# Characteristics of Drug Vendors on the Tor Network: A Cryptomarket Comparison

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Abstract:
Past research on drug-related vendors on Tor marketplaces indicate that sellers are motivated by greater anonymity afforded by the Tor Network. Limited research has even posited that some drug-related vendors on cryptomarkets sell to other dealers, adding another dimension to existing literature that highlights the retail nature (dealer-to-customer transactions) of these Tor-based drug markets. Yet, these past studies have been largely qualitative in nature. This study conducted a quantitative analysis of vendor accounts on Evolution and Agora to determine characteristics predictive of vendors advertising controlled substances, and to determine whether any statistically significant differences among drug vendor characteristics existed between the two sites.

Drug Vendor Characteristics on the Tor Network

Key Words:
- Drugs/Alcohol
- International
- Offenders



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## Introduction

The results from the latest global drug survey indicate that individuals are more commonly turning to the Internet to purchase and sell illicit substances (Global Drug Survey [GDS], 2015; Walsh, 2011). The Internet facilitates these drug-based transactions from the comfort of home, eliminating the need to engage with street-based or open-air drug markets, thus perhaps bypassing the inherent structural violence present within (Barratt, Lenton, & Allen, 2013; Bourgois, 1995; Rhodes, Wagner, Strathdee, Shannon, Davidson, & Bourgois, 2012; Mackey & Liang, 2011b; Werb, Rowell, Guyatt, Kerr, Montaner, & Wood, 2011). "Internet pharmacies" supply a variety of prescription drugs, shipping the items to the buyer without first requiring a prescription from a licensed physician (Castronova, 2006; *Consumer News*, 1999; Mackey & Liang, 2011a). However, these and related websites are hosted on the "clearnet" - the indexed, publically accessible corner of the Internet. The browsing histories of users on these clearnet pharmacy pages are vulnerable and subject to being tracked and identified; the IP addresses of these users are not hidden or distorted. As such, individuals have sought safer cyber alternatives within "darknets" to conduct drug-related transactions (Barratt, Ferris, & Winstock, 2014; Martin, 2014; van Hout & Bingham, 2014). Networks that feature a darknet, such as Tor, offer encrypted communications and anonymizing software, hampering any attempts by law enforcement entities to detect, track, or trace drug-related activities (Dolliver & Love, 2015).

Once connected to Tor, individuals are able to access and browse through countless marketplaces (i.e., websites similar to e-Bay or Amazon that offer a variety of legal and illegal goods and services for sale). Although much scholarly attention has been paid to drug trafficking and criminality in general on Tor Network marketplaces (e.g., Silk Road, Silk Road 2, Evolution) (Aldridge & Decary-Hetu, 2014; Barratt, 2012; Barratt et al., 2014; Christin, 2012;

Dolliver & Love, 2015; van Hout & Bingham 2013a; 2013b; Walsh, 2011), very few studies have investigated this criminal phenomenon from the drug vendor perspective. Further, the limited research that has touched on Tor drug vendors has been thus far non-generalizable, qualitative research (van Hout & Bingham 2014), with the exception of quantitative descriptive studies identifying patterns across source countries identified by vendor accounts (Dolliver, 2015a; Dolliver & Love, 2015).

As such, this study sought to address this gap in the literature by conducting a quantitative analysis of drug vendor characteristics on two popular Tor marketplaces, Agora and Evolution. Although both sites are no longer functioning,[1] data were collected from the sites while both were operational. More specifically, data on vendor accounts and their advertised items were collected from Agora and Evolution, then cleaned and coded for further analysis to examine potential differences in vendor accounts selling drug-related[2] (e.g., methamphetamine, 2-FMA, cocaine, heroin, methoxetamine) and non-drug related items (e.g., stolen credit card data, malware, counterfeit passports, jewelry, pornography) both within and between each site. This significantly contributes to the related literature by advancing the understanding of a unique category of drug offenders operating on an anonymous, "dark" network.

## Literature Review

### *The Tor Network and Associated Criminality*

The Tor Network is maintained and operated by the Tor Project (torproject.org), which is a 503c non-profit organization based in Cambridge, Massachusetts and partially funded by the National Science Foundation (NSF). The concept for building a network like Tor (originally known as The Onion Router) originated in the early 2000s and was based on the need for constructing a secure online environment in which to protect government communications with a

reduced or eliminated risk of having those communications intercepted. The concept was later funded by the U.S. Naval Research Laboratory (in addition to Defense Advanced Research Projects Agency (DARPA), Google, NSF, and the National Christian Foundation, among others (Tor Project, 2015a)) and made publically available by 2010, accessible once the free Tor browser had been downloaded from TorProject.org. The Tor Network employs anonymizing software that routes the user's Internet traffic through a series of rendezvous points set up by Tor nodes that essentially masks the user's IP address and ensures that the user's activities on Tor remain untraceable (Tor Project, 2015b).

