Original Article

An insight Into Prescription Drugs and Medicine on the *AlphaBay* Cryptomarket

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Abstract

Internet access has provided new ways to trade goods. Unlike conventional legal sale sites, cryptomarkets facilitate exchanges in a context where the anonymity of participants is warranted. The aim of this article was to obtain a better understanding of the trafficking of prescription drugs and medicine on the AlphaBay cryptomarket. The results showed that alprazolam, oxycodone, and Adderall were the most offered prescription drugs while alprazolam, diazepam, and oxycodone were the most sold substances. The sale was dominated by North America, Australia, and Western European countries. The revenue of prescription drugs was estimated to be more than US$65 million since the creation of AlphaBay, a small market in comparison with the worldwide legal pharmaceutical market's estimate of US$1.3 trillion in 2020. Digital traces offer a complementary way to understand the trafficking of prescription drugs and medicine and to identify the most prolific vendors and their implication in this trafficking.

Keywords

forensic intelligence, digital trace, revenue, geographical analysis

Introduction

The Internet has created new ways to trade licit and illicit commodities as well as to exchange information. Online platforms operating in the legal economy have had an impact on business models, customers, and vendors. This development has been mirrored in the illicit trade as it provides criminals with opportunities to grow their businesses as they can reach a large number of potential customers around the world (Décary-Hétu & Aldridge, 2015; Europol, 2017; Martin, 2014a). Along with the sale of prescription drugs and medicine, the sale of false and counterfeit medicines has also been facilitated by the Internet (European Monitoring Centre for Drugs and Drug Addiction, 2016; Gelatti et al., 2013; Inciardi et al., 2010; T. K. Mackey, 2018; Sugiura, 2018). In particular, legal online pharmacies have grown, broadening their supplies to performance-enhancing drugs, prescription drugs, and, more broadly, medicine

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(European Monitoring Centre for Drugs and Drug Addiction, 2016). This mode of business offers convenience and home delivery to patients. Legal online pharmacies comply with national and international regulations and standards, thus guaranteeing the quality of the product. Controlled medicine requires a valid prescription from the patient (European Monitoring Centre for Drugs and Drug Addiction, 2016; Levaggi et al., 2009). In recent years, there has been growth in the sales of prescription drugs and medicine in illicit online pharmacies (Cohen, Collins, Darkes, & Gwartney, 2007; Koenraadt & van de Ven, 2018; Lavorgna, 2015). Illicit websites have appeared through which prescription substances can be purchased without any prescriptions, at a lower price, and without having to discuss the medical problem (if any) with a doctor (Di Nicola et al., 2015; Forman, Woody, McLellan, & Lynch, 2006; Koenraadt & van de Ven, 2018). These sites are not registered with a recognized accreditation system and represent an issue for health care as the substances for sale are not regulated, the quality of the product is not guaranteed, and the products offered for sale might have been diverted from the licit market (Gelatti et al., 2013; Koenraadt & van de Ven, 2018; Sugiura, 2018). Mandated by the Center for Safe Internet Pharmacies (CSIP), a study conducted in 2016 (LegitScript, 2016) showed that approximately 30,000 pharmacies' hostnames were found online, potentially linked to 2,000 to 3,500 merchants. Among these, 96% operated illegally, 10% sold controlled substances (e.g., oxycodone, alprazolam) and 5% sold steroids (T. K. Mackey & Nayyar, 2016). Furthermore, according to the World Health Organization (WHO), around 50% of medicines sold online from illegal sites are counterfeits (WHO, 2010).

Numerous studies have been conducted to explore the online supply of medicines via online pharmacies, both legal and illegal (e.g., Di Nicola et al., 2015; European Monitoring Centre for Drugs and Drug Addiction, 2016; Forman et al., 2006; Gelatti et al., 2013; Koenraadt & van de Ven, 2018; Levaggi et al., 2009; McCoy et al., 2012; Orsolini, Francesconi, Papanti, Giorgetti, & Schifano, 2015). The project "FakeCare" was aimed at developing a more accurate understanding of the online trade of falsified medicine using different approaches (e.g., web survey, virtual ethnography, web content analysis, interviews, judicial cases, and honeypot websites; Di Nicola et al., 2015). The web survey was conducted in seven European Member States, targeting customers or potential customers who purchased medicinal products. An exploratory web content analysis was conducted on both legal and illegal online pharmacies. Their results, combined with several interviews, showed that 16.1% of the web survey respondents reported buying online. The most popular products reported being bought online were "lifestyle medicines" (i.e., erectile dysfunction medicine, weight loss medicines, birth control pills, or smoking cessation). In 2018, Koenraadt and van de Ven studied the demographic characteristics, methods, and preference of Dutch people who purchased prescription drugs through the web (Koenraadt & van de Ven, 2018). Based on two surveys, they reported that 10.2% of the Dutch adult population had bought prescription drugs online. According to the study, the main prescription drugs and medicine bought online were analgesic, appetite suppressant, tranquilizers, and vasodilator. Cicero and Ellis (2012) observed that consumers reported purchasing online (from licit online pharmacies) because it appeared to be cheaper than seeing a general practitioner or the dose prescribed was too small. Gelatti et al. (2013) ordered fluoxetine from several websites (none of them officially approved). About 20% of their purchase resulted in the delivery of the drugs, even without a medical prescription. However, the drug quality did not comply with European standards in terms of the presence of impurities, suggesting a risk for the users. McCoy et al. (2012) analyzed the content of databases and transactional metadata of GlavMed, SpamIt, and RX-Promotion pharmaceutical affiliate programs (i.e., affiliate websites that advertise and redirect the client to a main illicit shopping website; Levchenko et al., 2011). They observed that the market was steadily attracting new customers. Repeat orders by the same customers was also an important part of the system and constituted around one third of the entire revenue

for the two major programs (GlavMed and SpamIt), highlighting clear signs of customer satisfaction. The fact that drugs that have an abuse potential was overrepresented (in particular, on RX-Promotion) reinforces the hypothesis that abuse may be a driver of demand (McCoy et al., 2012). While GlavMed and SpamIt were located in Russia, the United States dominated the orders (75%), followed by Canada, Australia, and Western European countries. In 2010, Inciardi et al. analyzed five different data sets and showed that sourcing prescription drugs on the web was generally rare, particularly among the individual end users of these drugs (Inciardi et al., 2010). It was, however, stated that although the web might not be a major source for end users, it may play a role at the dealer level (European Monitoring Centre for Drugs and Drug Addiction, 2016; Inciardi et al., 2010).

