

Not an 'eBay for Drugs': The Cryptomarket "Silk Road" As a Paradigm Shifting Criminal Innovation

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ABSTRACT

The online cryptomarket Silk Road has been oft-characterised as an 'eBay for drugs' with customers drug consumers making personal use-sized purchases. Our research demonstrates that this was not the case. Using a bespoke web crawler, we downloaded all drugs listings on Silk Road in September 2013. We found that a substantial proportion of transactions on Silk Road are best characterised as 'business-to-business', with sales in quantities and at prices typical of purchases made by drug dealers sourcing stock. High price-quantity sales generated between 31-45% of revenue, making sales to drug dealers the key Silk Road drugs business. As such, Silk Road was what we refer to as a transformative, as opposed to incremental, criminal innovation. With the key Silk Road customers actually drug dealers sourcing stock for local street operations, we were witnessing a new breed of retail drug dealer, equipped with a technological subcultural capital skill set for sourcing stock. Sales on Silk Road increased from an estimate of \$14.4 million in mid 2012 to \$89.7 million by our calculations. This is a more than 600% increase in just over a year, demonstrating the demand for this kind of illicit online marketplace. With Silk Road functioning to considerable degree at the wholesale/broker market level, its virtual location should reduce violence, intimidation and territorialism. Results are discussed in terms of the opportunities cryptomarkets provide for criminologists, who have thus far been reluctant to step outside of social surveys and administrative data to access the world of 'webometric' and 'big data'.

INTRODUCTION

Silk Road was an online marketplace devoted primarily to the sale of illegal drugs including cannabis, a wide range of psychedelic drugs, stimulant drugs like cocaine, prescription drugs, and more. Drugs were purchased online from vendors displaying eBay-style shop fronts and delivered through the post. Buyers were protected by a system of escrow: they 'paid' for their drugs in the virtually untraceable cryptocurrency bitcoin (so no need for identity-carrying credit card payments), but payments were not released to vendors until buyers were satisfied with their deliveries. This market functioned successfully because it was part of the hidden or 'deep web' where all communications are anonymized by The Onion Router (Tor) service¹. The site was launched in February 2011 and ran successfully for over two and a half years until the United States FBI seized it on 2 October 2013. Until then Silk Road was a success, and it grew. The number of vendors increased rapidly during the first six months of 2012 from 220 to 564 (Christin 2013); and by the time of the data collection in September 2013 that we describe in this article, the number of vendors had nearly doubled again to over 1,000.

The very existence of an online cryptomarket for illegal drugs is a criminal innovation: it provides drug dealers with a virtual location to advertise and sell their products to a worldwide market, to do so anonymously, and to a great extent out of reach of law enforcement. Researchers have characterised Silk Road buyers as *drug users* making purchases for their *own consumption* (Christin 2013; Martin 2013). Indeed, the marketplace itself has regularly been characterised by academics (e.g. Barratt 2012), journalists (e.g. Economist 2012) and in media blogs (Chen 2011) as a kind of “eBay” or “Amazon” for drugs. At least superficially, the resemblance to these exemplars of “business-to-customer” e-commerce is compelling, because the site itself shared many structural features with these marketplaces, including buyers being able to leave feedback on their purchases.

But was Silk Road really like an eBay selling to drug-using customers? When we browsed its listings, it was apparent that many vendors were selling in quantities, at prices, and using terminology suggesting that they were knowingly selling to customers intent on resale: to customers who were themselves drug dealers. Perhaps, therefore, the “eBay for drugs” did not characterise all of the transactions on Silk Road. In order to get a handle on how important these high quantity/price sales were for site sales overall, we downloaded the contents of Silk Road: around 12,000 drug listings and the profile pages of the over 1,000 vendors listing them. In this paper we evaluate these data to address our hypothesis that Silk Road was an online marketplace catering primarily to those making purchases for *resale*; that is, to street drug dealers buying stock to sell offline, and to illegal drug manufacturers purchasing the products and services allowing them to synthesise illegal drugs.

In the first part of the paper, we review the concept of criminal innovation and argue for a distinction between *incremental* criminal innovation, and much less common but paradigm shifting *transformative* innovation, with online illicit markets like Silk Road an example of the latter. We then present our data collection methodology and measurements. Our findings show that a substantial part of Silk Road’s business was geared towards drug dealers and not drug users. We discuss the impact of this finding, including the emergence of a new breed of retail drug dealer equipped with a technological skill set for sourcing stock, alongside a likely reduction in the problems typically associated with organised criminal groups, including violence, intimidation and territorialism (Reuter 2009). We also detail the possibilities that webometrics (Thelwall 2009) open up for criminologists.

CRIMINAL INNOVATION: INCREMENTAL VERSUS TRANSFORMATIVE

It was more than 70 years ago that Merton (1938) first used the term ‘innovator’ to describe individuals who turn to crime. Merton viewed crime as a ‘normal’ adaptation to living in a competitive, materialistic society where not everyone can succeed through legitimate means. Offenders are innovators, for Merton, by virtue of their attempt to achieve material success via unsanctioned or criminal means. The drug dealer is – literally – a textbook example of criminal innovation.

The concept of criminal innovation has resurfaced more recently, but deployed not to explain the *existence* of crime, but instead, criminal *success*. When contemporary criminologists refer

to criminal innovation (e.g. Furnell, Chiliarchaki, and Dowland 2001; Lacoste and Tremblay 2003; Phua et al. 2007; Sawhney, Verona, and Prandelli 2005; Tuomi 2002) they typically refer to the tweaking of criminal scripts² – the step-by-step ‘how to’ for the commission of a particular crime – resulting in innovations that allow them to operate more successfully than their competitors and out of the reach of law enforcement.

The vast majority of these innovations, whilst important in determining *which* criminals succeed, primarily show evidence of only incremental levels of innovation. An example would be the cannabis cultivators studied by Bouchard and Tremblay (2005) whose moves to indoor hydroponic cultivation improved their ability to evade official detection following increased police attention to their field crops. Another example is found with Lacoste & Tremblay’s study of cheque fraudsters (2003). Cheque fraudsters required false identity cards to enable their work, and would often steal these from household mailboxes. Innovators would additionally break into homes to steal another, then use both to request a third, thereby building an entire identity ‘kit’. This kind of incremental innovation is important, but does not fundamentally change the criminal endeavour.

While innovation may come from anywhere, much of it over the last decade has been claimed to come from the Internet (e.g. Rose and Lyytinen 2001; Sawhney, Verona, and Prandelli 2005; Tuomi 2002), and it is here the extent of innovation steps up. One example is sex workers using online classified ads and discussion forums to advertise their services and ‘johns’ using the same forums to share techniques to evade the police (Holt and Blevins 2007). Another example of Internet-facilitate incremental innovation was credit card thieves use of Internet Relay Chat (IRC) and online discussion forums to advertise stolen credit cards and the goods necessary to clone them (e.g. Fallmann, Wondracek, and Platzer 2010). The innovation here was the automated system that recorded the feedback from past buyers of these stolen cards, giving buyers a sense of vendor reputation. Because of the only rudimentary security features of these online platforms, however, criminal operators there could face a considerable degree of victimisation or ‘treachery’ (Franklin et al. 2007) both from vendors and platform administrators. Thus, we observe ‘improvements’ for the criminal, but only in one or a few aspects of the activity. Improvements for the credit card thieves after moving online included access to a larger pool of buyers, but little or no gain in terms of their security, and the quality of the products they sought. These examples of innovation, resulting from a shift in the location of criminal transactions from the physical to the virtual world, therefore resulted in innovative change, even if only incrementally so.

This paper will showcase something less common: the creation of an entirely new criminal script; of paradigm shifting criminal innovation. One such example, arguably, was Napster (Heckert and Heckert 2004), which began operating in 1999 and became one of the first peer-to-peer (P2P) file sharing services that allowed individual users to obtain and share music in digital format for free, thereby skirting copyright law (Ku 2002). Although music piracy existed previously, this had been limited to individuals sharing copies of content they had bought themselves or received from friends, and required the physical exchange of storage media, like cassettes or CDs. By allowing users to share with unknown others through the Internet, the

sheer scale of exchange of unpurchased music was increased exponentially. The result was so game-changing that the music industry was forced to adapt its business model to take into account online distribution (Meisel and Sullivan 2002). Music piracy is now so prevalent that a large scale 2008 US schools-based survey found over half (52.2%) of adolescents had pirated in their lifetimes, 44% had in the past year, and 16.1% did so daily (Gunter, Higgins, and Gealt 2010 p. 664).

SILK ROAD AS A TRANSFORMATIVE CRIMINAL INNOVATION

Like Barratt (2012) and Martin (2013) we refer to Silk Road as a 'cryptomarket' following use of this term in hacker forums. A cryptomarket employs from amongst a range of strategies to hide the identity of its participants and transactions, and the physical location of its servers. These include: anonymisation services like Tor and I2P³ that hide a computer's IP address when accessing the site; decentralised and relatively untraceable cryptocurrencies like bitcoin and litecoin for making payments; and encrypted communication between market participants via PGP⁴.

