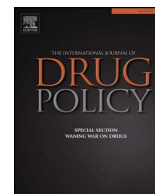




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Comparing cryptomarkets for drugs. A characterisation of sellers and buyers over time

Meropi Tzanetakis^{a,b,*}^a University of Oslo, Department of Criminology and Sociology of Law, St. Olavs plass 5, 0130 Oslo, Norway^b University of Vienna, Department of Political Science, Universitätsstraße 7, 1010 Vienna, Austria

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ABSTRACT

Introduction: Cryptomarkets operating on the darknet are a recent phenomenon that has gained importance only over the last couple of years (Barratt, 2012). However, they now constitute an evolving part of illicit drug markets. Although selling and buying a variety of psychoactive substances on the Internet has a long history, new technological developments enable systematic drug trading on the net. These technological innovations on the Internet allow users to proceed with (illicit) drug transactions with almost completely anonymous identities and locations. In this paper, we provide a systematic measurement analysis of structures and trends on the most popular anonymous drug marketplace, and discuss the role of cryptomarkets in drug distribution.

Methods: Data collection and analysis include a long-term measurement of the cryptomarket 'AlphaBay', the most popular platform during the survey period. By developing and applying a web-scraping tool, market data was extracted from the marketplace on a daily basis during a period of twelve months between September 2015 and August 2016. The data was analysed by using business-intelligence software, which allows the linking of various data sets. We found 2188 unique vendors offering 11,925 drug items. The findings of our long-term monitoring and data analysis are compared over time and across marketplaces, offering a detailed understanding of the development of revenues generated, characterisation of countries of origin and destination, and distribution of vendors and customers over time.

Results: We provide a nuanced and highly detailed longitudinal analysis of drug trading on the darknet marketplace 'AlphaBay', which was the largest cryptomarket in operation. 1) Total sales volumes for the 'drugs' section was estimated at approximately USD 94 million for the period from September 2015 to August 2016. 2) In addition, about 64% of all sales are made with cocaine-, cannabis-, heroin-, and ecstasy-related products. 3) Average selling prices increase over time for categories including cannabis and hashish, ecstasy, opioids, psychedelics and stimulants. 4) The five most frequent countries of origin as indicated by vendors are the United States, United Kingdom, Australia, the Netherlands and Germany. Moreover, it was demonstrated that drug distribution on cryptomarkets is conducted at a regional rather than global level. 6) Furthermore, 4.88% of vendors made over USD 200,000 and were responsible for 52.9% of total revenues generated over the period analysed. In contrast, 57.51% of vendors managed to sell drug items worth less than USD 10,000 within a period of twelve months. The findings suggest that 'AlphaBay' was a cryptomarket mainly from and for Western industrialised countries. In contrast, countries of the global South are neither among the main countries of origin nor destination countries.

Supply and demand on cryptomarkets

Though buying and selling drugs on the Internet go hand in hand with the rise of the Internet, the phenomenon of anonymous marketplaces¹ for, among other things, licit and illicit drugs has gained importance since the first platform 'Silk Road' went online in 2011

(Buxton & Bingham, 2015). On 'Silk Road', a set of technological innovations enabled, for the first time, systematic drug trading on the net (Barratt, Ferris, & Winstock, 2014; Martin, 2014a). These technologies include anonymising software (e.g. Tor) for communication purposes and virtual currencies such as Bitcoin to facilitate the trade of goods and services. The products ordered on the Internet are delivered by

* Correspondence to: University of Oslo, Department of Criminology and Sociology of Law, St. Olavs plass 5, 0130 Oslo, Norway.

E-mail address: meropi.tzanetakis@univie.ac.at.

¹ The terms anonymous drug marketplaces, cryptomarkets and darknet drug markets are used interchangeably and refer to the phenomenon of platforms for, among other things, licit and illicit psychoactive substances which can be accessed by using anonymising software such as Tor (short for The Onion Router).

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traditional postal services without their knowledge. By combining these technologies, illicit drug transactions proceed without any face-to-face meeting, and identities and locations remain anonymous. Thus, while cryptomarkets are easily accessible for users, they are very difficult for law enforcement agencies to shut down. In this regard, the technological innovation used on anonymous online drugs platforms can be seen as a trade-off between “possibility of freedom and necessity of control” (Jasanoff, 2004: 14).

Irrespective of current drug policy, internet technology facilitates an increasing global availability of a wide range of both controlled and new psychoactive substances (Trautmann, 2013). Moreover, supply and demand serve to self-regulate through informal social norms, conventions, values, and cultural beliefs, which have fuelled the growth of a global drug market on an unprecedented scale. User-friendly interfaces and features offered on drug platforms are similar to those provided by e-commerce companies on the World Wide Web, such as customer feedback systems that allow customers to rate sellers and review products. At the same time, customer feedback helps to build trust between sellers and buyers that do not know each other (Bakken, Møller, & Sandberg, 2017; Tzanetakis, Kamphausen, Wersé, & von Laufenberg, 2016). Furthermore, different payment systems are offered on these anonymous platforms which allow for dispute resolution, e.g., by a third party (such as the moderators), in case of conflict (Tzanetakis, 2015).

The original platform ‘Silk Road’ had a monopoly position offering a wide range of psychoactive substances by vendors for selling, but also pornographic material, and false documents like fake ID cards and driving licenses (Christin, 2013). At the beginning weapons were traded as well, though these were later moved to a separate platform. Since ‘Silk Road’ started operating in 2011, the majority of anonymous drug marketplaces have strictly rejected the use of the platforms for exchanging pornographic content involving children (Martin, 2014a). ‘Silk Road’ attracted a lot of attention from the media, government authorities and law enforcement, as well as the increased interest of scholars, which persisted when the platform was shut down by the FBI in 2013. Since then, numerous new platforms have opened, some closing voluntarily and others being taken down by law enforcement or ceasing operation after having scammed the sellers and customers (Tzanetakis & Stöver, *in press*). As of October 2017, almost two dozen platforms of varying sizes and feature sets are online (Darknet Stats, 2017). Customers can choose between various marketplaces and vendors, indicating a high level of competition between vendors and between platforms.

In a qualitative study, Van Hout and Bingham (2013a) explore purchasing practices, experiences and motives of users of the initial market ‘Silk Road’ and found that the relationship between vendors and customers is shaped by trust and professionalism. In a visual and narrative analysis of users’ motives, Van Hout and Bingham (2013b) conclude that the majority of users are male, have a history of drug use ranging from 18 months to 25 years, and are in professional employment or tertiary education. Moreover, Barratt et al. (2014) who conducted the first anonymous online survey among 9470 users from English-speaking countries found that drug purchases were made on ‘Silk Road’ because it offered a wider range of drugs, better quality and greater convenience than was usually available offline. Bancroft and Reid (2016) use discussions on a market forum and qualitative interviews to explore how drug quality is assessed by its users and how experiences of purity, dosing, effects and vendors are systematically shared. In contrast, Caudevilla et al. (2016) reported on the content and purity of drugs based on 219 samples tested in a laboratory. They found that 91.3% of the test results matched the advertised substance online and most samples were of high purity. Barratt and Maddox (2016) conducted digital ethnography to describe how the consumption behaviour of users changed due to the high availability of drugs on the darknet. Participants described a peak of drug consumption in the initial months of using ‘Silk Road’ and no longer needing to hoard drugs

due to the high availability of drugs on cryptomarkets, which helped some to moderate their drug use. In addition, Martin (2014b) was the first to discuss the possibility of cryptomarkets reducing violence. In an international survey, Barratt, Ferris, and Winstock (2016) found that cryptomarkets may reduce drug market-related violence compared to face-to-face drug buying.