Prescription drugs and medicine are also offered for sale on cryptomarkets located on the *Darkweb*. Cryptomarkets are "a type of website that uses advanced encryption to protect the anonymity of the users" (Martin, 2014b, p. 351). On these websites, a large range of illicit goods—mainly illicit drugs—are traded while taking advantage of various encryption techniques to obfuscate the participants' identity (Broséus et al., 2016; Demant, Munksgaard, & Houborg, 2018; Martin, 2014a). They have provided new opportunities and challenges for both health and law enforcement agencies (European Monitoring Centre for Drugs and Drug Addiction, 2016; T. K Mackey, 2018). According to the European Monitoring on Centre for Drugs and Drug Addiction (European Monitoring Centre for Drugs and Drug Addiction, 2016), cryptomarkets may become more involved in the supply of prescription drugs in the future. Although illicit drug trafficking in cryptomarkets have been thoroughly studied (see, for example, Barratt, Ferris, & Winstock, 2014; Broséus, Morelato, Tahtouh, & Roux, 2017; Broséus et al., 2016; Kruithof et al., 2016; Rhumorbarbe, Staehli, Broséus, Rossy, & Esseiva, 2016; J. Van Buskirk, Roxburgh, et al., 2016; Van Buskirk, Roxburgh, Bruno, & Burns, 2015), little research has focused exclusively on the trafficking of prescription drugs and medicine. The Enhancing Police Skills on Novel Psychoactive Substance (EPS NPS) project recently analyzed the market of prescription drugs, in particular benzodiazepines, on *AlphaBay* (Mignone & Novara, 2017) between 2015 and 2016. According to the results, prescription drugs and benzodiazepines represented almost 15% of the total drug market (including illicit drugs, steroids, etc.). Regarding benzodiazepines, alprazolam was the most offered for sale on *AlphaBay*, followed by diazepam. The next types of substances commonly offered on *AlphaBay* were erectile dysfunction medicine (e.g., sildenafil), opioid pain medications (e.g., oxycodone), and hypnotic drugs (e.g., zolpidem). According to their analysis, the United States, the United Kingdom, China, and India managed the trafficking of prescription drugs. In 2018, Martin, Cunliffe, Décary-Hétu, and Aldridge (2018) investigated the effect of restricting the legal supply of prescription opioids by the U.S. Drug Enforcement Administration in 2014 on the sales of these substances on cryptomarkets in the United States. They observed that this change coincided with a statistically significant increase in the transactions of opioids from the United States on cryptomarkets. More recently, Cunliffe, Décary-Hêtu, and Pollak, 2019) investigated the nature of the nonopioid prescription medications on cryptomarkets. They analyzed data collected on 31 cryptomarkets between 2013 and 2016 to uncover trends as well as total market activity. They observed that sedatives (tranquilizers) and central nervous system (CNS) stimulants (psychostimulants) had the greatest share of sales, but that usage and trends varied by location.

Given the limited number of studies that focused on the trafficking of prescription drugs and medicine on cryptomarkets, the aim of this article was to obtain a better understanding of the sales of prescription drugs on cryptomarkets. It was decided to focus on the *AlphaBay* cryptomarket, a well-known and popular cryptomarket at its time of activity (between December 2014 and July 2017). This article complements previous studies (Cunliffe et al., 2019; Martin et al., 2018) and brings further knowledge on the trafficking flows between countries and the sales and

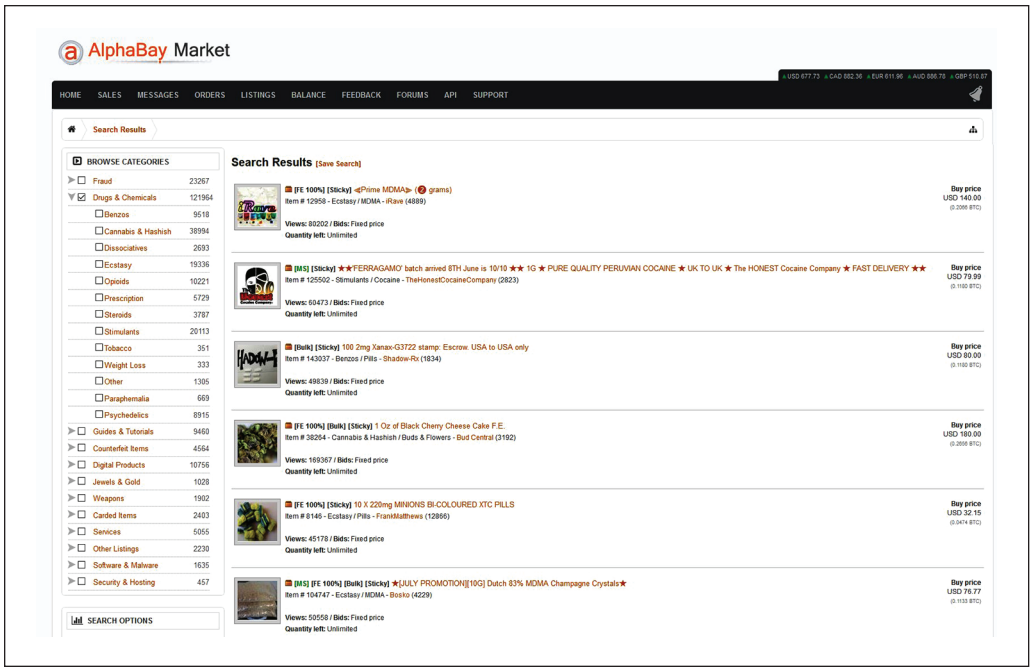

Figure 1. Snapshot of the *AlphaBay* cryptomarket.

revenue of vendors of prescription drugs and medicine on cryptomarkets. Rather than focusing on groupings of substances, it provides a closer look at individual substances.

Materials and Method

Data set

AlphaBay cryptomarket. This research relied on data extracted from *AlphaBay* (an active cryptomarket between December 2014 and July 2017; European Monitoring Centre for Drugs and Drug Addiction and Europol, 2017). Data extraction was conducted using a fit-for-purpose crawler. The global process is described in the following sentences. Only data related to the category "Drugs and chemicals" were extracted (excluding other categories such as weapons, carding, and other goods; see Figures 1 and 2). Several robots were designed to crawl the cryptomarket and parse data from the listings and vendors' profile pages. For each crawling session, dozens of TOR circuits were generated, which were used by the crawling robots to travel across the cryptomarket. A task management system was built to assign missions to each robot and control the success of its tasks. This system was set up to increase the quality and completeness of the extracted data.

Three crawls were obtained at different times (on February 13, May 24, and July 4, 2017). The last crawl was conducted a few days before *AlphaBay* was shut down by a law enforcement operation (European Monitoring Centre for Drugs and Drug Addiction and Europol, 2017). As listings can be taken down by vendors at any point in time and the data set is based on three crawls only, there is a possibility that the number of listings captured is underestimated. However, the number of listings crawled is consistent with another study. Paquet-Clouston, Décary-Hétu, and Morselli (2018) collected data in September, October, November, and December 2015 as well as in January and February 2016. They observed a gradual increase of listings over the

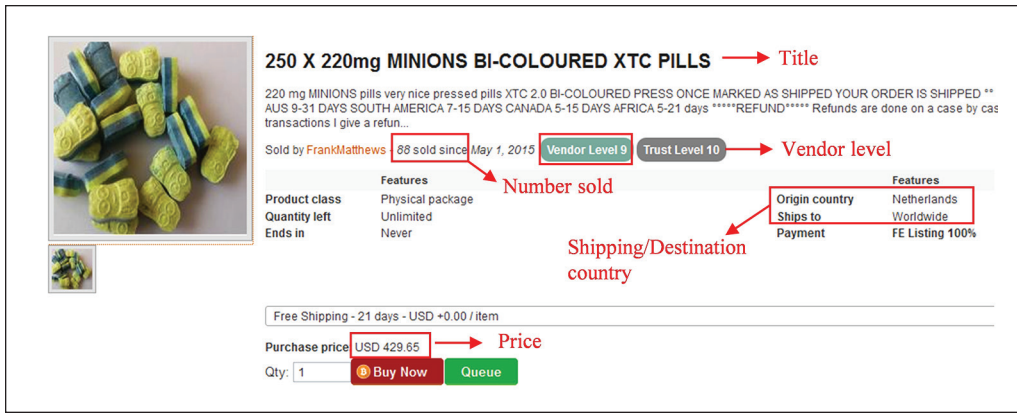

Figure 2. Snapshot of a listing on *AlphaBay*.

