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A geographical analysis of trafficking on a popular darknet market

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ABSTRACT

Cryptomarkets are online marketplaces, located on the *darknet*, that facilitate the trading of a variety of illegal goods, mostly drugs. While the literature essentially focus on drugs, various other goods and products related to financial or identity fraud, firearms, counterfeit goods, as well as doping products are also offered on these marketplaces.

Through the analysis of relevant data collected on a popular marketplace in 2014–2015, *Evolution*, this research provides an analysis of the structure of trafficking (types and proportions of products, number of vendors and shipping countries). It also aims at highlighting geographical patterns in the trafficking of these products (e.g. trafficking flows, specialisation of vendors and assessment of their role in the distribution chain).

The analysis of the flow of goods between countries emphasises the role of specific countries in the international and domestic trafficking, potentially informing law enforcement agencies to target domestic mails or international posts from specific countries. The research also highlights the large proportion of licit and illicit drug listings and vendors on *Evolution*, followed by various fraud issues (in particular, financial fraud), the sharing of knowledge (tutorials) and finally goods, currencies and precious metals (principally luxury goods). Looking at the shipping country, there seems to be a clear division between digital and physical products, with more specific information for physical goods. This reveals that the spatial analysis of trafficking is particularly meaningful in the case of physical products (such as illicit drugs) and to a lesser extent for digital products. Finally, the geographical analysis reveals that spatial patterns on *Evolution* tend to reflect the structure of the traditional illicit market. However, regarding illicit drugs, country-specificity has been observed and are presented in this article.

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1. Introduction

The Internet continues to play an important role in illegal trafficking. It acts as a facilitator, providing another medium for sales and purchases, and a platform for information sharing between users. Users can access both legal and illegal commodities online from anywhere around the world [1]. Cryptomarkets, located on the *darknet*, are only the last illustration of the transition from illegal markets in the real world to the virtual world [2]. Visually very similar to popular merchant websites like *eBay* and *Amazon*, cryptomarkets share several structural features with conventional online sales sites. Lists of products and services offered by sellers are organised into categories and subcategories. Sellers – and their

products – are evaluated according to the feedback left by their previous customers, trust and reputation being central components of the trade on cryptomarkets [3]. Unlike conventional sales sites, however, cryptomarkets facilitate exchanges in a context where the anonymity of administrators and participants is protected thanks to the combination of encryption features. They are the connections through relays to make them anonymous (using for instance the TOR – *The Onion Router* – browser) [4], the automatic encryption of all communications through PGP – *Pretty Good Privacy* – cryptography [5] and the payments with decentralised cryptocurrencies, mainly bitcoins [6].

At the end of 2014, judicial authorities and law enforcement agencies from worldwide countries launched an operation, code-

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named "Operation Onymous", to take down the marketplaces selling illegal items, such as drugs and weapons, on the *darknet* (Eurojust, 2014).[1] Although this operation was successful, the cryptomarkets community was prompt to adapt and thus new marketplaces were developed [7]. Considering the perpetual evolution of crime and the importance of the Internet in illicit activities, analysing any illicit market should rely on a more holistic approach and consider the physical (i.e. traditional trafficking) as well as the virtual (i.e. online trafficking) dimensions of the market. This analysis would enable a deeper understanding of the structure of criminal groups online and potentially draw the link between the virtual world and the physical world which is not currently known. Furthermore, analysing cryptomarkets represents an interesting approach to inform on trends and dynamics that may affect the offline market. A geographical analysis would also fuel hypotheses to better understand the role of cryptomarkets as a new distribution channel, as sellers can source as well as sell drugs online. Sellers may also move their trade to sell all or part of their merchandise while producers may decide to eliminate certain intermediaries and sell directly to consumers [8]. Combining geographical analysis with general knowledge about the traditional market might highlight the presence of new actors (e.g. producers or retailers) and clarify the role played by cryptomarkets in the distribution chain. In addition, from a country-specific perspective, trends regarding different categories of product might be detected, and eventually monitored, from both demand and supply points of view.

Despite the added value of a geographical analysis, only a few studies provide a country-specific perspective and they are focused on drug trafficking hosted on the *darknet* market named *Agora* [9,10]. Differences in the availability of specific substances among shipping countries were observed through these studies. It was concluded that spatial specificity can be due to different factors affecting countries differently, such as geographic isolation, stringent border controls, relaxed laws in regards to illicit goods, high prices of goods, strict control of Internet access, proximity to producing countries, domestic productions of goods and relative availability of illicit goods [9]. Most research on cryptomarkets has focused on drugs to evaluate the structure of the market [2,7,11], characteristics of vendors [12–14], consumers/users' demand [15,16], the investigation of sales volume [7], vendors' activity [17], wholesale vs. retail [18] and the coherence between digital and physical information [19]. A few agencies have developed monitoring strategies, recording illicit drug activities and publishing their results into periodical or casual reports [20]. A European project, mainly centered on the drug situation in the Netherlands, took place in 2016 and resulted in the RAND report [21]. In 2016, the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) published a report about the Internet and drug markets.[2] Other projects are based on interviews with drug market users, concerning the type of products proposed and their level of satisfaction, and resulted in the Global Drug Survey 2016.[3] In a few words, literature shows that cryptomarkets are dominated by English-speaking countries (the United States, the United Kingdom, Australia) and Western European countries (in particular, the Netherlands) and the main offered and purchased illicit drugs are cannabis, stimulants (cocaine and amphetamines), ecstasy (MDMA) and psychedelics (NPS, LSD) [9,11,16,21].

Although drugs are offered and sold prolifically online; various illegal services and products related to financial or identity fraud as well as counterfeit goods are also offered on the cryptomarkets. To our knowledge, no information is available on the proportions of these categories on *darknet* markets. In this context, this study will provide information on the types and frequencies of all the products offered on *Evolution*. Geographic information will also be analysed to highlight specific patterns in the trafficking of certain substances or goods and reveal specificities of the illicit market for a particular country (e.g. the specialisation in the distribution of certain types of products). Such analysis will provide a comparison of the distribution of physical and digital products and help to explain the relation between the shipping country and the type of product. In most studies, only the shipping country is analysed. Here, a combined analysis of shipping countries and destinations will be performed to highlight trafficking flows and therefore evaluate the trafficking nature from certain countries (i.e. domestic vs. international). Lastly, the structure of illicit drug trafficking as well as its geographic distribution will be investigated. The results will be confronted with knowledge regarding the traditional market to assess the relationship between the online and offline markets. The New Psychoactive Substances (NPS) will be specifically studied to evaluate which countries are at the forefront of the trafficking and even their role in the distribution chain. This specific example will indicate to what extent the online trade reflects the traditional trafficking.

