

Drugs for sale! An analysis and estimation of drug products on the cryptomarket ecosystem

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Abstract

Cryptomarkets are marketplaces on the dark web that facilitate the sale of mostly illicit goods and services between vendors and buyers. There were few to no studies that examine the cryptomarket ecosystem using data from multiple cryptomarkets collected at one point in time. This study strives to fill that gap by collecting all product information from eight large or notable cryptomarkets between June 2021 and January 2022 to understand the cryptomarket drug ecosystem, the products available, and identify factors that encourage or discourage vendors from shipping globally. The eight cryptomarkets annually trafficked an estimated 13.4 tons of drugs for \$188.3 million USD. The characteristics of drug products will be examined to determine whether it influences the vendor's willingness to ship globally. Larger quantities and less expensive products were more likely to be shipped globally. Specifically, products that cost less than \$50 were more likely to be able to ship globally.

Keywords: Cryptomarkets, cryptomarket ecosystem, drugs, revenue, global shipment

1. Introduction

Cryptomarkets are eBay-style marketplaces on the dark web that facilitate the trade of illicit goods and services between buyers and vendors (Christin, 2012; Martin, 2014; Bradley, 2019; Barratt, 2012). Vendors often have a large capacity for daily sales, averaging 73 sales per day for vendors who had any sales (Nurmi et al., 2017). There is no inherent trust between the vendors and buyers. Instead, cryptomarkets are used as a trusted third-party that will facilitate deals and reduce risk. Without trust, purchases between anonymous parties can be difficult when users can scam other users by saying they had already sent the product when they did not (on the vendor's side), or never received the product when they did (on the buyer's side). Vendors and buyers may be more hesitant out of fear of being

scammed and the associated financial loss, if they do not use a cryptomarket.

The dark web is an unindexed, encrypted, and anonymous section of the internet, which can be accessed using special software, like The Onion Router (Tor) (Unterfingher, 2019). Tor offers anonymity to the user and obscures their Internet Protocol address by sending it through the Tor relay network (Nastula, 2018), bouncing the user's data around multiple times, before delivering it to the intended destination. This provides the user with protection when browsing the dark web (Aldridge & Décary-Héту, 2014; Lane, et al, 2018). As a result of this anonymity and extra protection, the majority of cryptomarkets are only accessible on the dark web. These online markets allow vendors and buyers to trade without any in-person interactions when buying illicit goods and services, decreasing the risk of physical violence.

These markets are not permanent, nor do they remain active for a long time. New cryptomarkets appear and shut down regularly, without greatly affecting the number of vendors and buyers in the cryptomarket ecosystem (Bradley, 2019). The majority of cryptomarkets last a few months to a couple of years before they exit scam, shut down, or are seized by law enforcement (Branwen, 2018), and are rapidly replaced by new cryptomarkets. There have been at least 171 cryptomarkets that appeared between 2011 to 2022 (Branwen et al., 2015; Dark Web Link, 2021; Dark.link, 2022). Some cryptomarkets exit scam and steal all the remaining funds on the market when they disappear, others announce they will shut down and give their users the opportunity to withdraw their funds, while some are forcefully shut down, either being seized by law enforcement or hacked and unable to recover.

There are a few exceptions to the trend of short lived cryptomarkets, such as Dream market. It appeared in November 2013 and announced their shutdown in April 2019 (Madore, 2019). Many cryptomarkets are short lived, yet some are able to facilitate hundreds of millions of dollars' worth of drug trades (Aldridge & Décary-Héту, 2014; Zhou, et al, 2020).

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This study intends to examine the cryptomarket ecosystem as close to one time as possible to allow for a better understanding of the cryptomarket ecosystem. This simultaneous holistic approach would allow for a more accurate estimation of the number of transactions, revenue, trends and patterns of drug products, and how the characteristics of drug products may influence the vendor's willingness to ship a product globally.

Vendors do not personally deliver these drugs, they package the product, then deliver the package using a postal service. To reduce the odds of the package being seized, vendors use stealth methods when shipping the product. For example, vendors will use mylar bags, vacuum seals, and printed shipping labels during packaging to prevent the package from being flagged and to allow buyers peace of mind. Vendors will also rotate mailboxes when they drop off packages to try and hide their location (Aldridge & Askew, 2016; Smith & Frank, 2020).

Not all products can be shipped globally, there is a large percentage of products that only offer domestic or limited shipping to specific countries, likely because postal services tend to only search packages which are shipped across borders. Identifying and seizing packages may reduce the number of drug shipments by increasing the risk vendors face, thus, deterring them. Vendors appear to be rational, seeking profit and avoiding risk, allowing for the application of Rational Choice (Clarke & Cornish, 1985). It is hypothesized there are package characteristics which reduce the risk of package seizure or maximize profit, thus, influencing whether vendors are willing to ship the product globally. Characteristics examined will include products with a smaller quantity (hypothesis A), smaller common dose (hypothesis B), and less expensive products (hypothesis C). If policymakers can craft policy that targets packages which share many characteristics with global drug packages, the number of seized packages may increase, and the vendors may be deterred.

1.1. Trust to trade

Cryptomarket administrators run a business by being trustworthy, often using safety and security features to reduce the risks of scams so that anonymous parties are willing to trade with each other. The purpose of a cryptomarket is not to personally sell products, but to connect vendors and buyers for the sale of goods and services (Bradley, 2019; Barratt, 2012; Christin, 2012; Martin, 2014). In exchange for facilitating trades and offering a platform with safety features to trade on, cryptomarkets will take a percentage of each transaction (Christin, 2012; Martin, 2014). The cryptomarket administrators, vendors, and buyers are rational actors

who have deemed the potential benefit of trading on cryptomarkets to be worth the risk.