6-month period, with 25,395 listings in February 2016. Given that our data set was collected in 2017, a gradual increase of the listings was expected. In July 2017, a total of 31,859 unique sale proposals in the category "drugs and chemicals" were extracted on *AlphaBay*, in line with the gradual increase of listings observed by Paquet-Clouston et al. (2018). As three crawls were available, a listing may be represented in one or more crawls (3 times maximum). The final crawl[1] of each listing was considered for the analysis to avoid any duplicates and consider each listing as unique. Similar to Broséus, Morelato, et al. (2017) and Broséus, Rhumorbarbe, Morelato, Staehli, and Rossy (2017), listings were semiautomatically reclassified based on a list of keywords related to the type of products offered for sale.

Choice of substances. Out of the 31,859 sale proposals, 7,469 listings (23.4%) offered by 1,299 distinct vendors were related to prescription drugs and medicine. To cover the most popular substances, the substances accounting for more than 70% of the total number of listings of prescription drugs and medicine were selected (i.e., 24 substances). These substances, as well as their most common brand names, are summarized in Table 1. A brand name might include two active substances. For instance, Adderall® contains dextroamphetamine and amphetamine, Suboxone® contains a mixture of buprenorphine and naloxone, Norco® contains hydrocodone and acetaminophen, and Percocet® contains oxycodone and acetaminophen. Similar to the work by Cunliffe et al. (2019), diclazepam was also considered in the analysis, although it is not a prescription drug. It was considered as it is a functional analogue of diazepam and is likely to be purchased as a substitute for diazepam (Moosmann, Bisel, & Auwärter, 2014). Listings offering an illicit drug in combination with the selected substances ($n = 122$) were removed as the price would be inaccurate, resulting in the analysis of 5,439 listings (offered by 1,079 vendors).

Data Analysis

Volumes and revenues. For each substance selected, the number of unique listings and the number of vendors (distinguished by their usernames) were calculated to evaluate the volume of prescription drugs and medicine. In addition, the number and type of substances sold by each vendor were also calculated to describe the extent of their share in the market. In contrast to other cryptomarkets and previous studies (Cunliffe et al., 2019; Soska & Christin, 2015), the number of sales was directly available on *AlphaBay* (see Figure 2), so feedback was not used as a proxy of the number of sales.

Table 1. Targeted Prescription Drugs and Medicines (Active Substances and Common Brand Names).

Clinical description	Active substance	Brand	Company (country)	Approved
Tranquilizer	Alprazolam	*Xanax*	Pfizer (USA)	Yes
		Niravam	Schwarz Pharma AG (Germany)	Yes
		Cassadan	Temmler Pharma (Germany)	Yes
	Clonazepam	*Klonopin/Rivotril*	F. Hoffman-La Roche AG (Switzerland)	Yes
	Diazepam	*Valium*	F. Hoffman-La Roche AG (Switzerland)	Yes
		Diastat	Valeant Pharmaceuticals North America (Canada)	Yes
		Relanium	GlaxoSmithKline (UK)	Yes
	Diclazepam		F. Hoffman-La Roche AG (Switzerland)	No
	Etizolam	*Depas*	Yoshitomi Pharmaceutical Industries Ltd (Japan)	Yes
		Sylkam	Dr. Reddy's (India)	Yes
Analgesic	Buprenorphine	*Subutex*	Reckitt Benckiser (UK)	Yes
	Buprenorphine/Naloxone	*Suboxone*	Reckitt Benckiser (UK)	Yes
	Codeine	*Actacode*	Sigma Pharmaceuticals (UK)	Yes
		Optipect	UCB Pharma (Belgium)	Yes
	Fentanyl	*Sublimaze*	Janssen Pharmaceuticals (Belgium)	Yes
		Durogesic	Janssen Pharmaceuticals (Belgium)	Yes
		Actiq	Cephalon (USA)	Yes
	Hydrocodone	*Dicodid*	Abbott Laboratories (USA)	Yes
	Hydrocodone/ Acetaminophen	*Norco*	Actavis (USA)	Yes
	Methadone	*Adolan*	Abic Ltd (Israel)	Yes
		Dolophine	Roxane Laboratories Inc (USA)	Yes
		Ketalgin	Amino AG (Switzerland)	Yes
	Morphine	*Kapanol*	GlaxoSmithKline (UK)	Yes
		Oramorph	Boehringer Ingelheim (Germany)	Yes
	Oxycodone	*Oxycontin*	Purdue Pharmaceuticals LP (USA)	Yes
		Roxicodone	Roxane Laboratories Inc. (USA)	Yes
	Oxycodone/ Acetaminophen	*Percocet*	Endo Pharmaceuticals (USA)	Yes
	Tramadol	*Tramal*	Grünenthal GmbH (Germany)	Yes
		ConZip	Vertical Pharmaceuticals LLC (USA)	Yes
		Ultram	Janssen Pharmaceuticals (Belgium)	Yes
Psychostimulant	Dextroamphetamine/ Amphetamine	*Adderall*	Shire (UK)	Yes
	Methylphenidate	*Ritalin*	Novartis (Switzerland)	Yes
		Concerta	Janssen Pharmaceuticals (Belgium)	Yes
	Modafinil	*Modiodal*	Cephalon (USA)	Yes
		Provigil	Cephalon (USA)	Yes
Appetite suppressant	2,4-dinitrophenol (DNP)			No
	Phentermine	*Adipex*	Gate (USA)	Yes
Vasodilator	Sildenafil	*Viagra*	Pfizer (USA)	Yes
		Revatio	Pfizer (USA)	Yes
	Tadalafil	*Cialis*	Lilly (USA)	Yes
Hypnotic	Zolpidem	*Ambien*	Sanofi-Synthelabo (France)	Yes
		Stilnox	Sanofi-Synthelabo (France)	Yes

The price of the targeted substances was extracted from the listings' title. Revenues were then estimated by multiplying the number of sales by the price in U.S. dollar. Although the price may be altered over time and listings may change, it was assumed that all sales were made at the price

listed at the time the data were extracted. In addition, it is common practice on cryptomarkets to assign high prices to listings that are temporarily in shortage or unavailable, as the vendor does not want to lose visibility by removing their listing (Bakken, Moeller, & Sandberg, 2018; Soska & Christin, 2015). These prices—also known as "holding prices"—were considered as outliers and therefore removed from the revenue analysis similar to previous studies (Broséus, Morelato, et al., 2017; Décary-Hétu, Paquet-Clouston, & Aldridge, 2016; Soska & Christin, 2015). The listings with prices above US$10,000 were manually checked (based on the ratio of the mass sold and the price) and any listings considered inconsistent in terms of mass and price were also filtered out ($n = 370$; Aldridge & Décary-Hétu, 2016).

