Do Police Crackdowns Disrupt Drug Cryptomarkets? A Longitudinal Analysis Of The Effects Of Operation Onymous

In recent years, there has been a proliferation of online illicit markets where participants can purchase and sell a wide range of goods and services such as drugs, hacking services, and stolen financial information. Second-generation markets, known as cryptomarkets, provide a pseudo-anonymous platform from which to operate and have attracted the attention of researchers, regulators, and law enforcement. This paper focuses on the impact of police crackdowns on cryptomarkets, and more particularly on the impact of Operation Onymous, a large-scale police operation in November 2014 that targeted many cryptomarkets. Our results demonstrate that cryptomarket participants adapt to police operations and that the impact of Operation Onymous was limited in time and scope. Of particular interest is the finding that prices did not increase following Operation Onymous, even though many dealers retired shortly after it occurred.

Keywords: cryptomarket, police crackdown, displacement, illicit drug market

Introduction

While initially conceived as a tool to share information, the Internet has now become an important platform on which illicit goods and services can be bought and sold. This thriving underground economy is fueled by a dramatic growth in the number of individuals who participate in online illicit markets and an ever-increasing range of goods and services that are made available (Rush et al., 2009; Aldridge and Décary-Hétu, 2014). These markets traditionally focused on computer hacking, financial fraud and intellectual property fraud. Starting in 2011 however, a new breed of online illicit markets appeared, focusing on a whole new line of products: illicit drugs (Martin, 2014).
The European Monitoring Centre for Drugs and Drug Addiction points out that “the growth of online and virtual drug markets poses major challenges to law enforcement and drug control policies.” (EMCDDA, 2015a: 34). Indeed, online illicit markets, through the adoption of mitigating technologies, make it possible to sell any substance across the world. This new distribution channel, if adopted widely by drug dealers and drug users, holds the potential to disrupt the distribution and sales of illicit drugs, and consequently, to disrupt the ability of law enforcement to regulate these illicit markets. For now, little has changed in law enforcement’s approach which has focused on arresting and prosecuting online drug dealers, seizing their money, their drugs and the online markets they operate from (D.O.J., 2014; D.O.J., 2015). This strategy has had only limited success according to international agencies (EUROPOL, 2014; UNODC, 2014; EMCDDA, 2015a, 2015b), who have called for a deeper understanding of *cryptomarkets*, the name

given to the new breed of online illicit markets: "EU law enforcement, Europol included, has not fully conceptualised how to integrate this cyber dimension into all relevant aspects of police work, let alone devise a strategy and implementation plan to make this happen" (EUROPOL, 2014: 71). Some researchers have gone a step further and criticized the law enforcement strategies, arguing that they foster competition and innovation among online offenders and inadvertently provide free publicity to cryptomarkets (Van Buskirk et al., 2014; Buxton and Bingham, 2015). Law enforcement operations displace participants to alternative online drug markets but do not limit their activities. (Buxton and Bingham; 2015; Soska and Christin, 2015).

This paper will build on these research findings and provide a deeper understanding into how cryptomarkets react to law enforcement interdiction. The main objective of this paper is to describe and explain the impact of police crackdowns on cryptomarkets. To do so, this paper will center on a case study of the largest law enforcement intervention against cryptomarkets, *Operation Onymous*. The first section of the paper presents the literature on the enforcement of physical illicit drug markets and more particularly the impact of police crackdowns. The following section describes how cryptomarkets operate and have evolved. After introducing our data and methods, we then describe the state of cryptomarkets before and after Operation Onymous. Our results show that the operation did impact cryptomarkets in general but that this impact was limited to less than 2 months; some participants also displaced their activities following the operation. The conclusion present prospects for future research.

The enforcement of traditional illicit drug markets

The strategies to regulate illicit drug markets can target either the supply or the demand for illicit drugs. Demand control programs attempt to cut drug consumption by reducing the number of users and/or the quantity of drugs they consume (Rydell and Everingham, 1994; MacCoun and Reuter, 2001). Opioid substitution therapy and school-based drug education programs are typical examples of interventions aimed at reducing the demand for illicit drugs. Supply control programs affect drug consumption by targeting drug prices and availability (Reuter and Kleiman, 1986). The risks and prices model of Reuter and Kleiman (1986) assumes that compensation for non-monetary costs (risk of law enforcement and violence) is the main factor driving up the price of illicit drugs (Caulkins and Reuter, 1998). Law enforcement thus works like a tax, imposing additional costs on suppliers, who then pass them on to drug users (Reuter and Kleiman 1986). Users, in turn, adjust their consumption habits according to drug prices. The main difference, then, between demand side and supply side actions is that demand programs aim to affect drug use directly while supply programs aim to do so indirectly. While supply and demand programs can coexist, supply side programs have always received more attention and funding (Ramstedt, 2006; Reuter, 2006), even in countries with a lenient approach to drug use, such as the Netherlands (Rigter, 2006).

Supply side actions can target many links in the supply chain through a wide range of programs (see Moore, 1990). Of these, supply side enforcement efforts aimed at disrupting specific marketplaces (crackdowns) are the most popular (Babor et al., 2010).

Crackdowns can be generally defined as an intensive police operation characterized by increased severity or certainty of sanction and by a public relations campaign to advertise the operation (Scott, 2003). Despite their popularity, there is limited evidence to support the effectiveness of police crackdowns in reducing the supply and/or demand of illicit drugs (Edmunds et al., 1996; Weatherburn and Lind, 1997; Best et al., 2001; Scott, 2003; Wood et al., 2004; Kerr et al., 2005; Mazerolle et al., 2006). Indeed, most studies have found that police crackdowns have no or little impact on the number of drug users or suppliers (Wood et al., 2004; Kerr et al., 2005), drug prices (Weatherburn and Lind, 1997; Best et al., 2001; Wood et al., 2004; Kerr et al., 2005), or the number of users entering treatment centres (Weatherburn and Lind, 1997; Wood et al., 2004; Kerr et al., 2005). Mazerolle et al. (2006) point out that classic police operations are less likely to reduce street-level drug market problems than alternative approaches (community-wide policing, problem-oriented policing, hotspots policing).

While little evidence supports the use of police crackdowns to reduce the number of drug market participants and sales over the long term, there have been indications that crackdowns can have a time-limited impact on drug markets (Kerr et al., 2005). This impact is, however, offset by the adaptation of market participants through displacement techniques (Edmunds et al., 1996; Wood et al., 2004; Kerr et al., 2005).

Tactical displacement, the replacement of a crime commission script by another, is the most common form of adaptation to enforcement efforts against illicit drug markets. Police interventions may lead to a shift from “open” to “closed” drug markets with dealers that may adopt technological solutions such as cell phones and messaging applications to contact their suppliers and customers covertly and evade surveillance (Edmunds et al., 1996; Kerr et al., 2005; Small et al., 2006; Pollack and Reuter, 2014; Nguyen and Reuter, 2012).

Open markets are generally specific locations where drug users go to buy illicit drugs and are characterized by higher risk (both of enforcement and violence) since buyers deal with the dealers that are available at that moment and at that place rather a dealer they know. Closed markets are not tied to specific locations and work more like a network that only trusted participants can join. There is ample evidence that demonstrates that drug market participants have turned open markets into closed ones after police crackdowns in order to reduce the risks of enforcement (Bless et al., 1995; Edmunds et al., 1996; May and Hough, 2001).