Silk Road was therefore a platform where vendors could advertise listings for absolutely anything, licit or illicit, although it was known primarily for its drug sales (Christin 2013). Payments were made in bitcoins and held in escrow by the Silk Road administrators until the buyer was satisfied with the package received. There was a strong expectation that buyers would leave feedback on their interactions with vendors in order to root out 'scammers' in the market. According to Biryukov, Pustogarov, and Weinmann (2013), 1,175 requests were sent to Silk Road every two hours, making it the largest online illicit marketplace of its time.

With reference only to existing characterisations of Silk Road (Barratt 2012; Christin 2013; Martin 2013; Van Hout and Bingham 2014), we can see that Silk Road had hallmarks of substantial innovation. It provided drug dealers with (1) a worldwide market for their products, (2) the capacity to sell to customers not already known to them, (3) the ability to trade anonymously and (4) in a relatively low risk environment. This cryptomarket evidenced more than just incremental innovation; its innovation was both substantial and manifold.

Silk Road dealers could effectively transcend the physical restrictions of a local drugs market – the people they could physically reach to transact with – to supply through postal delivery a worldwide market of customers. And in spite of the fact that many (especially recreational) drug markets have moved from 'open' to 'closed' in recent years (e.g. May and Hough 2004), Silk Road made transactions with unknown customers a vastly less risky undertaking by putting in place a number of protections that had not been previously seen together in a criminal market. First, Silk Road protected itself by hosting its website on the Tor network. Tor makes it exceptionally difficult for anyone – including law enforcement agencies – to monitor the activities of individuals and websites, effectively making Silk Road dealers near invisible and untraceable⁵. Second, payments were made with the digital peer-to-peer cryptocurrency, 'bitcoin', the use of which is difficult to connect with users' real life identities. Bitcoins can be purchased through online exchanges like btc-e.com (Moore and Christin 2013) and locally via face-to-face meetings (localbitcoins.com). Third, Silk Road enforced a strict escrow system.

Although buyers paid up front for drugs, payments were only released to vendors when the delivery was confirmed. In case of a dispute, Silk Road administrators would adjudicate. And just as vendors' reputations in their previous transactions – through eBay-style 'feedback' – were available for buyers to see before making a purchase, the converse was also the case – a buyer's reputation in previous purchases was available for vendors to see before agreeing to make a sale. New buyers without a transaction track record might be required by a vendor to circumvent the protection escrow offered them by 'finalising' the sale (thus releasing funds to the vendor) before goods were received. All this meant that Silk Road's vendors were effectively able to trade in an environment with many fewer of the risks typically associated with drug markets, including non-payment from customers, theft of product and cash, and violence (Bouchard 2007; Bouchard and Tremblay 2005; Levitt and Venkatesh 2000; Reuter and Kleiman 1986). Recent research on Silk Road using a case study approach suggests that vendors commenced trading there because they perceived its infrastructure to be "low risk, high traffic, high mark-up, secure and anonymous" (Van Hout and Bingham 2014: 183). Silk Road, therefore, was more than just a 'criminal script' change; it changed the entire paradigm for drug sales by creating a massive, relatively safe worldwide market for the drug dealers who sold there. This assessment, however, is premised on the characterisation of Silk Road as a cryptomarket where only the vendors were drug dealers. If Silk Road's customers were also drug dealers sourcing stock there, the extent of this already substantial innovation becomes even greater.

RESEARCH AIMS

Our first and overarching aim was to develop further an understanding of Silk Road as a criminal innovation. As discussed above, the very existence of a cryptomarket that provides dealers the opportunity to trade anonymously with a worldwide market of customers in a low risk environment is a transformative innovation. However, contributors to the academic literature thus far characterised Silk Road as, first and foremost, a marketplace for *drug users* making purchases for their *own consumption*. Christin in his attempt to document, characterise and quantify the site concludes that "the quantities sold are rather small (e.g., a few grams of marijuana)" (Christin 2013 p. 218). Martin (2013) suggests that Silk Road's sellers were importers and cultivators, selling directly to consumers, literally bypassing the wholesale 'middle' level of the drugs market, although his work does not seem to have been based on reported systematic empirical observation. We believe that these authors draw this conclusion based either (1) on potentially erroneous assumption, or (2) on the evidence that the majority of listings found on Silk Road were for small quantities of drugs and at prices consistent with purchase for personal use. When we perused the Silk Road listings, it was apparent to us that many vendors were selling in quantities, at prices, and using terminology consistent with the conclusion that they were knowingly selling to customers intent on resale. We contend that getting a handle on precisely how much of Silk Road should be characterised as selling 'business-to-business' requires looking at the revenue generated by large versus small quantity listings, and not just at the listings themselves, as Christin did in his analysis. It is clear that Silk Road represents a criminal innovation, but this innovation will be more profound and have wider implications if its vendors and their purchasers are *both* involved in drug supply. Although the size of Silk Road was unquestionably small compared to the overall international drug

market (\$500 billion according to Thoumi (2005); “many tens of billions” just for cocaine according to Reuter and Greenfield (2001)), the business model that Silk Road created could have a lasting impact on the way that illicit drugs are sold and distributed, because its virtual location will impact on the social relations amongst its actors.

Our second aim was to assess the extent to which Silk Road may have been used by buyers looking to acquire the skills and expertise, as well as the chemical precursors required, to synthesise drugs themselves. Should this be confirmed, it provides further evidence that some vendors on Silk Road employed a business-to-business sales model.

Our final aim was to provide an up-to-date estimate of the revenue generated by the drug market on Silk Road. Our estimate is likely to be the last produced, since the site was seized by the FBI on 2 October 2013 – only 16 days after we collected the data on which this paper was based. We use a methodology roughly similar to that of Christin (2013) to show how much Silk Road had grown in the 15 months since his estimate. For drug cryptomarkets to be the important criminal innovation they have the potential to be, we must see evidence of considerable growth.

As Martin observes, Silk Road is just one amongst a “rapidly proliferating body of cryptomarkets”, including those for “stolen credit card information; forged identity documents; plagiarized university essays; hacking/cracking services; money laundering; child pornography; illegal firearms and ammunition; and even contract killing” (2013: 6). All of these represent not only important criminal innovations, but opportunities for criminologists, via ‘webometric’ style analysis (e.g. Thelwall 2009) to understand them. Criminologists primarily rely on (mostly incarcerated) offenders (e.g. Caulkins, Gurga, and Little 2009; Morselli and Tremblay 2004) to tell them about criminal transactions, generally using self-reported ‘typical’ or ‘recent’ transactions. Our use of unobtrusive webometric analyses of a cryptomarket should considerably improve the accuracy of data generated compared to self-reports, because these allow us access to actual transactions, whilst simultaneously generating substantially larger and more powerful data sets. Although webometric research like this is increasingly being taken up by criminologists (e.g. Blevins and Holt 2009 on prostitution; Bouchard, Joffres, and Frank 2014 on terrorism; Westlake, Bouchard, and Frank 2012 on online child pornography), these are only rarely published in dedicated criminology journals, often instead located in computer and information science publications. No publications in the journal *Criminology* have used webometric analysis. Whether this neglect amounts to oversight or misapprehension, social researchers outside of criminology have made a persuasive case that traditional survey and interview methods are increasingly dated (Savage and Burrows 2007), that webometric approaches to web-based content are of vital importance as social science data (Thelwall 2009), and that ‘digital traces’ might even be used to address important social theoretical debates (Latour et al. 2012). Criminologists may be witnessing the beginning of a new methodological era in which the necessity for gaining trust with criminal actors, and conducting interviews and surveys, are no longer always required to obtain high quality data that helps us engage with key contemporary criminological research questions. This article also addresses some of the methodological and uniquely ethical implications of this development as it concerns

cryptomarkets, and advocates for criminologists to be at the forefront of debates concerning webometric approaches in the social sciences.

DATA COLLECTION

Silk Road's design mimicked that of eBay or Amazon with searchable listings of products for sale. Each listing resided on its own webpage that contained a title (drug name and quantity), description, product category, price, vendor identification number, shipping country, shipping destinations, and postage options. Feedback left by past customers for the listing could also be found there. This feedback included a score (on a scale of 1 to 5), the date the feedback was posted and a section for written evaluation of the product and vendor. Each vendor also had his or her own profile page which contained the registration date, vendor description, a metric for buyer feedback, and the number of past transactions. Figure 1 presents an example of a drug listing on Silk Road as well as a vendor profile.