Cryptomarkets use a feature called escrow to prevent scams between buyers and vendors. The cryptomarket would have control of the money and retains control until the transaction is complete. Buyers will pay for a product and send the money to escrow, where the money is held until the product is delivered or the timer runs out and the deal is automatically finalized. Once the product is delivered, the buyer is expected to finalize the deal and release the money to the vendor. If the buyer is unsatisfied or the vendor did not send the product, the buyer can stop the automatic release on escrow to gain more time or attempt to obtain a refund. The cryptomarket will facilitate disputes and determine if the money should be released to the vendor or refunded to the buyer. With the market facilitating and ensuring fair deals, the need for trust between the vendor and buyer is diminished. So long as the buyer and vendor trust the cryptomarket, they can continue to trade with anonymous parties in exchange for a small fee.

The majority of cryptomarkets are global markets, however, there has been an increase in the number of vendors and small cryptomarkets that exclusively caters to a single country (Harviainen et al., 2021). The trust for vendors on country specific cryptomarkets may have differing considerations and values for trust compared to global vendors, such as drug quality, buyer ethnicity, and vendor reputation (Harviainen et al., 2021).

1.2. Revenue

The amount of revenue cryptomarkets and their users generate is increasing. To show the growth of cryptomarkets, this study used Monk and Frank's (2019) method to compare the revenue of Silk Road in 2013, Dream market in 2018, and White House Market WHM in 2021, the three largest cryptomarkets of their time. Silk Road's total revenue was estimated to be \$113.9 million USD in 2013, having grown over 6 times in just over a year (Aldridge & Décary-Héту, 2014). It was calculated by the number of monthly reviews multiplied by its listing price. Drug products contributed to 90% of all products (Aldridge & Décary-Héту, 2014), providing an estimated \$80.7 million of drug products from Silk Road in 2013. Dream market and its vendors generated a conservative estimated revenue of \$168 million, in 2018 (Zhou et al, 2020). The amount of money flowing through the largest cryptomarkets between 2013 to 2018 nearly doubled. WHM's revenue can be examined and compared to Silk Road and Dream market to study the cryptomarket ecosystem's growth.

1.3. Drug products

Cryptomarkets often allow a large range of products to be sold on their site. Commonly sold items include drugs, forgery, credit card and bank information, tutorials on various subjects, and databases from hacked sites. The majority of cryptomarkets will ban certain products to reduce the risk that law enforcement will target their cryptomarket, such as fentanyl (Bradley, 2019; Lane et al., 2018; Morselli et al., 2007). Other markets may allow those products specifically so interested buyers and vendors would have a platform to trade on, securing a client population.

Drug products are the most common listings available on cryptomarkets. It is estimated that between 63-80% of listings were drugs, or drug related products (Barratt, 2012; Christin, 2012; Baravalle et al, 2016; Broséus et al., 2017). There are certain product and package characteristics that are expected to affect the successful delivery of a product. Vendors are rational and will research cryptomarkets and weigh the benefits against the risks when making decisions (Hout & Bingham, 2014; Martin et al., 2020). It would not be odd for them to decide against shipping certain packages globally due to the risk.

As the most common product type, there are a great variety of drug products for sale. The specific drug types within the drug section will greatly differ between and even within markets (Hout & Hearne, 2017), because there can be many novel substances that are not easily classified within existing categories. Some novel substances include synthetic opioids or fentanyl analogs (Lamy et al., 2020). Despite the ban on the sale of fentanyl in most markets, there are listings that still offer fentanyl (Lamy et al., 2020). Lamy et al. (2020) found that the average price per gram of non-pharmaceutical fentanyl was \$1,494 for listings under 5 grams and \$139 for wholesale listings with 5 grams or more. This shows a significant discount for wholesale listings, potentially encouraging buyers to buy more fentanyl. Canada, for example, had a significant increase in the number of opioid overdose deaths from 2019 to 2020 (United Nations Office on Drugs and Crime, 2021a).

1.4. Wholesale

There are different definitions of wholesale drug products. Lamy et al. (2020) defined wholesale fentanyl products as 5 grams or more to acknowledge the potency of synthetic opioids. That definition is specific to opioids and would not apply well to other substances such as cannabis. Aldridge and Décary-Héту (2016) set a conservative estimate of \$1,000 because they expected that the majority of products costing over \$1,000 would be for resale or social use rather than personal use. This

study will use Aldridge and Décary-Héту's (2016) \$1,000 as the threshold for a product to be considered a wholesale product.

1.5. This study

Most of the literature surrounding cryptomarkets has focused on individual cryptomarkets rather than the overall ecosystem. A broad overall perspective can negate some of the individual cryptomarket differences that affect the types of products available. This study examines eight individual cryptomarkets within a year of each market to form a more holistic perspective of the products available on the cryptomarket drug ecosystem, and the drug revenue cryptomarkets are estimated to make. There will be: 1) an estimate of the total amount of currency flowing through the drug ecosystem based on the average price and number of sales in a month; 2) an analysis of the drug products and trends in the cryptomarket ecosystem; 3) examination of product characteristics that increase or decrease the likelihood of products having the option to ship globally or not.

2. Methods

2.1. Equipment

A web crawler created by the International CyberCrime Research Centre, called The Dark Crawler (TDC) was used to collect data from cryptomarkets. TDC contained six crawlers that would access cryptomarkets and collect pages of the market by searching each page for links to other pages and adding them to a queue for data collection. The entire cryptomarket was thus systematically collected, with each product page visited, and stored for analysis.