Geographical displacement is another common form of adaptation to police operations. Several studies have shown that police crackdowns are unable to reduce the number of transactions but may lead to a change in the physical location where dealers and users meet (Edmunds et al., 1996; Maher and Dixon, 1999; Best et al., 2001; Wood et al., 2003; Wood et al., 2004). For instance, Wood et al. (2004) show that a large scale police crackdown in Vancouver had no impact on the price of illicit drugs, the frequency of use, or the level of enrolment in treatment programs. Instead, their findings suggest that this large police operation merely displaced drug use from the area of the crackdown into adjacent areas of the city. Such displacement was however not seen in other controlled experiments (Weisburd & Green, 1995).

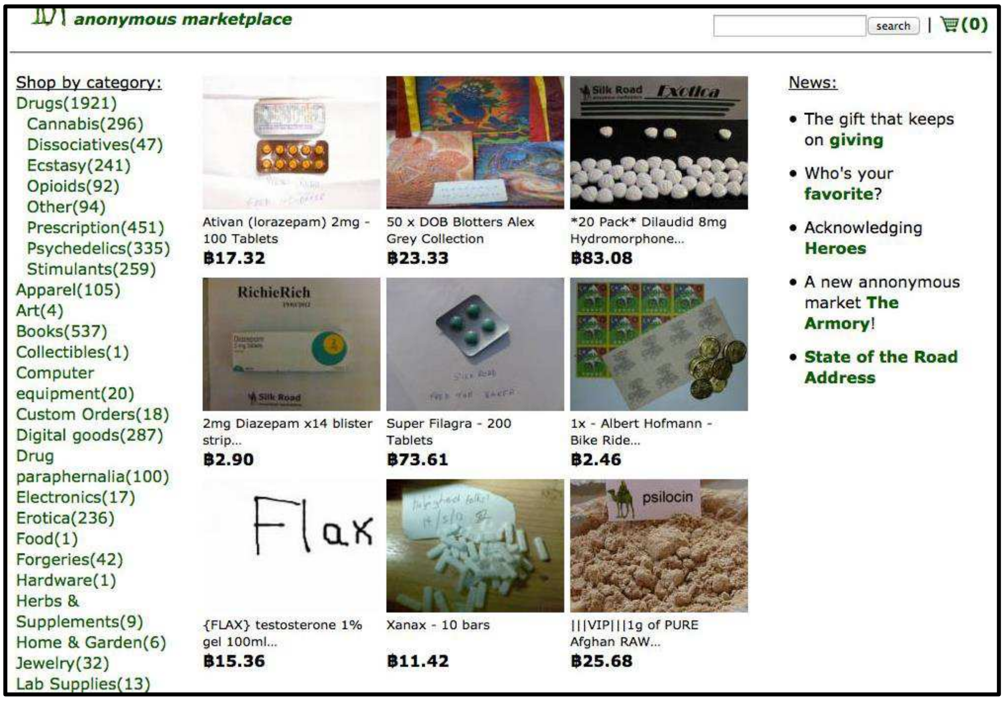
Cryptomarkets and law enforcement

While displacement in traditional drug markets is well understood, there are no best practices on how to enforce online illicit markets, and even less so for cryptomarkets. This is due in part to the scarcity of enforcement operations that have targeted cryptomarkets and to the recent emergence of these online illicit markets. It is likely that the particular nature of cryptomarkets will change the size and scope of the impact of enforcement. To understand how and why this is the case, we will now describe the characteristics of cryptomarkets and their evolution over time.

Cryptomarkets are websites that allow participants to buy and sell goods and services while providing some level of anonymity (Martin, 2014). They are sometimes used to sell hacking services, fake ID cards and stolen financial information. Most of their activities however focus on the sale of licit drugs sold illicitly (prescription drugs) and the sale of illicit drugs (cannabis, stimulants, novel psychoactive substances). The cryptomarkets' innovation originates not in the development of a new stealth technology but rather from the combination of many technologies that, when combined, provide an enhanced level of anonymity to participants. These technologies protect the identity of the participants by routing all of their traffic through the Onion Router (Tor) network (Dingledine et al., 2004), making it very difficult to find the participants' IP address as well as the IP address of the servers hosting the cryptomarkets. The anonymity of the participants is further enhanced by the use of bitcoins (Nakamoto, 2008) as the method of payment for purchases. Bitcoin is a virtual currency that can be exchanged online instantly and without having to identify either end of a transaction.

The first cryptomarket was SILK ROAD (SR1), which rose to fame through a 2011 news stories by Gawker Media that described it as "the underground website where you can buy any drug imaginable" (Chen, 2011). Figure 1 shows the main page of SR1, which resembles licit merchant websites such as eBay and Amazon. The FBI estimated that total sales on SR1 from February 2011 to October 2013 were in the range of $200 million USD (Flitter, 2015). This translates to about $80 million USD on average per year, a figure that is close to the one provided by academic researchers (Aldridge and Décary-Hétu, 2014). This marks a sharp increase from the 2012 estimate of $14.4 million USD by Christin (2013) who used a very similar methodology to that used by Aldridge and Décary-Hétu (2014) but represents much less than 1% of the overall illicit drug trade.

Figure 1: Main page of SILK ROAD



So far, two major police operations have targeted cryptomarkets. The first, on October 2, 2013, led to the shutdown of SR1 by US law enforcement, the seizure of over $33 million USD in bitcoins, and the arrest of its founder and administrator (FBI, 2013). SR1's participants quickly moved to other cryptomarkets, including AGORA, CLOUD-NINE, EVOLUTION, HYDRA, SHEEP, and SILK ROAD 2 (SR2).[1] A number of these cryptomarkets were active for only a short time as they were taken down during a second police operation, "Operation Onymous," launched on November 5, 2014. Operation Onymous was a combined effort by law enforcement agencies from 16 European countries and the US and led to the arrest of 17 people, including the administrator of SR2. It also led to the seizure of over $1.3 million USD in bitcoins, cash, precious metals, and drugs. At the time of Operation Onymous, the cryptomarkets with the most listings – the online name for a product page and a proxy for the size and relevance of cryptomarkets - were, in order, AGORA, SR2, EVOLUTION, ANDROMEDA, BLUESKY, CLOUD-NINE, and HYDRA (Buxton and Bingham, 2015).

The adaptation of cryptomarket participants to police operations

The launch of Operation Onymous confirmed the law enforcement's ability to target cryptomarkets and raised questions about the relative impunity and anonymity of participants. It also proved that shutting down SR1 was not a fortuitous event but possibly the first of many operations targeting cryptomarkets. Past research (Van Buskirk et al., 2014; Buxton and Bingham, 2015) concludes that the fear created by the police operation

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[1] SR2 was somewhat affiliated with SR1 as its main administrators had been moderators on SR1.

against SR1 was not sufficient to deter participants who were able to adapt through displacement.

The first displacement technique used by participants was to virtually move to new cryptomarkets. In the aftermath of SR1's shutdown, many participants moved to BLACK MARKET RELOADED (BMR) and SHEEP (Van Buskirk et al., 2014). In the six weeks following the shutdown of SR, BMR saw a twofold increase in the number of dealers; SHEEP's number of dealers was multiplied by more than four. Buxton and Bingham (2015) describe a similar virtual geographical displacement of participants following Operation Onymous, with activity on AGORA and EVOLUTION increasing in the subsequent weeks. Soska and Christin (2015) provided the most comprehensive study of the longitudinal evolution of the cryptomarket's ecosystem, showing its resilience to both scams and shutting downs. The authors show that shortly after the take down of SR, a vast part of the sales were absorbed by BMR, indicating the shift of sellers and buyers to the new cryptomarket. By contrast, they find that Operation Onymous significantly affected sales in the cryptomarket system, although sales in Evolution and Agora started growing quickly after a few weeks from the police intervention.