[FIGURE 1 ABOUT HERE]

There are many commercial and free software packages available that index and download HTML pages. None however is designed to access the deep web where Tor-hosted websites like Silk Road are located. We therefore created our own web crawler to fetch each of the nearly 12,000 web pages containing listings for the sale of drugs on Silk Road. Our program started from the Silk Road home page, indexed the URLs of each listing and downloaded them. As the listings contained hyperlinks to vendor profiles, our web crawler followed and automatically download these.

Data were collected 13-15 September 2013. This generated data on 1,084 vendors and 11,904 active listings for items in the 'drugs' section of Silk Road.

Some vendors retained listings for drugs that were out of stock, and we learned from carefully reading their listings that to discourage buyers from making orders, it was common practice to raise the price by an order of magnitude. Doing so allowed vendors to retain the listing until new stock again became available, and critically, to retain positive customer feedback for those listings. The extreme values in these highly priced listings would have skewed our results; we therefore excluded these 51 listings from the analyses that follow, leaving us with 11,853 active listings.

MEASUREMENTS

We collated data pulled from listings (N=11,853) for six categories of drug available on Silk Road: cannabis (n=2,661), ecstasy (n=1,059), opioids (n=262), prescriptions (n=3,953), psychedelics (n=1,539) and stimulants (n=1,274)⁶. These six categories comprise 90% of all drug listings on Silk Road.

To address our first aim, we needed to get a handle on the quantities of various drugs for sale, the prices at which they were sold, and the revenue generated through sales to 'personal use'

buyers as compared to sales to drug dealers seeking stock. However, it is not possible to determine, on the basis of the price or quantity of a transaction alone – without asking buyers themselves – whether a purchase is for resale or for use. An ounce of marijuana can, for example, be the purchase of someone stocking up for daily personal use, or the purchase by someone planning on profitable resale (or indeed both). Moreover, we know that a substantial grey area exists in the phenomenon of ‘social supply’. Coomber and Moyle (2013) argue that ‘social’ drug supply, often known in the UK as ‘sorting’ amongst friends (Aldridge, Measham, and Williams 2011), is a common way that friendship groups share supply activities in ways that are essentially non-commercial, or only minimally so. Social supply cannot neatly be categorised either as the actions of drug dealers nor of those purchasing for personal use only; it contains elements of both. We therefore faced a conundrum.

We settled on an inductive solution after various data exploratory strategies were employed. First, we ordered drug listings by purchase price (and later, by quantity), from lowest to highest. Then we explored drug purchase price by dividing the sample of listings into various quantiles (equal sized groups), and examined the minimum, maximum and mean prices in the quantiles when the sample was divided into two, three, four, five and six quantiles. For reasons we describe in the results, we finally settled on summarising and presenting the listing data in quintiles (five equally sized groups) by *price* in the following ways:

- (1) The *price range* including maximum, mean and standard deviation for each quintile in USD using the average exchange rate over the three days (September 13th-15th, 2013) we downloaded the data according to the BTC-e exchange. One bitcoin was US \$125.10.
- (2) The *number of transactions per day per listing* by dividing the number of feedback events posted in the last 30 days for each listing by its lifespan. Lifespan was measured by calculating the number of days between the date of the first feedback event of a listing (within the 30 day window) and the date of data collection. This measure is an indication of the number of sales a vendor should expect to make on any given day⁷. This is the same proxy transaction measure that was used by (Christin 2013). By only using the feedback events posted in the last 30 days, we make sure that our estimates reflect the latest trends on Silk Road before it was shut down by the US FBI.
- (3) *Yearly revenues* were the product of transactions per day for a listing by its price, then multiplied by 365. The sum of the revenues was calculated within each quintile. This gave us an estimate of the total yearly revenues generated on Silk Road for each quintile of each drug type.
- (4) The *market share* was obtained by dividing the yearly revenues of all listings in a quintile by the sum of all sales across all quintiles of a drug type. This provides an estimation of the relative importance of a quintile across each drug type.

Both the *price* of a drug listing (e.g. \$300 versus \$30), as well as the *quantity* sold in that listing (e.g. 300 grams versus 3 grams) can provide some clues about the likelihood that drugs are

being purchased for resale. Obtaining the listing price was straightforward, since our crawler automatically collected this information. However, we were not able to generate quantity data automatically, so we undertook a mostly-by-hand coding of *only a subset of listings*. We chose an ‘exemplar’ drug to represent each category: marijuana (n=430) in the ‘cannabis’ category; MDMA powder/crystal (n=293) in the ‘ecstasy’ category; Xanax (n=286) in the ‘prescriptions’ category; LSD blotters (n=165) in the ‘psychedelics’ category; and cocaine powder (n=407) in the ‘stimulants’ category. There was no single drug within the already comparatively limited listings for opioids, so no exemplar drug was selected for this drug category. Exemplars were chosen on the basis that they (1) had the most numerous listings, thus increasing the number of listings on which our analysis was based; (2) were well known drugs within their categories, and (3) the coding of quantity was relatively straightforward. For each quintile, the price per quantity unit was used to assess the presence of the bulk discounts drug dealer buyers would expect. Grams were used as units for marijuana, MDMA, heroin and cocaine, milligrams for Xanax and blotters for LSD.

Fulfilling the first aim of this paper is complicated by the fact that our capture of every listing on Silk Road will exclude some, possibly even many, of the listings for larger bulk purchases actually made there because not all sales on Silk Road were made via the ‘public’ listings. Vendors often sold drugs in larger quantities via private or ‘stealth’ listings. Some vendors gave prospective customers clear indications that alternative strategies for bulk purchases were possible.^{8,9} Because we know that these hidden listings were disproportionately likely to have been used by vendors selling larger amounts, we know that our counts of the number of high quantity/price listings will be under-counts, and that our estimates of revenue generation for high quantity/price listings will therefore also be underestimates. We are unable, however, to calculate by (even roughly) how much our estimates will be under-estimates.

To achieve the second aim of the paper (assessing the evidence that Silk Road may be used by buyers looking to acquire the chemical precursors, alongside the skills and expertise, to synthesise illegal drugs themselves), we identify the specific products offered for sale by vendors selling items they listed as ‘precursors’, and the types of drugs that could be synthesised using them.

To achieve the third aim of the paper (to track the growth in revenues on Silk Road since Christin’s mid 2012-based estimates) we estimated the total yearly revenues of all drug types and compared our results with Christin’s. This should allow us to gauge how much Silk Road grew in the 15 months between his data collection and our own. This comparison is likely to be affected by the scope of listings included as well as by methodological differences. Regarding the scope of listings, Christin indexed all listings on Silk Road whereas we only indexed listings in the drugs section. On this front, the differences between our estimates are likely to be minimal as drugs represented 17 of the 20 largest categories on Silk Road. The missing three categories combined represented 7.2% of listings (Christin, 2013). Still, our results will underestimate the growth of Silk Road compared to Christin to an extent. Regarding the methodological differences, Christin downloaded daily a copy of all new feedback events for existing and new listings that emerged over 30 straight days (prospective data collection). The price of listings

was multiplied by the number of feedback events, and this product for the month was then multiplied by 12 to estimate yearly revenues of about \$14.4 million. Our methodology was similar in that we used feedback events to estimate yearly revenues but did so using only the listings that were active on the first day of our download when listings were indexed on 13 September 2013 (retrospective data collection). Feedback events posted over the 30 days before our data collection associated with these listings were used to calculate the number of sales a vendor should expect to make on any given day, and this figure was multiplied by 365 to obtain the yearly revenues. The main difference between the two approaches is that Christin's method was prospective used a full month's worth of listings to estimate yearly revenues, while our methodology was retrospective and used one day's worth of listings to estimate yearly revenues.

RESULTS

HIGH PRICE LISTINGS INDICATIVE OF PURCHASE FOR RESALE

Evidence of 'business-to-business' sales was found in the terminology used by some vendors in their listings. This cannabis seller stated: "200 grams of commercial grade Hash straight from Morocco. This is a mid-grade commercial hash perfect for resale due to the low price". Here, a prescription drug seller refers to prices thought to attract drug dealers: "Modafinil 200MG - 1000 tabs dealers prices". It appears that vendors on Silk Road were aware that many of their customers were likely to be drug dealers sourcing stock.

Table 1 summarises the characteristics of the listings when ordered into quintiles by price, for the most common six categories of drug on Silk Road.

[TABLE 1 ABOUT HERE]

Most of the listings in every drug category we examined on Silk Road were for drugs sold at prices consistent with purchases being made for personal use. This was clear for listings in the first quintile for each drug category (that is, up to \$35.03 for cannabis; \$52.54 for ecstasy; \$38.78 for opioids; \$30.02 for prescription drugs; \$31.28 for psychedelics; and \$58.80 for stimulants). These maximum prices seem highly unlikely to be the purchases of drug dealers sourcing stock¹⁰, because they more typical of prices paid for one or a few doses, depending on the drug in question (Global Drugs Survey 2013).