Geographical analysis. Shipping countries and destinations were analyzed to evaluate the trafficking routes. Although it is not possible to verify the accuracy of the origin, we based our analysis on the assumption that the shipping country is the country of operation of the vendor, which is consistent with previous approaches (Aldridge & Décary-Hétu, 2016; J. Van Buskirk, Naicker, Roxburgh, Bruno, & Burns, 2016). To obtain an indication of the proportion of listings, sales, or vendors per inhabitants of a particular country, the values were normalized to 100,000 inhabitants (source: 2017 data from the United Nations Office on Drugs and Crime [UNODC][2]).

The revenue per country of origin and per vendor was also compared to identify the most prominent countries and vendors in the trade of prescription drugs. When a vendor indicated only one country, it was assumed that all products were shipped from that country. When a vendor indicated a particular country as well as "*Worldwide*," "*Worldwide*" was not taken into account. If a vendor was shipping from two or more countries, the country of the seller was labeled as "unknown."

Vendors' profile. To gain more information about prolific vendors, a qualitative analysis was conducted on the first 20 most active vendors (in terms of number of sales over the entire period studied).

Any information about the number of vendors involved, the language used, the shipping countries (and final destination(s)), and the supplier was highlighted and aggregated. The vendors' pseudonyms were anonymized, and their statements paraphrased to avoid giving away any identifying information that could contradict ethical and privacy recommendations (Martin & Christin, 2016).

Results and Discussion

Size and Nature of the Market

Listings of prescription drugs and medicine represented 23.4% of the total number of sale proposals in the category "drugs and chemicals." This percentage is in line with the results of Kruithof et al. (2016) who analyzed data from eight cryptomarkets (*AlphaBay* included): 24% of drug listings were reported to be prescription drugs and medicine. The targeted substances (see Table 1) covered 5,439 listings, which represented more than 70% of the prescription drugs and medicine's listings and were offered by 1,079 distinct vendors. Alprazolam, oxycodone, and the mixture dextroamphetamine/amphetamine (Adderall) accounted for the majority of listings and were offered by the majority of vendors, whereas alprazolam, diazepam, and oxycodone accounted for the majority of sales (see Figure 3).

Tranquilizers (mainly benzodiazepines) and analgesic (mainly opioid pain medications) accounted for approximately 70% of the prescription drug listings targeted in this study (respectively, 34.9% and 33.2%). According to Olfson, King, and Schoenbaum (2015) and the UNODC

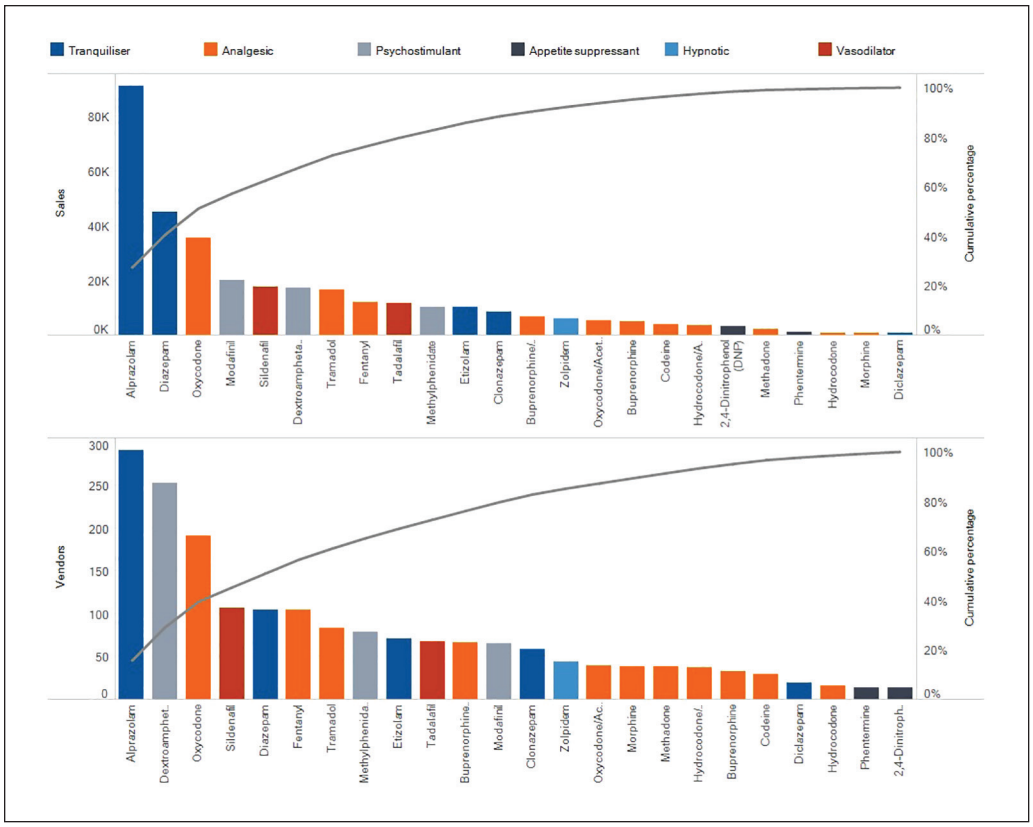

Figure 3. Proportions of sales and vendors offering the different active substances (n = 5,439 listings and 1,079 vendors).

Note. The gray line represents the cumulative percentage of vendors and sales for each type of products offered.

(UNODC, 2018), benzodiazepines are one of the most commonly prescribed drugs in developed countries. The UNODC reported that opioid pain medications (e.g., hydrocodone, oxycodone, and fentanyl), central nervous system depressants (e.g., barbiturates and benzodiazepines), and central nervous system stimulants (e.g., dextroamphetamine and methylphenidate) were the most common types of prescription medication used in a nonmedical context (UNODC, 2011, 2018). In our study, alprazolam was the most offered drug for sale (20.6%) as well as the most sold substance (27.2% of sales). Most commonly known as Xanax® (by Pfizer), it is a minor tranquilizer with a benzodiazepine core and often prescribed for anxiety and panic disorder. In the United States, alprazolam is among the prescription drugs most commonly diverted from the licit market (UNODC, 2017). There thus seems to be similar trends between prescription drugs commonly abused and diverted from the licit market and their sales on cryptomarkets.