The Tor Project staunchly situates the Tor Network on the "right to privacy" side of the privacy versus security debate with regards to the cyber domain, touting its many uses including protecting journalists' communication with whistleblowers and dissidents, allowing law enforcement entities around the world to conduct covert surveillance, and making sure citizens everywhere have the ability to "maintain civil liberties online" (Tor Project, 2015b). The Tor Network ensures these qualities not only through the anonymizing software, but because once connected to the Tor Network, the Tor user is able to access any clearnet site (e.g., Google, Facebook, Amazon, British Broadcasting Corporation [BBC]) in addition to Tor-specific sites, identified by *.onion* domain names.

Criminals have also discovered the benefits of an anonymous network, often using Tor marketplaces in place of clearnet sites (van Hout & Bingham 2013a; 2013b). Indeed, the Tor Network housed the well-known Silk Road, the first major international marketplace on Tor used by just under 1 million subscribers (Dolliver, 2015a). Following its termination by law enforcement in 2013, the Tor Network experienced a surge in daily directly-connected users and

a virtual explosion in the number of marketplaces, housing illicit items ranging from drugs, to stolen credit card data, to weapons of mass destruction (Dolliver, 2015a; Dolliver & Love, 2015).

To-date, many studies of criminality on the Tor Network have been descriptive, exploratory endeavors of a handful of marketplaces, documenting the range, type, and quantity of illegal items and services for sale (Christin, 2012; Dolliver, 2015a; Soska & Christin, 2015) with an often primary focus on the drug markets (Aldridge & Decary-Hetu, 2014; Martin, 2014; van Buskirk, Roxburgh, Bruno, & Burns, 2013; Walsh, 2011). However, qualitative studies have been conducted based on interviews with small groups of Silk Road users (van Hout & Bingham, 2013a; 2013b) and vendors (van Hout & Bingham, 2014). With regards to drug user characteristics, van Hout & Bingham (2013a; 2013b) found Silk Road users to be predominantly male, self proclaimed "drug connoisseurs" who used Silk Road in place of offline markets due to the anonymizing features of Tor and the corresponding reduced risk of law enforcement detection.

Van Hout and Bingham (2014) also interviewed 10 drug vendors via an online survey, finding again a male majority motivated to sell their products on Silk Road due to multiple factors including the site's harm reduction ethos, its 24-hour secure, anonymous nature, and the "supportive safety net" of the broader Silk Road community (p. 185). While this study was able to also collect information on the age and employment status of the vendors, few other drug vendor characteristics were gleaned from these data, none of which were generalizable due to the small sample size.

Other more recent studies of criminality on Tor Network cryptomarkets[3] have begun to branch out theoretically into the realms of communication studies and constructive activism (Maddox, Barratt, Allen, & Lenton, 2015), globalization studies (Dolliver & Love, 2015),

economics (Hardy & Norgaard, 2015), political science (Moore & Rid, 2016), and global security (Laura & Me, 2015). One recent study undertook a large-scale longitudinal effort to track the metrics of a large number of Tor marketplaces over time (Soska & Christin, 2015). However, much of the focus of current studies remains on old data pulled from the original Silk Road website and on qualitative assessments of user experiences (Maddox et al., 2015).

*The Current Study*

The current study seeks to expand on the work conducted by van Hout and Bingham (2014) by quantitatively assessing the characteristics of a unique offender population (i.e., drug vendors) operating on two major Tor marketplaces. By conducting a statistical assessment of the drug and non-drug selling vendors, this study will determine whether any predictive characteristics (e.g., geographic sources, price, vendor ratings, shipping methods) are inherent within drug vendors between and within Agora and Evolution. More specifically, the authors sought to address:

(1) Which source countries are drug vendors most likely to originate from on Agora, Evolution, or both?

(2) Which shipping methods and item prices are drug vendors most likely to use on Agora, Evolution, or both?

(3) What vendor rating are drug vendors more likely to have on Agora, Evolution, or both?