However, prices for listings in the top quintile (and in some cases the top two quintiles), in contrast, were in amounts consistent with the hypothesis that purchases were likely to have been made by buyers with re-sale intent; that is, by *drug dealers*. Only one study of which we are aware has collected data on typical purchases by drug dealers – Caulkins and colleagues (1998). Using their data based on interviews with 45 drug dealers between 1989 and 1996 in New York City, we calculated the average purchase price at the beginning of a sales 'cycle' to be \$1,396.16. Correcting for the drop in price that has occurred for many illegal drugs in the US and elsewhere (as well as for purity increases and inflation) we estimate that prices by 2007 will have dropped by around 80% (see Werb and colleagues (2013)¹¹). This means that the average

purchase price of stock for these New York City dealers in 2007 would be around \$280. For all drug categories, the minimum price for a listing in the top quintile in our data was near to this figure (\$260.21 for prescription drugs) or exceeded this amount, in some cases quite considerably so, thus providing some external validation of our assessment that purchases in the top quintile of drug listings on Silk Road would be likely to have been by drug dealers acquiring stock.

The top quintile (that is, the top 20%) of listings for cannabis, for example, had prices that ranged from \$355.29 to \$23,548.82. Although it is possible that some buyers making purchases of cannabis spending this amount of money *may* have been buying for personal use over a longer term, or perhaps making ‘social supply’ purchases on behalf of a group of friends, this is highly unlikely to be typical for all purchases made within these ‘top quintile’ listings. In the other five drug categories in the table too, the price range of listings in the top quintile seems likely to be predominantly aimed at buyers with resale intent. For ecstasy, it seems likely that the *top two* quintiles (that is, 40% of the listings) were aimed at buyers with resale intent, with prices for the listings in these quintiles ranging from \$342.78 to \$18,932.63. It is also likely to be true for stimulants, where the listings in the top two quintiles ranged in price from \$280.23 to \$44,680.72. We conclude, on this basis, that about 20% of the listings for the drugs we examined on Silk Road were aimed at buyers making purchases with resale intent. Silk Road seemed even more geared towards this kind of selling for ecstasy and stimulant drugs.

That ‘top quintile’ listings were likely to have been purchased by drug dealers sourcing stock seems even more likely when we look at *mean purchase price* in the top quintile for each drug category: \$1,474.93 for cannabis, \$3,494.04 for ecstasy, \$1,683.85 for opioids, \$1,129.65 for prescription, \$1,932.80 for psychedelics and \$2,640.86 for stimulants. These represent purchases in amounts highly unlikely to be typical of buyers making personal-use sized purchases. Indeed, some listings were priced sufficiently high (in excess of a few thousand dollars up to \$20,000 and more) to suggest that some vendors aimed their product at retail level drug dealers with a view to holding stock for long periods, or even to those operating at the wholesale level.

REVENUE GENERATED BY HIGH PRICE LISTINGS

It is not enough to know that there were *listings* on Silk Road aimed at a ‘drug dealer’ market. We need to know whether the frequency of purchases made in these top-quintile listings – and thus the revenue being generated – were important in understanding the marketplace; if only trivial numbers of transactions were generated with these high-priced listings, then we should rightly conclude that Silk Road was, contrary to our hypothesis, primarily a marketplace catering to drug users making purchases for personal use.

When we look at *the number of transactions per day per listing* in Table 1, we find that transactions were, predictably, less frequent for the most highly priced listings. So for cannabis, there were 0.28 transactions per day amongst the cheapest quintile listings, and this figure dropped to 0.06 transactions per day in the most expensive listings. The same pattern occurs for all drug categories in Table 1. (Note that the calculations included the 59% of listings with no

feedback events listed, and so transactions for these listings were coded as '0'.) However, as the *yearly revenues of all listings* makes clear, a majority of the revenue generated for most drugs – excluding opioids – on Silk Road was for highly priced listings. The highest price top quintile listings generated estimated sales across Silk Road in one year of: \$10.3 million for cannabis (accounting for 41% of all cannabis revenue on Silk Road); \$8.9 million for ecstasy (accounting for 45% of all ecstasy revenue); \$5.2 million for prescription drugs (accounting for 42% of all prescription drug revenue); \$2.8 million for psychedelics (33% of psychedelic revenue on the site), and \$5.2 million for stimulants, (accounting for 31% of all stimulant revenue on Silk Road).

The case for opioids was less straightforward. Although the top quintile also contained high price listings indicative of sales to customers intent on resale, these listings failed to generate more than the expected share (20%) of revenue, and did not therefore follow the general pattern we identified for all other drug categories. The fourth quintile, nevertheless, still contained high price listings up to a maximum price of \$260.21, and generated 39% of the revenue for this category of drug. However, we can be less sure that the same clear pattern of high priced listings generating consistently disproportionate amounts of revenue occurred for this category of drug. We take up this question in the discussion.

The bottom quintile of listings for the drugs we examined (for amounts unequivocally in 'personal use' quantities), in contrast, each generated only 3-4% of the revenue for the drug categories in the table.

Depending on the drug in question (but excluding opioids) therefore, between 31% and 45% of all revenue generated on Silk Road is generated by listings aimed at buyers who are very likely to be drug dealers purchasing stock. This finding stands in stark contrast to characterisations of Silk Road as selling primarily personal use quantities to drug users.

Although prescription drugs seem to be the most 'important' category of drug as evidenced by number of listings (the prescription category had by far the most listings of any drug category with 3,953), when we follow the revenue generated by prescription drugs, it is the fourth largest category (\$11.7 million annually), compared to \$24.8 million annually for cannabis – a category with substantially fewer listings (2,661). Silk Road seems predominantly (although not exclusively) to cater to the sales of drugs typically associated with 'recreational' use – cannabis, ecstasy and psychedelics together account for over \$53.3 million in revenue, whereas opioids, prescription drugs and stimulants together (\$32.2 million) generate 60% of that amount. Drugs typically associated with drug dependence, harmful use and chaotic lifestyles (heroin, methamphetamine and crack cocaine) do not much appear on Silk Road, and generate very little revenue. Listings for methamphetamine and crack cocaine were very few indeed: 8 for crack cocaine and only 3 for methamphetamine.

HIGH QUANTITY LISTINGS INDICATIVE OF PURCHASE FOR RESALE

Table 2 presents *quantity* advertised in a listing, and for each quintile presents minimum, maximum and mean price, alongside price per unit, for the 5 exemplar drugs for which we were able to code quantity.

[TABLE 2 ABOUT HERE]

All top quintile listings involve quantities sold consistent with purchase-for-resale likelihood. For marijuana, quantities in the top quintile range from 50 grams (nearly two ounces – highly unlikely to be a ‘personal use’ quantity) right up to over two kilos (2,267.95 grams), with the average purchase in this quintile of 269.13 grams – just over a quarter of a kilo of marijuana. For MDMA quantities are large enough to indicate dealer-level purchases in the top two quintiles: ranging from 10-50 grams in the 4th quintile (on average, 26.04 grams) and 50-1000 grams in the 5th quintile (with an average purchase of 207.88 grams). Assuming 10 doses per gram, this is the equivalent of 100 to 10,000 doses across the listings in both quintiles. Quantities sold ranged from 1000-100,000 mg in the top quintile for Xanax. Assuming 2mg per dose (the most common tablet strength sold on Silk Road), these listing quantities translate to doses ranging from 500 to 50,000, highly suggestive of quantities likely to be purchased for resale. For remaining drugs in the list, quantities likely to be associated with dealer-level purchases were found for LSD sold in blotters, ranging from 25 to 1,000 blotters (on average, 172.12 blotters), and for cocaine, between 10 and 250 grams (on average, 36.35 grams), perhaps not at the bottom end of the range, but certainly for the average in these top quintile quantities.

MULTIPLE QUANTITY LISTINGS AND BULK DISCOUNTS

If Silk Road indeed caters to buyers who are drug dealers making purchases of stock, we should find that vendors give discounts for bulk purchase. Table 2 gives a very strong positive answer to this question with clear and consistent reductions in price per unit for larger purchases. The price per unit (gram, blotter, and milligram) decreases with the quantity of drug listed across all our exemplar drugs. Moreover, the size of the discount is highest in the top quintile quantity listings. Listings that advertise larger quantities of marijuana (over 50 grams) have average ‘per gram’ prices of \$7.51. This is a 57.1% discount compared to the smaller listings that offer less than 3.5 grams of marijuana for an average of \$17.51 per gram. We see exactly the same discounts for MDMA, Xanax, LSD and cocaine, which offer respectively 80.3%, 91.9%, 54.5% and 58.0% markdowns when customers buy in top quintile quantities.