2. Dataset and methodology

The cryptomarket *Evolution* was studied since it was a popular cryptomarket during its period of activity, from January to March 2015.[4] In particular, it was very attractive to users since it survived "Operation Onymous" in late 2014 [20]. The dataset used in this study is a compilation of source codes collected, gathered and released by an independent researcher named Gwern Brawnen.[5] He performed data collection over 115 days between January 2014 and March 2015. 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 [22]. Therefore, the dataset used in this study can be considered representative for the purpose of the research.

This dataset has already been used in a previous research in order to provide an overview of *Evolution* in an attempt to evaluate the reliability of vendors' listings by purchasing illicit drugs and analysing them in our laboratory [19]. The present research is not only focused on drugs related listings but also on all goods offered on *Evolution*. Each listing of every category was parsed by the authors through a Python script[6] to extract its title, price and classification within the cryptomarket, as well as the vendor pseudonym and the geographical information—i.e. the mentioned shipping country and destination(s). Vendor username was used to evaluate the total number of vendors present on a cryptomarket as well as the product category where vendors were the most present [7,17]. Trafficking flows between countries were also obtained using the country of origin and the destination country. Section 3.5 deals with the evaluation of the role of countries within the distribution chain of NPS. For this purpose, the quantity and price of the offered products were investigated for each listing. All information was structured to allow further analysis and to accurately study the trafficking structure on *Evolution*. A new

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classification of listings was carried out. Indeed, the overview of the worldwide market would otherwise be uncertain and specific patterns (predominance of a product category, specific spatial distribution, etc.) could also be unclear or even hidden (see Appendix 1 for details about the new classification we performed), as also observed by other researchers [9,10,18,22].

Circular plots (also known as 'chord diagrams') are used to visualise the flows between countries from the claimed origin to the destination(s) [23]. Colours depict the origin country and the width of each arc is proportional to the number of listings from one country to one destination. They ease the overall analysis of the flows but since they are readable only with a limited number of relationships, only couples of origin/destination countries having a frequency of at least 1% of the total number of existing combinations are displayed.

Data analysis was performed using R [24], RStudio v. 1.0.136, Tableau Software Professional Edition v. 9.3 and Microsoft Excel v. 15.31. Trafficking flows (Section 3.3) were represented as chord diagrams using the R library *circlize*.[7] Only for this particular analysis, listings with unstated shipping destinations were removed (n = 40,851).

3. Results and discussion

3.1. Products offered

The extraction of each listing source code for every crawling date led to the identification of 92′980 *unique* sale proposals, after discarding six listings that stated unclear shipping country information. A total number of 4171 distinct vendor usernames was detected. Results show that a vendor may manage one or more listings (min = one listing, max = 1′441, median = 9, mean = 22, standard deviation = 49).

Most of the sale proposals (63%) concern licit or illicit drugs and paraphernalia, in particular, illicit drugs (close to 50% of all listings), as illustrated in Table 1. This is also the subcategory where vendors are the most present (close to 60% of vendors offer at least one product classified as illicit drugs). Specific trends concerning the distribution of illicit drugs will be discussed in Section 3.5. This category also includes prescription drugs and medicines (mainly benzodiazepines—34% and synthetic opioids—31%), performance and image-enhancing drugs (PIEDs, mainly steroids) as well as, to a lesser extent, laboratory supplies and paraphernalia. Listings related to various fraud issues represent almost a third of the total number of listings and close to half of vendors propose products classified in this category. Several activities and services related to *carding*[8] are particularly covered (listings classified as carding represent close to 70% of the listings grouped in "*Fraud Related*"). Goods with a high probability of forgeries are mainly concerned in the third category "*Goods, currencies and precious metals*". Indeed, luxury goods (essentially watches—89%) and clothes and accessories (glasses—21%, bags—18% and shirts—14%) represent about 60% of the sale proposals in this category. Interestingly, only a few vendors offer goods in these two categories. The "*ID Related*" category includes sale proposals related to ID theft (37%), various types of licences and legitimation documents such as bank statements or university diplomas (35%) and IDs (28%). ID theft mainly consists in "*fullz*", as advertised by

Table 1

Listings' and vendors' proportions for the different categories of products. Listing/Vendor percentages are calculated as the ratio between the respective number of listings/vendors for each product main categories and the respective total number of listings/vendors in the whole market (n = 92′980 listings and 4′171 vendors).

Category	Listings (%)	Vendors (%)[a]
Illicit drugs, drugs and paraphernalia	63	69
Illicit drugs	46	57
Cannabis[b]	39	52
Ecstasy & MDMA[b]	19	31
NPS[b]	10	17
ATS[b]	9	21
Cocaine[b]	8	25
LSD and derivatives[b]	5	11
Opioids[b]	4	11
NPS—Other[b]	2	8
NPS—Synthetic cannabinoid[b]	1	2
Other[b]	3	12
Prescription drugs and medicines	14	25
Performance and image enhancing drugs	2	3
Lab supplies and paraphernalia	1	4
Various fraud issues	30	44
Fraud related	13	32
Guides and tutorials	10	18
Goods, currencies and precious metals	4	9
Luxury goods[b]	46	9
Currencies and precious metals[b]	21	44
Electronic devices[b]	18	55
Clothes and accessories[b]	15	6
ID related	3	11
Firearms and weapons	1	4
Other	7	30
Custom listings	26	26
Miscellaneous	9	9

ATS: Amphetamine type substances (amphetamine and methamphetamine).

[a] Since a same vendor account may manage listings classified in different (sub-)categories, the number of vendors may be higher than the total number of vendors calculated according to their usernames.

[b] Listing/vendor percentages of subcategories are calculated as the ratio between the respective number of listings/vendors for each subcategory and the total number of listings/vendors of the main category.

vendors, that are archives containing financial information (bank account logins or credit card numbers) and personal information (name, address, e-mail, security social number, date of birth, mother's maiden name, etc.). According to the listing titles, the IDs subcategory includes scans of ID cards or passports, editable graphical material as well as genuine or forged IDs. Lastly, about 1′000 listings were classified as "*Firearms & Weapons*" in which a third of sale proposals concerns firearms.

