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Forensic drug intelligence and the rise of cryptomarkets. Part I: Studying the Australian virtual market

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A B S T R A C T

Analysing and understanding cryptomarkets is essential to become proactive in the fight against the illicit drug trade. Such a research seeks to combine a diversity of indicators related to the virtual (*darknet* markets) and physical (the traditional "offline" market) aspects of the illicit drug trade to provide information on the distribution and consumption as well as to assess similarities/differences between the virtual and physical markets.

This study analysed data that had previously been collected on cryptomarkets from December 2013 to March 2015. In this article, the data was extracted from two marketplaces, *Evolution* and *Silk Road 2,* and analysed to evaluate the illicit drug trade of the Australian virtual market (e.g. information about the supply and demand, trafficking flows, prices of illicit drugs and market share) and highlight its specificities.

The results revealed the domestic nature of the virtual Australian illicit drug trade (i.e. Australian sellers essentially ship their products to local customers). This may explain the coherence between supply and demand. Particularly, the virtual Australian illicit drug trade is dominated by amphetamine-type substances (ATS), mainly methamphetamine and 3,4-methylenedioxymethamphetamine (MDMA), and cannabis. Australia, as a shipping country, accounts for half of the methamphetamine offered and purchased on *Silk Road 2*. Moreover, it was observed that the online price fixed by Australian sellers for the considered illicit drugs is higher than for any other shipping countries, which is in line with previous studies.

Understanding the virtual and physical drug market necessitates the integration and fusion of different perspectives to capture the dynamic nature of drug trafficking, monitor its evolution and finally improve our understanding of the phenomenon so policy makers can make informed decisions.

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1. Introduction

Technology and globalisation provide new ways to access customers and suppliers while enhancing the security of off-line criminal activity [1]. Traditionally, the vast majority of the global illicit drug trade is conducted through interpersonal networks of drug manufacturers, wholesalers, traffickers and local distributors [2]. Since the launch of the first cryptomarket, *Silk Road*, in 2011, cryptomarkets have transformed the traditional drug sale by facilitating the creation of global networks of offenders (including both vendors and buyers) [3]. Cryptomarkets are "a type of website that uses advanced encryption to protect the anonymity of the users" [4]. The design of cryptomarkets is similar to that of eBay or Amazon, with searchable listings of products for sale. In contrast to those popular marketplaces, cryptomarkets are part of the *darknet*, an encrypted part of the Web. Their access necessitates a specific communication protocol such as an onion routing, TOR (*The Onion Router*) being the most popular one, used to hide a computer's internet protocol (IP) address. These cryptomarkets facilitate the online trafficking of illicit goods through encrypted communications and financial transactions using cryptocurrencies (e.g. Bitcoins) [2,5].

Drugs are the most offered products on cryptomarkets, precisely 57% of all products and services offered concern drugs according to a recent study [6]. Therefore, research has mainly

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focused on criminological aspects of drug trafficking such as the study of cryptomarkets' drug buyers through interviews and surveys [7–9], changes or stability in substances offered over time [6,10], supply (wholesale vs retail) [11], country-differences in substance availability and sales [12,13], purity and adulteration of drugs sold on the *darknet* [14] and the risk taken by vendors on cryptomarkets [3]. Surveys [7–9] showed that the drugs most commonly purchased on cryptomarkets were Ecstasy & 3,4-methylenedioxymethamphetamine (MDMA), cannabis, lysergic acid diethylamide (LSD) and new psychoactive substances (NPS) while cryptomarkets analysis show that cannabis listings were the most common across a large range of markets, followed by prescription drugs, Ecstasy & MDMA and stimulants (cocaine and amphetamines). There is a predominance of illicit drugs typically associated with recreational use [6]. Most cryptomarkets trans-actions are consistent with purchase for personal use or "social supply" [6]; however some countries (e.g. China, the Netherlands, Canada and Belgium) and some drugs (e.g. Ecstasy & MDMA and prescription drugs) were associated with wholesale revenue generation [11]. The types of substances for sale have been observed to be relatively stable over the years [6,10]. Van Buskirk et al. [12] noted the influence of several factors (e.g. geographical isolation, domestic production, population prevalence, legal context) in the number of vendors and types of illicit drugs for sale in the five countries investigated. Similar findings were observed for the United Kingdom, Australia and the United States [13]. Caudevilla et al. [14] analysed substances supposed to be purchased on cryptomarkets. In their results, 91.3% of specimens received contained the substance advertised and the purity of most specimens was relatively high. In regards to the risk taken by vendors to ship internationally, it seems associated with the weights of packages sold, the perceived effectiveness of law enforcement of certain countries and the added money they would make by selling internationally [3]. On a rarer occasion, researchers have focused on cryptomarkets through a forensic perspective [5,15]. Indeed, only a few studies emphasised the importance of analysing these marketplaces in combination to physical or/and chemical data to increase the knowledge on illicit drug trafficking, which is in line with a forensic intelligence perspective [5,15]. For example, Rhumorbarbe et al. analysed specimens ordered on cryptomarkets and observed, through the chemical profile, that the cocaine purchased online was similar to specimens seized on the street [15]. This would suggest that a link exists between online and physical markets. Although Horne et al. [16] did not analyse cryptomarkets per se, they were involved, through the Australian Federal Police (AFP) national forensic rapid laboratory (NFRL), in the analysis of mail items detected at the Australian Custom and Border Protection Service. According to their study, up to 75% of all mail items were purchased online. Through the analysis of the packaging (e.g. concealment; finger-marks; labels and stickers), they managed to identify organised crime groups sending a large amount of packages from Canada to addresses in Australia as well as locate the recipients of the packages.

Kruithof et al. [6] identified 50 live cryptomarkets on the hidden web in 2016. Cryptomarkets usually appear and disappear, often due to takedowns or exit scams. According to Soska and Christin [10] and more recently Van Buskirk et al. [17], the long-term marketplace environment appears to be resilient to law enforcement takedowns or exit scams. Although cryptomarkets contribute only slightly to the global illicit drug trade [6], the potential for growth of online drug supply appears considerable. For instance, this growth was observed with legal online shopping. Indeed, nowadays, it is common for customers to shop online. Furthermore, recent studies [6,10] have shown that the number of vendors on cryptomarkets more than doubled from

2013 to 2016, the number of listings has significantly increased and the average number of transactions per vendor has risen from five to nine transactions per month. Concerning customers, the last Global Drug Survey [18] reveals that 6.7% of the respondents bought drugs on the *darknet* in the last year, an increase of 2.2% compared to the 2015 survey. The proportion of respondents who declared a purchase on the *darknet* during the last year varies from country to country, ranging from 2.4% in New Zealand to 18.3% in the United Kingdom. In Australia, 8.3% of respondents mentioned buying drugs on the *darknet*. This trend can be partly explained by the fact that cryptomarkets represent an advantage in comparison to traditional markets as the vendors and buyers can interact anonymously, services can be easily advertised nationally and internationally (i.e. vendors can reach a greater audience) and there is no local competition between vendors [5,11,13]. In addition, most marketplaces provide a feedback system to enforce some kind of quality control [10]. Buyers are highly encouraged to leave feedback when making a purchase which is posted underneath a listing and can be used as a proxy to estimate transactions [10]. Buyers can choose among a large pool of vendors offering a wide range of drugs according to their positive/negative feedback and the shipping country [6]. As a consequence, analysing cryptomarkets is essential as the societal response might be too slow to keep pace with the growth of online drug supply [1].

The success of forensic drug intelligence processes relies on the detection, integration and fusion of different information to capture the dynamic nature of drug trafficking market, monitor its evolution and finally improve our understanding. Indeed, combining the results of concurrent processes based on traces of different nature would provide supplementary added value to draw the most comprehensive market situation [19,20]. Such an approach enables the discussion of the quality and precision of the market analysis since processes explore data through different lenses. Australia was chosen as an illustration of this forensic intelligence approach due to its domestic nature, allowing the comparison of the virtual and physical features of the illicit drug market. Studying a domestic market and showing the connection or differences between the virtual and physical market is of importance to understand the nature of the online trade. This article will be separated in two parts. Using data collected on specific marketplaces (i.e. *Evolution* and *Silk Road 2*), this study will define, in Part I, the characteristics of the online Australian illicit drug market (i.e. nature of trafficking flows (domestic vs. international), types of illicit drug sold and purchased, volume, prices), which will be contextualised in the international trade. In Part II, the data of the Australian virtual market will be compared to the data related to the traditional market such as national seizures and arrests, prevalence data as well as outcomes of specific surveys targeting users' behaviour online (e.g. types of drugs purchased). Using results obtained in Part I, Part II will address the relationship between the online and offline markets. This forensic intelligence approach takes advantage of the diversity of perspectives to provide an estimation of illicit drug distribution and use with the least uncertainty.