Moreover, a qualitative study exploring vendors’ accounts of ‘Silk Road 1’ concluded that sellers adopted a professional approach to running their businesses on the marketplace, providing quality service to maximise their profits, advertising of quality products, professional communication and regular forum activity, competitive pricing, good stealth techniques, speedy dispatch of slightly overweight products, and efforts to avoid customer disputes (Van Hout & Bingham, 2014). By using larger datasets, Décary-Héту, Paquet-Clouston, and Aldridge (2016) demonstrate that the majority of vendors on ‘Silk Road 1’ were willing to take the risk of shipping drugs internationally. The recent scholarship demonstrate the relevance of cryptomarkets by contributing to an overview of supply and demand on anonymous online markets.

In contrast to material drug markets, cryptomarkets allow the collection and analysis of ‘publicly available’ market data regarding revenues generated, drug listings offered, quantities, self-reported countries of origin and destination countries, and distribution of average price. Only these data are available on cryptomarkets because the physical identities and locations of the participants involved in trading are concealed by technological means. However, this novel possibility for conducting measurement analyses has been taken up by some scholars including Aldridge and Décary-Héту, 2014 Décary-Héту (2014,2016, Christin (2013), Cunliffe, Martin, Décary-Héту, and Aldridge (2017), Demant, Munksgaard, and Houborg (2016), Kruithof et al. (2016), Soska and Christin (2015).

While most scholarly contributions provide data on the initial marketplace ‘Silk Road’ (Aldridge & Décary-Héту, 2016; Christin, 2013; Soska & Christin, 2015), which was in operation between 2011 and 2013, this paper will present more recent drug market trends by conducting a long term measurement analysis on the cryptomarket ‘AlphaBay’ between September 2015 and August 2016. The paper aims to (1) provide a systematic measurement and analysis of patterns and trends of online drug marketplaces; (2) compare drug-related activities on the platform ‘AlphaBay’ across various marketplaces and over time; and (3) discusses the role of online drug markets in drug distribution.

The remainder of the paper is organized as follows. Following an introduction into the novel phenomenon and a review of literature regarding supply and demand on cryptomarkets, the measurement methodology is discussed in Section “Measurement methodology”. Section “Characterising the cryptomarket ‘AlphaBay’ and comparing markets over time” presents the findings of our long-term study on ‘AlphaBay’ and subsequently compares them over time and with findings of previous studies. Finally, Section “Conclusion” discusses limitations and provides a synthesis of key points, including open questions for further empirical research.

Measurement methodology

This section describes how data from the cryptomarket ‘AlphaBay’ was gathered and analysed. The platform ‘AlphaBay’ offered various psychoactive substances among other goods and services and has been operating as an anonymous marketplace between December 2014 and July 2017, which made it one of the longest running darknet drug markets (Europol, 2017; Gwern, 2017). In July 2017, ‘AlphaBay’ as well as a platform called ‘Hansa Market’ were taken down by a coordinated operation of multinational law enforcement agencies on various continents (Europol, 2017). ‘AlphaBay’, a screenshot of which is given in Fig. 1, was chosen for analysis as it was claimed to be the most popular active market at the time of data collection (Deepdotweb, 2015). In addition, the marketplace offered all transaction mechanisms available,

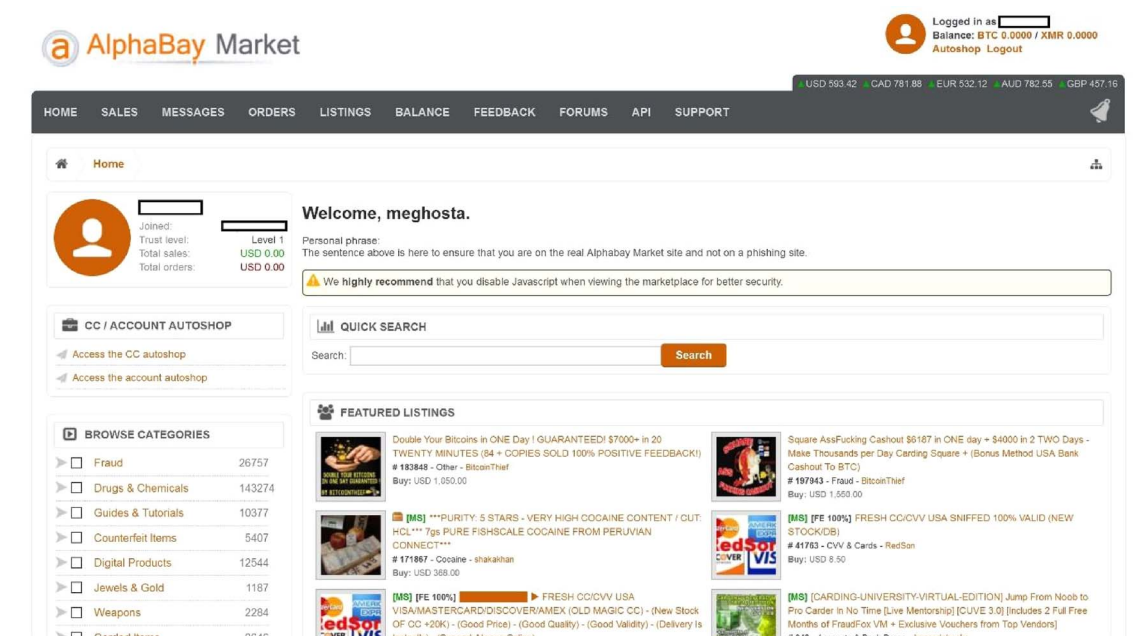


Fig. 1. Front page of the cryptomarket 'AlphaBay' offering, among other products and services, licit and illicit drugs.

including multi-signature transactions, finalize early for verified vendors, and the centralized escrow system (Tzanetakis et al., 2016).

Data collection was made by developing, adapting and applying a web-scraping tool, which enabled the automated extraction of data from 'AlphaBay'. Web-scraping is a method that uses software to extract information from a web page designed for a user, which is saved in a file for further processing (Poynter, 2010). Before performing the web-scrapings,² we manually created a free account on 'AlphaBay' and inspected the structure of the cryptomarket.

Following this, the web-scraping tool enabled us to automate the extraction of data, which was determined prior. The screen scraping included data like drug category, vendor pseudonym, payment method, drug listing, date, pricing information, country/region of origin, destination country/region, customer feedback, quantity, and unit. However, non-drug listings were not included in the extraction of market data. The process of performing a scrape continued with the listings page of each drug category, including the vendor's pages as well as the feedback section. The tool generated the URLs automatically, scraped the URLs and stored them as CSV (short for comma-separated values) files. The web-scraping tool was applied during a period of twelve months between September 2015 and August 2016 and produced 680 MB of data, or 234,760 CSV files. The twelve months of data gathering do not include the testing phase for adjusting the web-scraping tool, which was performed prior.