These results demonstrate that bulk purchasers could buy at prices allowing them to sell on for profit. As well, most of these vendors sold in multiple quantities, suggesting awareness of their buyers’ resale intent. A majority of vendors (72.5%) listed drugs in at least two quantities; just over half (56.1%) listed a drug in three or more quantities; nearly a quarter (23.3%) listed a drug in seven or more quantities; and over one in ten (11.8%) listed a drug in ten or more quantities. On average, vendors listed over six quantities (mean = 6.27) of each drug they sold.

SALES TO BUYERS WHO SYNTHESISE DRUGS

To better understand the place of drug supply on Silk Road, we now examine the 11 vendors who listed 49 products classified by them as ‘precursors’¹². Their average Silk Road lifespan was 768 days (compared to 587 for all other Silk Road vendors), and their average rank amongst vendors placed them in the ‘top 39%’ compared to the ‘top 46%’ for other vendors. The average number of transactions for the precursor vendors was 193 (compared to 179 for other vendors). This suggests that although precursor vendors were not numerous, they were longstanding, trusted and repeat sellers, with comparative site metric scores as good or better than the average for all other sellers. The total estimated sales per year was \$103,589.70.

Table 3 details the precursors listed on Silk Road alongside their probable uses in drug synthesis. A little over one third (35%) of the products listed were involved in the production of a range of psychedelic drugs, and about one quarter (26%) were involved in the production of amphetamine and/or methamphetamine. Just over one in five (22%) of the products listed were involved in the production of psychedelic amphetamines (‘MDxx’ – a common shorthand for drugs in this family including MDMA, MDA, MDEA, and others).

[TABLE 3 ABOUT HERE]

These precursor sales demonstrate that some vendors sold to customers who were illicit drug producers. Vendors were aware of the uses to which customers were likely to be putting their purchases. This listing for sassafras oil stated that each container held: “80-85% safrole, the precursor to MDMA”. This vendor of P2NP stated: “It can be reduced to amphetamine easily or can be reduced in the presence of a catalyst to produce phenylacetone, after that straight to methamphetamine.” Other vendors went so far as to offer potential customers step-by-step instructions in drug synthesis. This vendor of speed oil stated: “You only have to add sulphuric acid and methanol and in a few minutes you have pure speed... Ask for the syntheses, I will explain it step by step”. This vendor of dimethoxybenzaldehyde stated: “Used in the manufacture of 2cs, DOs and nbome derivatives. [...] A basic write-up of the 2c-b synthesis that includes pictures can be provided with this order on request.”

Another vendor specialised only in selling his expertise in drug synthesis in the form of ‘lab notes’ containing production guides and sources for the synthesis of LSD (\$925 USD), and for MDA and MDMA (\$571 USD). This vendor’s profile page informed potential customers: “You do not need to have chemistry experience to do this work. You do need to be able to learn and teach yourself as you go along. It helps to have an understanding of chemistry but you do not need to be a chef to master a single dish over time.” Even experienced chemists would benefit from the guides on sale, according to this vendor, by gaining improved quality and yield, and therefore profits. The vendor had been selling on Silk Road for 1 year and 8 months, had a perfect 5/5 average customer ratings, and had accumulated 190 transactions during that time. Evidently, some Silk Road vendors were willing and able to provide customers with the skills purportedly necessary to manufacture illegal drugs.

OVERALL REVENUE ON SILK ROAD

The revenues we calculated for the 90% of 'drug' listings we included in our analysis are found in Table 1. Across all six categories, we estimate the yearly sales on Silk Road at \$85.5 million, and when we add in the drug categories we excluded from the table this figure increases to \$89.7 million. This latter figure should be compared to Christin's (2013) estimate of \$14.4 million annual sales, based on his data collection up to the end of the first six months of 2012. This suggests that in the 15 months between Christin's calculation and our own, the revenue generated on Silk Road increased by a factor of six *at the very least*. This increase is not related to bitcoin inflation that occurred over the period¹³. In Christin's case, this figure refers to *all sales* on Silk Road, including both drug-related listings as well as non-drug-related listings. Our figure excludes non-drug sales revenue, which we did not collect. For this reason, our figure is an underestimate in comparison to Christin's. For the methodological reasons stated above (see 'Measurements') our estimate is also likely to be an underestimation compared to Christin's.

DISCUSSION

IMPLICATIONS OF OUR B2B FINDING FOR MARKET STRUCTURE AND CRIMINAL INNOVATION

The first and overarching aim of this research was to develop our understanding of Silk Road as a criminal innovation beyond that already characterised in the academic literature (Barratt 2012; Christin 2013; Martin 2013). Specifically, we hypothesised that not all purchases on Silk Road were made by drug users in personal use amounts, and set out to explore the data for evidence that a proportion of Silk Road transactions were likely to have been made by customers who were drug dealers sourcing stock. We found confirmation of this hypothesis:

1. The terminology employed by vendors explicitly recognised that some customers were drug dealers.
2. In the 20% most expensive listings, the average listing price was consistent with purchases made for resale: cannabis (mean = \$1,474.93), opioids (mean = \$1,683.85), prescription drugs (mean = \$1,129.65) and psychedelics (mean = \$1,932.80); this was also true in the 40% most expensive listings for ecstasy (mean = \$2,071.91) and stimulants (mean = \$1,547.62).
3. Excluding opioids, these high price listings generated 31-45% (depending on the drug in question) of the revenue in each drug category.
4. The 20% highest *quantity* listings were in quantities consistent with purchase for resale: marijuana (mean = 269 grams), Xanax (mean = 8,850.45), LSD (mean = 172 blotters), cocaine (mean = 36 grams); this appeared to be the case in the 40% highest quantity listings for MDMA (mean = 26 grams).
5. Most vendors sold drugs in multiple quantities.
6. Clear and substantial discounts were available for bulk purchases.
7. Some of the most longstanding and trusted vendors on Silk Road sold chemical precursors and the specialised skills (in the form of lab notes), in the main for the manufacture of psychedelic and stimulant drugs.

Taken together, these findings provide clear evidence that many customers on Silk Road will have been drug dealers sourcing stock, and that in revenue terms, these kinds of ‘business-to-business’ sales were key Silk Road business. Moreover, purchase price at the very top end was sufficiently high to conclude that at least some Silk Road customers were likely to have been operating at the wholesale end of the market themselves. ‘Precursor’ sales demonstrated that Silk Road may have helped to put not only access to bulk purchases of illicit drugs (or their precursors) into the hands of those without existing criminal connections to make these purchases offline, but may also have placed the kinds of skills previously restricted to trained and experienced chemists with an understanding of illicit synthesis into the hands of anyone with the time and inclination to learn.

Our results directly contradict the characterisation Martin (2013) makes of Silk Road, whose sellers, he says, are importers and cultivators selling directly to consumers, literally bypassing the wholesale ‘middle’ level of the drugs market. In contrast, we show that Silk Road is best characterised as the very location for the middle level of the drug market. Indeed, Silk Road seems to have functioned as a virtual broker, connecting upper, middle and retail level sellers. The predominance of business-to-business transactions on Silk Road was clear even without us being able to include in our calculations the largest bulk order purchases actually placed there (see discussion in ‘Measurements’ on stealth listings).

The Silk Road drug cryptomarket is therefore a more important criminal innovation than either Christin’s or Martin’s characterisations can accommodate because it wasn’t (just) a kind of ‘eBay for drugs’. In our terms then, this cryptomarket was a transformative (as opposed to incremental) criminal innovation because, *inter alia*, its customers were drug dealers too. Before the advent of online availability of bulk-quantity illegal drugs, dealers had to have on-the-ground connections and relationships of trust built with middle level drug dealers and/or importers in order to be able to acquire product (McCarthy and Hagan 2001; Morselli 2001), alongside a tough reputation (Topalli, Wright, and Fornango 2002). With the advent of the cryptomarket, almost anyone with sufficient technological skills can access stock. In other words, the type of ‘subcultural capital’ (Thornton 1995) required to be a drug dealer is likely to be different for those who operate on a cryptomarket. This new breed of drug dealer is also likely to be relatively free from the violence typically associated with traditional drug markets (Blumstein 1995; Caulkins and Reuter 2009; Reuter 2009). Whereas violence was commonly used to gain market share, protect turfs and resolve conflicts, the virtual location and anonymity that the cryptomarket provides reduces or eliminates the need – or even the ability – to resort to violence. This changes are likely to have a deep impact on the skills needed to succeed in crime markets (McCarthy and Hagan 2001). In the drugs cryptomarket era, having good customer service and writing skills, having a good reputation via ‘feedback’ as a vendor or buyers – may be more important than muscles and face-to-face connections.