2. Method

2.1. Data collection

This research relies on the publicly available HTML source code pages collected by Gwern Brawnen, an independent researcher (see http://gwern.net) [21], throughout the period *Silk Road 2* and *Evolution* were active, from December 2013 to November 2014 and

from January 2014 to March 2015, respectively.[1] This data is part of a larger collection of cryptomarket-related datasets gathered by Gwern Brawnen and a number of other individuals which is available for public scrutiny with configuration files and description of its limitations [22]. A large number of authors have used these datasets [6,22–25]. Brawnen developed a monitoring tool that logged into several cryptomarkets and downloaded listings, vendors' profiles and feedback [23]. Even though the crawling was irregular and partial snapshots were collected every time the tool was launched, it provides a description of the activities of cryptomarkets over an extensive period of time. As a consequence, this research relied on long-term trends to reduce the uncertainty related to the dataset. Furthermore, despite *Evolution* and *Silk Road 2* are no longer active and may therefore be regarded as outdated, they are still relevant to obtain an understanding of the online trade since both platforms were two important cryptomarkets during their activity. In particular, *Evolution* was very attractive to users as it survived "Operation Onymous", an international operation held in late 2014 aiming at shutting down several cryptomarkets [26]. It was mentioned by other authors who analysed *Agora* and *Silk Road 2* that the results can be generalised as these markets accounted for the majority of the global online market [10,24]. Moreover, working on data collected regularly throughout their period of activity – instead of a snapshot of the activity at a specific date – gives a more accurate overview of the structure of illicit drug trafficking on the *darknet*. Precisely, *Silk Road 2* was crawled 57 times while *Evolution* was crawled 115 times, during their respective period of activity. It is worth repeating that although the data is not exhaustive as the crawling was not conducted every day and the pages that presented an error were not downloaded, the crawls were frequent enough (weekly) and millions of pages were downloaded by the researcher [24]. As a consequence, the dataset used in this study can be considered representative for the purpose of the research.

2.2. Data extraction and structuration

The authors did not collect data on the *darknet*. Instead, the relevant information was extracted from the aforementioned raw data and structured using R scripts. For each listing, an ID, first and last dates of publication, a title, a description, a price (in bitcoins, converted to US dollars at the corresponding exchange rate for each respective date using data extracted from www.coindesk.com), the vendor's name, the shipping country and shipping destination(s) were extracted. The number of feedback left by customers was only extracted for *Silk Road 2*, since the way data on *Evolution* were collected did not make possible such analysis. These figures are an indicator of the number of transactions that really occurred. It was shown in previous studies that the count of customer reviews reflects actual transactions for a listing— precisely, 60–90% of transactions obtain a feedback [5,6,10,24].

2.3. Classification of sale proposals

Sale proposals were semi-automatically reclassified according to a list of keywords related to the type of products offered for sale. Indeed, the classification did not enable the comparison of the two cryptomarkets as the existing lists on both cryptomarkets were different. Furthermore, the existing list of categories present on cryptomarkets was inappropriate for our analysis. For instance,

categories did not inform on the type of illicit drugs but rather on their effect. The classification of sale proposals was based on [27]. Furthermore, duplicated listings were removed.

Once the classification was performed, the analysis only investigated the category "Illicit drugs". In regards to illicit drugs, the extraction of each listing source code for every crawling date led to the identification of 1081 vendors and 33,758 listings for *Silk Road 2* and 2372 vendors and 42,933 listings for *Evolution*. The source code on *Silk Road 2* changed between the 17th and 23rd of August 2014 and then the number of feedback associated with each sale proposal was clearly stated, making it possible to accurately extract these figures. Thus, only 17,304 listings and 679 vendors were used to conduct the analysis. These numbers are similar to the ones obtained in a previous study [22].

2.4. Data analysis

An analysis of shipping countries and destinations was performed to evaluate the trafficking trends and in particular the position of Australia in comparison to the countries that account for most illicit drug listings. On both cryptomarkets investigated in this study, vendors indicated the shipping country and destination(s) of their products. Although it is not possible to verify the true country of operation, the authors based their analysis on the reasonable assumption that the shipping country is the country of operation of the vendor, which is consistent with previous approaches [11,12]. On *Evolution*, only 5 listings provided non meaningful shipping country information and therefore were removed from further analysis (n = 42,928 listings and 2371 vendors). Nevertheless, a relatively high proportion of listings contained uncertain geographical information since "Worldwide" was mentioned as the shipping country/destination. Moreover, a large proportion of vendors did not select any country as the shipping destination which is thus recorded as "Undeclared" (78.4% of vendors corresponding to 45.2% of listings on *Evolution* and 5.3% of vendors corresponding to 2.4% of listings on *Silk Road 2*). On these cryptomarkets, a large part of the trafficking from or to certain countries may therefore be underestimated, in particular that of Australian vendors regarding our study. However, we may assume that vendors from any country may choose to indicate "Worldwide" or "Undeclared" and as such the proportions of each country may be quite accurate.

For each type of illicit drugs, the number of vendors (evaluated through the usernames) and listings (determined by the combination title/vendor) for both markets were calculated to obtain an indication of the supply. Indeed, since some vendors may flood the cryptomarket they are active on, a combination of the number of listings *and* vendors should be seen as a more accurate indicator of the offer and availability of substances. Furthermore, mass and price of cannabis, MDMA and methamphetamine – main substances offered online by Australian vendors, as discussed below – were extracted according to their origin and destination countries to obtain spatial information related to the price of illicit drugs. Revenues were then calculated by multiplying the number of feedback by the price in USD, only for listings proposed by Australian vendors. Outliers (e.g. holding prices, etc.) were removed from the analysis.

Finally, in order to investigate the retail vs. wholesale characteristic of the online Australian market, the mass of MDMA and methamphetamine was separated according to what is considered "less than trafficable" and "trafficable", using the Australian legislations, in particular the report from Hughes et al. [28]. The trafficable thresholds were set at 2 g for MDMA, methamphetamine, cocaine and MDMA and 250 g for cannabis and were used hereafter (see Section 3.3.3).

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[1] Gwern Brawnen released online one archive file, containing raw data for each cryptomarket, via a Reddit forum on the 19th of March 2015 with the indexed and compiled HTML source code pages (data downloaded on the 30th of April 2015 on https://reddit.com/2zllmv.
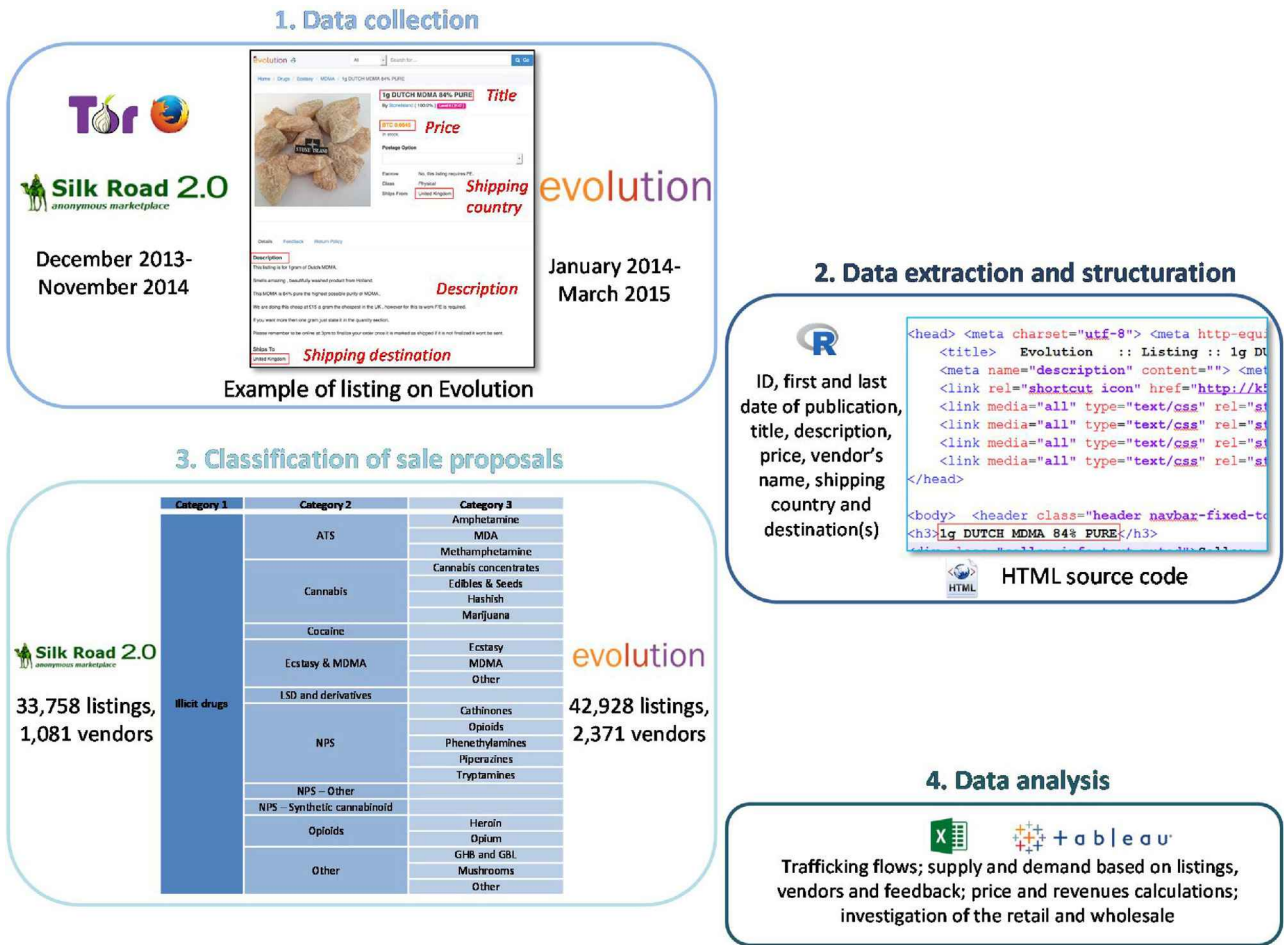
Fig. 1. Summary of the method used.