2.2. Cryptomarket selection

To represent the cryptomarket ecosystem, large cryptomarkets and markets that allowed the sale of high-risk products such as fentanyl or firearms were collected. A list of cryptomarkets was compiled in January and February 2021 from dark web forums, a spreadsheet from law enforcement, and dark web sites that listed cryptomarkets. The cryptomarkets were accessed using newly created accounts, to identify the number of products and users, and if the market allowed the sale of fentanyl or firearms. All cryptomarkets were examined twice, once when it was initially added to the cryptomarket list, then reviewed in March 2021 for any changes. If the cryptomarket was inaccessible from January to March 2021, it was reviewed in September 2021 to determine if the market was large or had notable

products to justify the time cost of crawling. There were 32 cryptomarkets identified.

Only English speaking cryptomarkets were considered for data collection because the language barrier would hinder the understanding of non-English cryptomarkets. Four of the cryptomarkets with the greatest number of products in March 2021 were collected; WHM, Dark0de Reborn (Dark0de), World market, and Versus. Two accessible cryptomarkets that sold firearms were collected: Yakuza and Babylon. After reviewing the inaccessible cryptomarkets, two cryptomarkets were identified as larger markets: DarkFox and ToRReZ. ToRReZ was scheduled to be collected because it was a larger market. DarkFox could not be collected because there were technical issues relating to the interaction between the site and TDC. Finally, WeTheNorth (WTN) was selected as the last cryptomarket to be collected. WTN was a Canadian cryptomarket that appeared in July 2021, after Canadian Headquarters (CanadaHQ) was seized. Data collection spanned eight months, from June 2021 to January 2022.

2.3. Procedure

The selected market would be examined for features and sections that were not relevant to the study, including the logout button, links leading the crawlers onto other sites, or any messaging features that would result in the crawler interacting with vendors or the administrator. Six accounts were created on each market, one per crawler. The crawlers were manually logged onto the selected cryptomarket and set to collect pages. If they ran into a Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA)s, the CAPTCHAs would be manually solved. The TDC was set to collect data until it ran out of new links in the queue. Once the data collection for one market was completed, the crawlers would be set onto another market to collect data, then repeat until all cryptomarkets had been collected. This form of data collection provides a delayed snapshot of each market.

After data collection was completed, rules were created to extract data such as products, vendors, and reviews. The data was cleaned and coded. Data was sorted into three spreadsheets in Excel; vendors, products, and reviews. The products and reviews were examined for duplicates by the product name, description, price, shipping information, if the payment was in escrow, vendor name, and review, date, and reviewer – when it was available. Excel was used to search and delete duplicate product listings and reviews. Reviews were used to indicate sales, similar to the methodology used by other studies to estimate sales (Aldridge & Décary-Héту, 2014; Zhou et al, 2020). All

currency in this study, unless stated otherwise, will be in USD.

2.4. Coding

Drug products were the most common products found in multiple studies and there has been no consensus on the specific drug categories used across studies (Hout & Hearne, 2017; Tzanetakis, 2018; Buskirk et al., 2016). There were drugs commonly available on cryptomarkets: benzodiazepines, cannabis, dissociatives, steroids, ecstasy, opioids, tobacco, weight loss, prescription, psychedelics, stimulants, and other. Drug products were examined for the quantity and number of units offered by using two python programs. The programs would search the product name and the quantity would be multiplied by the number of the form offered. For example, “Xanax 2mg Alprazolam 100 Bars” would output 0.2 grams because 0.002 grams is multiplied by 100 (the number of bars). “1g of top shelf strains” would output 1 gram because no other unit or quantity was found. Any listings over 100 grams would be manually examined to ensure the quantity was correct and to reduce potential skew. To test the accuracy, 242 listings were randomly selected from Dark0de and manually coded. The programs had an accuracy rate of 95%.

To examine the locations where products originated from and could be delivered to, only the first location the product ships to would be used. When examining if a product could be shipped globally or not, a binary variable was created where the product could either be shipped anywhere in the world or could not be.

Finally, the common dose variable was created from three sites to estimate the quantity required for the average user to experience the desired effect. TripSit was the first site used because it was a harm reduction site and may have more accurate information on the amount consumed by drug users (About, 2022). If TripSit did not contain the common dose, PsychonautWiki was used. PsychonautWiki created their dosage information from users’ experiences and research or harm reduction sites when there were no entries in the user experience (Unity, 2022). If neither site contained the common dose, Medscape was used. Medscape is intended for healthcare professionals and focuses on prescription medication for patients rather than drug users (About Medscape, 2022). The common dosage will likely be smaller because harm reduction sites encourage users to start with a smaller dose (About, 2022; Unity, 2022) and medical sites’ target audience are not drug users (About Medscape, 2022).

The common dose will only be used to compare drug products to each other; therefore, a smaller common dose will not have harmful effects on the

analysis. Drug products with a small common dose would often use less space to package compared to products with a larger common dose. For example, 1 gram of LSD can contain 8,000 doses while 1 gram of cocaine may only contain 13-14 doses.

3. Results

This study found 474,778 unique drug product reviews which shipped at least 4.5 tons, costing \$74.9 million in Versus, WHM, ToRReZ, Babylon, Yakuza, Dark0de, World market, and WTN. This does not consider any other factors, such as the number of sales that result in a review or the number of listings and reviews removed by the time of data collection. Not all listings contained a price or quantity, there were 473,478 reviews with a price and 395,326 reviews with a quantity over 0 grams. The average price was \$158, and the average quantity was 11.3 grams.