## Data and Methods

*Site Selection and Data Collection Methods*

Agora (Figure 1) and Evolution (Figure 2) were chosen for inclusion due to the sites' recognition in public forums in early 2015 as two of the largest and most popular Tor

cryptomarkets by trade volume (Agora Drugs, 2015; Fox-Brewster, 2015; DeepDotWeb, 2015a; 2015b). Further, following the termination of Evolution in March 2015, Agora was listed as the largest remaining international drug market on Tor (DeepDotWeb, 2015a). As such, both cryptomarkets (during their operation) captured a broad range of vendors advertising and selling a large variety of items for sale, maximizing the representative nature of international Tor marketplace vendors.

[INSERT FIGURE 1 HERE] [INSERT FIGURE 2 HERE]

Data were collected from Agora and Evolution using webcrawling techniques employed in past research (Aldridge & Decary-Hetu, 2014; Christin, 2012, Dolliver, 2015a; 2015b; Soska & Christin, 2015). Crawling each Tor site produces static copies of the sites, essentially replicating the websites at the time of each crawl. Each site's link-structure is retained in the crawling process, allowing the user to navigate the replicated static copy of the site as if browsing online in real time. Configuring the webcrawling software to accurately capture each site completely requires many hours of tedious work involving multiple full and partial test crawls to direct the crawler appropriately (e.g., to ensure an appropriate rate of the crawl and to ensure unwanted links, such as adding items to the cart to purchase, were not followed by the crawler). To ensure the crawling mechanism was accurately capturing the entirety of publically available data on the website (without leaving any items or pages out), the data were manually hand-checked using the same methods as Dolliver (2015b). The complete crawl of Agora data used was conducted in June 2015, requiring approximately 70 continuous hours to capture. The complete crawl of Evolution data included was conducted in September 2014, requiring over 14 continuous hours.

It should be noted that Soska and Christin's (2015) study raised concerns regarding the reliability of crawling the Agora marketplace: "Agora has relatively poor reliability and on average [by the authors' calculations], a single scrape will not manage to capture even half of the feedback present at the time on the site" (p. 38). Agora indeed proved difficult to crawl, as the webcrawling software would often timeout due to many factors, including the website undergoing frequent Distributed Denial of Service (DDoS) attacks. However, Soska and Christin's (2015) calculations were based on the assumption that it was impossible to know whether each crawl was complete, and as such assumed that the information collected was a lower bound of the total information on the site. Agora required many crawling attempts to glean information for the aforementioned study, so Soska and Christin concluded Agora to be too problematic for crawls be accurate. However, determining the approximate size of the site (i.e., volume of listings) is easily calculable. On both Evolution and Agora's websites, the number of approximate listings per category is given; this current study hand-checked each complete crawl of both cryptomarkets' data by expanding each category on the live website on the date of each complete crawl, counting the number of listings per page, then multiplying this number by the number of pages under each category. This final number was then compared to the total number of items collected from the complete crawl of each site.

Soska and Christin (2015) may have run into a number of problems that complicated their Agora crawls, including mirroring or "scraping" both text and picture data (collecting only HTML (i.e., text) data greatly increases the efficiency of the crawler and the time it takes to complete a crawl), mirroring forums (which, in and of itself contains a myriad of data), and collecting vendor feedback information. The current study was able to expedite the efficiency of the crawling software by instructing the webcrawler to only collect HTML data specific to this

study (e.g., including descriptions of each item advertised, geographic sources and destinations indicated by the vendor, the vendor's name and rating, shipping methods, and each item's price).

Once the complete crawls of Agora and Evolution data were verified as complete, sorting software was then used to record and categorize data from each advertisement into a series of variables for further cleaning and coding purposes. In this process, vendor account names were crosschecked between the two sites to determine the percentage of vendor accounts that advertised listings on both cryptomarkets; the percentage of overlap was found to be very low (approximately 8% of the vendor accounts appeared on both sites).[4] This indicated that the population of vendors on each Tor site were distinctly different from each other at the points of data collection, and thus allowed for meaningful comparisons to be made.

*Variables*

T*ype of vendor,* the central variable, sorted vendors into two categories. Drug vendors had to sell at least some controlled substances (e.g., narcotics, hallucinogens, prescription drugs, stimulants) and were coded as 1. Non-drug vendors did not sell any drugs and were coded as zero.