Data analysis was performed using R® (The R Foundation for Statistical Computing, version 2.15.1), RStudio v. 1.0.136, Tableau Software Professional Edition v. 9.3 and Microsoft Excel v. 15.31. Trafficking flows were represented as chord diagrams using the R library *circlize*.[2]

The method is summarised in Fig. 1.

3. Results and discussion

3.1. Structure of the international trade

On *Evolution* and *Silk Road 2*, respectively 46% and 50% of all sale proposals concern illicit drugs which is in agreement with Kruithof et al. [6] who analysed eight cryptomarkets in January 2016 and showed that about 57% of scraped listings offered drugs. Table 1 compares both cryptomarkets in regards to vendors and listings from countries accounting for most illicit drug offers. On *Silk Road 2*, Australia as a shipping country accounts for 14.6% of the total number of illicit drug vendors, ranking second as the most stated country for vendors, after the United States which are represented by 26.7% of vendors, but before the United Kingdom and "Undeclared". Australian vendors manage 9.5% of the total number of illicit drug listings, ranking sixth as the most stated country for listings, after the United States, the United Kingdom, the Netherlands, China & Hong Kong and Germany. On *Evolution*,

Australia as a shipping country accounts for 8.1% of the total number of illicit drug vendors, ranking sixth as the most stated country for vendors, after "Worldwide", the United States, the United Kingdom, Germany and the Netherlands. Australian vendors manage 5.9% of the total number of illicit drug listings, ranking sixth as the most stated country for listings.

The United States, the United Kingdom, the Netherlands and Germany concentrate most of the listings on both cryptomarkets (if "Worldwide" is not considered) (see Table 1). Slight differences are observed between the cryptomarkets, such as China and Hong Kong which account for a large proportion of listings on *Silk Road 2* while "Worldwide" accounts for a large proportion of listings on *Evolution* but is absent of *Silk Road 2*. The larger proportion of Chinese vendors on *Silk Road 2* may be explained by the higher proportion of sale proposals concerning NPS on this marketplace, products where Chinese vendors specialise in [27]. However, both markets are relatively close, with English-speaking and Western European countries dominating the sale of illicit drugs, which is consistent with Kruithof et al. and Van Buskirk et al. [6,12] who highlighted the prominent role of the United States, the United Kingdom, Australia, and the Netherlands as countries of operation of vendors.

Fig. 2 presents the percentages of all listings and vendors of the different drugs offered internationally (Australia included) on *Evolution* (blue) and *Silk Road 2* (orange). Using the listings and vendors, the key categories offered internationally on both markets are cannabis, ecstasy-type drugs and NPS. A large proportion of vendors offer cocaine but only a small percentage of listings are

Table 1
Spatial comparison on both cryptomarkets in regards to vendors and listings from shipping countries accounting for most illicit drug offers.

Origin country	Silk Road 2				Evolution			
	Listings (%)	Ranking	Vendors (%)	Ranking	Listings (%)	Ranking	Vendors (%)	Ranking
Australia	9.5	6	14.6	2	5.9	6	8.1	6
Belgium	1.4	9	1.8	10	1.2	10	1.1	9
Canada	5.4	8	7.2	7	5.2	7	5.7	7
China & HK	11.5	4	3.2	9	2.7	8	1.1	10
Germany	11.3	5	9.7	5	11	5	8.9	4
Netherlands	13	3	8.1	6	11.8	4	8.1	5
Sweden	1.4	10	4	8	2	9	3.1	8
Undeclared	7.6	7	12.5	4	–	–	–	–
United Kingdom	15.3	2	13.1	3	12.2	3	13.4	3
United States	18.3	1	26.7	1	24.9	1	29.9	2
Worldwide	–	–	–	–	14.8	2	37.3	1

present. The key categories offered are in agreement with [6] who showed a continuity of the type of drugs sold between 2013 and 2016. This observation is interesting as it confirms our initial hypothesis, assuming that, even though *Silk Road 2* and *Evolution* are no more active and may therefore be regarded as outdated, they are in fact still relevant to obtain an understanding of the online trade and its evolution. Thus, the trend does not seem to have changed significantly over the years from a global point of view.

3.2. Nature of illicit drug trafficking flows

The behaviour of vendors (i.e. willing to ship internationally or instead only shipping domestically) will influence the online offer. Indeed, we can reasonably assume that the substances most consumed by the local population will be offered in a more oriented domestic online market [12]. Studying the nature of trafficking flows is therefore important to explain the spatial trends associated with the supply. Fig. 3 shows the directional flows (origin and destination) of illicit drugs for the most frequent combinations of origin/destination countries (i.e. combinations having a frequency of listings of at least 1% in relation to the total number of existing combinations).

From Fig. 3, we observe that countries that mainly export internationally (e.g. the Netherlands and Germany) and those that mainly ship domestically (e.g. the United States and Australia) do so on both markets. This may be related to the role of these countries in the production of synthetic drugs and alternatively their stricter law enforcement and border control [6,29]. In particular, Australian vendors mainly propose illicit drugs to customers living in Australia, irrespective of the types of illicit drug (results not shown). Moreover, only a handful of vendors are ready to ship their products to Australia. Looking at the percentage of listings where Australia is mentioned either as the shipping country or the shipping destination, we observe on *Evolution* that 53.8% of listings shipped from Australia are intended for Australia, 39.6% of listings shipped from Australia are to "Undeclared" destinations, 4.2% of listings shipping from Australia are to "Worldwide" destinations and 2.2% of listings are shipped from other origin countries to Australia. A similar trend is observed on *Silk Road 2*, but the domestic flow is even more pronounced as 95.7% of listings shipped from Australia are intended for Australia, 3.7% of listings from Australia are shipped to "Worldwide" destinations and 0.6% of listings are sent from other countries to Australia. On both markets, only a few international vendors offer substances to Australia and on *Silk Road 2*, a large proportion of vendors from different countries even states "Worldwide except Australia" which was also noted on the eight cryptomarkets (*Agora*, *Evolution*, *Silk Road 2*, *Cloud-nine*, *Pandora*, *Hydra*, *Andromeda* and *Blue Skye*) analysed by Broséus et al. using data collected in 2014