The scrapes were performed on a daily basis with the exception of downtimes. One full scrape of 'AlphaBay' took three hours and 45 min, however, the average duration was one and a half hours. The difference in time can be explained as follows: a new scrape did not need to load the customer feedback already scraped the day before, but loaded only the new information, which reduces the time and capacity needed for scraping. Moreover, in cases where the marketplace was unavailable for hours or days, the scraping tool was able to extract the additional data when 'AlphaBay' was online again. In addition, we were careful not to

trigger a DDoS (short for Distributed Denial of Service) alarm and we therefore deliberately delayed the extraction from different pages within a scrape for several seconds. A DDoS attack is an attempt to make an online service, e.g. a cryptomarket, unavailable by overwhelming it with Internet traffic.

In a subsequent step, all text files were loaded into the business-intelligence software 'QlikView' and transformed during the ETL (Extract, Transform, Load) process in a way that allowed the software to provide optimum support for a systematic analysis and visualisation of the cryptomarket 'AlphaBay'. The process of data cleaning involved the removal of highly priced listings or listings with a price of zero, tracking the listings over time to identify these. Soska and Christin (2015) refer to this phenomenon as vendors' holding prices. This is a practice commonly used by vendors in order not to lose their feedback and rating when they are out of stock, while at the same time discouraging customers from making orders. However, including holding prices in the analysis would produce incorrect results. Moreover, we decided to maintain the original drug categories offered by 'AlphaBay' for this analysis, which include benzodiazepines, cannabis and hashish, dissociatives, ecstasy, opioids, prescription drugs, steroids, stimulants, tobacco, weight loss, other, paraphernalia, and psychedelics. Using the original categorisation would be problematic when comparing data from different cryptomarkets, as the categorisation usually varies slightly across marketplaces and therefore produces inaccuracies. However, it has been argued by Demant et al. (2016) that relying on the categorisation offered by the marketplace would distort data as vendors can choose individually into which predefined categories to place their good. The analysis and findings presented in the following section offer a detailed understanding of the development of revenues generated, characterisation of countries of origin and destination, and distribution of vendors and customers as well as comparison over time.

Characterising the cryptomarket 'AlphaBay' and comparing markets over time

The analysis of the marketplace 'AlphaBay' found that 2188 unique vendors offered goods in the 'drugs and chemicals' section (see Fig. 1). However, only 1750 of those vendors were actually able to sell drug items during the survey period. This figure was indicated by customers providing feedback on the listings of the sellers. Interestingly, the

² Our web-scraping tool was based on 'iMacros', a popular piece of software with which we were able to run all processes automatically: logging in, solving the CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart, a test designed to differentiate human users from automated programs), web automation, and data extraction. CAPTCHA is a test designed to differentiate humans from automated programs.

number decreases to 922 vendors selling drug items between 1 September 2015 and 31 August 2016, the period of data collection. The number of vendors operating successfully could be calculated precisely, as each item of customer feedback included a time stamp. Data was generated on 11,925 drug items offered, of which 8311 items were actually sold. While for the former no numerical or written customer feedback is provided, the latter are accompanied by reviews and hence indicate that the items were transacted. The data for this quantitative analysis only takes into account drug-related listings, thus non-drug listings were not collected and can therefore not be reported. The same applies for the total number of items offered by vendors.

Development of revenues

In this section, sales volumes for ‘AlphaBay’ (e.g., total sales, per month, per drug category, evolution of average prices) are discussed and compared over time with estimations for other cryptomarkets. Potential errors in data collection are also discussed. The total sales volume on the marketplace ‘AlphaBay’ for the ‘drugs’ section was estimated at USD 93.98 million for the period of September 2015 to August 2016. To contextualise this figure it is important to consider three aspects. First, during the twelve months of data extraction and analysis, about two-dozen platforms of varying sizes and features were online (Darknet Stats, 2017). However, ‘AlphaBay’ was claimed to be the most popular active cryptomarket at the time of data collection and therefore might have generated more sales than other marketplaces (Deepdotweb, 2015). This suggests that revenues generated on ‘AlphaBay’ might be higher than for smaller cryptomarkets operating simultaneously; however, they generate sales volumes of unknown amounts.

Second, the revenues estimated for ‘AlphaBay’ need to be related to previously published volumes of sales in order to understand its evolution over time. In an initial measurement analysis of the marketplace ‘Silk Road 1’, Christin (2013) analysed 24,385 unique drug listings sold by 1239 distinct sellers. Further, Christin calculated an annual sales volume of around USD 15 million by mid-2012. In another web-crawling study, Aldridge and Décary-Héту (2014) observed significant growth in the number of sellers and customers using ‘Silk Road 1’ and increased revenues totalling USD 89.7 million in September 2013, shortly before the platform was shut down. In a long-term measurement of 16 different anonymous online platforms between 2013 and 2015, Soska and Christin (2015) reported an increase of annual sales volume for ‘Silk Road 1’ to over USD 100 million for 2013. In addition, by January 2014 the sales volumes of all cryptomarkets analysed in the study greatly exceeded the estimation for ‘Silk Road 1’ prior to being taken down and reached ‘unprecedented highs’ in the autumn of 2014 (Soska & Christin 2015: 40). The researchers were also able to demonstrate the effects of a large international law enforcement operation in 2014, which resulted in the closure of numerous anonymous online marketplaces. This led to an immediate decrease in total sales but had no long-term effect as a renewed increase in revenues was observed shortly after the operation. Dolliver (2015) compared sales volumes of the marketplace ‘Silk Road 2’ with the original platform ‘Silk Road’. A replication of the study failed and resulted in controversy among scholars regarding the data upon which it was based (Aldridge & Décary-Héту, 2015; Van Buskirk, Roxburgh, Naicker, & Burns, 2015; Munksgaard & Demant, 2016). Demant et al. (2016) observed USD 66 million in sales on ‘Silk Road 2’ and USD 61 million on the marketplace ‘Agora’ between 28 November 2014 and 23 April 2015, which corresponds to a total combined revenue of USD 132.7 million from both platforms projected over a 12 month period. To sum up, estimating the sales volume for ‘AlphaBay’ at approximately USD 94 million in a year corresponds to previous measurements. However, ‘AlphaBay’ cannot directly be compared with ‘Silk Road 1’ as the former faces competition from various other cryptomarkets, while the latter had a quasi-monopoly position during the time it was online.

Third, the relevance of sales volumes generated on darknet marketplaces can be demonstrated by contrasting them with estimations for the material drug market. The EMCDDA estimated the EU retail drug market to be worth approximately EUR 24 billion per year in 2013, its estimations ranging from EUR 21 billion to EUR 31 billion (EMCDDA, 2016: 27). Although differences exist regarding the timeframe under analysis, indicated currency and geographical restriction of the market, comparing cryptomarkets to material drug markets allows us to illustrate that sales volumes on anonymous drug platforms still have only a small market share, which might be growing over time.