Buxton and Bingham (2015) observe also that, following these two main police operations, participants adopted more secure communication techniques, using out-of-band communication channels and point-to-point encryption to exchange messages. Cryptomarkets implemented more secure authentication methods, such as two-factor authentication. Participants also discussed about the possibility of moving cryptomarkets to a decentralized architecture which would limit the possibility of market take downs (see OpenBazaar [2015] for an example).

Modeling the impact of law enforcement on cryptomarkets

The limited literature on the impact of law enforcement on cryptomarkets provides some insights on how cryptomarkets react to law enforcement interventions. However, as Soska and Christin outline "[t]he effect of law enforcement take-downs […] is mixed at best" (2015: 41) though the lack of evidence regarding the effect of law enforcement take-downs is not proof that there were no impact at all. Van Buskirk et al. (2014) and Buxton and Bingham (2015) limited their analysis to an evaluation of the level of activity on cryptomarkets that survived the police crackdown, which, per se, is not an evidence of displacement. Indeed, while some dealers may have moved to new cryptomarkets, the activity intensity of cryptomarkets may be lower compared to their pre-Operation Onymous level. Soska and Christin's study (2015) represents the sole pre-and-post analysis. However, their longitudinal analysis on the effect of police interventions on cryptomarkets focuses almost exclusively on sales volumes and dealers' presence. Understanding the impact of police operations goes beyond the simple analysis of the level of activity of participants and needs to consider other dimensions of the supply, demand and prices of illicit drugs. Drug policy analysts have developed a mature design method to evaluate the impact of law enforcement on traditional drug markets looking at supply (Paoli et al., 2009), demand (Kilmer, 2002) and prices (Pollack and Reuter, 2014). We intend to apply this design method to Operation Onymous.

The main objective of this paper is to describe and explain the impact of police crackdowns on cryptomarkets. This impact will be measured through two dimensions. The first will be the changes in the prices, the supply and the demand for illicit drugs on cryptomarkets before and after Operation Onymous. The second will be the presence of displacement of cryptomarket participants from markets that were targeted by Operation Onymous to those that were not.

Based on past research, we expect to find stable levels of activities and prices on cryptomarkets following the Operation Onymous. Police crackdowns have shown to have little to no impact on drug market activities. The virtual setting of cryptomarkets raises questions about the applicability of research on traditional drug markets to their virtual counterparts. Décary-Hétu (2014) answers some of these questions in his evaluation of the impact of multiple international and large-scale police operations targeting the community of hackers responsible for the illicit distribution of copyrighted content online (e.g., books, software, games, and movies). Using an interrupted time series model, Décary-Hétu (2014) demonstrates that there were no significant changes in the number of active hacker groups or in the number of files released online following police operations, which suggests that police operations in the physical and virtual worlds have similar outcomes.

We also expect to find a displacement of participants from markets that were shut down to markets that were not. Buxton and Bingham (2015) and Van Buskirk et al. (2014) already found support for this hypothesis and we intend to extend their findings by analyzing data collected from five cryptomarkets (AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2) during the months before and after Operation Onymous.

This paper provides a much more comprehensive overview of adaptation techniques used by cryptomarket participants and adopts a research design developed for researching the effect of law enforcement on traditional drug markets. This paper will be of interest to a broad range of criminologists interested in the impact of new technologies on offenders. Virtual settings are expanding quickly and attracting a greater share of organized crime (Lavorgna, 2015). Many offenders are joining online communities and markets (see Holt et al. (2008) and Holt and Lampke (2010) for examples in prostitution and computer hacking). Differences between online and offline offending are therefore likely to shrink over time. Understanding the dynamics of participation in virtual illicit markets can provide us with an interesting new methodology for understanding crime. This paper also builds on the quantitative approach of Christin (2013), Aldridge and Décary-Hétu (2014) and Soska and Kristin (2015) who have explored how virtual drug markets can be used to better understand drug trafficking in general. It goes beyond past research by analyzing cryptomarkets as an industry rather than looking at only one specific market. It also provides longitudinal quantitative-based research that allows a much more robust analysis of displacement techniques using data that is not accessible to traditional displacement studies.

Cryptomarkets provide what may be the most comprehensive dataset ever available on the impact of police operations. Past research has had to rely on controlled buys, official records, and interviews with a limited number of market participants in order to evaluate the impact of police operations. With cryptomarkets, precise evaluations of the supply and consumption for drugs on those markets can be measured automatically across time. Cryptomarkets also provide an opportunity to study the evolution of drug prices. They thus provide a unique opportunity to advance the literature on displacement, offender adaptation, and the impact of police operations. The methodology used in this paper could be used to study many of the growing online communities where johns[2] and computer hackers meet. It could also be used to further understand some aspects of organized crime, which is increasingly moving into the virtual world (Lavorgna, 2015).

Data

This study uses data collected by an independent researcher who has been actively monitoring cryptomarkets since the beginning of 2014 (Branwen, 2015b; Branwen, 2015c). Branwen developed his own custom monitoring tool that logged in to cryptomarkets and extracted their listings, dealer profiles and buyers' feedbacks. While many small and large cryptomarkets were monitored by Branwen, we opted to focus on five of the largest cryptomarkets for this study: AGORA, CLOUD-NINE, EVOLUTION, HYDRA and SR2. Together, these cryptomarkets hosted the majority of all cryptomarket listings online and are therefore representative of the state of cryptomarkets during the sample period which ran from January 2014 to March 2015. Operation Onymous was launched on November 5, 2014 and led to the seizure of CLOUD-NINE, HYDRA and SR2. AGORA and EVOLUTION were not targeted by the police crackdown. Our dataset therefore contains data on the 41 weeks before or during Operation Onymous and the 21 weeks that followed. The dataset we received contained 1,746,737 listings and 136,963 dealer profiles, though many listings and dealers were duplicates from week to week. The dataset contained 226,297 unique listings and 7,280 unique dealers.

The dataset collected by Branwen is unique in that it provides an extensive look into the activities of cryptomarkets over an extended period of time. It is however not without limitations. First, while Branwen collected *some* data almost every week, he did not collect *all* of the listings, dealer profiles and customer feedbacks that were posted each week on each cryptomarket. This is due to the well-known unreliability of websites hosted on the Tor network. As a result, Branwen only collected partial snapshots of cryptomarkets each time he launched his tool. Second, Branwen's tool was also unable to infer, from its data collection, the total population of listings, dealer profiles and listings. It is therefore impossible to determine how incomplete each snapshot of cryptomarkets is. Lastly, Branwen's data collection was irregular at best. There could be anywhere from 0 to 4 snapshots taken during any given week. The quality of the data varies therefore from week to week.

These methodological issues led us to aggregate all of the data on a weekly basis (from

[2] Johns is a generic term that describes the men looking for escorts.