3.1. Drug revenue estimation

Across all cryptomarkets, \$74.9 million was the observed amount of revenue for drug purchases identified. There are likely a number of sales that did not leave a review. To increase the accuracy of the estimate, cryptomarkets that contained both the number of sales and reviews were examined (Versus, ToRReZ, World market and WTN) to create a sale to review ratio. It was found that 55.0% of sales resulted in a review.

WHM, ToRReZ, World market, Babylon and WTN had the date each review was posted. Estimating the sales per month controls for listings and cryptomarkets leaving the ecosystem to an extent, however, it does not fully control for it. June 2021 was used to calculate the revenue of drug products on the drug cryptomarket ecosystem because it was before data collection started on any cryptomarket that contained a review date. It was found that 11.5% of reviews were posted in June 2021. The delayed time when data was collected may have an impact on the number of purchases identified. To expand the estimate to include other cryptomarkets, it was assumed that the percentage of sales that occurred in June 2021 was similar across all other cryptomarkets. All cryptomarkets had 11.5% of their total reviews included as the number of reviews made in June 2021.

To account for the number of reviews removed, WHM was examined because it had the reviews available on the vendor's profile, allowing the reviews to remain after a listing was removed. These reviews only contain the vendor's name, review date, and product name. It did not have the price, description, shipment information, or if it was a drug product. All reviews were sorted into two categories, the reviews with the listings available and the reviews with listings

taken down. Multiple reviews for one product listing were removed to isolate the product listing. The number of available product listings was compared to the listings that had been removed. The difference was examined in each month to account for the number of accessible to removed listings across time. It was found that after four months, there would be more listings that were removed than listings still available.

WHM, ToRReZ, World, and Babylon completed data collection between September 22 to November 18, 2021. Some of the reviews will be missing, likely between 25% to 50% of all reviews because roughly half of the listings from four months prior were expected to have been removed. Increasing the estimate by a conservative 25%, eight cryptomarkets facilitated an estimated 16.8 tons of drugs for \$234.7 million.

It is estimated that there were 13.4 tons of drugs trafficked annually for \$188.3 million when accounting for the sales to review ratio, the reviews in the month of June 2021, and the average number of grams for listings with a quantity. This does not fully represent the drug product ecosystem on cryptomarkets because of two considerations, the estimate only includes English speaking cryptomarkets and not all large cryptomarkets could be collected.

WHM was the largest cryptomarket of its time in 2021. Accounting for the sales to review ratio and the number of missing products in June 2021, it is estimated that WHM had an annual income of \$145.6 million from drug transactions. There were another two large cryptomarkets on par or greater than the number of listings on ToRReZ which were not collected, DarkFox and CanadaHQ. Including those two markets and the number of likely missing data, the annual income for the cryptomarket ecosystem of drug products likely was in the range of 2.2 million drug purchases totalling 25.2 tons for \$354.3 million.

3.2. Favorite drug types

Stimulants were the most often purchased (29.8% of all purchases), generated the greatest amount of revenue (39.9% of the total revenue), and shipped the largest quantity (43.2% of all grams shipped) of all drug products. This was followed by cannabis, second in purchases (20.3%), revenue (14.9%) and quantity (31.6%). Opioids was third in the number of purchases (11.3%) and revenue (14.9%), yet only fifth in the quantity shipped (3.8%). The stimulant drug type primarily contained amphetamines, methamphetamine, and cocaine, contributing to 96.2% of all stimulants shipped. The amphetamines contained many speed paste products sold at low prices for large quantities. Cannabis listings primarily contained large quantities of the buds and flowers of marijuana. Finally, opioid type products were often heroin and codeine.

3.3. Wholesale purchases

Across all cryptomarkets, 98.5% of drug purchases were not wholesale, costing \$1,000 or more, however, they contributed to 19.3% of vendors' income. Over 75% of all purchases contained 5 grams or less while wholesale purchases averaged 116.4 grams or more for a sum of 672.3 kilograms of drugs. Wholesale drug products were 32 times more likely to be custom listings than non-wholesale products. Custom listings appear when the vendor and an individual buyer come to an agreement about what is sold at what price. The vendor posts the listing, stating the product is a custom listing and either adds part of the buyer's username or sufficient detail about what is contained within the listing to inform the buyer that it is for them. Once the buyer pays using escrow and receives the product, they complete the transaction by releasing the payment to the vendor. The listing can be removed once the transaction is complete, reducing the vendor's digital footprint. Half of the top 10 most expensive products were customized. There are likely more wholesale products unaccounted for than non-wholesale products.

3.4. Characteristics for global shipping

Not all drug products are available globally. Only 30.2% (n=91,738) of drug products offered global shipping. Some countries primarily avoided shipping globally such as the United States only shipping 4.7% (n=4,989) and Australia shipping 6.1% (n=1,369) of products globally. Other countries often had products that could be shipped globally, such as Europe with 85.6% (n=4,919) and the Netherlands with 83.4% (n=16,292) of products available to the global market. Finally, there were average countries such as Canada with 36.3% (n=1,878) of products available globally.

The majority of products from certain countries were limited in where they can be delivered. Many products from countries such as the United States or

Australia would not offer global shipment, preferring to ship the products domestically. The characteristics of drug products will be examined for what influences the willingness of a vendor to ship drug products globally, however, some products still offer global shipment. There may be characteristics that influence if a product can be shipped globally, such as: the common dose, the quantity ordered, and the price. The larger the common dose and quantity, the larger or more numerous the packages necessary to ship the product, potentially increasing the risk. The price of the product is the value that would be lost if the package is seized, which can increase the perceived risk. A binary logistic regression was conducted to examine the impact of these three drug product characteristics on the odds the package can be shipped globally. The t-tests in Table 1 show that the common dose, product price, and quantity of products that can be shipped globally and those that cannot are significantly different.