[5]. This may be explained by the behaviour of vendors, who appear to be reluctant to ship to countries with stricter law enforcement due to the risk involved [6]. Décary-Hetu et al. [3] attempted to explain the risk taking of vendors on cryptomarkets. They observed that many vendors are willing to take on the risk of shipping internationally but the perceived effectiveness of law enforcement appears to impact on the vendors' decision to sell internationally. Branwen [30] observed that as of May 2015, 62% of cryptomarkets vendors that had been arrested were arrested due to international shipments. It is hypothesised that the strict security dispositions at the Australian border to control importations of illicit products by post might be an explanation of this domestic trend [16,31]. Lastly, Australian sellers may get sufficient income from domestic sales (higher prices, wealthier population, and higher drug expenditures) and thus shipping internationally
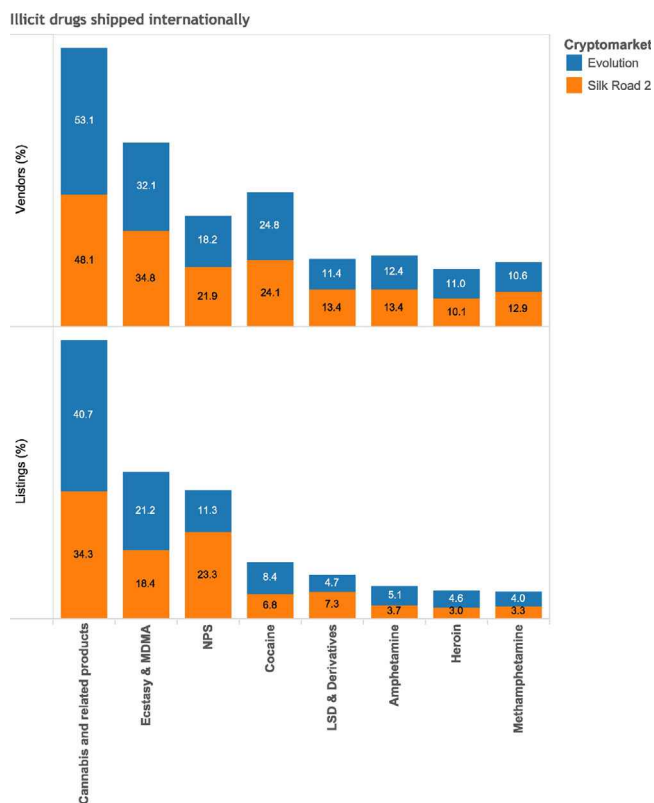

Fig. 2. Proportion of listings and vendors per type of illicit drugs on *Silk Road 2* (orange) and *Evolution* (blue) shipped internationally. Since vendors may sell different types of illicit drugs, the sum of percentages is higher than 100% on each marketplace. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
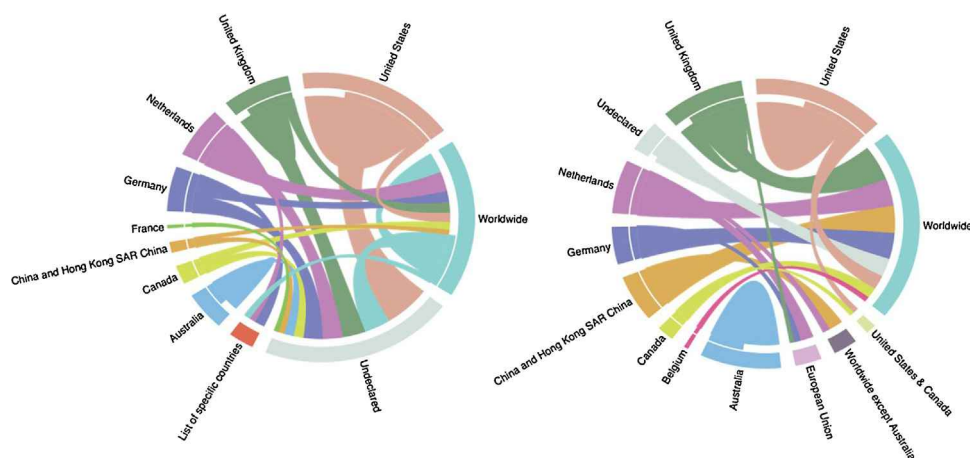
Fig. 3. Flows of illicit drugs on *Evolution* (left) and *Silk Road 2* (right).[3]
List of specific countries means that more than one destination country was mentioned in the listing.

would not be required. This point will be addressed in Section 3.3.2. On the basis of the similar trafficking flows and proportions of listings and vendors for the different types of illicit drugs on each cryptomarket, the following sections will be using either *Evolution* or *Silk Road 2* as an illustration. Indeed, similar trends are observed and it can be hypothesised that assessing only one cryptomarket might be sufficient to generalise the results as suggested by different authors [10,24,32], in particular when focussing on a spatial analysis.

3.3. Characteristics of the Australian online supply

3.3.1. Type of substances offered and comparison to the international trade

Fig. 4 contains the proportion of illicit drug listings and vendors for products shipped from Australia on *Evolution* and *Silk Road 2*. In contrast to the international trend and in addition to cannabis and Ecstasy & MDMA, the Australian online trade is dominated by methamphetamine, which only accounts for a small percentage in the overall international trend (see Fig. 2, Section 3.1). This was also observed in Van Buskirk et al. [26] and is supported by indicators of the traditional markets (e.g. drug arrests, seizures and drug prevalence in Australia) [33,34]. For instance, according to the Illicit Drug Data Report [34], which focuses on the Australian market, ATS account for the majority of drug arrests and seizures, after cannabis. Moreover, methamphetamine remains the main drug produced in clandestine laboratories detected in Australia. Given the domestic nature of the online trafficking, this could explain the large availability of this drug on cryptomarkets. This hypothesis will be further discussed in Section 3.4 as well as in Part II as it may be related to the structure of the traditional market. It is also interesting to note the limited number of vendors of LSD & derivatives on both cryptomarkets which could be indicative of a restricted and specialised market. In contrast, the number of listings of LSD is particularly important on *Silk Road 2*, indicating that a few vendors are responsible for a large number of LSD & derivatives listings.

Fig. 5 contains the proportion of listings and vendors per type of illicit drugs shipped from Australia in comparison to the other countries on *Silk Road 2* and *Evolution*. According to Fig. 5, Australia is responsible for 76.7% (31.4% and 45.3%, respectively) of all listings of methamphetamine, representing 75.3% (28.3% and 47.0%, respectively) of the total number of methamphetamine vendors on *Evolution* and *Silk Road 2*. In contrast to the other countries, the methamphetamine trade seems to be dominated by Australian vendors while the proportions of other substances offered by Australian vendors are lower. As mentioned previously, another interesting observation is the high proportion of LSD listings from Australian vendors on *Silk Road 2*. This might be a characteristic of *Silk Road 2*. Van Buskirk et al. [26] reported the proportions of Australian retailers in comparison to international retailers on the top five marketplaces (i.e. *Agora*, *Evolution*, *Silk Road 2*, *Pandora* and *Cloud Nine*). Similarly to our observations, they recorded a higher percentage of Australian vendors of LSD on *Silk Road 2* (10%) than on the other marketplaces investigated (5–7%). Furthermore, in another article, the same authors also reported that Australia had the largest number of vendors per capita on *Agora*, with a per capita estimate of 4.73 vendors per million [12].

3.3.2. Illicit drug prices

Among the different factors that may explain the domestic nature of the trafficking in Australia [12], sellers may get sufficient income from domestic sales and as mentioned in Décary-Hétu et al. [3], vendors in countries with wealthier population (like Australia) and higher drug expenditure are less likely to ship internationally. Prices given by vendors were therefore studied particularly for methamphetamine and MDMA — main substances proposed by Australian vendors along with cannabis related products. Table 2 represents the median price per gram or per pill of MDMA and methamphetamine according to their physical form and the main countries selling illicit drugs on *Silk Road 2*. The median price per gram of both MDMA (whether it is a pill or crystal/rock) and methamphetamine (crystal/ice) is higher when offered by Australian vendors than from other vendors, which was also observed on *Agora* and *Silk Road 2* in Demant et al. [24].