Sunday to Saturday) rather than on a snapshot basis. If data were collected more than once during a week, all of the snapshots were combined and the duplicate entries were removed. Where the information had changed during the week, the most up to date information was selected. This manipulation allowed us to compensate to a substantial extent for the unreliability of the data collection by combining multiple snapshots together. The risk that an information would be missing from our dataset was reduced though not completely eliminated. While imperfect, this dataset is still to our knowledge one of only two collections of cryptomarket data that was collected for such an extended period of time and the only one accessible to the researchers. The quality of the data also changed our research design and prevented us from building interrupted time series or means difference tests. We instead rely on long-term trends in the data which are less likely to be affected by the poor quality of the data for any given week. Our data may be somewhat biased but will still be able to show the trends in the evolution of activities and prices on cryptomarkets. All our figures also present a three-week moving average (week before, week of, week after) to reduce the noise in the data.

Methods

Our research design is based on past research that measured the effectiveness of police crackdowns in the context of traditional drug markets. It takes into account indicators of prices, the supply and the consumption of illicit drugs. Table 1 at the end of this section summarizes all the indicators.

Prices

Changes in the price of drugs is the first indicator of the impact of police crackdown on cryptomarket activities. We measured, for each listing, the variation of its price across time. To do so, we compared the price of a listing at week *n* to the price of the same listing at week *n-1* ($\frac{P_n - P_{n-1}}{P_n + P_{n-1}}$) . Since the type and weight of drugs in listings never change, we could measure whether the price of the listing had gone up or had gone down. We repeated this measure for all listings across all weeks. We then averaged the price change for each week. Listing prices that more than doubled or were cut by more than half over the course of a week were removed from the sample as these price spikes usually occurred when a dealer was out of stock and wanted to keep the listing alive while preventing customers from making a purchase that could not be filled. Significant price cuts were often the results of dealer mistakes that were captured in the scrapes before they could be corrected. Even though prices on cryptomarkets are listed in bitcoins, all prices are displayed in US dollars (USD). Data on the exchange rate was collected from Bitcoincharts.com, a well-known and respected website in the bitcoin community that archives the exchange rate for BTC-E, a leading exchange market for bitcoins. As dealers can peg the price of listings in bitcoins to specific prices in USD, we do not expect the exchange rate of bitcoins to affect the price trends.

Supply

The supply side indicators provide us with evidence of the impact of police crackdowns on the activities of cryptomarkets and the displacement capacity of drug dealers. Our analyses focus on the number of active dealers, the number of new dealers for each week, the total number of listings and the displacement of dealers across cryptomarkets. To improve the reliability of the analyses of supply, the names of dealers across all markets were compared using the Levenshtein distance, which calculates the number of characters that need to be changed to convert one string to another.[3] All dealer names were compared to each other and those that were the closest (Levenshtein distance of 25% or less of the number of characters in the dealer name) were manually compared to make sure that they did not represent the same dealer as dealers sometimes opened accounts on different markets using different but very similar names (ex: *weed_dealer* and **weed__dealer**)[4]. This method allowed us tie together accounts with different names. To measure the number of active dealers, a list of dealers was compiled from the listings (which provide the dealer's name) and the dealer profiles. Duplicate dealer names in each week were then removed. Dealers with no feedback during a week were considered to be inactive for that week and removed from the sample. As it is easy to create a dealer profile, many dealers put up listings on cryptomarkets but never have an actual sale, leading to an overestimation of the size of supply if we use number of available dealers. As a control measure, the proportion of active dealers was compared to the total number of dealers to detect changes or possible manipulation of the data.

We also assessed the number of new dealers on AGORA and EVOLUTION for each week between August 2014 and January 2015. We limited our analysis to these two markets as they are the only two that survived to the police crackdown. We also limited our sample period in order to focus on the trends immediately before and after the police operation. The short lifespan of dealer profiles (Soska and Christin, 2015) also suggested that extending the sampling period would increase noise and would include dealers that had stopped dealing for reasons unrelated to Operation Onymous.

We measured the availability of products through the number of listings posted each week on all cryptomarkets before the operation and on AGORA and EVOLUTION following it.

Finally, to test the displacement effect of Operation Onymous, we measured the number of dealers who moved to other markets following the police intervention. We classified dealers active in the five weeks leading to Operation Onymous according to three categories: 1) those selling only on cryptomarkets shut down during Operation Onymous; 2) those selling only on cryptomarkets that were not shut down during Operation Onymous and; 3) those selling on both cryptomarkets that were shut down during Operation Onymous and those that were not. Given the short lifespan of most dealer

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[3] The Levenshtein distance between compute and commute is 1, as changing one character, *p*, transforms the first string into the second.

[4] These are not actual dealer names but are indicative of the differences found in dealer names.

accounts (Soska and Christin, 2015), including all past dealers might have artificially increased the number of dealers who had stopped selling following Operation Onymous. The number of dealers in each of the three categories who continued to sell on AGORA and EVOLUTION after Operation Onymous was measured at 4 weeks, 8 weeks, and 12 weeks after Operation Onymous to detect a possible cooling down period.

It is possible that some dealers moved to physical drug markets following Operation Onymous. However, it is not possible to assess displacement to traditional drug markets or to distinguish dealers who stopped selling drugs following Operation Onymous from those who changed their dealer name but continued to sell on other cryptomarkets. Still, analysis of the displacement of those dealers we can track is likely to generate some insights into the displacement of dealers at the aggregate level.

Consumption

The *consumption* of drugs was measured by two indicators. The first, the number of feedbacks posted each week, was built using data on feedbacks from HYDRA, EVOLUTION, and SR2.[5] Further feedback data were collected in dealer profiles on AGORA, CLOUD-NINE, HYDRA, and EVOLUTION.[6] In all of these markets, dealer profiles detailed the aggregated number of feedbacks for each dealer across all their listings. To merge the two datasets, we aggregated the feedback data from the listings for each dealer for each week. We then compared this to the data from the dealer profile for the same week. If the two numbers did not match, we kept the bigger of the two. The number of feedbacks is the best proxy available for consumption of drugs on cryptomarkets. Buyers are strongly encouraged to leave feedback for each transaction and do so most of the time. Past evaluations of the correlation between the number of feedbacks and the advertised number of sales of vendors has shown a very high correlation (Aldridge and Décary-Hétu, 2014). The second indicator is the average market share controlled by dealers also refered to as the concentration of sales. To assess it, we divided the number of feedbacks of each dealer by the total number of feedbacks from all dealers on the same market. We limited our analysis to AGORA and EVOLUTION to provide a more robust comparison before and after Operation Onymous. Table 1 report the indicators that we used to understand the effect of Operation Onymous on cryptomarkets.

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[5] CLOUD-NINE did not provide any feedback information in its listing pages. Listings on AGORA only presented the last 20 feedbacks, preventing us from measuring the exact number of feedbacks for each listings.

[6] On EVOLUTION, the dealer profiles listed number of feedbacks up to 1,500. Dealers with more than 1,500 feedbacks were listed as having 1,500+ feedbacks. Given the small number of dealers with 1,500+ feedbacks, these dealers were removed from the datasets.