3.2. Shipping countries

On *Evolution*, vendors may inform on the shipping country and destination(s) of their products by selecting countries/regions from a preset list. According to our dataset, 93 shipping countries and 164 shipping destinations have been mentioned (see Appendix 2 Table B1). On a given sale proposal, vendors always mentioned one shipping country only, while a list of destination countries was sometimes stated. Vendors may manage several listings. A combined study of vendor usernames and shipping countries shows that vendors may state different shipping countries between their sale proposals, even though they mostly mention only one shipping country (see Fig. 1).

An analysis of the frequency of shipping countries indicates that "Worldwide" was mentioned by close to 50% of all vendors and stated in close to 40% of all listings. The predominance of this statement may be seen as a limitation for a valid assessment of the trafficking magnitude of specific countries when analysing the global market. Indeed, this high proportion implies that we may

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[7] https://cran.r-project.org/web/packages/circlize/index.html.

[8] Carding concerns the acquisition (through skimmers at ATMs or hacking an e-commerce, for instance) and resale of credit cards and bank accounts as well as related activities such as money laundering (e.g. money transfer using bitcoins, money transfer companies or acquisition of prepaid cards) or reshipping services through mules.
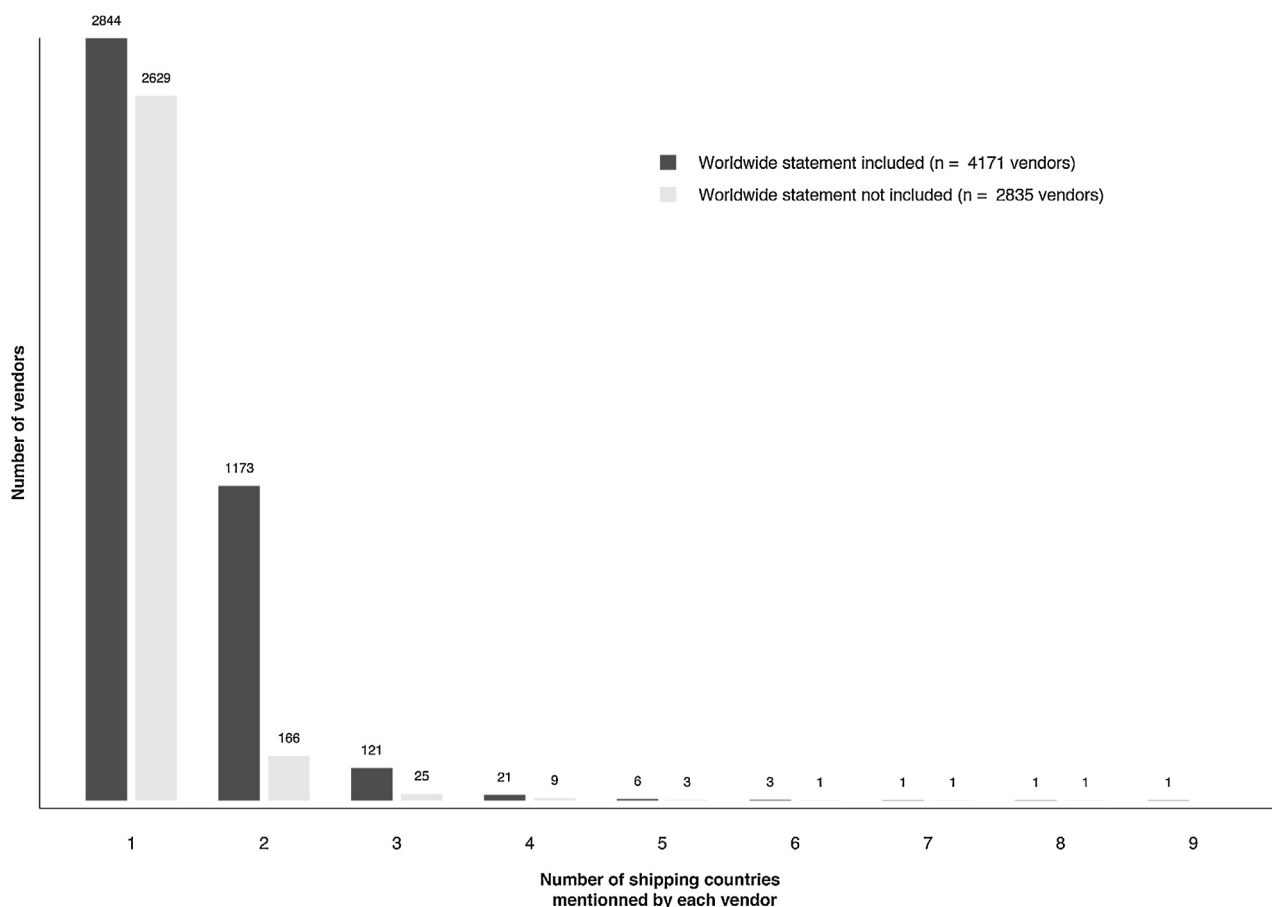
Fig. 1. Number of vendors mentioning one or more shipping countries in their sale proposals.

underestimate the position of a specific country in the market. However, we may also assume that vendors from any country may choose to indicate "Worldwide". In this case, the proportions may be quite accurate. Interestingly, stating "Worldwide" depends on the nature of the product proposed by vendors, as shown in Table 2. There is a clear division between digital and physical products. For instance, hacking services or material related to financial fraud ("*Fraud related*" category), manuals ("*Guides and tutorials*") and scans of IDs or legitimation documents ("*ID related*") are digital products. Instead, counterfeit goods ("*Goods, currencies and precious metals*"), chemicals ("*Lab supplies and paraphernalia*") or any type of drugs ("*Prescription drugs and medicines, PIED and Illicit drugs*") are physical. The origin country does not represent a meaningful information for digital goods that are sent through the Internet, which may explain the high proportion of vendors selecting "Worldwide" as the shipping country. In contrast, the

delivery mode of physical material makes it possible to check the coherence between the origin country stated online and that written down on the postal parcel. Therefore, vendors may not have interest to provide incorrect information since customers may leave a negative feedback in the case of inaccurate data [9]. This would explain why vendors mainly provide a meaningful shipping country when offering physical products and do not utilise the "Worldwide" statement. Vendors still stating their physical products as shipped from "Worldwide" may like to conceal the true origin of their merchandise or they prefer to provide details in the description part of the listing. Thus, the spatial analysis of trafficking on cryptomarkets is particularly

Table 2
Listings and vendors' proportions where "Worldwide" was mentioned as the origin country for each product category.