Four additional variables were employed: *country of origin, shipping method, item price,* and *vendor rating*. When a vendor creates a new listing, they are able to identify specific countries they ship their items to and from. On Evolution, vendors were given country choices via a dropdown menu; however, Agora vendors were able to write-in country choices. This resulted in a small percentage (less than 3%) of unidentifiable countries (e.g., "Torland"). In this case, unidentifiable write-ins were coded as "undeclared," while those able to be distinguished were recoded for each appropriate country (e.g., "United Snakes of America" was coded as "United States of America"). The individual countries that composed 75% of the single countries

(i.e., the countries listed in Table 1) were categorized individually. The remaining single countries were grouped together in the category of "other."[5] Data that listed the country as "worldwide," "undeclared," or left blank were collapsed into one "unidentified" category for the purposes of statistical testing. Further, all multiple countries were grouped together into an additional separate category.

Most vendors indicated only one (i.e., primary) shipping option available per item, though a small percentage of vendors indicated up to six different shipping options. To reduce missing data, only the primary shipping option was coded. The final variable for shipping method consisted of eight categories as displayed in Table 1.[6] Item price was the price at which each drug or non-drug listing was advertised for, which was set by the vendor during the creation of each ad. Though bitcoins are used in these markets, U.S. dollars were used to create the variable. Because of the wide variability of the item prices and the severe positive skew of the data, this variable was clustered into five evenly distributed categories for statistical testing purposes: $0.00 - $9.90, $9.91 - $40.00, $40.01 - $99.99, $100.00 - $320.00, and $320.01 - $450,000.[7] Vendor rating represented customers' rating on a 0 to 5 scale with 5 representing the highest positive rating.

## Findings

*General Site Characteristics*

The data identified 2,325 unique vendor accounts and 43,482 listings in total. Of the total listings, 29,146 (67.0%) advertised the sale of a controlled substance. The number of listings per vendor ranged from 1 to 1,185. The Agora site hosted approximately 1,059 vendor accounts offering 27,431 total item listings for sale. Of those that have been identified as drug vendors, 19,593 (67.2%) operated on Agora and 9,553 (32.8%) operated on Evolution. Total vendors

ranged in the number of active listings from 1 listing (62 vendors, 0.2% of the Agora site) to 1,185 listings (1 vendor, 4.3% of the Agora site) at the time of data collection. Agora averaged roughly 251.7 listings (*SD* = 357.0); the median number of listings was 72. Comparatively, Evolution hosted approximately 1,266 unique vendor accounts advertising 16,051 listings. The number of listings per vendor on Evolution ranged from 1 (157 vendors, 1.0% of the Evolution site) to 820 (1 vendor, 5.1% of the Evolution site) at the time of data collection. The average number of listings created by vendors was 86.2 (*SD* = 178.2) with a median of 25.

[INSERT TABLE 1]

Sixty-two distinct countries were identified as origins for all drug and non-drug items sold on both Agora and Evolution. The United States was the most frequently identified country of origin for drugs advertised on both sites (23.7% of drug listings), followed by the "unidentified" country category (17.7%), and the United Kingdom (11.9%). Table 1 indicates that two-thirds of the drug and non-drug vendors did not identify a preferred shipping method. All other preferred shipping methods comprised less than 10% of the listings. The composition of both sites was found to be similar, though drug listings were more evenly distributed across drug categories on both Agora and Evolution; non-drug listings were more tightly clustered around two of the ten non-drug categories (i.e., data dumps and eGuides).

With regards to item prices and vendor ratings, overall item prices ranged from $0 to $450,000. The average item price was $533.25 (*SD* = $6,218.59). The median price on the combined sites was $65.00. On Agora, the item price ranged from $0 to $380,000 with an average price of $524.8 (*SD* = $6,525.98) and a median price of $70.00. The two items priced at $0 were "Account Creator Extreme 4.1.1 – Free For All" and "Adobe Photoshop – Free For All,"[8] while the most expensive listing advertised 10kg of cocaine "shipped direct from

Columbia."[9] The range of item prices on Evolution was $0 to $450,000, with an average item price of $547.69 (*SD* = $7,118.59). The median price on Evolution was $58.26. There were 201 listings on Evolution priced at $0, for items including "Email Spam Service," "Text Message Flood Service," and "Free Porn Accounts."[10] The most expensive listing advertised 10kg of "the highest purity cocaine" shipped from the United States.[11] The average rating for all vendors (both drug and non-drug) was 4.61 (*SD* = 1.17). The average rating for Agora was 4.66 (*SD* = 1.04), while the average rating for Evolution was found to be 4.51 (*SD* = 1.36).