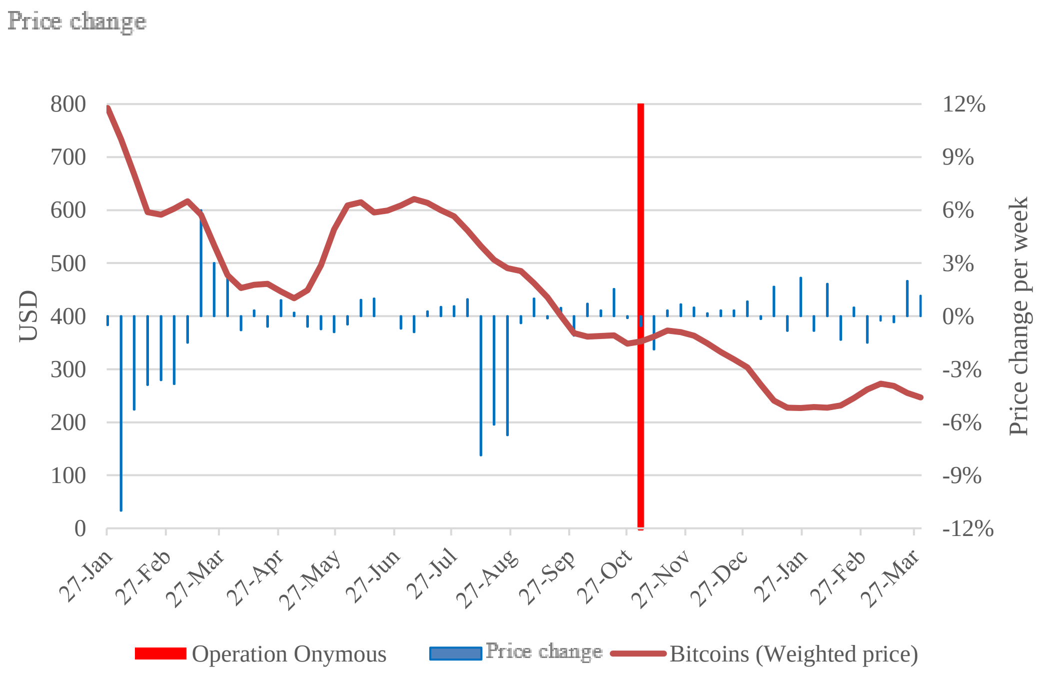
Table 1. Summary of methods and sampling period

Dimension	**Variable**	**Period**
Price	Average price change of listings	Jan 2014–Mar 2015
Supply	Number and proportion of active dealers	Jan 2014–Mar 2015
	Number of new dealers (AGORA, EVOLUTION)	Aug 2014-Mar 2015
	Displacement of dealers across cryptomarkets	Dec 2014-Feb 2015
	Number of listings	Jan 2014-Mar 2015
Consumption	Number of feedbacks	Jan 2014-Mar 2015
	Concentration of sales	Jul 2014-Mar 2015

Results

We begin our analyses by looking at trends in drug price changes across all five cryptomarkets (AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2) for the 41 weeks that preceded the police operation as well as the 21 weeks that followed it. Figure 2 shows that prices did not change drastically after the operation, staying well below a 2% average price change. Prices dropped during the first weeks of the sampling period but this could be explained by the drop in price of the value of bitcoins. On some markets dealers could peg their listing price (which had to be in bitcoins) to the US dollar but not all markets had that feature enabled from the start, which could explain the drop in price. As the price of bitcoins continued to fluctuate, the impact on markets seemed to disappear. There is a slight drop in the price of listings following Operation Onymous, but this drop is not significantly different from the many others that occurred during our sampling period. Figure 2 demonstrates the stabilization of prices over time. The largest peaks and valleys are found at the beginning of the sampling period when the markets were not yet mature. Over time, the price of listings generally varies by less than 3%, a change that could be the result of having to convert the price of drugs into bitcoins.

Figure 2. Average price change of listings per week in AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2



Moving to the supply side of drug markets, Figure 3 presents the evolution of the number of active dealers (those with at least one feedback during the prior week) over time. It shows a largely upward trend in the number of dealers in the five cryptomarkets in the period before Operation Onymous. In the period that followed Operation Onymous, the number of active dealers on AGORA and EVOLUTION registers an important drop. This drop stops in December 2014 when the number of dealers appears to increase again. The increase is particularly striking in the case of EVOLUTION, the market that contains the largest share of active dealers. At the end of the sampling period, the number of active dealers appears to have risen almost to its high of October 2014, even though only two markets out of five were still active. The upward trend in the number of active dealers that began in December 2014 suggests that the number of active dealers might have surpassed its high for the year if the sampling period had been extended. The total number of dealers appears to follow a similar trend to that of active dealers. The proportion of active dealers hovers between 55% and 70% for much of the sampling period, meaning that there was no vast increase in the number of inactive dealers before or after Operation Onymous.

Figure 3 Number and proportion of active dealers per week on AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2

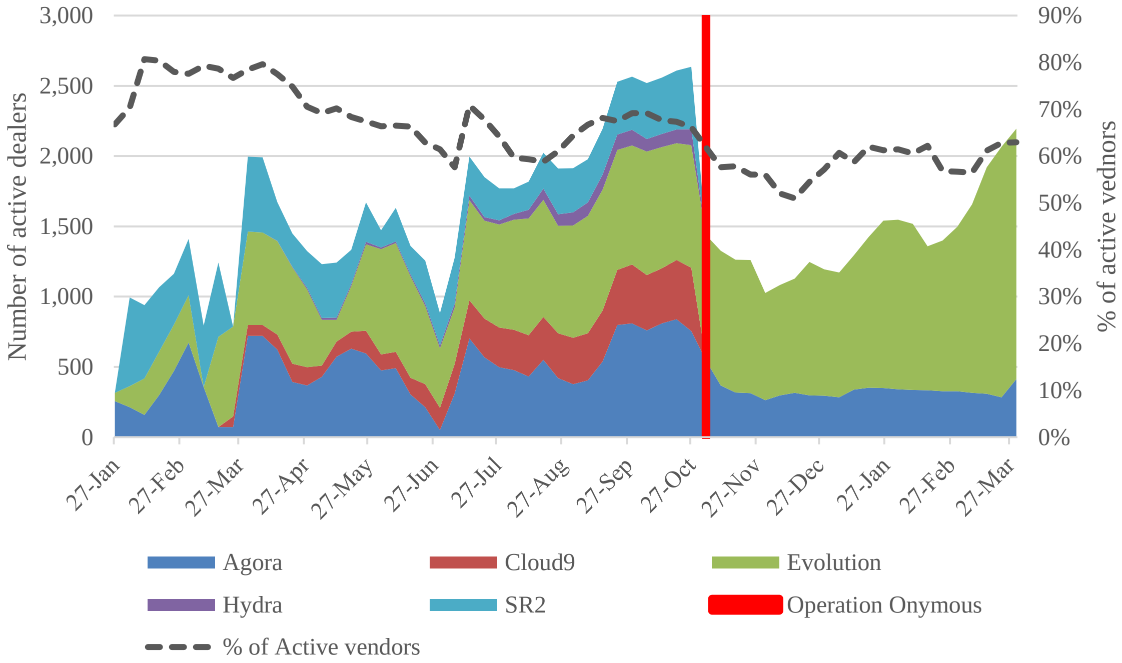


Figure 4 investigates the displacement impact of Operation Onymous further by presenting the number of new dealers who signed up on AGORA and EVOLUTION each week. It shows a largely upward trend in the number of new dealers on both markets before Operation Onymous, suggesting that the cryptomarkets were in an expansion phase. Following Operation Onymous, this trend is reversed and shows a decrease in the number of new dealers for the following weeks. The number of new dealers per week only increases again at the beginning of 2015.