Category	Listings (%)	Vendors (%)
Fraud related	90	88
Guides and tutorials	87	94
ID related	86	86
Miscellaneous	67	58
Firearms and weapons	34	55
Goods, currencies and precious metals	27	65
Lab supplies and paraphernalia	24	38
Prescription drugs and medicines	18	32
Performance and image enhancing drugs	17	34
Illicit drugs	15	37

Table 3
Proportion of listings and vendors for the shipping countries having at least 1% of the total number of listings.

Country/region	Listings (%) (n = 92'980)	Vendors (%)[a] (n = 4'171)
Worldwide	38.6	62.4
United States	18.6	26.1
United Kingdom	8.9	10.8
Germany	6.5	6.8
Netherlands	6	5.1
Australia	4.5	5.8
China & Hong Kong SAR China	3.6	1.2
Canada	2.9	3.8
Sweden	2	2.3
Belgium	1.6	0.7
France	1.5	2.2

[a] Since vendors may mention different shipping countries between their listings, the sum of percentages is higher than 100%.
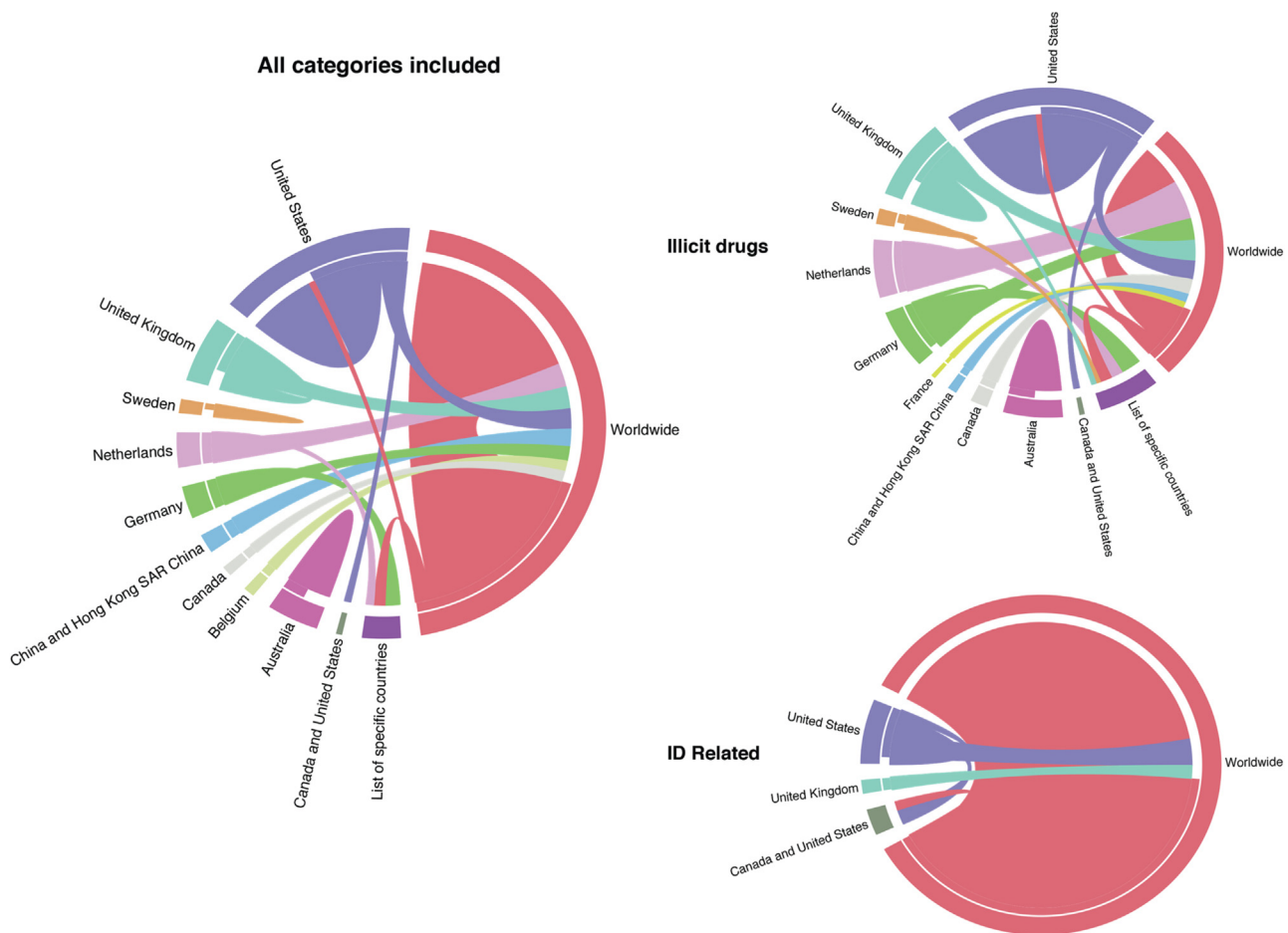
All categories included

Fig. 2. Structure of trafficking considering the whole market (left) and two categories of physical (top right) and virtual products (bottom right). The circular plot shows the directional flows (origin and destination) of products for the most frequent couples of origin and destination countries (i.e. couples having a frequency of at least 1% in relation to the total number of existing combinations)[9].

meaningful in the case of physical products and to a lesser extent for digital products.