According to the Illicit Drug Data Report 2014–2015 [34], the price of MDMA pills varies between USD 9–44 in the different States and Territories (using the conversion rate AUD–USD of October 2014, which corresponds to the middle of the period during which the prices were recorded on *Silk Road 2*). The price of
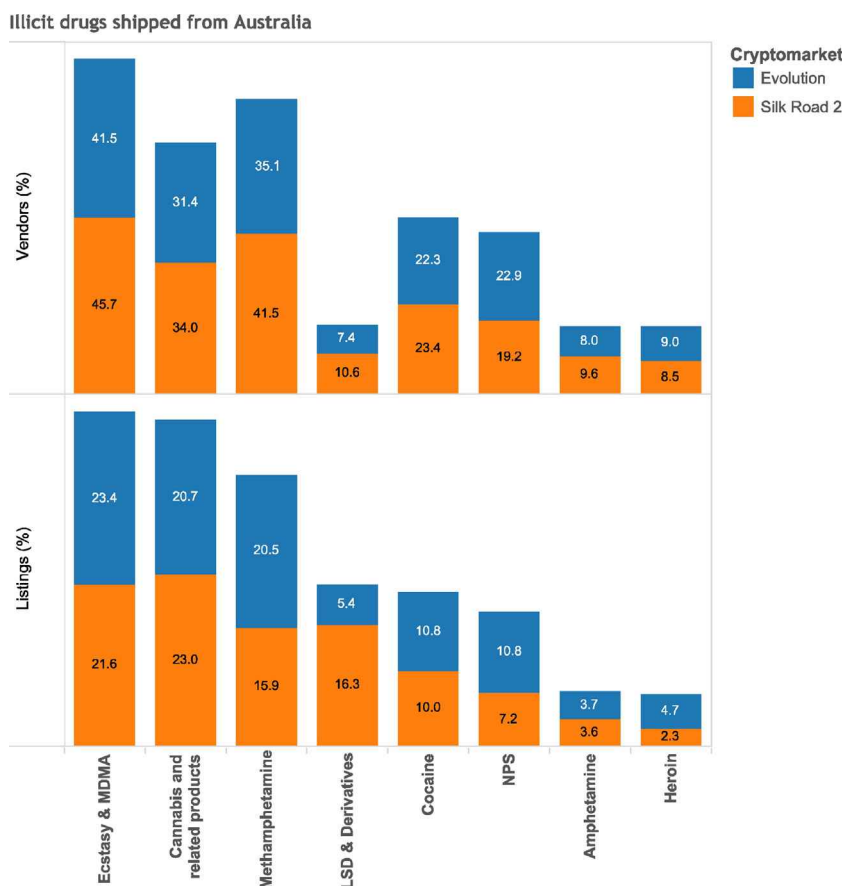
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[3] The origins and destinations of illicit drugs are represented by the circle's segments. Specific colours are assigned to the flows and circle's segments of a particular country. The size of the flow is indicated by the width of the link and its basis. The direction of the flow is encoded both by the origin colour and by the gap between link and circle segment at the destination. The direction goes from a non-gap to a gap. A number of listings of n = 42,928 for *Evolution* and n = 17,304 for *Silk Road 2* were thus used to create the flows.

Illicit drugs shipped from Australia

Fig. 4. Proportion of listings and vendors per type of illicit drugs on *Silk Road 2* (orange) and *Evolution* (blue) shipped from Australia. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

one gram of methamphetamine varies between USD 219–1051. As a consequence, the price of MDMA and methamphetamine on cryptomarkets corresponds to the lower end of the price range and thus cryptomarkets might be attractive to customers. This was also noted in Van Buskirk et al. [31]. Indeed, although the Australian sample size was limited to psychostimulant users, Van Buskirk et al. reported that participants largely cited the cheaper price online as their main motivation for purchasing online over street markets [31].

Figs. 6 and 7 represent the median price per gram of MDMA crystal or/and rock and methamphetamine respectively according to the shipping and destination country on *Silk Road 2* (only countries with at least ten listings are represented) (see Appendix A for more information about the spread of prices per country and the median prices of MDMA pills). The price per gram of both MDMA and methamphetamine is higher when sold to Australia, to the exception of Canada for MDMA. However, the high price of MDMA in Canada is due to one particular vendor who offers a lot of listings at a higher price, increasing the median price of MDMA shipped from Canada (see Appendix A, Fig. A3). The higher price of these substances in Australia in comparison to the rest of the world was also observed in Van Buskirk et al. [35] who analysed *Silk Road* between September 2012 to February 2013. The risk taken by shipping internationally should usually be compensated by the profits that can be made [3] which is not the case for Australian vendors as the price of drugs offered is higher in Australia than around the world [26]. As a consequence, Australian vendors do not have advantage to ship internationally.

3.4. Comparison of the supply and demand sides of the Australian online trade

According to the number of feedback on *Silk Road 2*, Australian vendors contribute to 10.4% of illicit drug sales, after the United Kingdom (22.3%), the United States (20.4%), Germany (15.8%) and the Netherlands (12.2%). More specifically, Fig. 8 represents the proportion of feedback per type of illicit drugs that are shipped from Australia in comparison to all the other countries. It is interesting to see that, on *Silk Road 2*, Australia not only offers the majority of methamphetamine (see Fig. 5, methamphetamine represent 45.3% and 31.4% of listings on *Silk Road 2* and *Evolution*, respectively) but also sells the majority of it (52.3% of methamphetamine sold on *Silk Road 2,* see Fig. 8). Australian sellers also contribute importantly to the worldwide sale of LSD & derivatives and Ecstasy & MDMA, which is in agreement with Fig. 5. Since the Australian market is predominantly domestic (see Fig. 3), we can infer that the Australian buyers are very active on cryptomarkets.

Fig. 9 represents the percentage of vendors, listings, feedback and revenues on *Silk Road 2* for each type of illicit drugs shipped from Australia. Amphetamine type substances, in particular Ecstasy & MDMA, methamphetamine and, to a lesser extent, amphetamine, dominate most of the vendors (91.9%), listings (38.1%), feedback (37.8%) and revenues (61.3%). It is interesting to see that although the proportion of vendors of Ecstasy & MDMA and methamphetamine is the highest, cannabis seems to be the most purchased by customers (i.e. higher number of feedback comments). Similarly to their previous study on *Silk Road* [13], Barratt et al. [7], using the Global Drug Survey covering the period
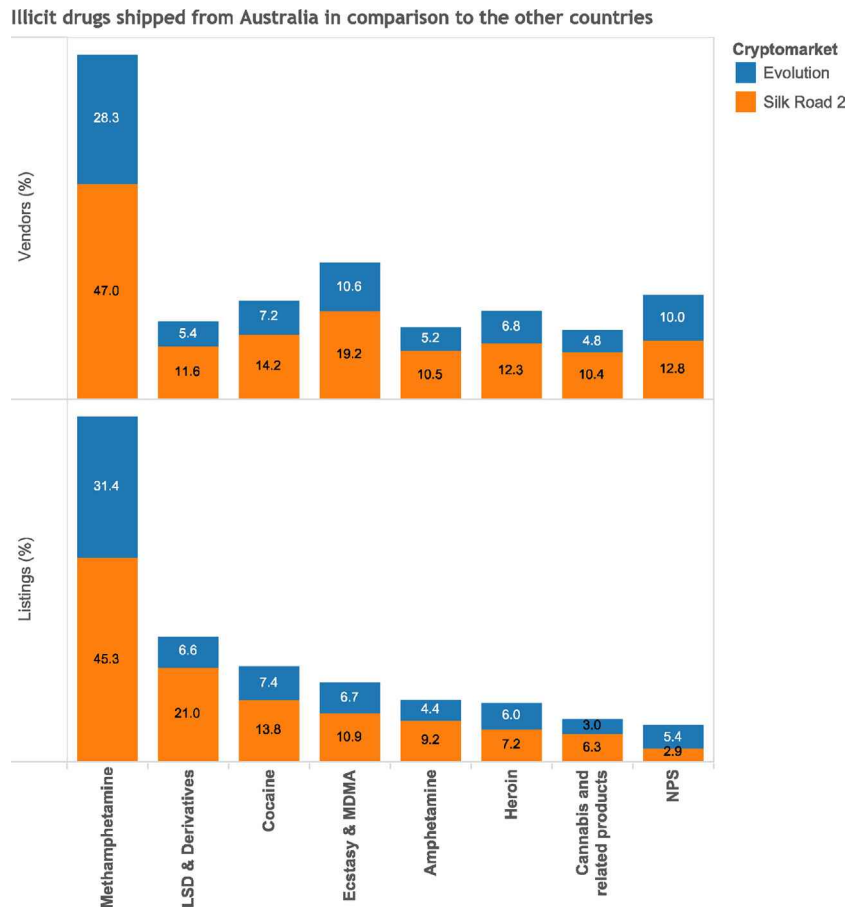
Illicit drugs shipped from Australia in comparison to the other countries

Fig. 5. Proportion of listings and vendors per type of illicit drugs on *Silk Road 2* (orange) and *Evolution* (blue) shipped from Australia in comparison to the other countries. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

between 9 November 2014 to 3 January 2015, observed that the drug most commonly obtained through cryptomarkets was Ecstasy & MDMA (54.6%), followed by cannabis (42.9%) and LSD (34.8%). This is supported by longitudinal analyses of cryptomarket feedback across multiple marketplaces [10] and the Ecstasy and Related Drugs Reporting System (EDRS) in Australia in 2015 [36]. In Barratt et al. [13], although methamphetamine was included in the category "amphetamine (all)", the top drugs purchased from *Silk Road* by Australians were MDMA, Cannabis, LSD and cocaine. In contrast, the number of vendors, listings and feedback comments for methamphetamine seem to be much higher in our dataset. However, as mentioned by the authors, the study was purposive and might not be representative of drug purchasers more generally in each country [13].