Revenue of Prescription Drugs and Medicine

Based on unique sale proposals, the revenue of the targeted prescription drugs and medicine on *AlphaBay* was estimated to be more than US$65 million, a very small market in comparison with the worldwide legal pharmaceutical market's estimate of US$1.3 trillion in 2020 or the global counterfeit drug market's estimate that ranges from US$75 to US$200

Table 2. Revenue and Its Percentage per Type of Substances.

Clinical description	Active substance	Revenue (US$)	Revenue (%)
Tranquilizer	Alprazolam	38,368,717	58.3
	Diazepam	1,939,202	2.9
	Etizolam	587,771	0.9
	Clonazepam	659,488	1.0
	Diclazepam	51,255	0.1
	Total	**41,606,433**	**63.2**
Analgesic	Oxycodone	9,649,604	14.7
	Fentanyl	3,771,940	5.7
	Tramadol	644,180	1.0
	Buprenorphine/Naloxone	752,555	1.1
	Hydrocodone/Acetaminophen	1,007,753	1.5
	Methadone	250,780	0.4
	Oxycodone/Acetaminophen	1,403,979	2.1
	Morphine	46,230	0.1
	Buprenorphine	302,617	0.5
	Codeine	124,003	0.2
	Hydrocodone	66,660	0.1
	Total	**18,020,300**	**27.4**
Psychostimulant	Dextroamphetamine/Amphetamine	3,392,000	5.2
	Modafinil	873,227	1.3
	Methylphenidate	619,987	0.9
	Total	**4,885,214**	**7.4**
Vasodilator	Sildenafil	371,405	0.6
	Tadalafil	344,355	0.5
	Total	**715,760**	**1.1**
Appetite suppressant	2,4-Dinitrophenol (DNP)	122,307	0.2
	Phentermine	72,931	0.1
	Total	**195,238**	**0.3**
Hypnotic	Zolpidem	384,658	0.6
Total		**65,807,605**	**100**

Bold values represent the total per category

billion[3] (International trade administration, 2016). However, it is important to keep in mind that our estimate may be an underestimation as the price may have changed over time and holding prices were removed even though the listings may have been sold before running out of stock. According to Table 2, the sales of alprazolam (i.e., Xanax®) accounted for almost 60% of the total revenue, a large percentage in comparison with the percentage of listings and vendors, respectively. Interestingly, a number of alprazolam listings included very large quantity (1 kg) of the substance and were sold up to 25 times. According to the Enhancing Police Skills on NPS project (Mignone & Novara, 2017), benzodiazepines (e.g., alprazolam) are the most prescribed drugs and most sold in the physical world too. They are also commonly misused by polydrug users. Oxycodone is commonly used in combination with alprazolam for recreational purposes. These findings are worrying as it was shown that the nonmedical use of benzodiazepines in combination with prescription opioids had been involved in a number of overdoses and acute intoxication (UNODC, September, 2017).

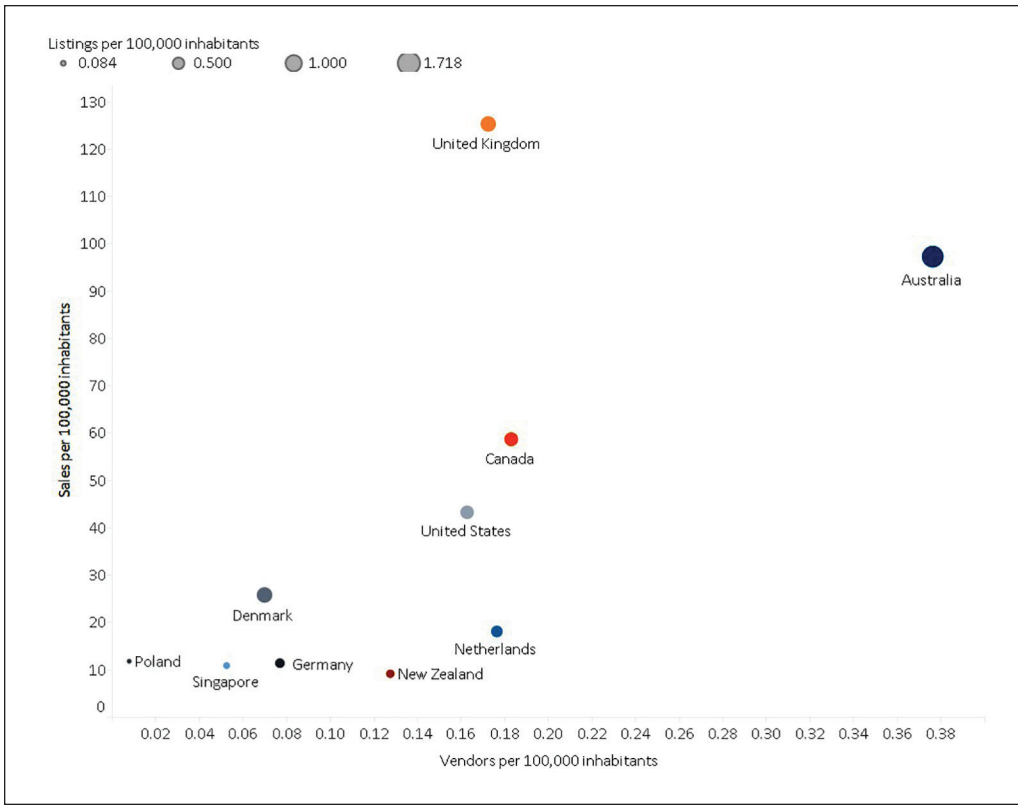

Figure 4. Number of sales (*y*-axis) per vendors (*x*-axis), per shipping countries, and per 100,000 inhabitants ($n = 5{,}439$ listings and 1,079 vendors).
Note. The number of listings per 100,000 is represented by the size of the dots. Only the first 10 countries contributing to the majority of sales per 100,000 inhabitants are represented.

Geographical Analysis

Figure 4 represents the number of listings, sales, and vendors per country and per 100,000 inhabitants. Only the first 10 countries contributing to the majority of sales per 100,000 inhabitants are represented. English-speaking countries, as well as European countries, seem to dominate the market (i.e., the United States, the United Kingdom, Australia, Canada, and Germany) for listings, sales, and vendors. These findings were also noted for illicit drugs, where the trafficking was dominated by English-speaking and Western European countries (Broséus, Rhumorbarbe, et al., 2017; Cunliffe et al., 2019; Kruithof et al., 2016; J. Van Buskirk, Naicker, et al., 2016). This may, however, only reflect countries' Internet access and digital literacy (Büchi, Just, & Latzer, 2016; Demant, Aldridge, Décary-Hétu, & Munksgaard, 2018).