Without considering "Worldwide", the analysis of the stated origin countries shows the dominant position of English-speaking countries (the United States, the United Kingdom and Australia) and Western European countries (Germany and Netherlands) which was also observed in Ref. [21] (see Table 3). Although since 2013, several non-English language markets have appeared, English seems to remain the dominant language. This might be a result of the central position of English-speaking countries in online trades or the fact that English is usually the trading language which might deter non-English vendors from offering goods [21]. It is worth noting that while some countries have similar proportions of both listings and vendors (the United Kingdom, Germany or Sweden, for instance), the listing proportions of China & Hong Kong are three times higher than their respective vendor proportions. This clearly reveals a specificity of their market structure: a few vendors are involved but they manage a large number of listings. Since each listing may be purchased several times by customers, this result may indicate that vendors have stock and thus have access to a steady long-term supply of the products they offer. The small number of Chinese vendors may be explained by the very strict control of China's Internet traffic [25]. In addition, trafficking on online *darknet* platforms might not be considered as effective for Chinese vendors for various reasons. Indeed, the registration process on the *darknet* markets (e.g. fees, access constraints, etc.) may be considered by Chinese vendors as too restrictive, urging them to adopt other ways of distribution such

as dedicated websites on the clear web. Thus, the clear web may be the main reason explaining the relatively minor position of the Chinese market on the *darknet*, since it represents an efficient method for the distribution of products in which Chinese vendors specialise, as it will be discussed further below (see Sections 3.4–3.6).

3.3. Trafficking flows

A combined analysis of shipping countries and destinations was performed to evaluate the market flows for the main countries (see Fig. 2).

First, Fig. 2 clearly shows the distinction between physical (e.g. illicit drugs) and digital (e.g. ID related) goods discussed above. The "Worldwide" origin is indeed more common for ID related goods than for illicit drugs (see Table 2 and Fig. 2). In addition, this analysis reveals the behaviour of vendors and the extent of the market for each origin country, and reciprocally. Interestingly, the flow of illicit drugs is primarily domestic in Australia (i.e.

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[9] The origins and destinations of products are represented by the circle's segments. A specific color is 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 color and by the gap between link and circle segment at the destination. The direction goes from a non-gap to a gap. Listings with unstated shipping destinations were removed from the analysis (n = 40,851).

	North America		Europe							Asia					
	United States (%)	Canada (%)	United Kingdom (%)	Germany (%)	Netherlands (%)	Sweden (%)	Belgium (%)	France (%)	Spain (%)	China & HK (%)	India (%)	Australia (%)	Other country* (%)	Total (%)	N
Illicit drugs	64.0	85.3	64.5	80.5	93.5	48.9	35.4	74.0	69.7	35.2	6.5	66.0	56.4	66.3	36593
Prescription drugs and medicines	25.5	12.0	20.5	11.8	4.2	44.6	6.9	9.4	26.8	6.3	91.6	15.1	17.9	18.5	10217
Goods, currencies and precious metals	1.3	0.2	2.0	0.8	0.5	0.1	1.5	4.5	0.9	54.9	0.4	1.0	3.6	4.6	2531
Performance-enhancing drugs	1.4	1.1	4.6	1.4	0.2	0.6	0.1	0.1	0.3	0.8	1.3	8.0	14.1	2.9	1583
Fraud Related	2.2	0.3	3.8	1.8	0.7	0.2	2.2	4.2	1.1	1.1		3.1	3.8	2.2	1214
Guides & Tutorials	0.8	0.0	1.6	0.2	0.0	0.1	54.0	3.7		0.4		0.2	0.4	2.1	1147
Lab supplies & Paraphernalia	2.5	0.6	2.2	0.4	0.4	2.8	0.1		0.3	0.6	0.2	2.8	0.9	1.6	865
Firearms & Weapons	0.9	0.2	0.1	3.0	0.3	2.8		2.8	1.0	0.6		3.6	2.2	1.3	694
ID Related	1.3	0.2	0.9	0.2	0.1			1.4				0.3	0.8	0.7	369
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	55212
N	16680	2630	8092	5885	5424	1796	1441	1336	699	3313	465	3872	3579	55212	

Fig. 3. Distribution of listings in product categories for every shipping country (without considering the worldwide statement). Excluding Lab supplies, Firearms and ID Related products, there is a moderate relationship between the categories of products and the countries ($\chi^2 = 46360$, $p < 0.001$, V Cramer = 0.42). Excluding Sweden, Belgium, China & Hong Kong, and India, the relationship is significant but weak ($\chi^2 = 5220$, $p < 0.001$, V Cramer = 0.15). *Country with less than 1% of the total number of listings.

Australian sellers only propose products to customers living within the country), and is mainly domestic in the United States. The domestic pattern may be explained by the intent of both customers and vendors to reduce their risks (such as a parcel loss, interception by authorities or arrest) by selling or purchasing only within their country of residence [26]. Accordingly, Kruithof et al. [21] mentioned that many vendors appear to be reluctant to ship to countries with stricter law enforcement and border controls such as Finland, Australia, the United States and Canada. By contrast, Germany, Canada and the Netherlands mainly export internationally. This may be related to the role of these countries in the production of synthetic drugs, such as Ecstasy & MDMA and amphetamines (see Section 3.5) [27,28]. In the same line, a relative easy access to illicit drugs in the domestic market would not stimulate local users to purchase substances on cryptomarkets and would motivate sellers to export to foreign customers [26]. A more competitive domestic market from vendors' point of view would have the same consequence. The analysis of trafficking flows also helps to understand and explain the offer patterns. For instance, if a domestic market is observed, we may expect a good correlation between the types and frequencies of products offered and the prevalence data of the local population (or at least, the sub-population sourcing drugs on cryptomarkets) (see Section 3.5).

	North America		Europe							Asia				
	United States	Canada	United Kingdom	Germany	Netherlands	Sweden	Belgium	France	Spain	China & HK	India	Australia	Other country*	N
Illicit drugs	710	135	317	211	193	73	26	60	40	25	8	193	207	2198
Prescription drugs and medicines	441	48	131	71	27	41	7	12	12	21	10	73	93	987
Goods, currencies and precious metals	67	3	31	17	9	1	3	8	2	13	2	16	29	201
Performance-enhancing drugs	27	3	17	10	1	3	1	1	1	3	2	18	17	104
Fraud Related	131	4	67	30	14	3	2	16	1	4		26	34	332
Guides & Tutorials	36	1	18	6	2	1	1	6		2		7	6	86
Lab supplies & Paraphernalia	58	6	18	7	7	6	1		1	6	1	18	8	137
Firearms & Weapons	31	1	6	19	6	8		9	1	1		10	12	104
ID Related	38	2	21	5	3			7				6	11	93
N	1078	159	444	274	210	93	30	88	49	50	20	239	301	

Fig. 4. Number of vendors for each shipping country and product categories. One vendor may sell several categories of products. Thus, the sum of the number of vendors over all categories may be higher than the total number of distinct vendors. The total (N) in the last line is the sum of distinct vendors' names. Excluding Lab supplies, Firearms and ID Related products, there is a significant, but weak relationship between the categories of products and the countries ($\chi^2 = 237$, $p < 0.001$, V Cramer = 0.11). *Country with less than 1% of the total number of listings.