Figure 4. *Number of new dealers signing up on AGORA and EVOLUTION per week*

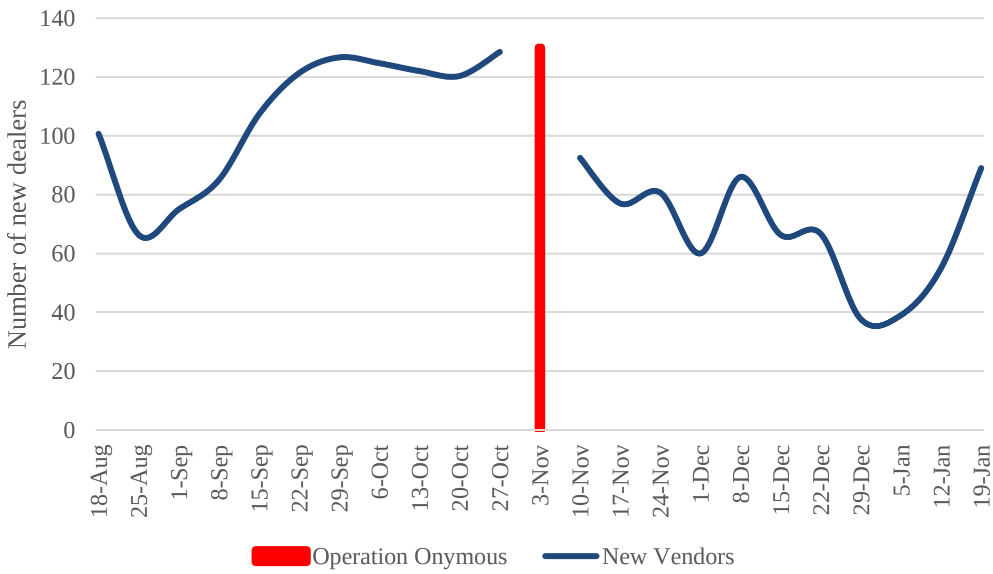


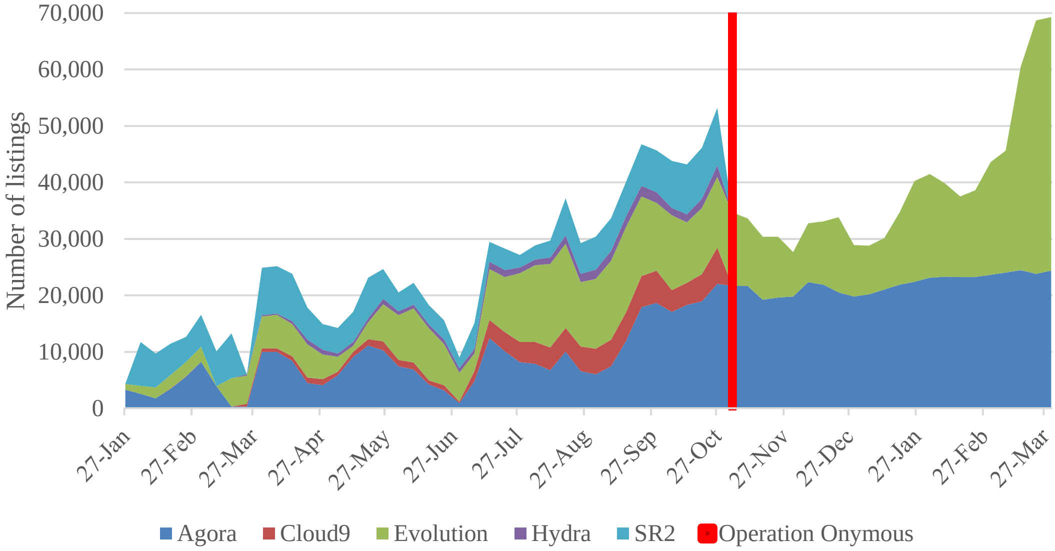
Table 2 presents the percentage of dealers who continued to sell illicit drugs in cryptomarkets after Operation Onymous. The results show that Operation Onymous had the strongest impact on dealers of cryptomarkets that were shut down (CLOUD-NINE, HYDRA, and SR2). The first row of Table 2 shows that in the 4 weeks following Operation Onymous, only 6% of dealers who were exclusively active on markets that were shut down displaced their activity to AGORA and/or EVOLUTION. This proportion increased to 7% and 8% respectively in the 8 and 12 weeks that followed the operation, an increase that is too small to be interpreted as significant or otherwise. The proportion of dealers originally active on AGORA and EVOLUTION who stopped selling following Operation Onymous is much lower. Only 25% of dealers quit selling drugs in the 4 weeks following the police operation while 75% of them continued dealing on AGORA and/or EVOLUTION. This proportion increases to 80% and 81% in the 8 and 12 weeks following Operation Onymous. Dealers who were active on both cryptomarkets that were shut down and those that were not continued to sell in a majority of cases (86% after 4 weeks). This proportion increases to 89% after 12 weeks. These results per se are not indicative of the deterrence impact of Operation Onymous. Indeed, it is still possible that dealers who appeared to have ceased their illicit activities used a tactical displacement to sell in physical instead of virtual markets. It is also possible that dealers changed their dealer name to reduce the risks of being associated with their past activities on markets that were shut down. It is possible, finally, that dealers moved to cryptomarkets other than AGORA and EVOLUTION.

Table 2. Displacement of dealers across cryptomarkets after Operation Onymous

Still selling *X weeks* after Operation Onymous	**4 weeks**	**8 weeks**	**12 weeks**
Dealers from markets that were shut down	6%	7%	8%
Dealers from markets that were NOT shut down	75%	80%	81%
Dealers from both types of markets	86%	88%	89%

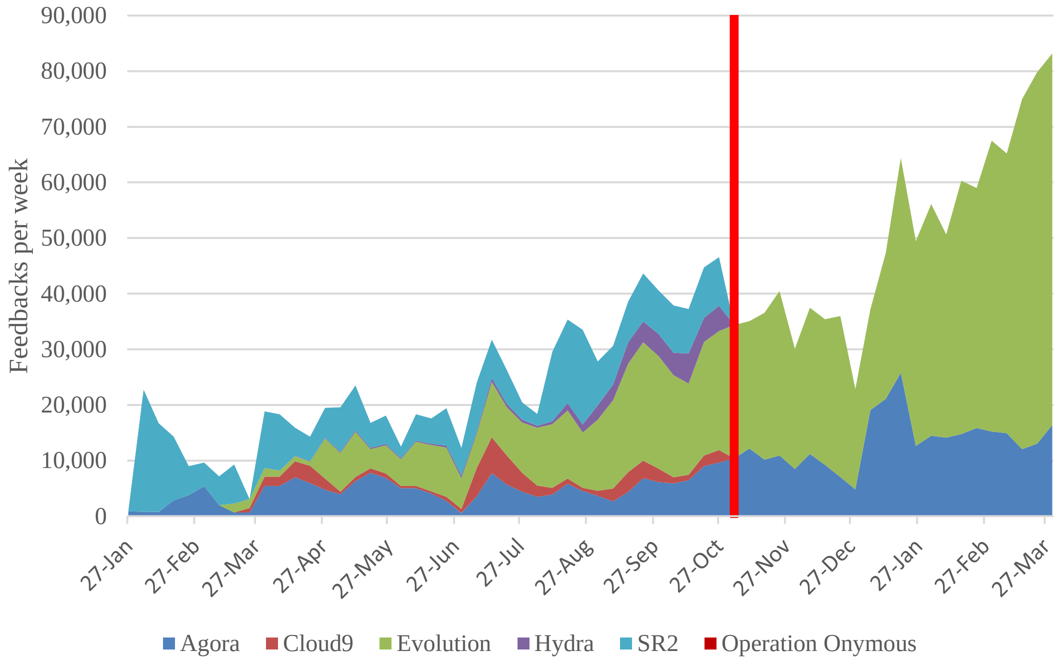
Figure 5 presents the number of listings per week, a measure roughly comparable to the availability of illicit drugs in traditional drug markets. The main outcome of Operation Onymous was the elimination of the listings on CLOUD-NINE, HYDRA, and SR2. The impact on AGORA and EVOLUTION appears to be marginal. Indeed, while the total number of listings available in cryptomarkets dropped in the weeks immediately following the operation, the number of listings in the remaining markets remained stable. This suggests that Operation Onymous was unable to substantially affect the availability of drugs on cryptomarkets. Indeed, even though the total number of listings decreased, the large number of listings still online probably offered enough supply to satisfy all potential customers.