Australia stands out for all three parameters (number of listings, vendors, and sales). Interestingly, a limited number of vendors from the United Kingdom offer a few listings in comparison with the number of sales they generate (country with the highest number of sales). Another interesting country is Denmark, which is ranked fifth in the number of sales per 100,000 inhabitants. Denmark is characterized by a small number of vendors compared with the number of listings and sales. This may suggest that only a few vendors managed most of the listings coming from this country and that the number of sales from this country is relatively high in comparison with its population. It is difficult to explain whether the predominance of these countries on cryptomarkets is due to their role in the trafficking of prescription drugs and medicine or to their

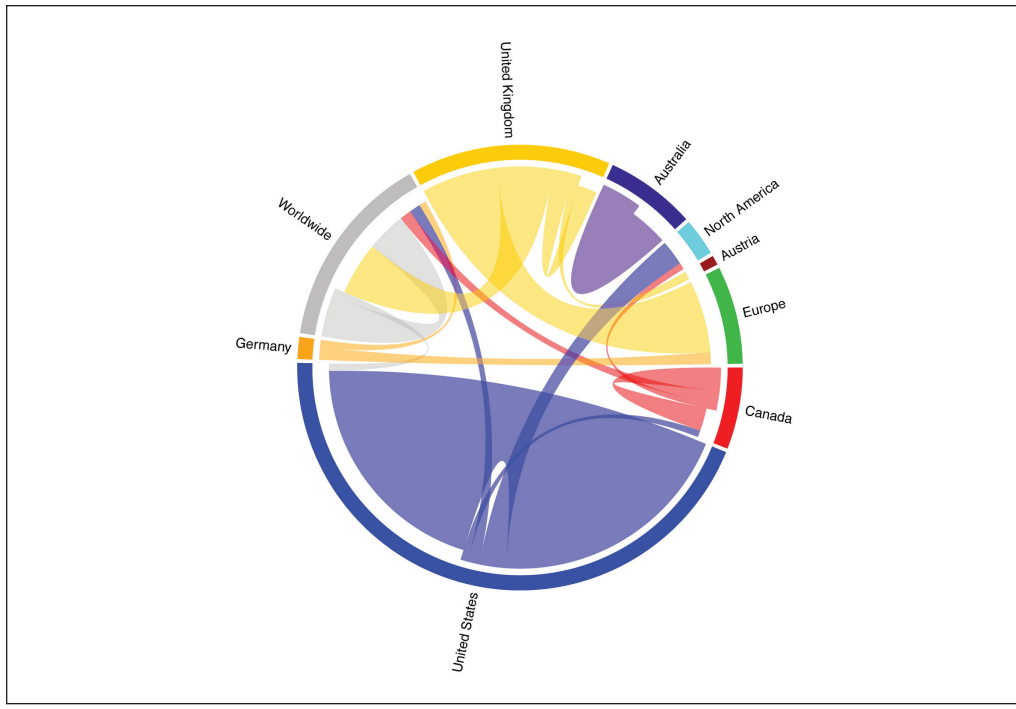

Figure 5. Prescription drugs trafficking flows (based on the number sold).
Note. Only combination of origin/destination countries having a frequency of listings of at least 1% in relation to the total number of sales were considered (i.e., combinations with number of sales above 3,354).

access to the Internet and marketplaces located on the Darkweb. For instance, certain countries like China have introduced censorship and content filtering to control Internet trafficking, and access to specific sites is very complex. This may explain their minor presence on these marketplaces (Ensafi, Winter, Mueen, & Crandall, 2015).

Figure 5 shows the directional flows (origin and destination(s)) of prescription drugs and medicine for the most frequent combinations of origin/destination countries.[4] This representation reveals the extent of the trafficking for the main countries involved in the trafficking of prescription drugs and medicine as well as the nature of the trafficking (domestic vs. international).

Although Europe and North America are not countries, vendors can choose these regions as a destination. They might be willing to ship their goods to all European countries or to all countries in North America while avoiding the rest of the world to prevent interception at borders or expensive shipping fees. The market is domestic in Australia (i.e., Australian vendors offer prescription drugs to Australian customers) and mainly domestic in the United States. In contrast, the Netherlands and Germany principally export internationally (to "*Worldwide*" or Europe). Similar results were observed for illicit drug trafficking (Broséus, Morelato, et al., 2017; Broséus, Rhumorbarbe, et al., 2017). For example, the United States and Australia were shown to offer their substances domestically, whereas the Netherlands mainly offered internationally. The geographical isolation, domestic production, higher prices, population prevalence, legal context, and the risk associated with selling internationally were among the factors raised to explain domestic trafficking (Broséus, Morelato, et al., 2017; J. Van Buskirk, Naicker, et al., 2016).

Only looking at the trafficking flows is not sufficient as vendors from a particular country could sell a limited number of goods in large quantity and at a high price. In contrast to the

Table 3. Revenue and Its Percentage per Shipping Country (n = US$65,807,605).

Country	Revenue (US$)	Revenue (%)	Number sold
United States	28,820,429	43.8	133,522
Canada	21,422,994	32.6	19,563
Worldwide	6,965,332	10.6	30,833
United Kingdom	3,213,965	4.9	71,999
China	1,999,814	3.0	1,072
Australia	1,909,306	2.9	21,805
Germany	545,485	0.8	8,778

Note. Only countries whose revenues are more than US$500,000 between December 2014 and July 2017 are presented.

United States, Canada and China only sold a limited number of goods, but their revenue appeared to be high, an indication of business-to-business sales and possibly those being origin countries (see Table 3). This was also observed in previous studies, which indicated that vendors from these countries were able to source large quantities of products, from either illicit production (e.g., China) or through online pharmacies and other wholesale distribution sources (e.g., Canada; Aldridge & Décary-Hétu, 2014; Cunliffe et al., 2019). According to Table 3, English-speaking countries (i.e., the United States, Canada, Australia, and the United Kingdom) account for approximately 84.1% of the total revenue. It may reflect the countries' Internet penetration rates[5] or the fact that non-English speakers may be more likely to go to national non-English language markets (European Monitoring Centre for Drugs and Drug Addiction and Europol, 2017). Without considering "*Worldwide*," North America largely dominates the market (i.e., 76.3% of the total revenue). Alternatively, the issue related to prescription drugs and, in particular, prescription opioids use in the United States in comparison with other countries has been raised in recent years and several reasons have been hypothesized, such as less severe regulatory systems operating in the United States than in other countries, a change of legislation, and the different prescription and dispensing practices (European Monitoring Centre for Drugs and Drug Addiction, 2016; Fischer, Keates, Bühringer, Reimer, & Rehm, 2014). These reasons could explain the predominance of North America in these markets. Interestingly, China's revenue is high in contrast to the number of vendors stated to operate from this country (results not shown) as well as the number of sales generated. Furthermore, they are willing to take the risk to ship their substances "*Worldwide*" (see Figure 2). This reveals a feature in their market structure in which a few vendors manage all listings that are mostly of large quantity. This was also noted by Broséus, Rhumorbarbe, et al. (2017).

Analysis of the Main Vendors

Type of goods offered for sale. Figure 6 represents the type of substances sold by the 20 most prolific vendors in terms of the number of sales. Most vendors seem to diversify their sales as 13 out of 20 offer a variety of prescription drugs and medicine. Eleven of them sell alprazolam. Usually, vendors offering sildenafil also offer tadalafil. This seems to differ from the research on illicit drugs, which was conducted by Paquet-Clouston et al. (2018) who showed that product diversification is low. However, the categories used in their research were broader and included illicit drugs (e.g., ecstasy, cannabis, psychedelics, stimulants, prescriptions, opioids, and others) and their analysis was conducted on all the vendors. Access to different types of illicit drugs is more complicated. It is thus difficult to directly compare the findings.