In an intelligence perspective, the identification of an important domestic market such as the one in Australia or the United States may encourage a tighter control of mail inside the country. The identification of the main countries that export internationally (e.g. China, the Netherlands or Germany) may help to target parcels sent from these specific countries. Furthermore, combining the trafficking flows information to the types of good and the concealment methods indicated by sellers online, which tends to match that of the delivered packages [19], may be of added value and could help to target specific types of packages from specific countries.

3.4. Spatial specificity

To evaluate the specialisation of vendors from any country and their respective importance in the market, the distribution of listings and vendors for every country was analysed (Figs. 3 and 4) as well as their contribution to the total number of listings for each product category (Fig. 5). For instance, Fig. 3 indicates that illicit drugs and prescription drugs represent respectively 66.3% and 18.5% of all listings (when worldwide is excluded). We also observe that 64% and 6.5% of the listings "from" respectively American and Indian vendors concern illicit drugs. They are respectively managed by 710 and 8 vendors (see Fig. 4). Lastly, the analysis

of Fig. 5 shows that the United States accounts for 30% of all sale proposals on *Evolution* (worldwide excluded). Moreover, vendors from the United States – in line with their number (see Fig. 4) – are the main contributors on *Evolution* since they dominate the distribution of illicit drugs (29.2% of listings classified in the category are managed by "American" vendors), prescription drugs (41.6%), fraud related (30.4%), lab supplies (48.1%) and ID Related (59.1%).

Figs. 3 and 4 highlight the specialisation in prescription and illicit drugs of vendors from the Netherlands (98% of listings), Canada (97%), Spain (96%) or Sweden (94%). The specialisation of 'Dutch vendors' has also been observed by a study based on more recent datasets that concluded that they use cryptomarkets almost exclusively for drug sales and particularly ecstasy-type drugs and stimulants [21]. The specialisation of Indian vendors in the distribution of prescription drugs (see Fig. 3) is also worth being highlighted, especially when considering the small number of vendors they represent, compared to that of the other countries present in the category (see Figs. 4 and 5). This was also observed on the cryptomarket *Agora* [10]. By contrast, sellers 'from' Australia, Germany, the United Kingdom or the United States seem to diversify their activities. In line with their number of vendors (see Table 3) they are predominant in each of all categories (Fig. 4), which is also corroborated by the study of the origin of

		Illicit drugs (%)	Prescription drugs and medicines (%)	Goods, currencies and precious metals (%)	Performance-enhancing drugs (%)	Fraud Related (%)	Guides & Tutorials (%)	Lab supplies & Paraphernalia (%)	Firearms & Weapons (%)	ID Related (%)	Total (%)	N
North America	United States	29.2	41.6	8.5	14.5	30.4	12.2	48.1	22.8	59.1	30.2	16680
	Canada	6.1	3.1	0.2	1.9	0.7	0.1	2.0	0.6	1.4	4.8	2630
Europe	United Kingdom	14.3	16.2	6.3	23.4	25.2	11.1	20.1	1.2	19.0	14.7	8092
	Germany	13.0	6.8	1.9	5.1	8.5	1.0	2.8	25.4	3.0	10.7	5885
	Netherlands	13.9	2.2	1.1	0.7	3.2	0.2	2.4	2.0	1.4	9.8	5424
	Sweden	2.4	7.8	0.0	0.6	0.2	0.1	5.8	7.3		3.3	1796
	Belgium	1.4	1.0	0.8	0.1	2.6	67.8	0.1			2.6	1441
	France	2.7	1.2	2.4	0.1	4.6	4.3		5.5	5.1	2.4	1336
	Spain	1.3	1.8	0.2	0.1	0.7		0.2	1.0		1.3	699
Asia	China & HK	3.2	2.1	71.8	1.8	3.0	1.1	2.4	3.0		6.0	3313
	India	0.1	4.2	0.1	0.4			0.1			0.8	465
	Australia	7.0	5.7	1.5	19.5	9.9	0.8	12.4	20.0	3.5	7.0	3872
	Other country*	5.5	6.3	5.1	31.9	11.1	1.3	3.6	11.2	7.6	6.5	3579
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	55212
	N	36593	10217	2531	1583	1214	1147	865	694	369		55212

Fig. 5. Contribution (in terms of listing proportions) of each shipping country in product categories (without considering the worldwide statement). There is a moderate relationship between the categories of products and the countries ($\chi^2 = 48703$, p < 0.001, V Cramer = 0.33). The relationship is strong if we exclude all drugs (illicit, prescription and performance-enhancing, $\chi^2 = 9127$, p < 0.001, V Cramer = 0.52). *Country with less than 1% of the total number of listings.

| | North America | | Europe | | | | | | | Asia | | | | | |
	United States (%)	Canada (%)	United Kingdom (%)	Germany (%)	Netherlands (%)	Sweden (%)	Belgium (%)	France (%)	Spain (%)	China & HK (%)	India (%)	Australia (%)	Other country* (%)	Total (%)	N
Amphetamine	0.3	1.5	3.9	10.5	9.8	22.8	5.3	3.9	0.6			3.4	6.8	4.8	1753
Cannabis	53.2	50.0	38.2	37.6	17.4	33.8	31.2	49.9	75.4	0.3	20.0	19.4	41.0	38.6	14113
Cocaine	6.9	5.6	12.1	6.0	10.5	5.1	7.3	5.9	4.7			10.1	9.6	8.0	2926
Ecstasy & MDMA	8.9	14.0	17.1	31.7	43.8	24.8	42.7	16.8	0.2	1.4		21.9	14.3	20.1	7350
LSD and derivatives	5.0	4.2	5.4	4.5	4.1	5.5	2.4	2.8	0.4			5.0	4.9	4.5	1650
Methamphetamine	5.2	2.5	2.0	1.8	0.4	0.5	2.4	0.7	1.4			19.1	3.1	3.8	1403
NPS	9.7	11.6	10.4	2.9	5.3	4.2	0.2	4.3	11.9	93.3	53.3	10.1	8.8	10.7	3930
Opioids	4.7	3.1	6.4	1.8	3.5	0.7	8.0	15.4	2.7		16.7	4.4	4.5	4.3	1587
Other	6.1	7.4	4.5	3.2	5.3	2.7	0.6	0.3	2.7	5.1	10.0	6.4	7.1	5.1	1881
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	36593
N	10683	2244	5220	4739	5074	879	510	988	487	1166	30	2554	2019	36593	