An additional explanation for the likelihood that cryptomarkets will have the implication of reducing the risk to drug dealers who buy there is found in research by Mohamed and Fritsvold (2010) in their study *Dorm Room Drug Dealers*. These mostly white, middle class, highly educated drug dealers in Californian universities did not resort to violence. This may result from

the fact that the actors in those markets were different from those on which other drugs market research is typically based. Silk Road operators may share more in common with Mohamed and Fritsvold's dorm room dealers than they do with traditional 'street' based drug dealers. Thus, cultural expectations for violence may be very different for different kinds of drug dealers, and violence, therefore, may not be an inherent and inevitable part of illicit markets, as Reuter (1983) has posited. Future research needs to establish the characteristics of drug dealers operating on drug cryptomarkets: both those who sell there, and those who source stock there.

Accessing drugs in the 'virtual' world is likely to have the consequence of reducing other types of risk too because the site's features (escrow, feedback, mail order) may function to reduce problems with non-payment. As well, the widespread use of credit by drug dealers when acquiring stock, termed by Salinas (2014) as 'black credit', is not possible on a drugs cryptomarket, which operates more like a virtual cash-and-carry business. This makes the bar for market entry (i.e. cash up front for stock purchase) for a drug retailer higher, but also reduces the risk of conflict connected to non-payment of debt. This is not to deny that newer and different risks will not accompany virtual drugs markets, and future research will be required to document these.

Our analyses also point to a perhaps unexpected finding. If Silk Road was exclusively or primarily a 'business-to-customer' site as suggested by Christin (2013) and Martin (2013), providing drug users with drugs for their personal use, it would not have been surprising that the drugs associated with dependence and chaotic lives (heroin, crack cocaine, methamphetamine) tended not to be sold there. However, given that the key business of Silk Road was drug dealers sourcing stock to sell offline in local drugs markets, it is not clear why sales should not include these drugs. And yet, it is primarily the drugs associated with 'recreational' use that dominated. In annual revenue terms, the vast majority of sales were for cannabis (\$24.8 million) ecstasy (\$19.9 million) and psychedelics (\$8.6 million), consistent with survey findings by (Barratt, Ferris, and Winstock 2014). One possible explanation is that Silk Road began its existence selling primarily to drug using customers rather than to drug dealers; in other words, its 'business-to-business' model evolved from a 'business-to-customer' one. The site may therefore have suited purchases by recreational users with the resources and time to place orders and wait for deliveries; dependent users with chaotic lifestyles, in contrast, were likely to have had neither. So, even as this cryptomarket evolved into a business-to-business site, the predominance of sales of mostly recreational drugs was by then established.

An alternative explanation may be related to the shape of drugs markets for particular drugs. Producers of methamphetamine, for example, are also often its retail sellers (see, for example, Brownstein et al. 2010), and dealers of crack cocaine might purchase cocaine powder from cryptomarkets to convert or 'cook' into crack themselves (Caulkins et al. 1998), making cryptomarkets redundant for dealers wishing to acquire and sell these drugs. We also know that many drugs of dependence (e.g. oxycontin) were available in the prescription drug category on Silk Road (although the range of prescription drugs available on Silk Road was wide, including for example, Viagra and many other substances) even though this entire category was

not on its own an especially large revenue-producing category. Nevertheless, this may be something to watch in second generation cryptomarkets: we might hypothesise that drugs of dependence may emerge as much more important in future.

Drug cryptomarkets may influence the drug users who do not make purchases there. Because the key business of Silk Road was drug dealers sourcing stock to sell offline in local drugs markets, the fact of them being able to source from amongst the wide range of (relatively) high quality substances available to them online may actually influence the drugs they make available to their customers. Both Christin (2013) and Martin (2013) suggest that the ‘feedback’ feature of Silk Road is likely to result in the availability of high quality drugs, and we concur. Our observations of exceptionally positive feedback¹⁴ found for listings that often even included the ostensible results of lab tests for strength/purity suggests that buyers were convinced they were getting what they paid for. Research using the ‘test purchase’ methodology (e.g. Brandt et al. 2010) is required to provide empirical evidence for this possibility. Future research is needed to determine whether sales on drug cryptomarkets might actually function as a predictor, or ‘early warning’ for new drugs appearing in local street markets.

Finally, our results demonstrated *at least* a six-fold increase in sales on Silk Road in the period of just over a year prior to our data collection (to \$89.7 million) from Christin’s estimation 15 months previously (\$14.4 million). This demonstrates an exceptionally strong demand for this kind of illicit marketplace. Although the original Silk Road is no more, a spin-off site, Silk Road 2.0, launched 5 November 2013 and at the time of writing, a number of competitors for illicit drugs-dominated cryptomarkets have come and gone (e.g. Sheep, Black Market Reloaded) and others are growing. It seems unlikely that this kind of development in anonymous online sales of illegal drugs is going to disappear, in spite of law enforcement crackdowns.

THE WEB AS LOCATION AND METHODOLOGY FOR CRIMINOLOGICAL RESEARCH

Our aim was to identify the existence of ‘business-to-business’ sales on Silk Road. It was not possible, as we argued, to identify which listings would be purchased by drug dealers, and which by drug users, on either the basis of price or quantity. No cut-off point could neatly distinguish these: large purchases could be users ‘stocking up’ over the long term, just as smaller ones could involve resale for profit. Our inductive strategy of exploring the data by ordering (on the basis of price and quantity) listings from low to high allowed us to discern an ‘upper end’, in price and quantity terms, that nevertheless obviously dominated by drug dealer customers. Of course “business-to-customer” sales will also exist in lower quintile listings (and the reverse will also be true). The alternative – asking buyers to tell us the reason for their purchase (even assuming accurate and honest reporting) – is limited by the much smaller and biased samples (due to uneven non-response) that will result. The strength of our methodology is knowledge generated on the basis of a substantial and powerful data set; the weakness: our estimates of population parameters for customers who are dealers remain indicative rather than absolute and categorical.

The methodological literature for researchers who collect data online is maturing (e.g. Fielding, Lee, and Blank 2008; Hewson et al. 2003), with some addressing specifically criminological

concerns (see Holt 2010 for a discussion of web based qualitative data). We consider here two issues pertinent to data generated from illegal activities on cryptomarkets: the extent to which we might consider these data public, and the ethical implications of accessing, analysing and publishing these data.

Some have argued that data generated by the activities of individuals on the Internet (e.g. online forums, newsgroups) are effectively public documents. Using this data is therefore nothing more than naturalistic observation, and so research subjects should not fall within the remit of the 'human subject paradigm' (Kitchin 2003: 399). Wilkinson and Thelwall concur, arguing that obtaining consent is unnecessary so long as 'text authors' remain anonymous (2010: 397). This conceptualisation of internet-derived data is simplistic but compelling, and consistent with ethical decisions researchers typically take in the non-virtual world. Nevertheless, the expectation of privacy is fundamental, especially in cryptomarkets where the innovation is the ability to engage in criminal activities anonymously. This may prompt some researchers to treat online activities as 'private', perhaps even convincing them to request the consent of actors to make use of data connected to their activities.

Commentators have usefully suggested turning to the norms of the virtual community/subculture itself for guidance (e.g Rosenberg 2010). Where Silk Road is concerned, Silk Road's creator and many who participated on its forums espoused 'crypto-anarchist' (see May 1994) and radical libertarian principles, leading us (and Christin 2013) to believe that they would undoubtedly have come down on the side of viewing its content as public. Of course no community is homogeneous in orientation, so this question is by no means settled for researchers who wish to turn to cryptomarkets for data.

It is possible for research based on webometrics to draw official attention to criminal activities and even to lead to arrests. Researchers aim to protect the people studied so that research does *not* put them at risk – the 'do no harm' principle; and most would agree that research actions that lead to arrest or imprisonment should be classed as causing considerable harm. Our research made use of quotes from specific vendor profiles and listings, potentially drawing attention from crime agency officials to particular vendors. Since the FBI seizure, our concerns in this regard have abated. However, it is worth pointing out that some commentators have suggested that participants should be approached for consent if verbatim quotes are used by researchers (see for example Eysenbach and Till 2001); an alternative is to employ paraphrased quotations. Obfuscating the name of the online platform studied in the research as well as clues as how to access it may be other strategies that researchers might want to adopt, although this reduces the possibilities for other researchers to replicate findings (Aldridge, Medina, and Ralphs 2008). This remains a particularly thorny issue, and challenges criminologists to examine the political and public functions they serve as researchers (Loader and Sparks 2013). At the time of writing, a number of new illegal drug cryptomarkets have appeared, and criminologists are likely to be excited by the opportunities they afford to better understand the latest developments in illicit markets. Criminologists must remain at the forefront of methodological and ethical debates connected to webometric research in their field.