Table 2 below displays the vendor accounts producing 25% of all listings on both Agora and Evolution (specific vendor account names have been redacted). The vendor with the largest number of listings overall (1,185, 2.7% of the combined sample) is "Vendor1," a drug vendor operating on the Agora marketplace. Interestingly, out of the five top vendors, only "Vendor1" and "Vendor5" have listings that advertise drugs and "Vendor4" was the only vendor to operate on the Evolution marketplace. Further, only 5 of the 25 vendor accounts within the top quartile operated on Evolution.

[INSERT TABLE 2]

*Examining the Difference between Drug and Non-Drug Vendors on Both Sites*

Table 3 shows that drug and non-drug vendors differed on countries of origin ($X^2$ = 12,000, *p-value* < 0.001). Drug vendors, in general, were most likely to ship from the U.S. (21.8%) while non-drug vendors were more likely to leave their country of origin as unidentified 44.5). There were differences in shipping methods between drug and non-dug vendors as well ($X^2$ = 2,700, *p-value* < 0.001). While both drug and non-drug vendors were most likely to leave their method of shipping unidentified, drug vendors were more likely than non-drug vendors to use free shipping (9.3% versus 5.0%), standard shipping (7.4% versus 5.2%), Priority Mail

(4.5% versus 0.6%), and country specific methods (6.1% versus 0.6%). Item price categories were also found to be different between drug and non-drug vendors ($X^2$ = 7,100, *p-value* < 0.00). Drug vendors (25.7%) were most likely to sell their products in the highest price category ($320.01 - $450,000.00) while non-drug vendors (39.0%) were most likely to sell their products in the lowest price category ($0.00 - $9.90). Lastly, vendor ratings for drug vendors were somewhat lower, on average, (M = 4.55) than those for non-drug vendors (M = 4.72), *t* (43,480)= 14.3, *p-value* < 0.001. Separate comparisons by each site found similar trends as those reported for the combined sites.[12]

[INSERT TABLE 3]

Next, $X^2$ and *t*-tests were used to test for differences among drug vendors on Agora and Evolution concerning country of origin, shipping method, price, and vendor ratings. Table 4 presents the column percentages comparing drug vendors on Agora to drug vendors on Evolution, and provides the significant $X^2$ and *t*-tests. As shown in Table 4, a higher percentage of drug-vendors on Evolution (23.5%) were more likely to hide their country of origin than were drug vendors on Agora (2.5%). Drug vendors from Agora were more likely than those on Evolution to use an unidentified shipping method (77.7% of Agora vendors versus 11.6% of Evolution vendors). Also, drug vendors on Evolution (15.4%) were more than two times more likely to ship their items for free compared to drug vendors on Agora (6.3%). Regarding the price of drug products, approximately half of Evolution's (49.7%) and Agora's (51.5%) drug vendors sold their product within the top two highest price categories ($100.00 - $320.00 and $320.01 - $450,000.00). Drugs were least likely to be sold in the lowest price category ($0.00 - $9.90) for both Agora and Evolution overall. But, for those drug vendors that did sell within this category, those on Agora (12.2%) were more likely than those on Evolution (7.6%) to do so.

When testing for differences among the drug vendor ratings for both Agora and Evolution, Agora the highest overall average vendor rating (4.62 versus 5.54) ($t$ (29,144) = 5.8, $p$-$value$ < 0.001).

[INSERT TABLE 4]

Lastly, the authors employed logistic regression modeling to test for associations between drug vendors and 1) the site the vendor advertised merchandise on, and 2) their corresponding ratings. Vendors on Evolution are 1.8 times less likely to be drug vendors than those vendors on Agora ($OR$ = 0.58, $95\%$ $CI$ = 0.56 – 0.61). The results also show that as vendor ratings increase, there was a lower likelihood that the vendor advertises the sale of drugs ($OR$ = 0.85, $95\%$ $CI$ = 0.84 – 0.87). For each unit increase in a vendor's rating, there was approximately an 18% decrease in the likelihood that a vendor will sell drugs. Table 5 illustrates these results, reporting odds ratios and 95% confidence intervals.