Revenues generated by sellers on *Silk Road 2* during the period investigated are also represented in Fig. 9. Although cannabis mass sold by Australian vendors is the largest in comparison to the other categories, its total revenues are quite low. It accounts for 11.6% of the revenue of illicit drugs in Australia for the particular period investigated. In contrast, methamphetamine and Ecstasy & MDMA account for the majority (respectively 38.3% and 20.6%) of the revenues during that particular period. The market shares in Australia are significantly different than that of the worldwide market. Indeed, Kruithof et al. [6] found that cannabis generates the highest revenues (31% of all drug revenues), followed by stimulants (i.e. cocaine and amphetamines, 24%), ecstasy-type (i.e. MDMA and ecstasy, 16%), psychedelics (8%) and finally opioids (i.e. heroin, 6%). Similar findings were observed on *Silk Road* [37], *Silk*

Table 2
Median prices per gram or per pill (USD) for MDMA and methamphetamine according to their physical form (as mentioned in titles) and shipping countries (countries with at least 10 listings) on *Silk Road 2.*

Origin country	MDMA pills	MDMA crystal/rock	Methamphetamine crystal/ice
Australia	14.9	182.6	383.2
Belgium	5.4	16.2	–
Canada	–	40.3	93.8
Germany	3.5	20.4	96.6
Ireland	7.3	–	–
Netherlands	5.0	20.4	68.6
South Africa	10.0	–	63.1
Switzerland	–	–	164.9
Undeclared	–	21.4	100.0
United Kingdom	9.1	42.9	307.5
United States	12.0	51.9	64.8

Fig. 6. Median prices per gram (USD) for MDMA crystal and/or rock according to the shipping countries and destinations (countries with at least 10 listings) on *Silk Road 2.*
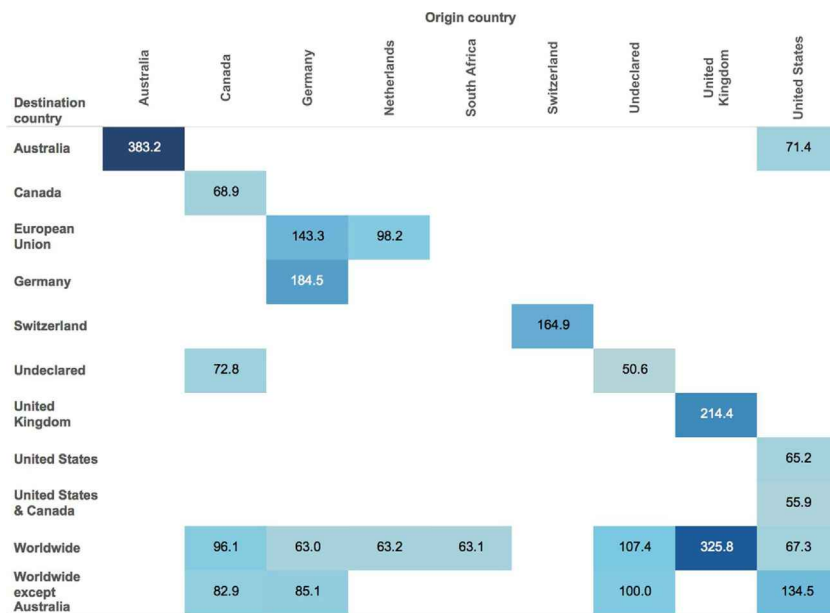

Fig. 7. Median prices per gram (USD) for methamphetamine crystal and/or ice according to the shipping countries and destinations (countries with at least 10 listings) on *Silk Road 2.*
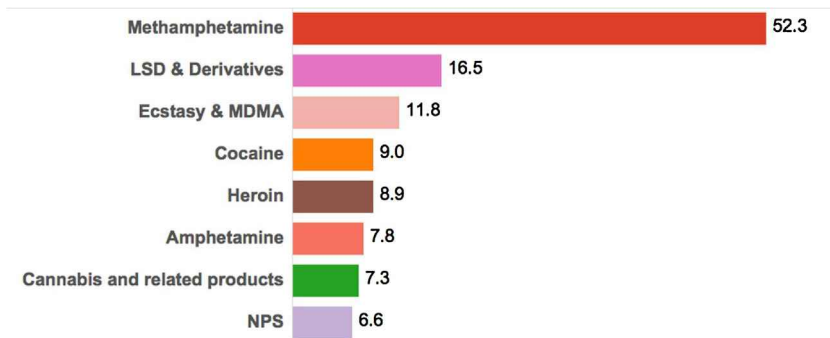

Fig. 8. Proportion of feedback per type of illicit drugs from Australia in comparison to the other countries.
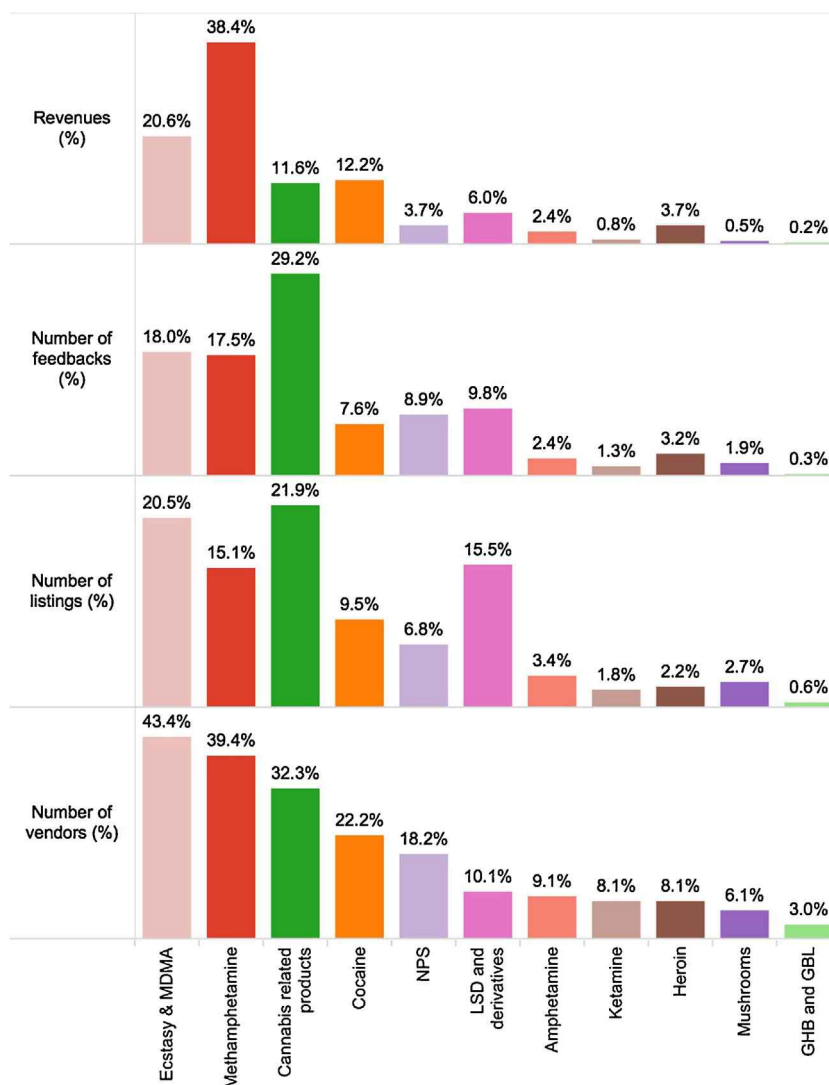
Fig. 9. Percentage of vendors, listings, feedback and revenues per types of illicit drugs on *Silk Road* 2 (for Australia as a shipping country).

Road 2 and *Agora* [24]. Our results might therefore indicate a specificity of the Australian market and will be further developed in Part II. According to the Australian Crime Commission [38], even though cannabis remains the most commonly used drug in Australia, methamphetamine poses the highest risk. Since 2012, strong increases in methamphetamine seizures have been recorded in Australia [29,34].

3.4.1. Cryptomarkets and distribution chain

In most States and Territories in Australia, three trafficking thresholds have been described based on the quantity of drug: trafficable, commercial and large commercial [28]. Although the thresholds in Tasmania are significantly higher, most States and Territories have a trafficable threshold of 2 g of pure methamphetamine/amphetamine, between 0.5 g to 3 g of pure MDMA and between 50 to 1000 g of cannabis. The Criminal Code Regulations 2002 [39] is the Australian legislation that regulates the importation of illicit drugs into Australia and the use and trafficking of illicit drugs in the Australian Capital Territory (ACT). It is used as a guideline to assess the relative position of cryptomarkets in the distribution chain. In this document, the trafficking threshold for MDMA, methamphetamine and cannabis (in any forms except cannabis resin or fibre) are defined as 0.5 g, 2.0 g and 250 g, respectively.