CONCLUSION

It is undeniable that the size of Silk Road was negligible in comparison to the overall international drug trade: revenues on Silk Road were calculated in tens of millions of dollars whereas the international drug trade is measured in hundreds of billions of dollars (Thoumi, 2005). The importance of Silk Road does not stem from the revenues it has generated but rather from the impact it is likely to have on how drugs are bought and sold in the future: its potential and actuality as a transformative criminal innovation. Even if we do not see drug cartels logging on to second generation drugs cryptomarkets to sell 100 kilograms of cocaine to Spanish distributors, there is a strong possibility that the lower level of drug distribution networks (those that deal in kilos) may use cryptomarkets to streamline their activities and reduce their risks of arrests. Just as computers changed the way we manage and consume information, cryptomarkets have the potential to change how drug markets operate in a way that may set back regulation efforts by decades.

Researchers will need to pay close attention to the scalability of online drug marketplaces. We have seen how Silk Road sales grew by a factor of at least 6 in only 15 months. But growth of this kind comes with accompanying problems. Cryptomarket administrators will need to build and support the infrastructure of large marketplaces that are likely to incur high starting costs. They will need to protect their users not just from law enforcement agencies, but from unscrupulous administrators themselves, as the theft of 96,000 bitcoins from an early successor to Silk Road, Sheep Marketplace, demonstrated in that it was believed to have been an inside job (Walker 2013). The use of mail delivery may also become more of a problem than a solution at some point. While it may be easy to ship a gram of cocaine, shipping a kilogram is much more difficult, especially if the package has to cross international borders.

Another area of interest will be the internationalisation of cryptomarkets. Silk Road allowed drug users to order from almost any country. Buyers can therefore shop around for drugs that would not be available to them locally, or find dealers with much lower prices. The question remains, however, as to whether drug users will take advantage of online illicit marketplaces to find mostly local suppliers or whether will they, in contrast, seek the best price for their drugs no matter the location. The answer to this and many more questions will come as more research is conducted into online illicit marketplaces. Cryptomarkets may very well become the innovation that fundamentally changes the drug trade in the decades to come.

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¹ The Onion Router (Tor) is a software package that encrypts all communications of a computer and sends it through at least three other computers to hide the original identity of its sender (Dingledine, Mathewson, and Syverson 2004).

² Cornish (1994: 1) proposed the idea of scripts as a way of “generating, organizing and systematizing knowledge about the procedural aspects and procedural requirements of crime commission”.

³ I2P is an anonymizing service similar to Tor (Zantout and Haraty 2011).

⁴ Pretty Good Privacy (PGP) is an encryption protocol that allows anyone to encrypt a message in a way that ensures that only the recipient can decrypt the data (Zimmermann 1995).

⁵ The technology behind Tor network still appears to be operating effectively at the time of writing. Even with the FBI's 2013 seizure of Silk Road, human intelligence in the form of informants was used to pinpoint the exact location of its servers (Zetter 2013).

⁶ There were a number of additional categories under which drugs were sold on Silk Road that we do not present in our tables, because the substances involved were not illegal, or the number of listings was very small: ‘unclassified’ (n=503), ‘dissociatives’ (n=160), ‘tobacco’ (n=235), ‘intoxicants’ (n=67), ‘digital goods’ (n=1) and ‘other’ (n=77). We excluded ‘precursors’ from the analysis in this section because we analyse this category separately in the article.

⁷ We believe that customer feedback events fairly closely mirror actual transactions for two reasons. We calculated the number of feedback events summed across all of a vendor's listings, expressed as a percentage of Silk Road's ‘vendor transactions’ metric (but only for vendors whose vendor transactions were fewer than 300, since the top score for this metric was 300). On average, 88% of a vendor's ‘transaction’ metric were picked up by summing across feedback events, suggesting that our method is a reasonably good proxy measure for transactions.

⁸ This vendor's profile, whose public listings for cocaine go to a maximum of 28 grams (1 ounce), explained that much larger orders could be placed: “PLEASE MESSAGE BEFORE PURCHASING BULK FROM LISTINGS! We can

provide bulk orders up to 10kg at present. We can also provide custom listings for amounts not listed. We currently only sell bulk domestically. Message us if you're interested :)"

⁹ Additional insight into the process was provided by a self-proclaimed former Silk Road drug dealer, who, on September 1st, 2013, began a discussion on Reddit, inviting others to ask him "anything" about his experiences. He described making about 200 weekly shipments to customers, ranging in value from \$30 to \$4,000, but stated that "Most of the bigger orders don't use public listings, people would contact [me] asking for custom orders and I'd fill those individually". For larger orders, usually anything over \$1,000, he would send the buyer a link to a 'stealth' listing not visible to any Silk Road user without the link. (Reddit 2013).

¹⁰ An alternative explanation: some drug dealers who may have been considering larger future purchases may have been making 'sample' purchases to test quality.


¹¹ We do not have data to suggest how drug prices might have changed between 2007 and our data collection in 2013.

¹² Not all the listings were chemicals that are, in drug synthesis terms, 'precursors'; nevertheless, all the products for sale considered here were listed by their vendors as such.

¹³ Although it is true that the value of bitcoins rose considerably between Christin's study (approximately \$10 USD/BTC) and our own (\$125.10 USD/BTC), the price of drugs listed on Silk Road did not go up correspondingly, as vendors lowered their prices in response to the increasing value of bitcoins. Indeed, most vendors typically elect to set their price for a listing in US dollars, allowing the publically visible price in BTC to fluctuate along with the often wildly changing exchange rate. The 'real price' for drugs on Silk Road will not therefore have fluctuated with the exchange rate, and so revenue generation estimates we produce are based on the real price for drugs at the time.

¹⁴ Feedback for listings overall was exceptionally positive: only 7.1% of vendors had an average rating of less than 4.5/5.

Figure 1. Sample drug listing and vendor profile from Silk Road




Silk Road
anonymous market

messages 0 | orders 0 | account **B0.0000**

a few words from the Dread Pirate Roberts

Hi, **S0kumba**
logout

Shop by Category



1 Gram Heroin #4

B1.9463 [add to cart](#)

seller: 10toes(97)
ships from: United States of America
ships to: Worldwide
category: Heroin

[bookmark this item](#)

postage options:
free (\$0.0000)

Description

1 Gram Heroin #4
(Any requests for different shipping options will be ignored!)
****NO PRIVNOTE NO PRIVNOTE NO PRIVNOTE****
Off the brick


6/17 New batch

For intranasal, iv, inhalation, or oral use

HD Pic
<http://xqz3u5drneuzhaeo.onion/users/qicpic/files/ku.JPG>

USA buyers with 5 or less successful transactions must finalize early prior to shipment, you will be sent a reminder after confirmation. If you have any issues with this requirement please do not order.

International -



Silk Road
anonymous market

messages 0 | orders 0 | account **\$0.00**

a few words from the Dread Pirate Roberts

Hi, **StExoBackup**
logout

Shop by Category

hammertime

[send a message](#)


has been a vendor for **8 months**
was last seen: **today**
ranked in the **top 3%** of sellers with **99.9%** positive feedback from **more than 300** transactions
has **564** fans - [become a fan](#)

I look forward to providing quick and excellent service to my buyers and to helping make this website an incredible and reliable resource.


-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.4.12 (MingW32)

```
mQENBFBxRxcBCADSlabChlyy2OarVWMOkin8nh91hOB/hQz22thXESVjKyyV9HLL
RN58e4zTF+HJKLxkCEKSUUpQKkOBR6cHmkDofAymapaZDoFRUDKBBGGXD3EieIm
+OWTUrDpXyN9s/YWqY5i62ObHhP1efbQCl/5z+RpN2fwhvF0O668Huk11aumjFJ
/Hicb4TOnVORWtOPfO/fJFGXnNMqdrGP3OQML5+WH2fS7F2dofg2GJnmSBYmg
KR6mw9ISG3XozAIV5OMJUmSdrkC1YAB7JXJLBHS8Oj7b+zRwLNJ4Q6ezskq5/
e76Cg3ZWEfms+VpE0vB627BYuQAG+dXdVABEBAAg0/GhnbW1ciA8aGFtbWVy
dGllZTJAdG9ydyWFpbC5vcmc+QE4B6MBAgAIBQJcUcXhSDBgsJCAcDAGYVCAIJ
CgsFjdAqleAQXgAAKRCACAZr4F4fne3ic8/9r+IDQSuCmSSVZqHj2RRk7K81
kChn47bdDMXG3AuyPkja29gkPkb3xkMShFEVD1G4T2KsiraqNjKOF CxaAYe11
RnqenE64fNjnF8DwdYwFVMZ+Ys9mBZgOIdgz3rGSH1KpCryQeTPcqZAYMdnG0C
mRT18QeWBFFiQ4F+h9t1+Ze5GbP86arYzFolDJRvoDxRSKpP8m+VG6vUJP3Xru
njHRm326UW/sKxvJfoQsdxMhwbXNtyobG2L1VYxvF+66SBZaMT1wkTCJ7C/L
XhLD3vKLaZJMkthh+QZCFJSLJMJZUm9EsMsAtGeZa3LbmsJ2AdmCWRM7uQEN
BFBxRxcBCADAJIAFT1WX3LLkgcAL/y8+Ys3UxwvVQoZA26kPwq4g9iIDGNIHaj
vQ7Z0VOM1VET/TP/q2bQhdKQwc3r08rdzD1mJqGgtq9A2Xbk8kMxhQ9p6zkWll
ZKRiis+s1zoe1G96AysLZnp/qwc+nee7IPQBPI8f5waEcXoMP46wA3xEE9KVEN
piR07TrHytb0v4sekPgvkLjyXSVr5vO3P1nh7SvaGM8wO8MzyivQZv9n0uFVc
YZIs1KQX1ZOKNJAuqL4hL7wkr98Tqd1NL/SvFaGTNrmOUFD0QCT9qEhSYKZHR
qdF+qw5A0U74gevW4A0T48cVVRISVc9ABEBAAAGJAR8EGAECaAKFAIBxRxcGwwA
CnkRq2W6fBeH1XhCnppu1n7z1+DnM8zmbh1FTn7eDvYkrBGFvxx33Yv7Mv3E
```