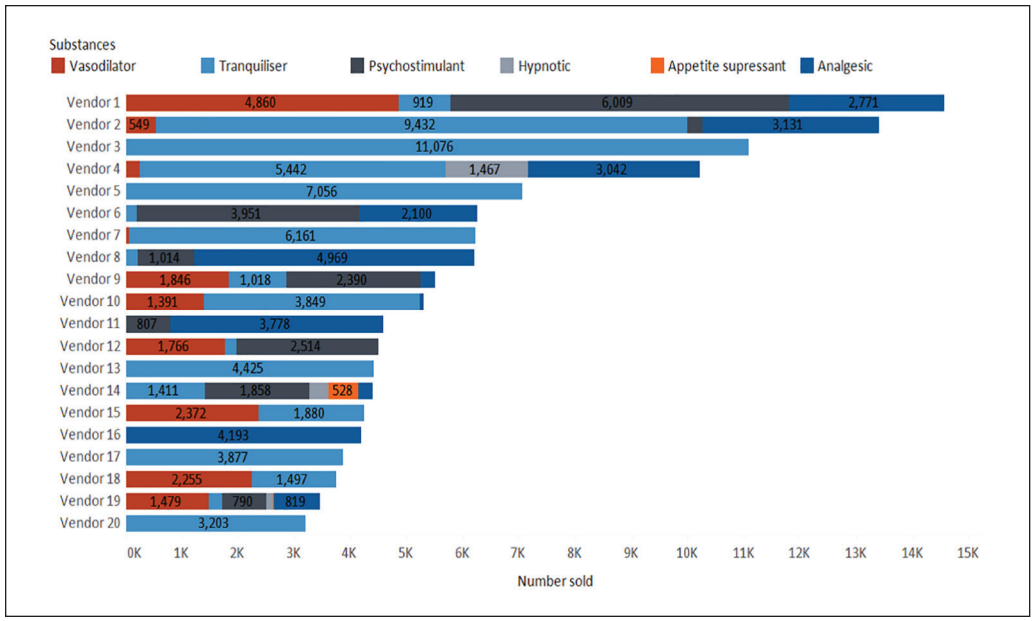

Figure 6. Prescription drugs and medicine sold by the first 20 most active vendors.

Vendors' profile. The length and content of the vendors' description profile seem to have no influence on their popularity as half of them provided a short description (i.e., eight vendors) or no description (i.e., four vendors). The popularity of certain vendors may be explained by their presence on different cryptomarkets. Indeed, 41.6% of vendors stated to be present on other cryptomarkets. Furthermore, vendors may be present on both the web and the Darkweb. It is not uncommon that vendors mention a website in their description profile. In 2015, Soska and Christin conducted a 2-year study on multiple cryptomarkets and observed that a large proportion of vendors sold on multiple marketplaces at the same time (Soska & Christin, 2015). Another study focusing on the Canadian market also showed that some vendors are present on several cryptomarkets to increase their visibility and their profit (Broséus et al., 2016).

The origin of the products they offer for sale was difficult to establish as the vendors did not provide complete information about their suppliers. Almost 50% of them did not mention any suppliers. This might be for safety reasons. Vendors want to provide sufficient information to attract customers while maintaining their anonymity. Pharmacists and doctors may play a role as suppliers, knowingly or unknowingly, as some vendors reported the use of real prescriptions for their supply. However, pharmacists and doctors may be unaware as many methods of diversion exist, such as "Doctor shopping" (obtaining prescription drugs from different doctors, a U.S. phenomenon), sourcing drugs through someone else's legitimate prescription, or even theft (Han, Jones, Blanco, & Compton, 2017; UNODC, September 2017). Five vendors stated that they produced their own products. Bakken et al. (2018) stated that direct contact with the manufacturer could mean that consumers purchasing from these vendors could receive more information about the drugs they are using, which could, in turn, reduce the harm of drug use (Barratt et al., 2014; Van Hout & Bingham, 2013).

Finally, products other than prescription drugs and medicine were also offered by 25% of vendors. A diversification of the market might attract more buyers. Some vendors offered illicit drugs, such as lysergic acid diethylamide (LSD) and cannabis, in combination with prescription drugs. The combination of illicit drugs and prescription drugs is commonly

Table 4. Revenue and Percentage of Vendors Whose Revenues Are More Than US$500,000.

Vendor	Ship from	Revenue (US$)	Revenue (%)	Vendor level	Number of people involved
Vendor 5	Canada	17,149,200	26.1	9	More than one
Vendor 20	Canada	4,934,730	7.5	10	More than one
Vendor 6	United States	3,685,980	5.6	10	More than one
Vendor 21	United States	3,160,727	4.8	10	More than one
Vendor 11	United States	2,493,450	3.8	10	More than one
Vendor 22	United States	2,028,800	3.2	7	More than one
Vendor 23	United States	1,852,200	2.8	9	One person
Vendor 24	United States	1,525,570	2.3	8	One person
Vendor 2	United States	1,434,855	2.2	10	Unknown
Vendor 25	United States	1,189,500	1.8	8	More than one
Vendor 26	China	998,678	1.5	9	More than one
Vendor 27	China	726,435	1.1	8	More than one
Vendor 28	United States	649,050	1.0	9	One person
Vendor 29	United States	618,905	0.9	8	One person
Vendor 30	United States	566,040	0.9	8	More than one
Vendor 1	Germany	504,928	0.8	8	More than one
Total		43,726,048	66.4		

used for recreational purpose (Kelly, Wells, Pawson, LeClair, & Parsons, 2014; Mignone & Novara, 2017).

Vendors' revenue. Table 4 summarizes the revenue of vendors who have made more than US$500,000 since the creation of *AlphaBay*, representing 66.4% of the total revenue of prescription drugs. Vendors from the United States were the most prolific vendors of prescription drugs on *AlphaBay*. The vendors with the highest revenue also sold prescription drugs in large quantity. Soska and Christin found that around 70% of vendors sold less than US$1,000 worth of products and only 2% of vendors sold more than US$100,000 worth of products (Soska & Christin, 2015). They thus seem to have access to a large quantity of these substances. Interestingly, the majority of sales from Vendor 24 are quantities of fentanyl, between 0.05 and 5 g. However, they sold 15 times a quantity of 500 g costing US$75,000. Even though this price is very high, it cannot be considered as a holding price due to the quantity being offered. It appears that this vendor has access to a large quantity of fentanyl. Demant, Munksgaard, et al. (2018) studied the reasons why buyers purchase illicit drugs on cryptomarkets. According to the results, they also observed that vendors from *Silk Road 2* and Agora selling a high quantity of products generated the highest revenue. A possible hypothesis could be their involvement at a high level in the distribution chain, supplying substances for distribution rather than consumption. As a consequence, cryptomarkets may also be a business-to-business market, which was also noted in Aldridge and Décary-Hétu (2014), Bakken et al. (2018), and Cunliffe et al. (2019). Paquet-Clouston et al. showed that only a small portion of vendors succeed in generating regular sales, whereas the majority of vendors seem to be spectators with a limited number of sales (Paquet-Clouston et al., 2018). They also showed that a high number of start-up entities compete only at minimal performance levels, and there are only a few vendors who achieve some level of establishment.