This brings us to two issues regarding the accuracy of the measurement when estimating sales volumes. Firstly, revenues are generated by multiplying the number of instances of customer feedback for an item with the average price of the item, as customers are encouraged to leave a review when making a transaction (Christin, 2013; Aldridge & Décary-Héту, 2014; Soska & Christin, 2015). In contrast to previous measurement analyses, the present study did not estimate the daily sales volumes and multiply them by 30 days to estimate the monthly revenues (Christin, 2013), nor were the daily transactions multiplied by 365 to estimate yearly revenues (Aldridge & Décary-Héту, 2014). By contrast, sales volumes were calculated on the basis of the transaction sum indicated by the customer review and the time stamp (date) of the transaction. As these data were scraped on a daily basis for twelve months, it was not necessary to extrapolate the daily transactions to monthly or yearly sales. Instead, this measurement analysis estimated sales volumes with data for every single day within the period of twelve months, resulting in a differentiated understanding of the development of sales volumes during the survey period. To estimate the total sales volumes, any duplicates were removed beforehand so that each single transaction sum or drug listing was only counted once. In addition, it was not necessary to identify the point in time at which the feedback was left as the marketplace ‘AlphaBay’ indicated an exact date for each transaction.

Secondly, ‘AlphaBay’ offered detailed information on a transaction sum, which is relevant for estimating revenues and a novelty for measuring revenues on cryptomarkets, as it allows us to estimate revenues more precisely and accurately. The challenge of making estimations for purchased drug items is illustrated by Soska and Christin: “An order for an item may be of varying quantity, so a customer that purchases a single quantity of a product, and a customer that purchases multiple quantities of a product will both leave a single feedback. In an effort to be conservative, we make the assumption that for every feedback observed, only a single quantity was purchased” (Soska & Christin, 2015: 38). The following example will illustrate how the estimation of sales was made previously: Let us assume an item of 2.5 g of MDMA was ordered and a customer reviewed this transaction: it was not verifiable for a researcher if 2.5, 5, or 25 g were actually purchased. For this reason, previous measurement analyses had to make a conservative assumption that the drug item was ordered exactly as indicated on the listing and not at a different quantity, because the cryptomarket analysed usually did not provide any other information. However, on ‘AlphaBay’ this problem was solved by extracting the sum for every transaction in addition to the type of drug and its quantity, and therefore allows a more accurate estimation of sales. An additional source of error is identifying the exact value of a transaction, as prices for items may vary over time due to adjustments made by the vendors (Soska & Christin, 2015). However, in our analysis we were able to use the transaction sum exactly as indicated on the cryptomarket and thereby circumvent this problem.

According to the procedure outlined above, total annual sales on ‘AlphaBay’ were plotted on a monthly basis. Fig. 2 illustrates the monthly revenues in USD between September 2015 and August 2016. The monthly sales are displayed in chronological order and the average sales made on the marketplace per month are also indicated. Hence, the average volume of sales stands at USD 8 million per month during the analysed period of twelve months. The diagram shows that revenues are

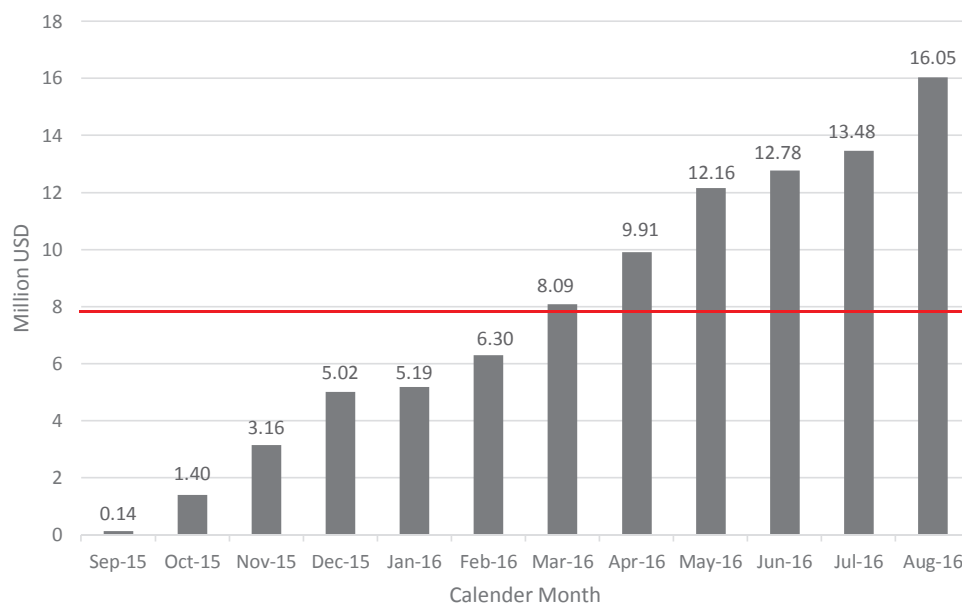


Fig. 2. Monthly revenues generated on 'AlphaBay'.

increasing over time and there is a peak during the summer period. This might indicate that more revenues are generated during the summer months. One explanation is that festivals are held in summer, leading to increased demand for drugs, as well as larger-scale sales opportunities. This is in line with studies indicating that music festival attendees use illicit drugs more commonly than the general population (Lim et al., 2008; Van Havere et al., 2011). However, future measurement analyses of cryptomarkets need to consider that revenues may vary during the year. Previous analyses usually extrapolated daily sales to monthly sales or annual sales, which might be an additional source of error not taken into account so far.

In addition, revenues were estimated per drug category, which is illustrated in Fig. 3. According to our analysis, the highest revenues were generated with stimulants (e.g., cocaine, speed, crystal meth) with

Drug Category	Percentage
Stimulants	20.98
Cannabis & Hashish	18.47
Opioids	12.69
Ecstasy	11.69
Psychedelics	9.56
Benzos	7.87
Prescription	5.78
Dissociatives	5.59
Other	2.66
Steroids	2.58
Weight Loss	1.50
Tabacco	0.66

Fig. 3. Percentage of revenues pre drug category offered on 'AlphaBay'.

a market share of 20.98%, followed by cannabis and hashish with a market share of 18.47%, opioids (e.g., heroin, fentanyl, oxycodone) with a market share of 12.65%, and ecstasy/MDMA with a market share of 11.69%. These four types of drugs traded on the cryptomarket 'AlphaBay' between September 2015 and August 2016 account for about 64% of all sales. This corresponds with findings published by Soska and Christin (2015), who found that 70% of all sales were of cannabis-, ecstasy- and cocaine-related products in their analysis of 16 different marketplaces between 2013 and 2015. The three most popular drugs on cryptomarkets are consistent regardless of the specific marketplace analysed and across time (Aldridge & Décaray-Héту, 2016; Barratt et al., 2014; Barratt et al., 2016; Demant et al., 2016; van Buskirk, Naicker, Roxburgh, Bruno, & Burns, 2016; Bingham, 2013a, 2013b;). Contrary to most other studies where cannabis has the greatest market share, stimulants generate the highest revenues in our analysis. One explanation is that we maintained the original drug categories offered by the marketplace, while most previous studies applied their own categorisation (see above). This may result in differences in allocation as we did not modify the categorisation of drug items by the vendors.