Fig. 10 represents the distribution of listings, feedback and revenues according to the mass of methamphetamine crystal/ice, MDMA crystal/rock and marijuana offered by Australian vendors on *Silk Road 2*. Such representation enables to observe the quantity of illicit drug that is the most offered (listings), sold (feedback) and that accounts for the most revenue. It is interesting to see that the quantity offered depend on the type of illicit drug. For example, 0.5 g and 1 g of methamphetamine are the quantities most offered and sold on *Silk Road 2* but only generate small revenues while higher quantities (e.g. 14 g and 28 g) generate the most revenues. In regards to MDMA, 0.5 g and 1 g are also the mass most offered and purchased but 3 g followed by 25 g generate the most revenues.

Finally, the retail vs. wholesale characteristic of the online Australian market was investigated. It is always difficult to determine threshold values regarding what is considered as less than trafficable quantity and trafficable quantity. Aldridge et al. [11] used the price of illicit drugs sold on cryptomarkets to evaluate the retail vs. wholesale transactions. However, in our article, we decided to use the values (i.e. Australian Model Criminal Code) reported in the report from Hughes et al. [28] rather than price or legal definitions which differs from one State or Territory to another. The trafficable thresholds used were thus 2 g for both MDMA and methamphetamine. Table 3 represents the percentage
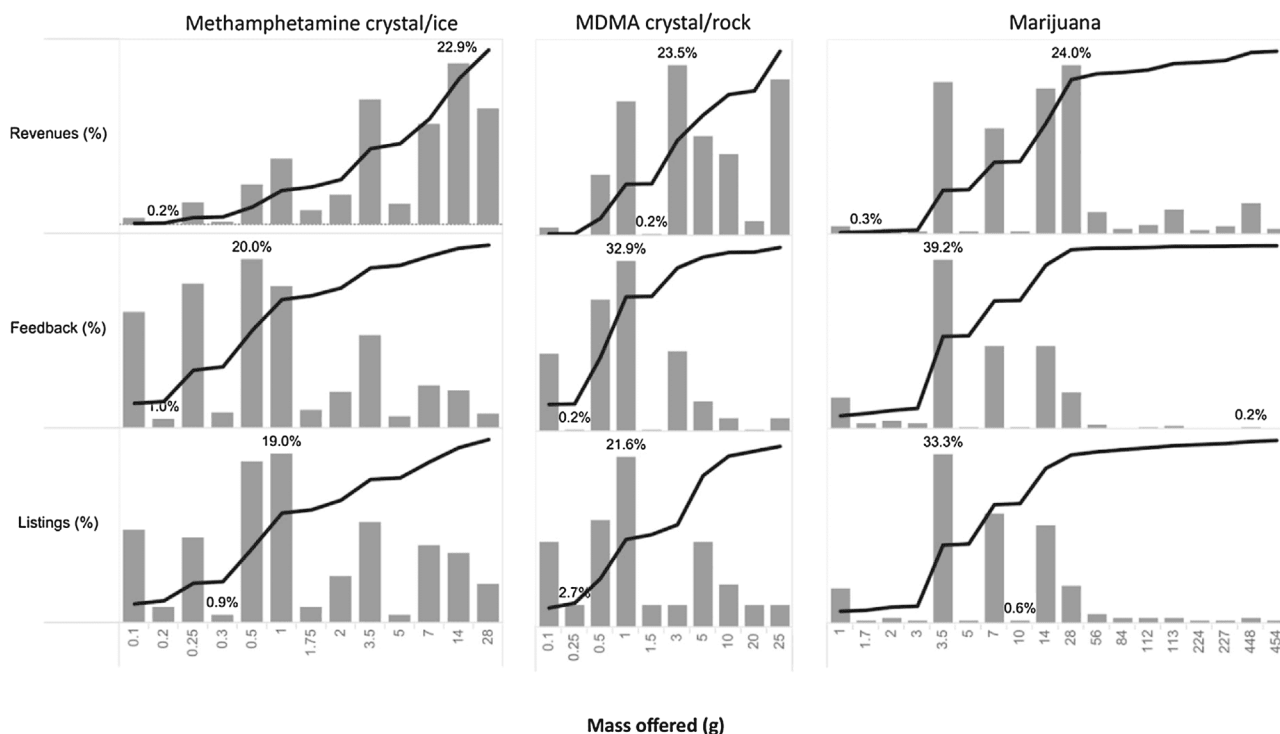
Fig. 10. Distribution of listings, feedback and revenues according to the mass of methamphetamine crystal/ice, MDMA crystal/rock and marijuana offered by Australian vendors on *Silk Road 2*. The line corresponds to the cumulative sum of listings, feedback and revenues respectively.

of listings, feedback and revenues according to the Australian Model Criminal Code.

Using the quantity of the Australian Model Criminal Code (2 g), a similar pattern is observed for both MDMA and methamphetamine. The percentages of listings less than the trafficable quantity threshold (e.g. presumably for personal consumption) are slightly higher than the ones above the trafficable threshold, while the percentages of feedback (i.e. what is actually purchased and thus reflecting the demand) are much higher for personal consumption. Furthermore, the majority of the revenue comes from "trafficable quantity" for both illicit drugs. This observation leads to the hypothesis that the purchase of illicit drugs on *Silk Road 2* tends to be more for personal consumption rather than distribution but most of the revenues are made through the sale of trafficable quantities.

4. General discussion and conclusion

This paper presented key characteristics of the Australian virtual market through the analysis of two cryptomarkets (*Evolution* and *Silk Road 2*). Particularly, this study intended to compare the Australian trade with the international trade, explain the online supply in terms of substances offered and prices, the online demand using feedback and finally the role that

cryptomarkets play in the distribution chain using the mass of illicit drugs.

At an international level, Australia ranked second on *Silk Road 2* and sixth on *Evolution* as the most stated country for vendors, and sixth as the most stated country for listings on both cryptomarkets. Compared to countries such as the Netherlands or the United Kingdom, Australia showed essentially a domestic trafficking. Several factors were raised to explain this trend, such as the geographic isolation of Australia, the tighter control at borders preventing vendors from selling to Australia, the higher price range of illicit drugs in Australia (i.e. vendors do not require to sell internationally) and the high number of clandestine laboratories detected resulting in domestic production of the most offered substances on cryptomarkets [12]. The supply side of the Australian virtual market was characterised by a high percentage of vendors and listings of methamphetamine on both *Evolution* and *Silk Road 2*, which was higher than the international trend. This observation seems to characterise the Australian market and will be investigated further in Part II. Another interesting observation was the higher price of illicit drugs, in particular MDMA and methamphetamine, when the shipping country was Australia which could also partly explain the domestic trafficking on cryptomarkets. Indeed, the risk taken by shipping internationally is high and non-profitable for Australian vendors and as a consequence, they have no incentive to ship internationally.

Table 3
Distribution of listings, feedback and revenues on *Silk Road 2* according to the threshold quantities reported in Hughes et al. [28] for methamphetamine crystal/ice and MDMA crystal/rock.

	MDMA crystal/rock		Methamphetamine crystal/ice	
	Less than trafficable[a]	Trafficable[a]	Less than trafficable[a]	Trafficable[a]
Listings (%)	53	47	62	38
Feedback (%)	73	27	72	28
Revenues (%)	28	72	22	78

[a] MDMA, methamphetamine: less than trafficable quantity <2 g, trafficable quantity ≥2 g.

From the demand side, Australia (as a shipping country) accounted for more than 50% of the total sales of methamphetamine on *Silk Road 2*. Furthermore, although the proportion of vendors offering Ecstasy & MDMA and methamphetamine is the highest, cannabis is the substance most purchased by customers according to the number of feedback. In regards to the revenues, cannabis only accounts for 11.6% of the revenue of illicit drugs in Australia while methamphetamine and Ecstasy & MDMA account for the majority (respectively 38.3% and 20.6%) of the revenues. It would be interesting to compare these results to more recent and still active cryptomarkets to assess if the trends observed in this study are still relevant and have evolved since *Evolution* and *Silk Road 2*.