Featured listings:



1 Gram/High Quality Crystal Meth/Rapid Shipping
\$99.23



1/2 Gram/High Quality Crystal Meth/Rapid Ship
\$61.15



1.75 Grams/High Quality Crystal Meth/Rapid Ship
\$146.50

Table 1. Distribution of price, transactions and revenues of drug listings on Silk Road, by quintile

	QUINTILES	MAX PRICE (USD)	MEAN PRICE (USD)	S.D. (USD)	TRANSACTIONS PER DAY PER LISTING	YEARLY REVENUES (USD)	MARKET SHARE
Cannabis (N = 2,661)	Q1	\$35.03	\$21.27	\$7.51	0.28	\$1,075,466.91	4%
	Q2	\$71.31	\$52.54	\$10.01	0.18	\$1,855,856.64	7%
	Q3	\$141.36	\$102.58	\$20.02	0.25	\$4,726,007.42	19%
	Q4	\$355.28	\$230.18	\$60.05	0.16	\$6,845,565.46	28%
	Q5	\$23,548.82	\$1,474.93	\$2,070.41	0.06	\$10,281,125.38	41%
Ecstasy (N = 1,059)	Q1	\$52.54	\$27.52	\$13.76	0.31	\$625,264.38	3%
	Q2	\$140.11	\$88.82	\$26.27	0.20	\$1,313,005.83	7%
	Q3	\$342.77	\$227.68	\$57.55	0.20	\$3,451,913.72	17%
	Q4	\$1,129.65	\$635.51	\$221.43	0.13	\$5,634,438.96	28%
	Q5	\$18,932.63	\$3,494.04	\$3,401.47	0.05	\$8,902,127.09	45%
Opioids (N = 262)	Q1	\$38.78	\$20.02	\$8.76	0.40	\$139,986.86	4%
	Q2	\$87.57	\$61.30	\$12.51	0.32	\$400,538.07	11%
	Q3	\$190.15	\$130.10	\$32.53	0.44	\$976,822.67	27%
	Q4	\$444.11	\$280.22	\$62.55	0.29	\$1,443,426.17	39%
	Q5	\$19,454.30	\$1,683.85	\$2,773.47	0.06	\$718,072.01	20%
Prescription (N = 3,953)	Q1	\$30.02	\$12.51	\$8.76	0.13	\$506,903.08	4%
	Q2	\$66.30	\$46.29	\$10.01	0.10	\$1,318,313.91	11%
	Q3	\$127.60	\$93.83	\$17.51	0.07	\$2,022,103.75	17%
	Q4	\$260.21	\$173.89	\$36.28	0.05	\$2,699,606.03	23%
	Q5	\$49,338.19	\$1,129.65	\$2,851.03	0.03	\$5,194,428.70	44%
Psychedelics (N = 1,539)	Q1	\$31.28	\$17.51	\$7.51	0.21	\$381,927.70	4%
	Q2	\$63.80	\$46.29	\$8.76	0.22	\$1,160,079.86	13%
	Q3	\$125.10	\$90.07	\$17.51	0.17	\$1,738,474.94	20%
	Q4	\$352.78	\$206.42	\$65.05	0.12	\$2,512,971.69	29%
	Q5	\$14,965.71	\$1,932.80	\$2,961.12	0.03	\$2,832,404.87	33%
Stimulants (N = 1,274)	Q1	\$58.80	\$30.02	\$15.01	0.24	\$674,529.33	4%
	Q2	\$125.10	\$87.57	\$18.77	0.24	\$1,988,683.98	12%
	Q3	\$280.22	\$186.40	\$46.29	0.24	\$3,972,925.51	24%
	Q4	\$683.05	\$440.35	\$113.84	0.13	\$4,974,321.58	30%
	Q5	\$44,680.72	\$2,640.86	\$4,903.92	0.05	\$5,165,648.78	31%

Table 2. Distribution of quantity of drug listings and price per unit on Silk Road, by quintile

	Quintiles	Min. quantity	Max. quantity	Mean quantity	Average price (USD)
Marijuana (grams) N = 430	Q1	0.10	3.50	1.93	\$17.51
	Q2	3.50	7.00	5.30	\$16.26
	Q3	7.00	14.18	11.02	\$12.51
	Q4	14.18	50.00	28.66	\$11.26
	Q5	50.00	2,267.95	269.13	\$7.51
MDMA (grams) N = 293	Q1	0.20	1.00	0.78	\$82.57
	Q2	1.00	5.00	2.18	\$63.80
	Q3	5.00	10.00	7.02	\$37.53
	Q4	10.00	50.00	26.04	\$27.52
	Q5	50.00	1,000.00	270.88	\$16.26
Xanax (milligrams) N = 286	Q1	0.50	50.00	16.26	\$2.50
	Q2	50.00	100.00	80.52	\$1.25
	Q3	100.00	300.00	198.28	\$1.25
	Q4	300.00	1,000.00	567.07	\$1.25
	Q5	1,000.00	100,000.00	9,629.63	\$0.20
LSD (blotters) N = 165	Q1	1.00	4.00	1.94	\$13.76
	Q2	4.00	5.00	4.91	\$12.51
	Q3	5.00	10.00	9.33	\$12.51
	Q4	10.00	25.00	20.30	\$8.76
	Q5	25.00	1,000.00	172.12	\$6.26
Cocaine (grams) N = 407	Q1	0.01	1.00	0.49	\$163.88
	Q2	1.00	1.00	1.00	\$121.35
	Q3	1.00	3.50	2.71	\$112.59
	Q4	3.50	10.00	5.73	\$98.83
	Q5	10.00	250.00	36.35	\$68.81

Table 3. Items listed for sale as 'precursors' on Silk Road

	Products*	% of products listed
Product sold involved in the production of:		
<i>Psychedelic drugs</i>	1, 9, 10, 11, 17, 18, 20, 23	35%
<i>Stimulant drugs (meth/amphetamine)</i>	3, 4, 6, 7, 16, 21	26%
<i>MDxx (MDMA, MDA, MDEA, etc.)</i>	2, 8, 15, 19, 22	22%
Product used in the synthesis of multiple drugs	5, 12, 21, 22	9%
A substance not involved in drug production	13	4%
Tools/machinery	14	4%
* Products	Probable use in drug production	
1. 2,5-Dimethoxybenzaldehyde	precursor for psychedelic phenethylamines	
2. Sassafras	containing safrole; precursor to MDxx	
3. P2NP	precursor to amphetamine/methamphetamine	
4. Mercury salts	catalyst for production of methamphetamine	
5. Sodium borohydride	common reagent in drug synthesis	
6. Speed oil	amphetamine freebase	
7. Red phosphorus	catalyst for production of methamphetamine	
8. Helional	precursor to MDxx	
9. Nitromethane	reactant in the production of phenethylamines	
10. Allyl-2-methoxyphenol (eugenol)	precursor for psychedelic amphetamines	
11. Para-benzoquinone	precursor to psychedelic phenethylamines	
12. Sodium iodide	common reagent in drug synthesis	
13. Vistaril	antihistamine hydroxyzine, used to potentiate opiates/opioids	
14. Tablet press machine		
15. 1,2-Dihydroxybenzene (catechol)	precursor to methylone and MDxx	
16. 2-Bromo-4'-methylpropiofenone	precursor to mephedrone	
17. Triethylamine	reactant in LSD synthesis	
18. 3,4,5-Trimethoxybenzaldehyde	precursor to synthetic mescaline	
19. Nitroethane	reactant in the production of MDxx	
20. Sodium bromide	used in the production of 2C-B	
21. Ephedra powder	precursor to methamphetamine and methcathinone	
22. Methylamine	reactant in the production methamphetamine and MDMA	
23. Potassium cyanate	reactant in the production of 4-methylaminorex	