Moreover, the material retail drugs markets in Europe are divided between cannabis, accounting for about 38% of the total, heroin (28%), cocaine (24%), amphetamines (8%) and ecstasy (3%) (EMCDDA 2016: 27). By contrasting the global drug market shares for the anonymous marketplace 'AlphaBay' with estimations provided by the EMCDDA (2016) for the EU retail drug market, it can be concluded that the market shares for different types of drugs traded online largely correspond with those for the drugs distributed on the darknet. However, there are two exceptions: heroin has a higher market share on material drug markets and ecstasy/MDMA have a higher market share on cryptomarkets.

Fig. 4 shows how the average prices per drug category in USD evolved between September 2015 and August 2016 on 'AlphaBay'. A peak occurs when the prices for drug items increase. The peak in November 2015 was due to one particular vendor offering tutorials on how to produce certain drugs, including LSD, crystal meth, fentanyl, GHB/GBL, scopolamine, MDMA, MDA, and DMT. Each of the tutorials offered was priced at about USD 10,000 and therefore the average price for the drug categories concerned increased. While there is a fluctuation in average selling prices across drug categories, the average prices increase over time for some categories, including cannabis and hashish, ecstasy, opioids, psychedelics and stimulants. However, no specific

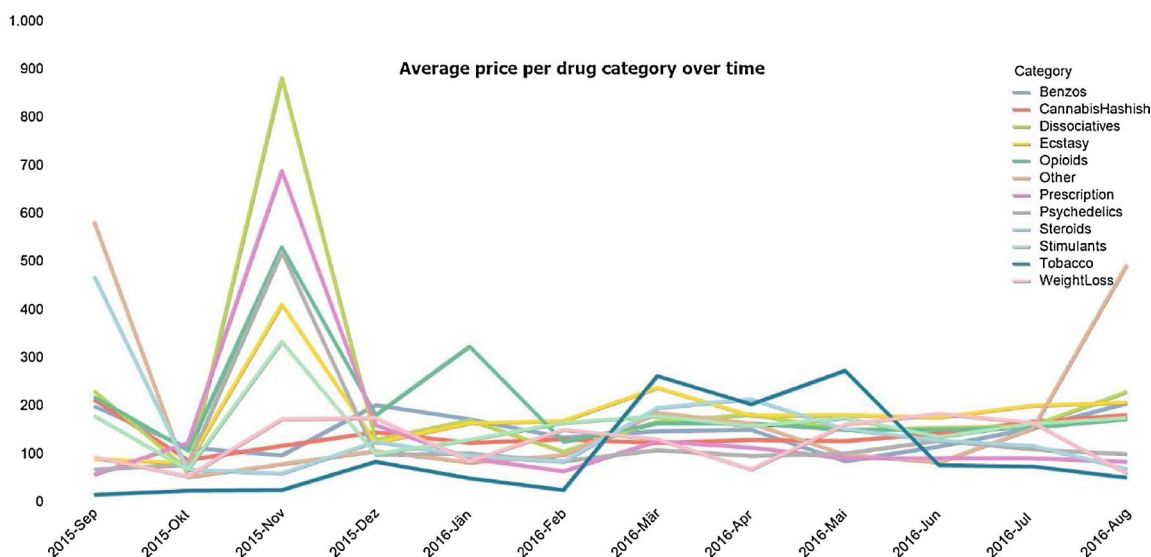


Fig. 4. Development of average price in USD per drug category over time.

development is identifiable for prescription drugs, steroids, tobacco and weight loss items. At this point, a limitation should be added as the average price may increase due to more expensive single items being added to a drug category. Therefore, the evolution of average prices is not necessarily an indicator for increasing prices for certain drug items and Fig. 4 thus depicts a relative, and not absolute, development.

Characterisation of countries of origin and destination

Another focus of our analysis is on the countries of origin and destination for licit and illicit drug shipments. Some implications are discussed here. According to our analysis, 25.3% of all vendors operating on the cryptomarket ‘AlphaBay’ indicated that shipment was from the United States, followed by 9.26% shipping from the United Kingdom, 8.47% from Australia, 8.37% from the Netherlands, 7.17% from Germany, 4.38% from Canada, 2.29% from France, and 1.69% from Spain and China alike. All other countries are mentioned as the country of origin in less than 1% of cases each. However, almost a quarter of all vendors (24.4%) on the platform did not indicate a place of origin for shipping and were therefore categorised as unknown. As Fig. 5 shows, self-indicated countries of origin by vendors are illustrated for ‘AlphaBay’. To sum up, one quarter of vendors reported that shipment was from the United States, one quarter indicated dispatch from Europe, one quarter did not declare where shipment was from, 8% dispatched from Australia, 4% shipped from Canada, and the remaining share is distributed among various countries.

This data analysis largely confirms previous findings on countries of origin on various cryptomarkets and different points in time (Aldridge & Décary-Héту, 2016; Christin, 2013; Dolliver, 2015; Kruithof et al., 2016; van Buskirk et al., 2016). Various studies, including the present analysis, suggest that the five most frequent countries of origin – either by number of listings or according to revenues generated – are the United States, United Kingdom, Australia, the Netherlands, and Germany. However, according to Christin (2013) and Aldridge and Décary-Héту (2016), Canada is within the top five countries of origin. Interestingly, both studies were conducted on ‘Silk Road 1’. By contrast, Aldridge and Décary-Héту (2016) found that for ‘Silk Road 1’, as van Buskirk et al. (2016) also noted for ‘Agora’, China was also among the five most popular country of origin. Drug listings from China are largely associated with new psychoactive substance (NPS), as van Buskirk et al. (2016) have noted.

On a cryptomarket a vendor is able to choose where to ship to. To provide the customers with shipping information, the vendor may

Country of Origin	Percentage
United States	25.30
Unknown	24.40
United Kingdom	9.26
Australia	8.47
Netherlands	8.37
Germany	7.17
Canada	4.38
France	2.29
Spain	1.69
China	1.69
New Zealand	0.70
Czech Republic	0.60
Poland	0.60
Brazil	0.60
Belgium	0.40
Slovakia	0.30
Denmark	0.30
Norway	0.30
Switzerland	0.30

Fig. 5. Self-reported countries of origin by vendors on ‘AlphaBay’.

Destination Countries	Percentage
Worldwide	43.03
United States	23.23
Europe	11.64
Australia	6.99
North America	5.15
United Kingdom	4.77
Germany	1.84
New Zealand	0.63
Switzerland	0.46
France	0.38
Norway	0.17
Oceania	0.08
Brazil	0.08
Sweden	0.08
Finland	0.04
Netherlands	0.04
Africa	0.04
Ireland	0.04

Fig. 6. Self-reported countries of destination for shipping drug items.

indicate on his/her profile page where he/she ships from and to by stating either worldwide or naming a region (e.g., Europe, North America) or a specific country. However, naming the country/region of origin and destination are self-reported information, which has certain implications. It is not possible to verify if the vendor is actually physically located in the self-reported country by relying only on this information. The shipping information rather indicates where the vendor will ship from in order to help the customer make a choice about the risk associated with domestic, regional or international shipment of illegal drugs (Tzanetakis et al. 2016). Moreover, a vendor might prefer to indicate that he/she is shipping from, for example, Austria instead of a neighbouring country. A possible explanation is the following: Austria is a relatively wealthy country and thus enjoys a better reputation compared to, e.g., Slovenia. Therefore, a particular vendor might prefer to cross the Schengen border to ship his/her drug items from Austria instead of Slovenia. This specific relation might not be the case for other countries; however, crossing the border to ship the package might occur for other reasons and depends on the regional context.