Only 237,576 cases were included in the analysis because they contained the common dose, product price, and quantity. The model was significant; however, the Hosmer Lemeshow test was significant so the model was not well specified. There was a significant difference between the predicted and observed values. This could be due to the violation of the assumption of linearity, as found by the Box Tidwell test. The relationship between the independent variables and the log odds of global shipping will be underestimated. The null model of the logistic regression in Table 2 could predict if a product offered global shipment with 68.3% accuracy. Including the independent variables, the accuracy increased to 68.5%, a difference of 0.2%. Nagelkerke R² is 0.059 and the Area under the Curve value is 0.700, ($p < 0.001$), which is a moderate benchmark for criminology (Rice & Harris, 1995).

All variables were significant. The common dose had no effect on whether a product offered global shipping or not. A one dollar increase in the price of the product decreased the odds that a product would offer

Table 1. T-Test of drug product characteristics and global shipping options.

Characteristics	Global M (SD)	Not Global M (SD)	T-Test Results
Common Dose*	86.34 (297.75)	129.77 (448.64)	t (236013.09) = -25.71, $p < 0.001$, d = 43.42
Product Price*	220.45 (436.91)	126.06 (527.37)	t (150916.35) = -47.83, $p < 0.001$, d = 94.39
Quantity (grams)*	12.14 (77.07)	9.43 (52.30)	t (117172.45) = 9.22, $p < 0.001$, d = 2.72

Notes. *Levene's test is significant

Table 2. Binary logistic regression of product characteristics to odds of having a global shipment option.

Characteristics	B	S.E.	Wald	Df	Exp(B)
Common Dose	0.000	0.000	786.44	1	1.000*
Product Price	-0.002	0.000	5874.90	1	0.998*
Product quantity (g)	0.006	0.000	1594.95	1	1.006*

Notes. * $p < 0.001$.

global shipping by 0.2%. A one-gram increase in the quantity shipped increased the likelihood that the product would offer global shipping by 0.6%.

3.4.1. Variables and global shipment

All variables and global shipping were non-linear, therefore, examining the common dose, quantity, and price in groupings may provide specific insight into what products are often able to ship globally. Table 3 contains the percentage of products able to ship across the world based off groupings of their characteristics. It was found that while a general increase in the price decreased the odds it is available to be shipped globally, products costing between \$10-\$50 were most likely to be shipped globally, followed by a steep decrease in the likelihood of products costing \$200 or more being shipped globally. For quantity, it was found that the larger the quantity, the more likely it was to be shipped globally. Products that contained 200 grams or more were more likely to be shipped globally, however, those products were skewed by speed paste products.

3.5. Cryptomarket and street prices in Canada

The prices of drug types on cryptomarkets and the street prices in Canada were compared to determine how expensive the price on cryptomarkets were. The street price for drug products in Canada was created using data

from the most recent year available, 2018, by the United Nations Office on Drugs and Crime (2021b). As shown in Table 4, the products available on cryptomarkets were uniformly less expensive than street products in Canada and across the globe.

The cryptomarket price for products shipped within Canada differs from the price of products in the rest of the world. Domestic products that were shipped were more often expensive than the average price found on cryptomarkets. Amphetamine, heroin, ketamine, and oxycodone within Canada were more expensive than their counterparts around the world. The amphetamine subcategory within Canada primarily contained pills rather than speed paste like other places around the world. Some products were similar in cost between Canada and the rest of the world, such as ecstasy. Finally, there were products that were sold in Canada for significantly lower prices than the average price for the rest of the world: cocaine, magic mushrooms, and methamphetamine.

4. Discussion and conclusion

Eight cryptomarkets were collected, and there were 474,778 unique product reviews which shipped at least 4.5 tons, costing \$74.9 million on those markets. There were a few limits to the data in this study. Data was collected consecutively between June 2021 to January 2022, one cryptomarket at a time, by using the data in

Table 3. Percentage of price, common dose, and quantity product characteristics able to ship globally.

Characteristics	Groupings	No Global Option % (n)	Global Option % (n)	Total % (n)
Price (USD)	< \$10	59.92% (13,543)	40.08% (9,057)	7.40% (22,600)
	\$10 ≤ x < \$50	55.01% (49,950)	44.99% (40,859)	29.73% (90,809)
	\$50 ≤ x < \$200	74.35% (100,423)	25.65% (34,653)	44.23% (135,076)
	\$200 ≤ x < \$500	86.38% (36,779)	13.62% (5,799)	13.94% (42,578)
	\$500 ≤ x < \$1,000	82.28% (8,076)	17.72% (1,739)	3.21% (9,815)
	\$1,000 ≤ x (Wholesale)	82.59% (3,747)	17.41% (790)	1.49% (4,537)
Total:		69.58% (212,518)	30.42% (92,897)	100.00% (305,415)
Common Dose (mg)	x < 1mg	54.45% (11,591)	45.55% (9,698)	7.90% (21,289)
	1mg ≤ x < 10mg	65.63% (18,752)	34.37% (9,822)	10.60% (28,574)
	10mg ≤ x < 50mg	72.52% (94,149)	27.48% (35,679)	48.16% (129,828)
	50mg ≤ x < 200mg	67.54% (51,792)	32.46% (24,891)	28.45% (76,683)
	200mg ≤ x < 2000mg	38.02% (2,162)	61.98% (3,525)	2.11% (5,687)
	2000mg ≤ x	84.13% (6,324)	15.87% (1,193)	2.79% (7,517)
Total:		68.54% (184,770)	31.46% (84,808)	100.00% (269,578)
Quantity (g)	x < 1g	66.53% (61,042)	33.47% (30,703)	36.49% (91,745)
	1g ≤ x < 5g	74.39% (65,568)	25.61% (22,570)	35.05% (88,138)
	5g ≤ x < 20g	70.88% (32,453)	29.12% (13,333)	18.21% (45,786)
	20g ≤ x < 50g	78.79% (12,160)	21.21% (3,274)	6.14% (15,434)
	50g ≤ x < 200g	53.53% (4,364)	46.47% (3,789)	3.24% (8,153)
	200g ≤ x < 500g	71.43% (1,100)	28.57% (440)	0.61% (1,540)
	500g ≤ x	42.05% (267)	57.95% (368)	0.25% (635)
Total:		70.38% (176,954)	29.62% (74,477)	100.00% (251,431)