The review of the profiles of the Top 5 vendors who generated the highest revenue highlighted that English was the language used in all profile description. Vendor's levels were reported.[6] The vendor level is a number from 1 to 10 and is allocated to each respective vendor. It is based on a combination of the number of sales, vendor revenue, and feedback. As observed in

Table 4, vendors who generated large revenues also had a high reputation level. It was shown that consumers are willing to pay higher prices for goods sold by reputable online vendors compared with goods sold by unrated vendors (Paquet-Clouston et al., 2018; Smith & Brynjolfsson, 2001).

General Discussion and Conclusion

This study investigated the trafficking of prescription drugs on the *AlphaBay* cryptomarket. It was found that analgesic (in particular, opioid pain medications) and tranquilizers (in particular, benzodiazepines) were the most offered and sold prescription drugs on *AlphaBay*. The nonmedical use of benzodiazepines with opioids has been concerning for control and prevention measures (UNODC, 2017). They represent a significant risk to public health due to their abuse potential, and their use has been involved in a rising number of fatalities in North America and Europe (UNODC, 2017). Alprazolam was found to be the most offered and sold prescription drug on this cryptomarket. In comparison with other benzodiazepines, alprazolam has a high misuse liability and its consumption results in more severe withdrawal syndrome (Ait-Daoud, Hamby, Sharma, & Blevins, 2018). In the United States, alprazolam is considered to be among the three main prescription drugs that are diverted from the licit market, which could explain its high availability on this cryptomarket (UNODC, 2017). It has also received increasing media coverage due to its alleged recent normalization in hip-hop culture in the United States and its links to the death of numerous famous artists (Beaumont-Thomas, 2017; Cunliffe et al., 2019). In addition, there have also been recent reports of pills sold on cryptomarkets as "Xanax" that contained other benzodiazepines (International Energy Control, 2019).

North America (the United States and Canada) seems to play a major role in the sale of prescription drugs and medicine. In both the United States and Canada, a large proportion of prescription opioid harms have been associated with oxycodone formulations (in particular Oxycontin; Fischer et al., 2014). The problem of prescription opioid is particularly important in North America, and the extent of this phenomenon has not registered anywhere else in the world. The North American trend that we observe on cryptomarket could be due to the demand and offer. It was estimated that about 80% of all prescription opioids formulations in Canada are dispensed in the community or through community pharmacies with no postdispensing control mechanisms in place. This would allow an easy diversion of these substances. Furthermore, medical prescription opioid use seems to be much higher in Canada than it is in any other country. Access control and dispensing modalities thus seem to differ between North America and Europe. There is also a higher reliance on treating illness by prescribing drugs in North America (Fischer et al., 2014). As a consequence, this could also be a reason as to why North America is overrepresented in the trafficking of prescription drugs and medicine on *AlphaBay*.

In regard to vendors, the majority seems to diversify their listings of prescription drugs and medicine, and the most prolific vendors seem to have access to large quantities of the substances offered. Although Paquet-Clouston et al. showed that vendors are much more specialized than diversified, it is difficult to compare our findings with theirs as their drug categories were larger than ours (ecstasy, cannabis, psychedelics, stimulants, prescriptions, opioids, and others; Paquet-Clouston et al., 2018). With relatively low risk in comparison with the high profits that prescription drugs and medicine can make, it is not surprising that criminals have a vested interest in this trade (O'Hagan & Garlington, 2018). Perhaps, law enforcement agencies should place greater emphasis on targeting the most prolific vendors, rather than shutting down specific cryptomarkets. Décary-Hétu et al. reported that "Operation Onymous" directed at cryptomarkets Cloud Nine, Hydra, and SR2, had deterrent effects in the short term and showed recovery of vendors and sales on existing and/or novel cryptomarkets following a 1- to 2-month period (Décary-Hétu & Giommoni, 2017). Therefore, the reemergence of cryptomarkets is recurring over time, whereas the return of vendors following police crackdowns may not be so, probably due to fears

of being continually monitored by law enforcement and loss of reputation. Furthermore, according to Paquet-Clouston et al. (2018), only a few vendors manage to conduct constant sales over time. Given the large proportion of sales made by a few vendors, it is likely that a large number of customers are also concentrated around these vendors (Felson & Clarke, 1998).

Although prescription drugs require a valid prescription to be purchased, they are not illegal, and one may ask themselves why are people using cryptomarkets to purchase licit commodities? Several reasons may be raised, such as the nonmedical use of these drugs, the addictive potential of certain substances (e.g., tramadol and oxycodone), the opportunity given by cryptomarkets (i.e., access to a large number of illegal substances as well as prescription medicine), difficulty to obtain a prescription, lower price, quantity consumed is larger than the prescribed dose, anonymity, embarrassment, and speed of delivery (Barratt et al., 2014; European Monitoring Centre for Drugs and Drug Addiction and Europol, 2017; UNODC, 2018). Furthermore, illegal online activities lead to a decline in the traditional hierarchical distribution chain and an expansion of more flexible and informal criminal networks, which might attract consumers (Di Nicola et al., 2015). Whatever the reasons are, this market seems to be quite small. According to Abouchedid, Gilks, Dargan, Archer, and Wood (2018), there has been an increase of websites selling the nonregistered benzodiazepines drug (i.e., diclazepam, flubromazepam, and pyrazolam) between 2014 and 2016 in the United Kingdom/Europe. They reported that the most prominent themes regarding the motivations behind the use of these substances were the treatment of anxiety, sedation/sleep aid, to avoid benzodiazepines withdrawals, and "come down" after the use of stimulants such as amphetamines or cocaine. There seems to be a difference between substances purchased through online pharmacies (both legal and illegal) and through cryptomarkets. Indeed, according to the FakeCare project (Di Nicola et al., 2015), lifestyle drugs and performance-enhancing drugs are often sought on the Web, whereas recreation drugs or prescription drugs such as benzodiazepines and opioids seem to be mainly purchased on the Darkweb. This was confirmed in our study and has also been raised in Cunliffe et al. (2019).

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Notes

1. The last crawl is not always the third one as a listing might be removed from sale by the vendor.
2. United Nations, Department of Economic and Social Affairs, Population Division. (2017). World population prospects: The 2017 revision. *DVD Edition*. Retrieved from https://population.un.org/wpp/Download/Standard/Population
3. It is not clear how this global estimate was calculated.
4. A color is attributed to each country. The length of an arc represents the size of the flow and its direction is represented by the size of the gap between the circle and the flow; the smallest gap represents the origin of the flow and the largest gap its destination(s). The dimension of the arc is proportional to the number of listings counted for the original country to its destination.

5. Internet World Stats, https://www.internetworldstats.com/top25.htm (finally seen February 13, 2019)
6. See https://darknetmarkets.co/alphabay/

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