Figure 4. Number of listings per week on AGORA, CLOUD-NINE, EVOLUTION, HYDRA and SR2



Moving to the consumption side of cryptomarkets, Figure 6 presents the evolution of the number of feedbacks per week, a proxy for the number of sales on AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2. Until Operation Onymous, the number of feedbacks posted each week continued to increase. Operation Onymous appears to have a chilling effect on sales, as the number of feedbacks drops between the week of November 3, 2014 and the week of December 29, 2014. The effect of the operation extended beyond CLOUD-NINE, HYDRA, and SR2, reducing sales on AGORA and EVOLUTION for the period between November 3 and December 29. Figure 6 demonstrates the presence of a nine-week cooling down period during which the number of sales appears to decrease. Starting in the first week of 2015, the number of feedbacks per week rebounds, however, eventually surpassing by far the number of feedbacks posted before Operation Onymous. This growth is particularly evident in the case of Evolution, which moves to account for about 72% of all feedbacks.

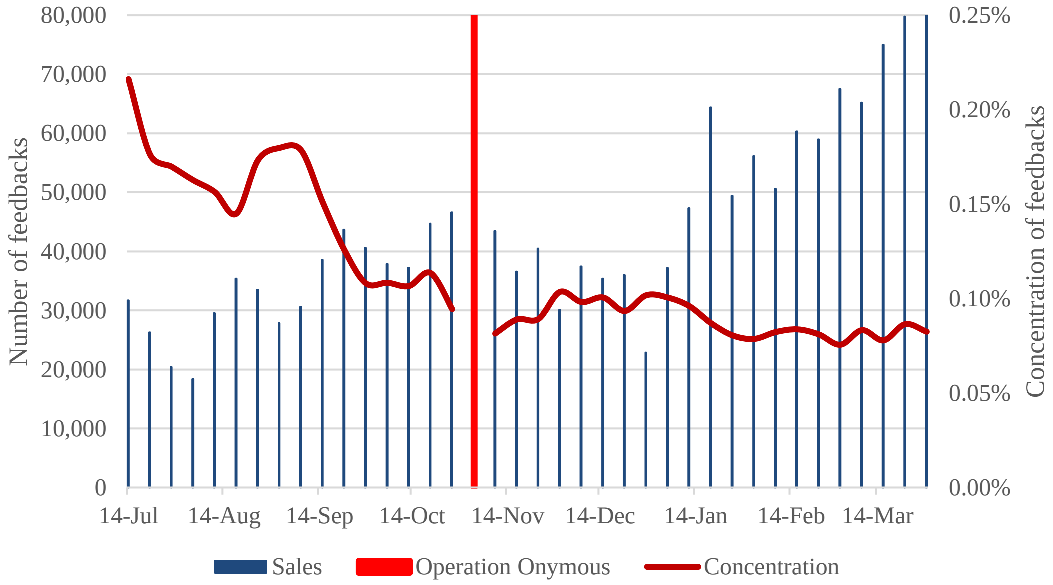
Figure 5. Number of feedbacks per week on AGORA, CLOUD-NINE, EVOLUTION, HYDRA, and SR2



Finally, Figure 7 shows the average concentration of feedbacks for dealers on AGORA and EVOLUTION as well the number of active dealers for the two markets. This figure shows data for the period between the weeks of July 14, 2014 and March 14, 2015. Unlike the previous figures, we do not report values for the first half of 2014 because the spikes in this period would add noise to the trend that follows Operation Onymous. Indeed, between January and June 2014, values on the concentration of sales show an unstable trend, with spikes and valleys ranging between 0.1% and 0.8%. However, beginning in July 2014, concentration of feedbacks is quite stable, though decreasing. Operation Onymous stopped this decreasing trend, changing the slope of the curve and stabilizing the concentration of sales around 0.1%. This indicates that the operation affected the behaviour of buyers, who, in response to it, concentrated their purchases with a lower number of dealers.

The trend for the whole time series (from January 2014 to March 2015) suggests that after an initial period where a few dealers captured a larger share of feedbacks, the number of buyers, dealers, and sales increased, leading to higher competition and a smaller market share for dealers in general. As we saw with drug price changes, cryptomarkets appear to stabilize in the weeks that lead to Operation Onymous. The police operation affected this equilibrium.

Figure 6. Concentration of feedbacks per week and number of active dealers per week on AGORA and EVOLUTION



Discussion

Our results demonstrate, first and foremost, the diffusion of the benefits of Operation Onymous. The operation, though directed at CLOUD-NINE, HYDRA, and SR2, impacted the supply and consumption of drugs on AGORA and EVOLUTION. Indeed, in the weeks that followed Operation Onymous, the total number of dealers and the number of new dealers who registered on AGORA and EVOLUTION each week dropped. Furthermore, the vast majority of dealers on markets that were shut down did not displace to AGORA and EVOLUTION. A much smaller number of dealers on markets that were not targeted also quit selling. On the consumption side, the number of sales (as estimated by the number of feedbacks) also dropped.

While impressive at first, these results are offset almost completely when we look at the impact of Operation Onymous over the longer term. The number of active dealers recovered to almost its pre-operation level within a month; the number of new dealers per week took a bit longer, at two months. On the consumption side, the number of sales appeared to be twice as high two months after Operation Onymous as it had been before. Our results, in line with past research on physical drug markets (Weatherburn and Lind, 1997; Best et al., 2001; Wood et al., 2004; Kerr et al., 2005), demonstrate that the police operation had a deterrent effect but one that was limited in time to one or two months.

Brixton and Bingham (2015) and Van Buskirk et al. (2014) have suggested that police operations could actually be beneficial for cryptomarkets in general as they increase awareness of the virtual drug markets among drug users and dealers. Such an impact is not apparent in our results. The rate at which new drug dealers entered the markets was lower in the follow-up period than in the period before Operation Onymous. The number of active dealers was also lower. On the consumption side, the number of sales (as measured by feedbacks) vastly increased in the months that followed Operation Onymous. It is not possible at this point to distinguish between the effect of an increased awareness of cryptomarkets among drug users and the organic growth that cryptomarkets had been experiencing before the police operation. The creation of the Tor browser has vastly improved the ease of access to cryptomarkets but there are still technological challenges, such as the management of bitcoins, which market participants have to solve before they can become active participants. These technological hurdles could explain the lack of impact of the publicity or the month or two delay between the publicity associated with Operation Onymous and the rise in sales.