From a forensic point of view, data extracted from cryptomarkets can be considered as digital traces which are remnant of criminal activities that produced them [40] or if analysed in real time, can be used to prompt the development of preventive programs through an early warning system where changes in drug sold or purchased are monitored [41]. As any forensic traces, digital traces are fragmented and imperfect and thus the analysis of cryptomarket should not be used as a standalone approach but instead compared to traditional or recent approaches such as national arrests, seizures, prevalence data, toxicological results or

wastewater studies to get a comprehensive overview of distribution and use of illicit drugs. This aspect will be developed in Part II. The authors argue that the success of forensic drug intelligence processes relies on the integration and fusion of different types of information to capture the dynamic and complex nature of drug trafficking market, monitor its evolution and finally improve our understanding. Moreover, such an approach enables studying whether cryptomarkets are an extension of the traditional market or a completely separated market. The combination of the different sources of information would provide drug policy makers with a more complete picture of what is actually happening and offer them an improved avenue to make informed decisions.

Acknowledgement

Appendix A

The following figures (Figs. A1–A3) represent the spread of prices per country and the median prices of MDMA pills, crystals
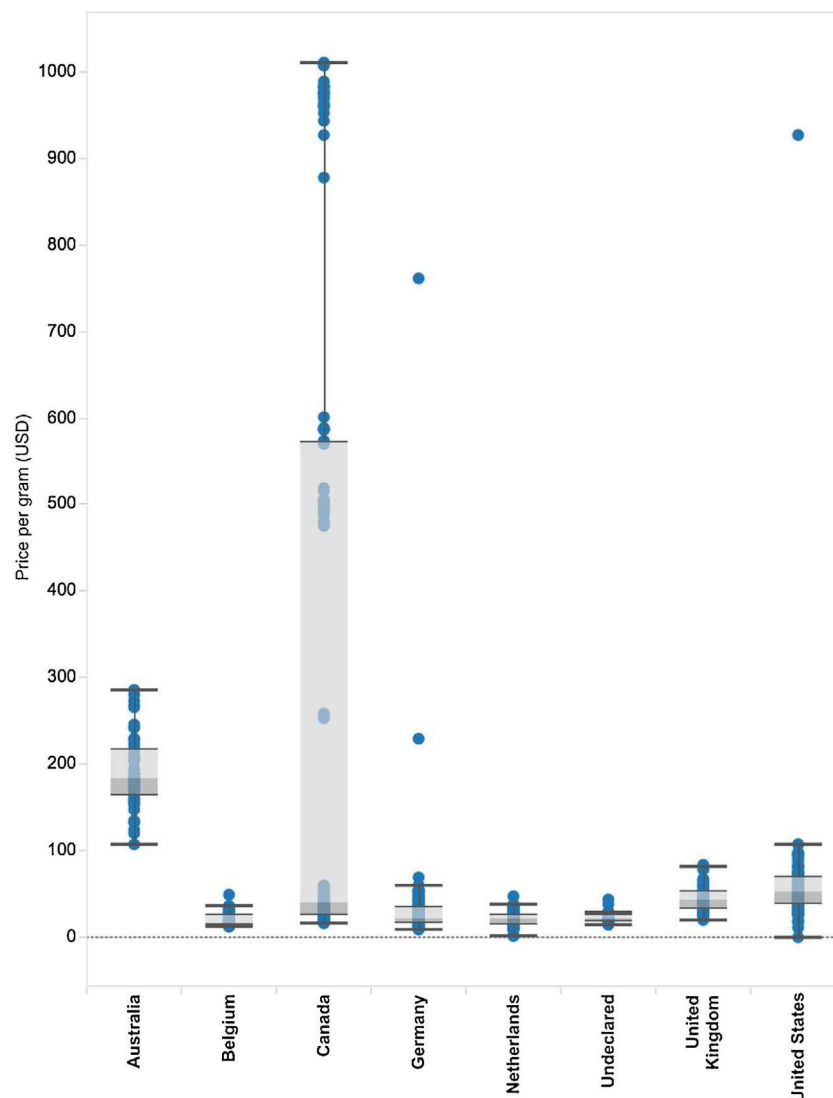

Fig. A1. Boxplots of prices per gram (USD) for MDMA in the form of crystal and/or rock according to the shipping countries (countries with at least 10 listings).

and methamphetamine crystals. Fig. A4 represents the median price per MDMA pill according to the shipping and destination country on *Silk Road 2* (only countries with at least ten listings are represented).
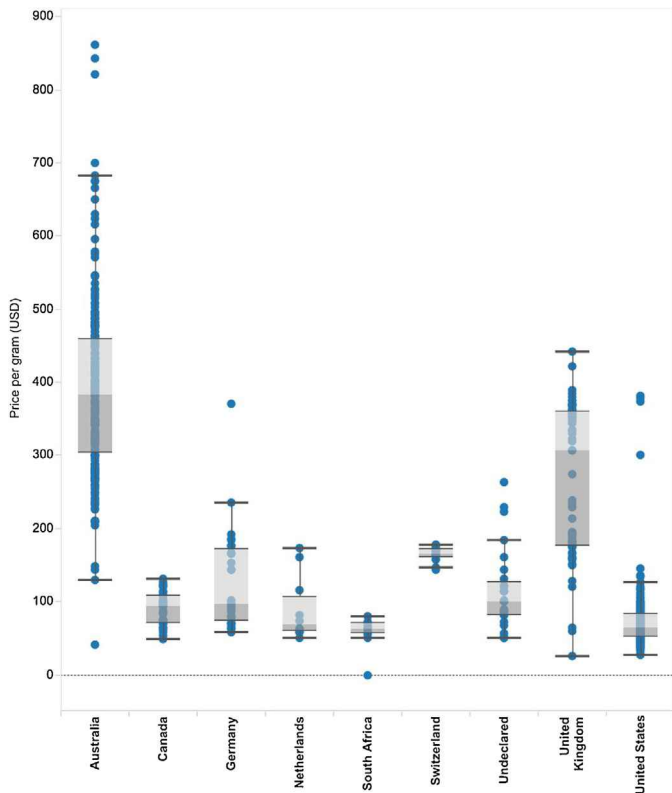

Fig. A2. Boxplots of prices per gram (USD) for methamphetamine crystal and/or ice according to the shipping countries (countries with at least 10 listings).
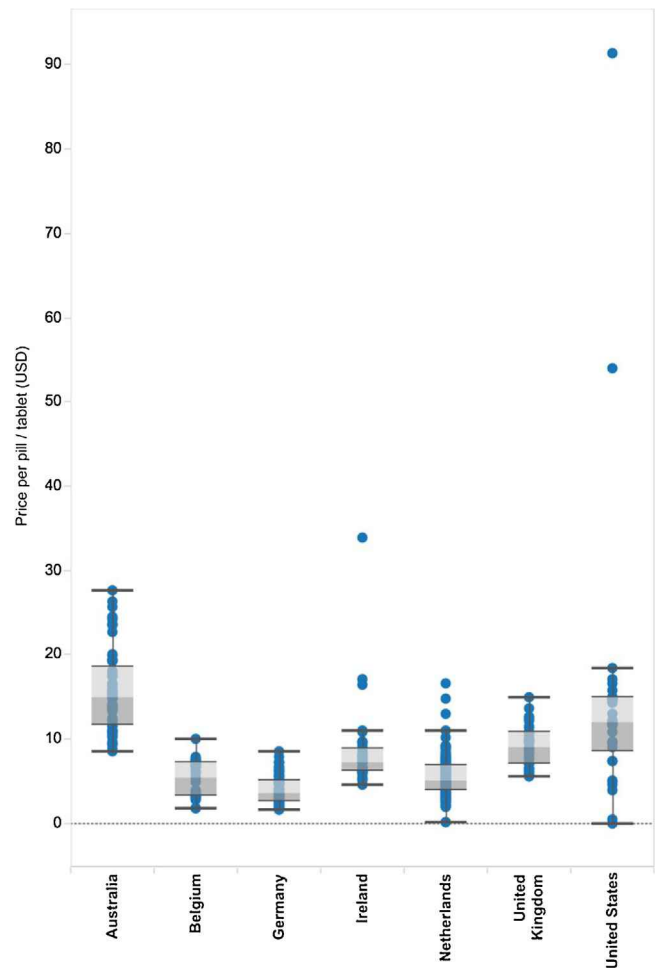

Fig. A3. Boxplots of prices per pill (USD) for MDMA in the form of pills according to the shipping countries (countries with at least 10 listings).

Destination country	Australia	Belgium	Germany	Ireland	Netherlands	United Kingdom	United States
Australia	15.1				11.7		
European Union			7.9		4.9		
United Kingdom						9.8	
United States							13.7
United States & Canada							7.4
Worldwide	14.9	5.6	3.4	7.3	4.8	8.9	4.7
Worldwide except Australia		2.8	3.7	16.8	5.2		

Fig. A4. Median prices (USD) for MDMA pills according to the shipping countries and destinations (countries with at least 10 listings) on *Silk Road 2*.

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