In addition, the self-indicated regions and countries of destination by vendors on 'AlphaBay' are presented. The most frequent shipping destinations for drug items are shown in Fig. 6. Our analysis found that 43% of vendors offering their drug items on 'AlphaBay' were willing to ship worldwide and take a presumably high risk. This is followed by 23.23% of sellers willing to ship to the United States, 11.64% shipping to Europe, 6.99% shipping to Australia, 5.15% shipping to North America, 4.77% shipping to the United Kingdom, 1.84% shipping to

Germany, and 1.17% shipping to Canada. To sum up, almost half of the vendors indicate that they ship worldwide, one quarter ships to the United States, 20% ship to Europe and 7% ship to Australia. Interestingly, there is a positive correlation between vendors indicating that they ship from and to the United States, as 70.67% of vendors shipping from the United States report that they ship only to the United States. In addition, 93.76% of vendors indicating that they ship from Australia ship only to Australia. Cunliffe et al. (2017) confirm that Australian vendors tend to ship domestically only. A different picture is found in Europe. Only 23.16% of the vendors ship only within Europe, whereas 76.6% indicate that they ship worldwide. However, we are currently not aware if orders are actually placed from all over the world or mainly within the same region. The same is true of the United States and Australia.

What are the possible implications of vendors indicating countries or regions of destination? As vendors are free to choose one or multiple destination countries, or to vary the destination according to the item sold, figures on destination countries should be put in perspective in order to avoid any misunderstandings. Furthermore, this information does not allow reliable conclusions to be drawn about where the customers are located. Self-reported countries of destination are rather related to differing drug legislations and an indicator of the risk vendors are willing to take (Décarry-Héty et al., 2016; Kruithof et al., 2016; Tzanetakis et al., 2016). Vendors take, as a general observation, less risk when shipping domestically and more risk when shipping internationally, where the risk of interception and, subsequently, risk of detection is assumed to be relatively high. Moreover, self-reported countries of origin are also related to the reputation a country has. Hence, a vendor might attract more customers if it is indicated that illicit drugs are being shipped from a low-risk country instead of the Netherlands or Colombia, which are regarded as high-risk countries. In addition, it can also be stated that privacy of correspondence (Babcock & Freivogel 2015; Desai, 2007) might be guaranteed for domestic mail in most countries of the global North but not for international shipments, which is important to buyers.

To sum up, vendors face a trade-off between: a) offering international shipment, which attracts more customers and has higher prospects of profit, but means higher risk of interception at borders; and b) offering domestic or regional shipment, which attracts fewer customers and has lower prospects of profit, but means lower risk of interception at borders. According to our findings, about 50% of vendors are willing to take the risk and offer worldwide shipment and about 50% prefer to ship within the same region.

Characterisation of vendors and customers

This section focuses on the number of vendors operating on 'AlphaBay', its methodological implications, the business model of cryptomarkets and types of vendors selling drug items. In the context of the measurement analysis, we observed 2188 unique sellers on 'AlphaBay' offering items in the 'drugs' section. However, only 1750 vendors were able to sell drug items. This can be further differentiated into 922 vendors selling drug items between September 2015 and August 2016. These figures do not include sellers who offered their goods or services in any other category than 'drugs and chemicals', nor are numbers included for vendors running a single vendor-account. Fig. 7 illustrates how the number of vendors increases continuously during the period of twelve months. The red line indicates that an average of about 400 vendors were offering drug items throughout the period analysed. These numbers are in line with previous results of quantitative studies and prove the general trends of continuously increasing numbers of vendors operating on cryptomarkets (see below).

As a general observation, the number of unique vendors operating on a marketplace has increased continuously since 'Silk Road 1'. In the first measurement analysis ever conducted on a cryptomarket, Christin (2013) identified 220 sellers offering items on 'Silk Road 1' on

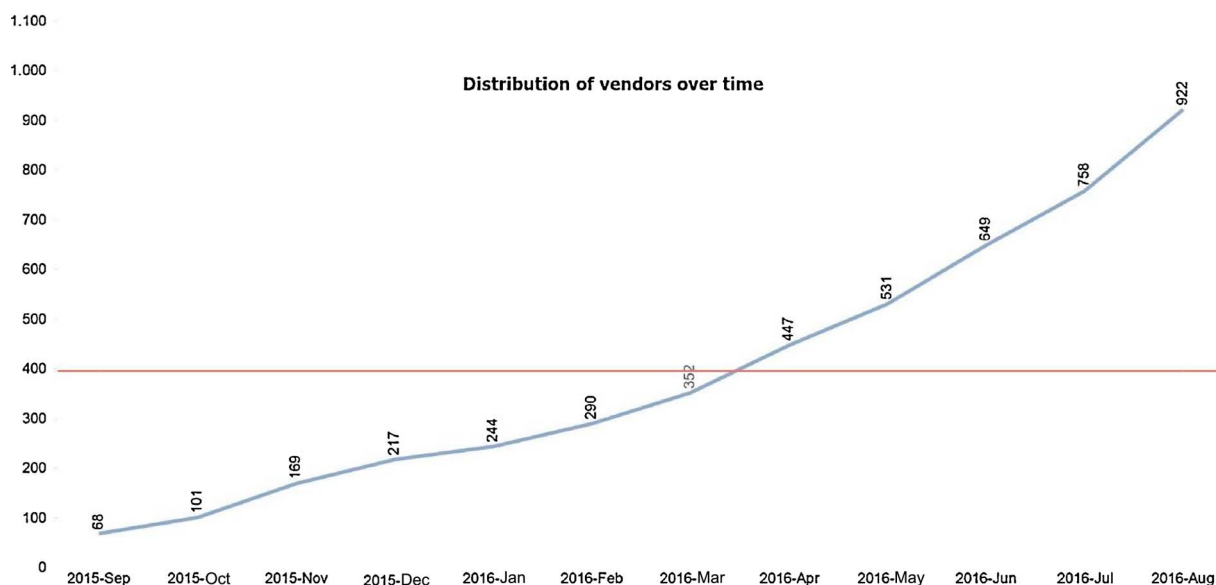


Fig. 7. Development of the number of vendors operating on AlphaBay over time.