More surprising was our finding that Operation Onymous was able to deter almost all of the active dealers in CLOUD-NINE, HYDRA, and SR2. Indeed, only a very small fraction of dealers who were selling on these markets displaced to AGORA and EVOLUTION. This does not indicate per se that dealers stopped dealing in illicit drugs. Dealers could have changed their dealer name, moved to other cryptomarkets, or simply stopped selling online (but continued to sell in / move to physical markets). Testing either of these hypotheses is beyond the scope of this paper but suggests that virtual dealers are, just like physical drug dealers, more risk-averse than profit-oriented (Leclerc and Wortley, 2014; Reuter and Kleiman, 1986). It is possible that, in their view, the risk associated with their dealer name exceeded the profits they could generate through their established reputation. This is somewhat surprising, given the low risk of arrest of dealers, even following a major police operation (Branwen, 2015a). Of course, it is also possible that dealers waited more than the 12-week follow-up period of this study to transfer their accounts to the new markets.

Regarding the prices of drugs before and after Operation Onymous, there is no evidence that prices increased following Operation Onymous, despite the assumptions of the Risks and Price model (Reuter and Kleinman, 1986). Indeed, it seems that while a portion of dealers stopped selling, those that kept on selling did not raise their prices. This suggests that the perception of risks by dealers who continued to sell remained the same. It may also suggest that dealers were not able to take advantage of the reduced level of competition following Operation Onymous by increasing their prices or gaining a greater control over the market. As in physical drug markets, dealers in cryptomarkets are “price-takers rather than price-givers” (Paoli, 2002: 67). An alternative explanation is that dealers sought to preserve the loyalty of their customers by maintaining their prices at the same level. The risk analysis of dealers who continued to sell appears to be different than that of dealers who stopped selling following Operation Onymous. Indeed, though we were unable to track all of them, some dealers apparently perceived risks to be so high that they decided to stop selling online. A last explanation would be that the dealers did not change their listings but instead changed the product they shipped. Dealers could cheat their customers by sending smaller weights than advertised or by reducing the amount of active ingredients in their drugs. This technique would have the benefit of keeping the prices at the same level and of increasing the dealers’ profits to match the new level of risks. Further investigation will be needed to better understand how and why the perception of risks of dealers varies in time and whether changes in the level of satisfaction of buyers could be used to detect adaptation techniques that cheat customers.

Just as in a traditional drug market, buyers in cryptomarkets adapted to the increased level of enforcement through tactic displacement. Indeed, in the weeks following the operation the concentration of sales show almost opposite trends. As a consequence of the higher perception of risk of being arrested by law enforcement agencies, buyers in cryptomarkets adapted, concentrating their purchases with a lower number of dealers. As open drug markets have often turned into closed ones (Edmunds et al., 1996; May and Hough, 2001; Bless et al., 1995), cryptomarket participants may adapt to a police crackdown by concentrating their transactions with fewer but trusted dealers. The possibility of safely adapting to the higher level of enforcement may explain why Operation Onymous was less effective against buyers than dealers. Indeed, the drop in the volumes of sales per week after the operation is less pronounced than the fall in the number of active dealers.

This discussion on the average price change and the rapid recovery of cryptomarkets highlights the maturity of virtual illicit drug markets. According to most measures, it appeared to be business as usual on AGORA and EVOLUTION two months after the police operation. Furthermore, there was no decline in the number of listings on AGORA and EVOLUTION and no increase in prices, even though the number of dealers decreased. Another indication of the maturity of cryptomarkets is the stabilization of the concentration of sales following Operation Onymous. The average market share of dealers was much higher in the first months of 2014 but dropped continuously until Operation Onymous. This is a surprising result as cryptomarkets in general are a fairly new phenomenon and the markets that were affected by Operation Onymous (directly or indirectly) were all less than one year old. Such a finding demonstrates the power of new technologies to create communities and to ease adaptation. Two decades ago, technology had already been cited as a driving force in the transition from open to closed drug markets (Edmunds et al., 1996; May and Hough, 2001; Bless et al., 1995). Technology, it now seems, is responsible for the creation of a new breed of open markets that offer much improved security for all participants. The main consequence of Operation Onymous seems to have been a chilling effect on the stable growth in the volume of sales, flattening the trends in the weeks between November 3 and December 29.

Conclusions

This paper focuses on the impact of police crackdowns on cryptomarkets. Our results demonstrate that Operation Onymous affected participants but only for a short time. Both the supply of and the consumption of drugs were impacted, though drug prices appear to have remained unchanged. The operation had an effect beyond the markets that were shut down, affecting also AGORA and EVOLUTION. Only a small percentage of dealers made use of "geographic" displacement by moving to alternative cryptomarkets after Operation Onymous, while buyers used tactical displacement, concentrating their purchases with fewer, and probably more reliable, dealers.

Our results indicate that police crackdowns, as is the case for traditional drug markets, are not effective measures to lower the volume of sales on online illicit drug markets. Cryptomarket participants have been shown to have a minimal reaction, or one that is temporary, to overtly large shows of force and to have the ability to adapt through displacement techniques. Investing time and resources into the seizure and take down of cryptomarkets therefore appears to be an ineffective way to enforce drug laws on the Internet, whatever their symbolic value to enforcement and to politicians of showing that something is being done. Other approaches could be investigated by law enforcement, including the targeting of key participants and the disruption of trust. Soska and Christin (2015) explain that a small fraction of dealers are responsible for a large portion of the sales. By targeting these individuals, law enforcement would force a large number of participants to find new suppliers and to build up trust again with new dealers. Much of the benefits of cryptomarkets come from the feedbacks and reputation systems cryptomarkets use. Past research (Décary-Hétu and Laferrière, 2015) has shown that attacks that target reputation systems could be used to destabilize online illicit markets and disrupt their activities.

Future research should look into the impact of such law enforcement techniques on the activities of cryptomarkets and online illicit markets. The growing number of law enforcement operations on the Internet should provide interesting case studies in the years to come. Future research should also expand the research on cryptomarkets, a prime example of a criminal activity that has transitioned from the physical to the virtual world. Examining the structure of cryptomarkets and the operations of their participants provides new insights on how drug markets are organized, making it possible to provide answers to previously raised questions. Of most interest for further research are the evolution of drug prices and the differences between national dealers. Anecdotal evidence suggests that dealers in different countries sell different types of drugs and at different price points. Cryptomarkets can provide the data researchers need to look at use patterns and drug penetration in countries around the world.

The main limitation of this paper comes from the quality of the data that was collected by Branwen. Soska and Christin (2015) faced similar challenges when collecting data on a massive scale on cryptomarkets. Through our careful approach, we sought to minimize the uncertainty of the representativeness of the data by aggregating data on a weekly basis and by looking at long-term trends. By doing so, we reduced the week-to-week variations and managed to identify trends in the dataset. Another limitation of this paper is the relatively short follow-up period and the dynamic nature of cryptomarkets. Time series analyses usually require that a full cycle be analyzed before and after an event. Given that the operation occurred less than a year before we wrote this paper, it was not possible in this case to conduct more rigorous statistical analyses of the data. Our goal was to provide an overview of the impact of Operation Onymous and future studies should look into the longer-term impact of the law enforcement operation. This task will be made difficult by the constantly changing nature of cryptomarkets. New cryptomarkets are created every month and participants may move from one market to another. Separating the impact of a police operation from the natural expansion and contraction of cryptomarkets will be a daunting task that should be achieved by incorporating more qualitative analyses from interviews and observation of participants’ discussions on online forums. Doing so will provide a more in-depth understanding of the reaction of cryptomarket participants and the impact that anonymity and the Internet have on police crackdowns.

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