Fig. 6. Distribution of illicit drug listings for every shipping country (without considering the worldwide statement). Excluding China and Hong Kong, and India, there is a significant, but weak relationship between the categories of illicit drugs and the countries ($\chi^2 = 9229$, $p < 0.001$, V Cramer = 0.23). *Country with less than 2% of the total number of illicit drugs listings.

listings for each category (Fig. 5). In fact, these four countries together dominate the distribution of products in the majority of categories, such as illicit drugs (about 77% relative to the total number of listings of the category), prescription drugs (73%), PIEDs (63%), fraud related (77%), lab supplies (86%), firearms (71%) and ID related (86%). 'Guides and Tutorials' and "Goods, currencies and precious metals" are the only two categories where vendors from these countries are not predominant. "Guides and Tutorials" has been flooded by one Belgian vendor who is responsible for 68% of listings in the category. The "Goods, currencies and precious metals" category seems to be controlled by Chinese vendors (71.8% of the listings, see Fig. 5), while their number (13) is lower than other countries present in the category such as the United States (67), the United Kingdom (31), Germany (17) and Australia (16) (see Fig. 4). In particular, they manage almost 99% of all listings classified as "Luxury goods", which mainly consist of watches & jewellery, and 85% of that classified as "Clothes and accessories". Most of the listing titles mention luxury brands, contain the term "replica" and are sold at cheap prices. For instance, concerning watches (n = 1347 listings), Rolex is the most proposed brand (n = 314) followed by Omega (n = 217), Emporio Armani (n = 197), Breitling (n = 172) and Audemars Piguet (n = 149) and their prices range from 50 to 200 USD. Overall, all watch brands but one (Emporio Armani collection of the Giorgio Armani industry) are affiliated with the Federation of the Swiss Watch Industry (FH), according to its official website.[10] These results are consistent with the few sources of information regarding the trafficking of luxury goods [29].

The evaluation of the impact of countries in the trafficking of specific products as well as their role in the distribution chain was found to be particularly relevant in the case of illicit drugs and is therefore developed in the following section. Indeed, they represent the main good offered (see Table 1) as well as the category where Worldwide is less stated (see Table 2 and Fig. 2).

3.5. Illicit drugs

As mentioned in the introduction, English-speaking countries (e.g. the United States, the United Kingdom, Australia) and Western European countries (e.g. the Netherlands) dominates the trafficking of illicit drugs on cryptomarkets while cannabis, stimulants (cocaine and amphetamines), ecstasy (MDMA) and psychedelics (NPS, LSD) are the main drugs offered. In addition, compared to the traditional market, the relative low offer and purchase of substances such as cocaine and heroin were noted by Kruithof et al. [21]. This may be the consequence of the predominance of recreational consumers or psychonauts on cryptomarkets [14,30,31]. The elements of planning and having to wait for delivery which characterised cryptomarkets might deter excessive consumers or the ones not able to plan their consumption [12,21]. This may be the case of regular cocaine and heroin consumers, which may have timely access to their substances through traditional means of supply (street dealer, contacts). These observations are further emphasised in our study (see Figs. 6–8).

Similarly to the previous section, Figs. 6–8 provide information about the distribution of illicit drug listings and vendors for every country (Figs. 6 and 7) and their contribution to the total number of listings for each category of illicit drugs (Fig. 8).

Cannabis related products represent the main illicit drug category for most of the countries. These products are also the illicit drugs mainly offered (38.6%) considering all illicit drug listings (see Figs. 6 and 7). In addition to the adaptation to the customer demand, the predominance of cannabis may be explained by the easy access to the product. Indeed, cannabis is not only the most consumed drug worldwide, it also represents the most widely cultivated drug crop according to the UNODC [27]. Among the main stated countries, Australia, China and the Netherlands are the only ones from which cannabis is not the main proposed product. Vendors from Australia propose at similar frequencies Ecstasy & MDMA, cannabis and methamphetamine, which is tightly related to the indicators of the traditional market

	North America		Europe							Asia				
	United States	Canada	United Kingdom	Germany	Netherlands	Sweden	Belgium	France	Spain	China & Hong Kong	India	Australia	Other country*	N
Amphetamine	16	7	20	76	55	22	8	5	1			15	32	257
Cannabis	359	75	160	124	69	41	11	43	32	1	2	59	117	1093
Cocaine	121	26	100	54	74	11	9	16	7			42	49	509
Ecstasy & MDMA	146	37	95	97	108	23	11	16	1	4		78	51	667
LSD and derivatives	77	13	37	21	26	8	4	7	1			14	27	235
Methamphetamine	80	11	19	13	5	2	3	3	1			66	16	219
NPS	115	17	83	16	30	7	1	8	6	22	3	43	33	384
Opioids	83	19	42	14	20	2	4	9	1		2	17	20	233
Other	105	33	59	29	39	7	2	2	3	9	1	34	37	360
N	710	135	317	211	193	73	26	60	40	25	8	193	207	

Fig. 7. Number of vendors for each shipping country and categories of illicit drugs. One vendor may sell several categories of illicit drugs. Thus, the sum of the number of vendors over all categories may be higher than the total number of distinct vendors. The total (N) is the sum of distinct vendors' pseudonyms. Excluding Spain, China and Hong Kong, and India, there is a significant, but weak relationship between the categories of illicit drugs and the countries ($\chi^2 = 540$, $p < 0.001$, V Cramer = 0.17). The main categories remain Cannabis, Cocaine and Ecstasy & MDMA. Amphetamine are over represented for Germany, Netherlands, Sweden and Belgium. *Country with less than 2% of the total number of listings.