the starting pages to find new pages. When there were no links to certain pages or sections from the product home page, such as an inactive vendor with no product listings or buyer profile pages, the pages could not be collected. Custom listings may have also been accessible for a shorter period of time, making them less likely to be identified during this crawl and underrepresenting them in the data.

There was an estimated 16.8 tons of drug products trafficked for \$234.7 million across eight cryptomarkets. WHM drug products contributed a conservative estimate of \$145.6 million. Silk Road contributed an estimated \$80.7 million annually (Aldridge & Décary-Héту, 2014). From 2013 to 2021, the revenue generated from drug products on cryptomarkets increased by 80.4% and is likely to continue growing.

The most popular drug products across eight cryptomarkets were stimulants, cannabis, opioids and benzodiazepines. Cryptomarkets can be used as an alternative method to access these products. Buyers of wholesale products likely requested more custom products because each purchase would cost a significant sum. Wholesale listings were 32 times more likely to be purchased as a custom listing, with the potential to disappear quickly after the transaction has been completed. There are likely more wholesale products that could not be found compared to non-wholesale. If the custom listing is removed and no review is left, it would be difficult to identify it in the estimate.

Some products were only shipped domestically, likely because of the perceived increase in risk associated with global delivery. Drug products from certain countries have a high percentage of products that cannot ship globally, such as Australia and the United States. Other countries have most of their drug products capable of shipping globally, including Europe and the Netherlands. There are shipping policies and regulations that discourage drug trafficking using cryptomarkets. Vendors have gotten more cautious in recent years and

are less willing to take risks to ship globally compared to before (Buskirk et al, 2016; Christin, 2012). The hypothesis argued that vendors believed certain drug package characteristics were safer and more profitable to ship, such as a smaller quantity (hypothesis A), smaller common dose (hypothesis B), and less expensive products (hypothesis C).

Partial support was found for the hypothesis. The greater the number of grams shipped, and smaller the price, the more likely the product would offer global shipping. The nature of the relationship between the independent variables and the log odds of the global shipping option. Wholesale products were less likely to offer global shipping than non-wholesale products, with only 17.4% of wholesale products offering shipping globally compared to the 30.4% of non-wholesale products. Products costing between \$10-\$50 were most commonly able to ship globally. Buyers likely desire a sufficient supply to last until their next purchase and vendors were less willing to risk the loss of expensive products that could cause a large deficit in their operations. If they offer half a refund when a package is seized, expensive packages are a greater financial risk to their business. If they do not offer some opportunities for a refund when other vendors do, the vendors unwilling to offer refunds become less competitive (Xu et al., 2017).

Products that contained 200 grams or more were more likely to be shipped globally, however, those products were skewed by speed paste products. If those products are excluded, then products that contained large amounts between 50 grams to 200 grams were most likely to be shipped globally. Cryptomarket drugs are less expensive than street drug prices (United Nations Office on Drugs and Crime, 2021b), yet also have fewer reports of products with low purity (Barratt et al., 2016). The drug vendors in Canada primarily sold cocaine and methamphetamine within Canada. The low prices within Canada from a few vendors may push

Table 4. Drug price index global, Canada specific, and street prices in Canada.

Drug	Price (grams) (All)	Price (grams) (Canada)	Street Price (grams) (Canada)	N
Amphetamine	\$13	\$1,101		36,304
Buds and Flowers	\$6		\$8-16	47,935
Cocaine	\$71	\$44	\$78.74	59,290
Fentanyl	\$106			811
Heroin	\$58	\$101	\$110-472	26,416
Ketamine	\$24	\$43		12,918
Magic Mushrooms	\$5	\$3		10,270
MDMA	\$14	\$15		25,310
Methamphetamine	\$20	\$17	\$24-118	23,905
Oxycodone	\$306	\$450		6,689

Notes. This table only contains 10 drug products out of 232 drug products. The full index is available upon request.

other vendors to reduce the price of their products until they are competitive, driving the price down.

The differences in price between countries often shows the products and the ability of vendors within a country to obtain the product. If the product is less expensive, it may be a more commonly found product that can be created or obtained easier than in other countries. There was a large difference in the price of amphetamines in Canada when compared to the rest of the world because Canada did not have speed paste that sold exclusively to Canada. Canada's amphetamines were primarily pills. Location, form, and vendor access to products may all influence the price.

The country drugs originated from likely affects the product's price and if a product can be shipped globally. To reduce global drug trafficking, the shipping policies and regulations of countries that can hinder drug trafficking should be examined and compared to countries where drug trafficking is not hindered. Future research may explore if there are any limits to drug products within Australia or the United States to be shipped to different states of the same country.

