increases, so do the odds of attracting customers.

**Hypothesis 3.** Vendors who are accused of fraud will be less likely to attract buyers.

Further, Tor drug purchasers often pay a higher premium on drug prices than real-world drug buyers (UNODC, 2016). This leaves two possibilities. The first is that buyers will seek to reduce costs even further, opting for the best deal. Alternatively, buyers may be less concerned with costs because cost may be taken as an indicator of quality or because buyers may expect to pay higher costs when purchasing drugs online. If there is little variation in the prices of drugs in the observed network, there may be little incentive for buyers to consider the price of products alongside the trustworthiness of vendors. Similarly, buyers may be willing to pay a premium to trustworthy vendors when there is high uncertainty about the quality of products (e.g. Bancroft and Reid, 2016).

[4] Throughout the article, we refer to the network as both a drug distribution network and drug market to indicate that while the network acts as a market, it is also a form of international drug distribution.

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