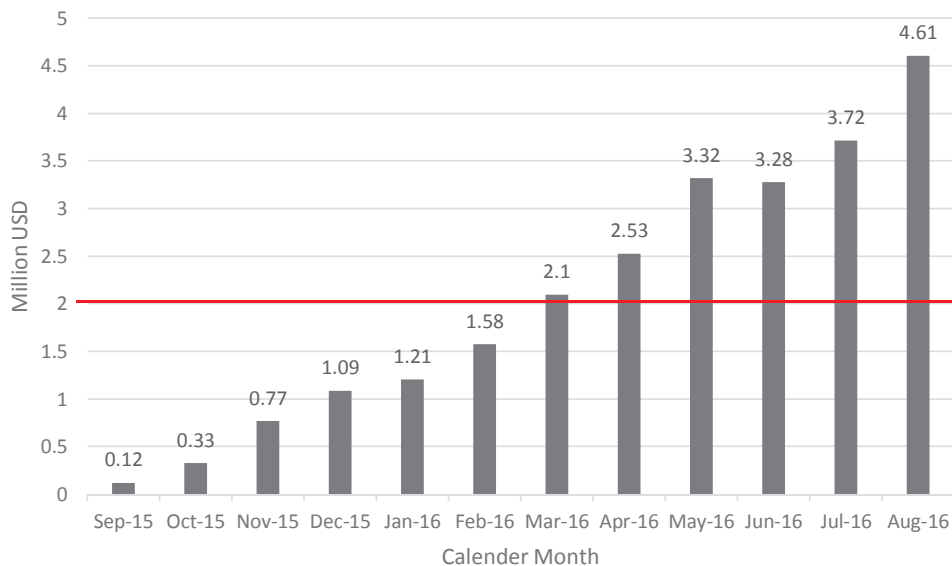


Fig. 8. Monthly revenues generated on AlphaBay for drug transactions over 1000 USD.

November 29, 2011, which increased to 564 distinct vendors on July 24, 2012. During the measurement interval of February 2012 to July 2012, Christin identified 1239 sellers. According to Aldridge and Décarry-Héту (2014), the number of vendors on ‘Silk Road 1’ increased to 1084 for data collected September 13–15, 2013. In a follow-up analysis, Soska and Christin (2015) conclude that the number of sellers increased to around 1400 by October 2013, when ‘Silk Road 1’ was taken down. In their long-term measurement analysis of 16 different cryptomarkets, the scholars identified 9386 vendors who were active between July 2013 and June 2015. In addition, Kruithof et al. (2016) monitored eight cryptomarkets for a period of five days starting on January 11, 2016 and identified 5063 active sellers.

What are the methodological implications when measuring and comparing the number of vendors? Numbers of sellers vary according to whether one takes into account those vendors simply listing items for sale, listing drug items for sale, having actually sold (drug) items or vendors using multiple accounts within and across marketplaces. Furthermore, the number of sellers active on one marketplace also depends on the market share a particular cryptomarket has at a given

time. ‘AlphaBay’, for example, was assumed to be the most popular active cryptomarket (Deepdotweb, 2015) at the time of data collection and therefore might have attracted more vendors and generated more sales than smaller marketplaces. The same holds true for ‘Silk Road 1’, ‘Silk Road 2’, ‘Evolution’, and ‘Agora’ as each had a large market share during a specific period of time (Soska & Christin, 2015).

Another aspect to be taken into account when comparing numbers of sellers from different studies is the time period of data gathering. If data is only collected and analysed for a single day, the number of vendors identified is a snapshot and, generally speaking, varies compared to data gathered for, e.g., a month or a year. This can be explained with an observation made by Christin (2013). He found that the majority of sellers actively offering their items for sale were disappearing within three months of their arrival on the marketplace 2012. Soska and Christin (2015) found that more than 10% of vendors were active throughout the entire measurement interval between July 2013 and June 2015. Even if it is safe to assume that the duration of being active has increased since 2012, the implication that only a minority of vendors offer their goods on a long-term basis is a valid one.

Type of vendor	Percentage
Less than 1,000 USD	21.96
1,000 – 10,000 USD	35.55
10,000 – 50,000 USD	24.07
50,000 – 200,000 USD	13.54
More than 200,000 USD	4.88

Fig. 9. Distribution of revenues generated per type of vendor.

Hence, instead of measuring the number of active vendors at a certain point in time, which does not reflect how many sellers remain in or leave a cryptomarket, it might be more meaningful to measure how long sellers offer their items on a particular marketplace, or even on various marketplaces, which requires long-term measurement analysis.

In addition to the number of vendors offering their drug items, this study examined the business model of cryptomarkets and, subsequently, revenues generated by type of vendor. This will be covered with two different figures in the following. Fig. 8 shows the revenues generated for drug transactions over USD 1000, while Fig. 9 illustrates the value of transactions for drug items per type of vendor. Fig. 8 will be discussed first and Fig. 9 follows.

Since Barratt (2012) published the first scholarly contribution on the initial cryptomarket ‘Silk Road 1’, academic literature has been concerned first and foremost with the question of whether the phenomenon of anonymous online markets on the Internet can be characterised as a business-to-consumer or business-to-business model. Inspired by Aldridge and Décary-Héту (2016), we selected the drug transactions that involved single purchases worth over USD 1000 and illustrated their distribution over the period of twelve months, as shown in Fig. 8. Interestingly, transactions over USD 1000 make up one quarter of overall revenues generated on ‘AlphaBay’. The red line indicates the average level of transactions over USD 1000, which stands at USD 2 million per month. This finding confirms the observation made by Aldridge and Décary-Héту (2016) for 2013, as well as supporting Demant et al.’s (2016) conclusion, in that a significant part of revenues generated for a period of five months in 2014/2015 is intended for redistribution.

Furthermore, we were looking at how transactions worth over USD 1000 are distributed among different categories of drugs. 20.87% of revenues for redistribution were made with stimulants, followed by 17.9% with ecstasy, 15.14% with cannabis and hashish, 12.82% with opioids, 9.97% with dissociatives, and 7.51% with benzodiazepines. The remaining share was spread among the other drug categories. However, by simply conducting a quantitative measurement analysis, it is impossible to verify if drug items bought on a cryptomarket are actually redistributed to friends or acquaintances either for profit (Reuter, 1983), minimal profit (Coomber, Moyle, & South, 2016) or without profit (Taylor & Potter, 2013). Furthermore, it is unclear whether drugs bought on cryptomarkets are actually redistributed on various platforms on the Internet or on material drug markets.

Aldridge and Décary-Héту (2014) found that between 31% and 45% of revenues generated on ‘Silk Road 1’ (depending on the drug category) were found to be drug dealers sourcing stock. In a subsequent publication with a revised approach for calculating reselling transactions on ‘Silk Road 1’, Aldridge and Décary-Héту (2016) estimated that in September 2013 one quarter of revenues was derived from re-selling transactions. These findings are consistent with Barratt et al. (2016), whose larger-scale survey showed that one quarter of participants who reported obtaining drugs through cryptomarkets also supplied to others. In their web-crawling study on the cryptomarkets ‘Agora’ and ‘Silk Road 2’ in November 2014 to April 2015, Demant et al. (2016)

found that business-to-business drug distribution on cryptomarkets generates most of the revenues, although the demand is primarily intended for personal use or social dealing.