Vendors tend to privately communicate with individual buyers and personalize wholesale listings with the specifics requested by the buyer. These custom listings leave a smaller digital footprint because once the transaction is completed, the listing is taken down and becomes inaccessible. A one-time crawl of a market is insufficient to accurately estimate wholesale drug products. Cryptomarkets must be studied longitudinally to gain a clearer understanding of the number and quantity of wholesale products trafficked as custom listings. Such a longitudinal data collection would also allow for the more accurate understanding of custom listings, as with a single swath of data collection there are likely a number of products missed.

To longitudinally monitor cryptomarkets, a web crawler such as TDC is needed. Initial crawl would take longer because the cryptomarket must be fully crawled. The vendor profiles and number of reviews for products must be able to update every time the crawlers need to collect new information from the cryptomarket. One possible way to do this is to use the vendor profile pages as an index to identify if there have been changes to their products, either in the products available or the reviews on their products. Ensure there is a timestamp to state when the data was collected. Finally, have crawlers log onto cryptomarkets once a day and start data collection by sorting for the most recently added products. New vendors will be added to the vendor list once they post a product listing. When the crawlers run out of new product listings and begin to rediscover products they had already collected, the crawlers can move on to updating the vendor's information. By selectively crawling sections of the cryptomarket, the amount of

time necessary for each update would be reduced. This would provide an up-to-date picture of each market, allowing for law enforcement to efficiently prioritize their resources, and better attack this problem.

Cryptomarkets are proving themselves to be attractive alternatives to traditional in-person drug dealing, with lower prices, contactless, and a large variety of drug products in varying quantities available for the buyer's perusal. The drug revenue for cryptomarkets and its vendors increased by 80% from 2013 on Silk Road (Aldridge & Décary-Héту, 2014) to 2021 on WHM, showing a significant amount of growth in the ecosystem. The cryptomarket ecosystem is expected to facilitate an increasing amount of illicit goods and continue growing in the coming years. Machine learning may become a solution to better search and identify drug packages during the shipping process, based on the characteristics of drug packages. With more packages being seized vendors may avoid shipping globally because of the heightened risk and potential for financial loss.

5. References

- About Medscape. (2022). Retrieved February 17, 2022, from <https://www.medscape.com/public/about>
- About. (2022). Tripsit. Retrieved February 17, 2022, from <https://tripsit.me/about/>
- Aldridge, J., & Askew, R. (2016). Delivery dilemmas: How drug cryptomarket users identify and seek to reduce their risk of detection by law enforcement. *The International Journal of Drug Policy*, *41*, 101–109. <https://doi.org/10.1016/j.drugpo.2016.10.010>
- Aldridge, J., & Décary-Héту, D. (2014). Not an Ebay for Drugs: the Cryptomarket's Silk Road' as a paradigm shifting criminal innovation. *Available at SSRN 2436643*.
- Baravalle, A., Sanchez Lopez, M., & Sin Wee Lee. (2016). Mining the Dark Web: Drugs and Fake Ids. *2016 IEEE 16th International Conference on Data Mining Workshops (ICDMW)*, *0*, 350–356. <https://doi.org/10.1109/ICDMW.2016.0056>
- Barratt, M. J. (2012). Silk Road: Ebay For Drugs. *Addiction*, *107*(3), 683–683. doi:10.1111/j.1360-0443.2011.03709.x
- Barratt, M. J., Ferris, J. A., & Winstock, A. R. (2016). Safer scoring? Cryptomarkets, social supply and drug market violence. *The International Journal of Drug Policy*, *35*, 24–31. <https://doi.org/10.1016/j.drugpo.2016.04.019>
- Bradley, C. (2019). *On the resilience of the Dark Net Market ecosystem to law enforcement intervention* (ProQuest Dissertations Publishing). Retrieved from <http://search.proquest.com/docview/2371879163/>
- Branwen, G., (2018). Darknet Market Mortality Risks. *Gwern*. Retrieved February 4, 2022, from <https://www.gwern.net/DNM-survival>
- Branwen, G., Christin, N., Décary-Héту, D., Munksgaard, R., El Presidente, & Anonymous (2015, July 12). Dark net market archives, 2011–2015. <https://www.gwern.net/DNM-archives>