[INSERT TABLE 5]

## Conclusion

While the sale of controlled substances online finds its roots in the early days of the ARPANET (Markoff, 2005; Walsh, 2011), recent global trends have indicated a more common participation in online drug distribution (GDS, 2015; Martin, 2014). This trend is not wholly unexpected, given the pace of Internet connectivity rates worldwide and the spread of globalization (Dolliver & Love, 2015). Many Internet-based sources of drugs have been housed on the clearnet in the form of Internet pharmacies (Castronova, 2006; Drug Enforcement Administration, 2005; Mackey & Liang, 2011a), where individuals can sell and purchase prescription drugs from these online venues (often housed in countries outside of the United State). However, selling controlled substances illegally via these sites leaves the offenders

vulnerable to law enforcement detection by way of tracking and tracing IP addresses (for instance). As such, individuals have begun to utilize the Tor Network for these purposes, protected by the anonymizing software developed and maintained by the Tor Project. On this platform, users' IP identities and Internet traffic are encrypted and anonymous, allowing drug sellers to set up virtual shops on any one of Tor's marketplaces with a reduced likelihood of law enforcement detection.

Though studies have focused on Tor network criminality and drug trafficking in general (Barratt et al., 2014; Christin, 2012; Dolliver, 2015a; Dolliver & Love, 2015; Laura & Me, 2015; Maddox et al., 2015; Martin, 2014; Soska & Christin, 2015; van Hout & Bingham 2013a; 2013b; Walsh, 2011), few researchers have focused on drug vendors themselves. The most informative study conducted from the drug vendor perspective was a qualitative endeavor involving interviews with 10 drug vendors on Silk Road (van Hout & Bingham, 2014). However, while the results confirmed prior studies as to the motives of using Tor in place of the clearnet venues (Barratt et al., 2014; van Hout & Bingham, 2013a; 2013b), the study was severely limited by the small sample size and focus on one marketplace.

As such, the current study sought to expand the literature on the unique offender category of Tor-based drug vendors by conducting a quantitative analysis of drug vendors on two major international Tor marketplaces: Agora and Evolution. The current research compared drug vendors and non-drug vendors on these sites to assess how they differed on country of origin, shipping method, item prices, and vendor ratings. A number of important findings emerged.

First, vendors on Evolution were 1.8 times less likely to sell drugs than on Agora, indicating a heavier concentration of drug vendors on the Agora marketplace (67% of vendors sold drugs on Agora, compared with 33% of vendors on Evolution). The volumes of all listings

were found to be greater on Agora than Evolution (27,431 active listings and 16,051 active listings, respectively); however, the landscapes of Agora and Evolution were found to be relatively comparable in terms of the number of total vendor accounts (1,059 and 1,266, respectively) and approximate composition of drug (e.g., MDMA, synthetic THC products, mephedrone, LSD, ketamine) and non-drug items (e.g., money laundering services, digital "how-to" guides, hacking software, counterfeit Euros).

Explanations for these differences cannot be provided from our web-crawling data. Future research might examine several possibilities. For example, the Agora marketplace might have a more reliable reputation as a safe Tor site to conduct drug transactions than Evolution. An additional possible explanation involves Evolution's origins; Evolution has been posited as initially a "carding forum"[13] (DeepDotWeb, 2015c), allegedly only months later evolving into a drug market. As such, the data sample from Evolution may reflect lingering sentiment among Tor vendors and buyers who perhaps viewed Evolution as more than a primary drug marketplace. However, the data were collected in September 2014 – eight months after the site launched. To-date there have not been published studies as to the point at which the transition from carding to drugs occurred on Evolution (or the extent to which Evolution was ever primarily a carding forum). Further, the ratios of drugs-to-non-drug items found on Agora and Evolution in this research were similar (i.e., Evolution was not found to have an overrepresentation of carding-related listings; see Table 1). Future research should further investigate this relationship.

Second, drug vendors differed from non-drug vendors on both Agora and Evolution in terms of the countries vendors shipped their items from. That is, drug vendors were more likely to ship from the United States, the United Kingdom, Germany, and Australia than non-drug

vendors, though non-drug vendors were more likely to ship from China. However, non-drug vendors were 4.7 times more likely than drug vendors to leave the country of origin as "unidentified." This finding is particularly interesting, given the assumption that drug vendors would be less likely to identify any particular country of origin due to the nature of their products (e.g., fear of parcel tracking, interception, and subsequent arrest by law enforcement). Perhaps on these large international cryptomarkets, however, vendors desired to gain trust among their customer-base by listing the origin of shipments, or purposefully advertised the origin of drug listings to draw new customers to their virtual shop, as the quality and purity of controlled substances are known to vary geographically (United Nations Office on Drugs and Crime, 2015). Another potential explanation includes the evasive strategy of creating an "illusion of normalcy;" perhaps drug vendors sought to appear as if they were in compliance with controlled substance laws by listing a country of origin. Existing evidence from prior studies (van Hout & Bingham, 2014) did not include insight on whether (or why) vendors explicitly stated or withheld the country of origin for drug shipments. However, van Hout and Bingham (2014) did find that only "a minority of participants reported concern around product interception" (p. 187), indicating that possibly the handful of vendors interviewed were less concerned about identifying their shipping origins and were confident in their methods of package concealment. It should also be noted that listings with digital deliveries (e.g., electronic "how-to" manuals, hacked PayPal accounts, stolen personal information) might disproportionately impact non-drug items on this variable (i.e., there is little need to list the country that a PDF is emailed from). More comprehensive research on this subject is needed to better understand the relationships uncovered here.