The distribution of revenues among different types of vendors is shown in Fig. 9. For this purpose, revenues were divided into five categories, the categorisation of which was inspired by Soska and Christin (2015), who grouped the total value of transactions depending on the amount of revenues generated. In our analysis, 21.96% of vendors generated revenues below USD 1000 over the period of twelve months, 35.55% of the sellers generated sales between USD 1000 and USD 10,000, 24.07% generated between USD 10,000 and 50,000, 13.54% made between USD 50,000 and 200,000 in sales, and 4.88% made more than USD 200,000 in sales. These figures suggest that only a small share of vendors (about 5%) managed to sell drug items worth more than USD 200,000, which corresponds to 52.9% of all revenues generated. However, 57.51% of vendors managed to sell drug items totalling less than USD 10,000 within a period of twelve months. Similarly, Soska and Christin (2015) found that 70% of all vendors never managed to sell more than USD 1000 worth of items. They also calculated that 1% of vendors who made over USD 1 million were responsible for 51.5% of total revenues generated over the period analysed. Both studies illustrate that a majority of darknet drug dealers make moderate revenues.

Conclusion

The implementation of technological innovations, including anonymising software for communication purposes and virtual currencies, has enabled the distribution of licit and illicit drugs without geographical or temporal restrictions. An important implication of this novel criminological phenomenon is that cryptomarkets facilitate the increasing availability of a wide range of psychoactive substances. Another novelty is that sellers actively and openly advertise their (illegal) products, including special offers or discounts. In addition, a key feature of this phenomenon is the feedback system, which serves as a self-regulative mechanism for making transactions between vendors and customers (Tzanetakis et al., 2016). At the same time, the level of transparency increases; e.g., customers can compare information about the type and quality of drugs, prices and vendors prior to making an order, as well as obtaining and exchanging information and experiences on various related forums.

This comprehensive measurement analysis of the marketplace ‘AlphaBay’ continues the tradition of conducting systematic measurement analyses on cryptomarkets, which was pioneered by Christin (2013). We identified trends and patterns over time by scraping market data on a daily basis between 1 September 2015 and 31 August 2016. This generated data on 2188 unique vendors and 11,925 drug items offered. We estimated total sales volumes for the ‘drugs and chemicals’ section at approximately USD 94 million for the period of twelve months. The revenues are in line with previous estimations of annual revenues (Aldridge & Décary-Héту, 2014; Christin, 2013; Demant et al., 2016; Dolliver, 2015; Soska & Christin, 2015) and indicate stable sales volumes over time.

Furthermore, the most popular types of drugs traded were found to be cocaine-, cannabis-, heroin-, and ecstasy-related products, which account for roughly 64% of revenues generated. This suggests continuity regarding the main type of drugs bought and sold on cryptomarkets over time, across marketplaces and scholarly publications. Average selling prices increase over time for categories including cannabis and hashish, ecstasy, opioids, psychedelics and stimulants, although prices fluctuate.

Moreover, countries of origin of vendors and shipping destinations were analysed. While both data sets are based on self-reported information provided by vendors, they provide valuable shipment information. However, the self-reported claims are not necessarily always 100% correct, as discussed above. There is likely a high correlation between the proportion of vendors who self-report as being located in a

particular country/region and the proportion of vendors who ship to that same country/region. It is significant that more than two thirds (70.67%) of United States-based vendors operate only domestically in the United States and nine out of ten (93.76%) Australia-based vendors operate only domestically in Australia. One explanation is the restrictive drug policy in both countries and, consequently, the higher risk associated with shipping internationally. In contrast, European vendors have a different approach, as only one quarter (23.16%) operates only within Europe, while more than two thirds (76.6%) ship worldwide. Further research is needed to better understand when and why vendors might limit sales to domestic customers or operate internationally, and why there are regional differences.

Another focus of the analysis was the distribution of vendors and customers. The number of vendors actively selling on 'AlphaBay' was found to be increasing over time. Furthermore, one quarter of all revenues were estimated to be made with transactions priced at over USD 1000. It can be assumed that these items are bought on the marketplace for redistribution to friends or acquaintances either for profit, minimal profit or without profit via the Internet or physically. A figure of 4.88% of vendors made over USD 200,000 of revenues; however, they were responsible for 52.9% of total revenues generated over the period analysed. In contrast, 57.51% of vendors sold drug items worth less than USD 10,000 within a period of twelve months. This implies that the majority of vendors operating on 'AlphaBay' were small-scale dealers and about 5% of the sellers can be labelled as wholesale dealers. However, further analysis is necessary to examine other criteria for wholesale drug trading, such as, e.g., duration of operation.

The analysis found, in addition, some limitations regarding the comparability of data gathered on various cryptomarkets. As explained in the previous section, each marketplace provides slightly different data and has slightly different structural organisation, which is highly valuable in order to make measurement analyses, but brings with it a lack of comparability. Customer reviews on 'AlphaBay', for example, include the item, date, transaction sum per purchase and link to the item, while reviews on 'Silk Road 1' included only the item and price. The provision of a transaction sum on 'AlphaBay' allowed for a very accurate estimation of revenues as no average price of an item needed to be taken into account. Another aspect of comparing quantitative data from different marketplaces is related to the duration of data gathering. It is hardly possible to take data obtained over several days and compare them to data obtained over twelve months or longer because the significance varies. Furthermore, in order to make data comparable across a specific analysis, it would be useful to follow an approximately similar approach for data gathering. In particular, drug items offered for sale on a marketplace do not automatically generate sales and are therefore a weak proxy for estimating revenues.

The following conclusions may be drawn from this long-term measurement analysis of the cryptomarket 'AlphaBay'. A majority of vendors indicated that they ship at regional level rather than globally. This is a new finding for a phenomenon that was presumed to be global in nature. Additionally, it was striking to observe that none of the countries of the global South was among either the main countries of origin or destination countries. Moreover, none of the traditional cultivation countries had a relevant share as a country of origin or destination. Consistently, our findings suggest that 'AlphaBay' is a cryptomarket mainly from and for Western industrialised countries. Hence, the drug trade via cryptomarkets neither facilitates the international drug trade of material drug markets, nor interferes with the classical transportation routes; rather, it can be characterised as a supply network within the same region of the global North.

Additionally, it is useful to know more about who the customers are. Previous scholarly publications depict a demographic profile of customers buying on cryptomarkets (Bancroft & Reid, 2016; Barratt et al., 2016; Barratt & Maddox, 2016; Maddox, Barratt, Allen, & Lenton, 2016; van Buskirk et al., 2016; Van Hout & Bingham, 2013b). According to these studies, the majority of cryptomarket users are male (at least

80%), aged early- to mid-20s, are in professional employment or tertiary education and could mostly be characterised as occasional or recreational drug users, some as dependent and potentially problematic. The demographic profile of customers may explain why market shares for different types of drugs traded on 'AlphaBay' correspond to market shares for the EU retail drug market. Moreover, the higher market share of ecstasy/MDMA on cryptomarkets can also be explained by its customer population. In the same way, it is instructive that heroin has a higher market share of the EU retail drug market compared to darknet markets. The demographic profile of the customers matches the most popular drugs traded on the cryptomarket and hints at the issue of who has the digital literacy to perform transactions on darknet drug markets.

Conflict of interest

The author declares no conflict of interest.

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