- Broséus, J., Rhumorbarbe, D., Morelato, M., Staehli, L., & Rossy, Q. (2017). A geographical analysis of trafficking on a popular darknet market. *Forensic Science International*, 277, 88–102. <https://doi.org/10.1016/j.forsciint.2017.05.021>
- Buskirk, J., Roxburgh, A., Bruno, R., Naicker, S., Lenton, S., Sutherland, R., ... Burns, L. (2016). Characterising dark net marketplace purchasers in a sample of regular psychostimulant users. *International Journal of Drug Policy*, 35(C), 32–37. [10.1016/j.drugpo.2016.01.010](https://doi.org/10.1016/j.drugpo.2016.01.010)
- Christin, N. (2012). Traveling the Silk Road: A measurement analysis of a large anonymous online marketplace. Retrieved 2020, from https://www.cylab.cmu.edu/_files/pdfs/tech_reports/CMUCyLab12018.pdf
- Clarke, R. V. & Cornish, D. B. (1985). Modeling offenders' decisions: A framework for research and policy. *Crime and Justice (Chicago, Ill.)*, 6, 147-185.
- Harviainen, T., Haasio, A., Ruokolainen, T., Hassan, L., Siuda, P., & Hamari, J. (2021). Information protection in Dark Web drug markets research. In *Proceedings of the 54th Hawaii International Conference on System Sciences* (pp. 4673–4680). (Proceedings of the Hawaii International Conference on System Sciences). University of Hawaii Press. [10.24251/HICSS.2021.567](https://doi.org/10.24251/HICSS.2021.567)
- Harviainen, J. T., Haasio, A., & Hämäläinen, L. (2020). Drug traders on a local dark web marketplace. In *Proceedings of the 23rd International Conference on Academic Mindtrek*, 20–26. [10.1145/3377290.3377293](https://doi.org/10.1145/3377290.3377293)
- Hout, M., & Bingham, T. (2014). Responsible vendors, intelligent consumers: Silk Road, the online revolution in drug trading. *International Journal of Drug Policy*, 25(2), 183–189. <https://doi.org/10.1016/j.drugpo.2013.10.009>
- Hout, M., & Hearne, E. (2017). New psychoactive substances (NPS) on cryptomarket fora: An exploratory study of characteristics of forum activity between NPS buyers and vendors. *International Journal of Drug Policy*, 40, 102–110. <https://doi.org/10.1016/j.drugpo.2016.11.007>
- Lamy, F. R., Daniulaityte, R., Barratt, M. J., Lokala, U., Sheth, A., & Carlson, R. G. (2020). Listed for sale: Analyzing data on fentanyl, fentanyl analogs and other novel synthetic opioids on one cryptomarket. *Drug and Alcohol Dependence*, 213, 108115–108115. <https://doi.org/10.1016/j.drugalcdep.2020.108115>
- Lane, B., Lacey, D., Stanton, N., Matthews, A., & Salmon, P. (2018). The Dark Side Of The Net: Event Analysis Of Systemic Teamwork (East) Applied To Illicit Trading On A Darknet Market. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 62(1), 282–286. <https://doi.org/10.1177/1541931218621065>
- Madore, P. H. (2019). Dream Market Shuts Down. Retrieved March 18th, 2022, from <https://www.ccn.com/dream-market-shuts-down-has-the-dea-claimed-another-darknet-victim/>
- Martin, J. (2014). Lost on the Silk Road: Online drug distribution the 'cryptomarket'. *Criminology & Criminal Justice*, 14(3), 351-367.
- Martin, J., Munksgaard, R., Coomber, R., Demant, J., & Barratt, M. J. (2020). Selling Drugs on Darkweb Cryptomarkets: Differentiated Pathways, Risks and Rewards. *British Journal of Criminology*, 60(3), 559–578. <https://doi.org/10.1093/bjc/azz075>
- Monk, B., & Frank, R. (2019). Discovering wholesale activity through ecstasy transactions on a cryptomarket [Unpublished manuscript]. Criminology, Simon Fraser University.
- Morselli, C., Giguère, C., & Petit, K. (2007). The efficiency/security trade-off in criminal networks. *Social Networks*, 29(1), 143-153.
- Nastula, A. (2018). New threats in the cyberspace based on the analysis of The Onion Router. *Zeszyty Naukowe Wyższej Szkoły Finansów i Prawa w Bielsku-Białej*, 22(4), 26–31. <https://doi.org/10.5604/01.3001.0012.9839>
- Nurmi, J., Kaskela, T., Perälä, J., & Oksanen, A. (2017). Seller's reputation and capacity on the illicit drug markets: 11-month study on the Finnish version of the Silk Road. *Drug and Alcohol Dependence*, 178, 201–207. <https://doi.org/10.1016/j.drugalcdep.2017.05.018>
- Rice, M. E., & Harris, G. T. (1995). Violent Recidivism. *Journal of Consulting and Clinical Psychology*, 63(5), 737–748. <https://doi.org/10.1037/0022-006X.63.5.737>
- Smith, R., & Frank, R. (2020). Dishing the Deets: How Dark-Web Users Teach Each Other About International Drug Shipments. In *Proceedings of the 53rd Hawaii International Conference on System Sciences*.
- Tzanetakis, M. (2018). Comparing cryptomarkets for drugs. A characterisation of sellers and buyers over time. *The International Journal of Drug Policy*, 56, 176–186. <https://doi.org/10.1016/j.drugpo.2018.01.022>
- United Nations Office on Drugs and Crime. (2021a). *World Drug Report 2021 - Executive Summary*. Retrieved on March 5, 2022 from https://www.unodc.org/res/wdr2021/field/WDR21_Booklet_1.pdf
- United Nations Office on Drugs and Crime. (2021b). *Statistical Annex*. [Data]. Retrieved on March 5, 2022 from https://www.unodc.org/documents/data-and-analysis/WDR2021/8.1_Prices_an_purities_of_Drugs.pdf
- Unterfingher, V. (2019). How to Get on the Dark Web. *Heimdall Security Blog*. Retrieved March 18, 2022, from <https://heimdalsecurity.com/blog/how-to-get-on-the-dark-web/amp/>
- Unity. (2022, February 1). *Network*. PsychonautWiki. Retrieved February 17, 2022, from <https://psychonautwiki.org/wiki/Network>
- Xu, X., Munson, C. L., & Zeng, S. (2017). The impact of e-service offerings on the demand of online customers. *International Journal of Production Economics*, 184, 231–244. <https://doi.org/10.1016/j.ijpe.2016.11.012>
- Zhou, Zhuge, J., Fan, Y., Du, K., & Lu, S. (2020). A Market in Dream: the Rapid Development of Anonymous Cybercrime. *Mobile Networks and Applications*, 25(1), 259–270. <https://doi.org/10.1007/s11036-019-01440-2>