Third, both types of vendors on Agora and Evolution were less likely to identify a particular shipping method, leaving the shipping method unidentified (though this was more common with non-drug vendors than drug vendors). When a specific shipping method was identified, drug vendors more frequently used free shipping, standard shipping, Priority Mail, and country-specific postal carriers than non-drug vendors. Both types of vendors utilized Express Mail shipping methods equally.

Fourth, perhaps the greatest difference between drug and non-drug vendors was found within the item price categories. Drug items were most frequently listed at the two most expensive price categories ($100.00 - $320.00 and $320.01 - $450,000.00) while non-drug items were most frequently listed at the cheapest price category ($0.00 - $9.90).[14] Moreover, the percentages across all price categories for drug listings were relatively consistent with a slightly positive skew, indicating a gradual but steady increase in price for drug listing frequencies. These are particularly interesting findings, given that individual retail-level drug sales (i.e., sales of small amounts of drugs for personal consumption) do not often total more than $320 per transaction. It should be noted, however, that the transactions themselves were not captured; thus, frequencies of listings do not reflect products that are sold more often (i.e., lower priced items may be sold much more often than higher priced items). Additional research, however, is needed to further investigate this area.

Fifth, drug vendors consistently had *lower* ratings on average than their non-drug counterparts. That is, for each unit increase in a vendor's rating, there was an approximate 18% decrease in the likelihood that the vendor would sell drugs. These findings are unexpected, given the perceived risks involved in completing drug transactions (e.g., van Hout & Bingham 2013a; 2013b) would conceivably lead drug buyers to seek experienced, trusted (i.e., highly rated)

vendors. Possible explanations of these findings may be due to the potentially broad range of drug sellers internationally (ranging from organized, professional drug dealers to individual, inexperienced teenagers), or perhaps drug buyers were more critical of drug products' psychoactive effects and, therefore, rated drug vendors more harshly.

Finally, drug vendors on Agora differed from drug vendors on Evolution on a number of variables. While drug vendors on both sites shipped from the United States and the United Kingdom in roughly equal proportions, drug vendors on Evolution shipped more frequently from the Netherlands and Germany, and drug vendors on Agora shipped more frequently from China and Australia. Further, drug vendors on Agora were much more likely to identify a country of origin than drug vendors on Evolution. Substantial differences were also found among shipping methods used by drug vendors between marketplaces; that is, vendors on Agora were 6.7 times more likely to use unidentified shipping methods to transport their drugs to their customers, while drug vendors on Evolution more evenly utilized identified methods of shipment (including standard shipping, free shipping, and country-specific couriers). Interestingly, the price of drugs on Agora and Evolution were comparable across all price categories. Lastly, drug vendor ratings were higher on Agora than Evolution; this may have resulted from the fact that Agora experienced a heavier concentration of drug vendors than Evolution, or perhaps the lower ratings for drug vendors on Evolution was reflective of lower quality drug products.

Given the scope and nature of the data employed, a number of limitations were encountered. First, the findings cannot be generalized to all vendors operating on every Tor marketplace, and only offer a snapshot of drug vendor characteristics on two of the largest marketplaces at one point in time. This analysis was also unable to estimate revenue per vendor or the amount of transactions completed.[15] Due to the nature of the data and Tor's anonymizing

software, this findings are not useful in determining whether the same individual(s) operated multiple vendor accounts on either/both Agora and Evolution, or whether the same individual(s) operated different vendor accounts on each site (the same individual may sell, for instance, only drug items on Agora and only non-drug items on Evolution). Thus, individual attribution per vendor account cannot be definitively confirmed, nor can the accuracy of information provided by each vendor account (e.g., a vendor may list the country of origin as "USA" but actually ship from Canada). Finally, the authors did not test for differences in drug vendor characteristics between different drug-types (e.g., hallucinogens, narcotics, stimulants); this is an excellent avenue for future research to explore.

While not representative of all drug vendors operating on the "darknet" of Tor, this analysis was the first to conduct a comprehensive examination of a unique offender population operating on two of the largest drug marketplaces on Tor at the time of data collection. These findings give policymakers, academics, and law enforcement alike a starting point from which to better understand the phenomenon of Tor-based drug trafficking and the individuals behind this cybercrime component. Future research is needed, though, to build on this study's findings and expand the literature surrounding this unique offender group, particularly given the dynamic nature of the Tor Network. By doing so, this line of research will advance the field's knowledge in drug sellers' adaptations to cyberspace.

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[1] Evolution went offline in March 2015 due to an alleged exit scam by the site's operators, and Agora voluntarily went offline in June 2015 to allegedly increase the site's security.
[2] "Drugs" in this study refers to all controlled substances, including legally manufactured prescription drugs.
[3] "Cryptomarkets" is a term frequently used by scholars (e.g., Barratt et al, 2014; Martin, 2014) to refer to "darknet markets" on Tor (i.e., Tor-based websites/marketplaces) that sell legal and illegal goods and services.
[4] This was a 1:1 comparison; in other words, the exact vendor name was compared across both sites (regardless of capital letters). However, due to the anonymous nature of Tor, there is no way to determine whether the same individual held different vendor accounts on each site; similarly it cannot be determined if (for instance) vendor "Y1" on Evolution was the same individual as vendor "Y1" on Agora (many of the overlapping names were common words or phrases, such as "Nissan" or "blue"). As such, data for the 8% of vendor accounts were not omitted from the dataset.
[5] "Other" countries included: India, Sweden, France, Hong Kong SAR China, Poland, Belgium, Spain, Italy, South Africa, Ukraine, Denmark, Austria, Norway, the Czech Republic, the Philippines, Mexico, New Zealand, Switzerland, Thailand, Argentina, Colombia, Singapore, Belarus, Hungary, Latvia, Ireland, Slovenia, Guatemala, Brazil, Fiji, Finland, Seychelles, Luxembourg, Slovakia, Pakistan, Serbia, Lithuania, Belize, Cambodia, Croatia, Malaysia, Romania, Turkey, Aruba, Bosnia and Herzegovina, Bulgaria, Chile, Djibouti, Estonia, Ghana, Japan, Maldives, Saint Vincent and the Grenadines, and Swaziland. Some vendors shipped merchandise from multiple countries. These multiple countries groupings included: Europe; Philippines, United Kingdom, and United States; Philippines and United Kingdom; Canada and United States; and United Kingdom and United States.
[6] Country specific category included: United States Postal Service (USPS), German Post, Canada Post, Royal Mail, France Post, Netherlands Post, Australia Post, Italy Post, Denmark Post, New Zealand Post, United Kingdom Post, Norway Post, Sweden Post. Other methods represented those that did not comprise 75% of the methods used.
[7] $450,000 was the highest priced item in the dataset. The price data were cleaned and coded, with significant outliers removed from consideration. In some cases when vendors were sold out of a product, they would list the price at exorbitantly high amounts (e.g., $5.9 million, $999,999) and alert customers in the comments section of that listing that they were temporarily "sold out" of the product. In one case, a vendor posted a "test listing," setting the price at $458,999,999.95. The number of listings that were flagged as outliers and subsequently omitted from analysis totaled 35.
[8] Other low-priced item included "Netspend vanilla reloadit packs to BTC exchange" advertised for $0.02, and "Western Union to BTC exchange service – offer for one week only" advertised for $0.02.
[9] Other high-priced items included 1,000,000 30mg tabs of ephedrine advertised for $371,297.00, and 5kg of cocaine advertised for $200,000.00.
[10] Other items priced at $0 included free samples of various drugs (e.g., wax, 25c-nbome, weed, cocaine, MDMA, MXE), "Sony Vegas Pro 13" software, and "Free Guide to Making Good Money."
[11] Other high-priced items included 3,000 liters of phenylacetone sold in 1,000 liter batches for $207,305.00, and 14g mephedrone (4-MMC) sold in 100g batches for $136,221.00.
[12] These analyses can be requested from the author.

[13] Carding forums are marketplaces that specialize primarily in obtaining and selling stolen credit card data, counterfeit identifications and currencies, and stolen personal information.
[14] All prices in this study are given in USD, though transactions made on both Agora and Evolution are in Bitcoin.
[15] Some scholars (e.g., Christin, 2012; Soska and Christin, 2015) attempt to estimate sales volumes by calculating the number of customer comments or feedback left on each vendor's page.