(arrests, seizures and prevalence data) according to the Australian Intelligence Crime Commission [32]. We may reasonably assume that such trend is the consequence of the domestic pattern observed for the Australian illicit drug trafficking (see Fig. 2). Lastly, the high proportions of listings of Ecstasy & MDMA and amphetamine from Dutch vendors, and to a lesser extent from German vendors (see Fig. 6), can be explained by the main role these countries play in the production of such drugs [28]. As shown in Fig. 8, together they cover more than half of the sale proposals of both Ecstasy & MDMA (50.7% of all listings in the category) and amphetamine (56.8%). Concerning Ecstasy & MDMA, while production is now global, Europe – in particular the Netherlands – is considered as the world's leading source of the drug [33]. Clear spatial specificity can be observed for amphetamines, which are mainly proposed from Germany, the Netherlands and even Sweden (Fig. 6) and methamphetamine, which is mainly offered from Australia and the United States. Amphetamine is still mainly produced in Europe while methamphetamine production is limited to the Baltic region and Central European countries. Moreover, the use of methamphetamine in Europe is limited compared to that of amphetamine and is restricted to a group of geographically close countries [34]. By contrast, as noted in the last World Drug Report [27], "*although methamphetamine is a feature of ATS markets worldwide, it is particularly dominant in East and South-East Asia and North America*". In Australia, methamphetamine remains the main drug produced in clandestine laboratories detected [32]. Finally, the main proportion of illicit drug listings is proposed from the United States (29%). The country concentrates the largest number of vendors (more than twice that of the United Kingdom) and is the lead country of a wide number of illicit drug categories (see Fig. 8). For instance, its leadership in the opioids category may be explained by the increase in heroin use in North America in the past decade (high prevalence compared to the worldwide mean). In contrast, the trends of heroin consumption

since the late 1990s in Western and Central Europe have been stable or declining on the long-term [27]. Finally, Chinese vendors, while five times fewer in number than Americans, lead the NPS category (27.7% of NPS listings). As further developed below, they specialise in the distribution of NPS (see also Figs. 6 and 7), in which they play a strategic role. Another interesting observation is the non-existence of cocaine and heroin producing countries online (e.g. South American countries or Middle East/South East/ South West Asia). In general, these countries do not have access to the same technological infrastructure (e.g. the Internet, secure mail system) as westernised countries [8,18]. Furthermore, cryptomarkets may not represent a relevant distribution channel between producers and retailers in the case of cocaine and heroin.

3.6. A specific analysis of new psychoactive substances

Regarding the worldwide market, 384 vendors manage 3930 listings classified in NPS (all three NPS related categories grouped). This represents almost 11% of the illicit drugs category (see Fig. 8). As shown in Table 3, listings about illicit drugs shipped from China and Hong Kong represent about 4% of the total number of listings proposed on *Evolution*. However, the majority of their illicit drug listings concern NPS (93% precisely, see Fig. 6). They cover almost 28% of all the NPS listings proposed on *Evolution* with only 22 vendors, which makes it the lead country, followed by the United States (26.5%—115 vendors) and the United Kingdom (13.9%—83 vendors) (see Fig. 8).

The combined analysis of masses and prices of the NPS proposed reveals geographical differences between the shipping countries (see Fig. 9). Most countries are characterised by a majority of listings offering small quantities of NPS (less than one gram or less than ten grams). However, vendors from China and Hong Kong offer larger quantities of NPS, between 10 g and 100 g, or even more. Thus, we may assume that vendors from China have

		Amphetamine (%)	Cannabis (%)	Cocaine (%)	Ecstasy & MDMA (%)	LSD and derivatives (%)	Methamphetamine (%)	NPS (%)	Opioids (%)	Other (%)	Total (%)	N
North America	United States	1.7	40.3	25.1	12.9	32.6	39.9	26.5	31.4	34.5	29.2	10683
	Canada	1.9	8.0	4.3	4.3	5.8	4.1	6.6	4.3	8.8	6.1	2244
Europe	United Kingdom	11.5	14.1	21.6	12.2	17.0	7.3	13.9	21.2	12.5	14.3	5220
	Germany	28.5	12.6	9.7	20.4	13.0	6.0	3.5	5.4	8.0	13.0	4739
	Netherlands	28.3	6.2	18.2	30.3	12.5	1.3	6.8	11.3	14.2	13.9	5074
	Sweden	11.4	2.1	1.5	3.0	2.9	0.3	0.9	0.4	1.3	2.4	879
	Belgium	1.5	1.1	1.3	3.0	0.7	0.9	0.0	2.6	0.2	1.4	510
	France	2.2	3.5	2.0	2.3	1.7	0.5	1.1	9.6	0.2	2.7	988
	Spain	0.2	2.6	0.8	0.0	0.1	0.5	1.5	0.8	0.7	1.3	487
Asia	China & Hong Kong		0.0		0.2			27.7		3.1	3.2	1166
	India		0.0					0.4	0.3	0.2	0.1	30
	Australia	5.0	3.5	8.9	7.6	7.8	34.9	6.6	7.1	8.7	7.0	2554
	Other country*	7.8	5.9	6.6	3.9	5.9	4.4	4.5	5.7	7.7	5.5	2019
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	36593
	N	1753	14113	2926	7350	1650	1403	3930	1587	1881	36593	

Fig. 8. Contribution (in terms of listing proportions) of each shipping country in illicit drug categories (without considering the worldwide statement). There is a weak relationship between the categories of illicit products and the countries (χ^2 = 9340, p < 0.001, V Cramer = 0.24). *Country with less than 2% of the total number of illicit drugs listings.

the capacity to provide bulk quantities. Indeed, typical quantities for NPS consumption are usually very low, suggesting that quantities over 100 g may already be considered as bulk. Price ranges also corroborate this finding. Listings offered for sale from China and Hong Kong show a median price lower than 10 USD per gram, while median prices are relatively higher for every other country. Of course, vendors usually propose products at prices decreasing gradually when quantity increases. However, Chinese vendors are able to offer a lot of listings at high quantities at competitive prices in comparison to vendors from other countries. In conclusion, these results may indicate that Chinese vendors have easily access to these products or even may be involved in their production which would be in agreement with Smith and Garlich who stated that China played an active role in the domestic production of NPS [35]. Furthermore, this analysis corroborates the statements of vendors on their profiles concerning their ability to offer both small and very large quantities of NPS at lower prices.

The importance of Chinese sellers in NPS production or distribution does not seem to be cryptomarket specific. Indeed, recent research studying country specific differences in substance availability on the *Agora* cryptomarket found that China, despite a small number of sellers, was overrepresented in NPS [9,10]. Using only the number of listings and sellers to draw their conclusions, the authors mentioned that China was probably involved in the production of NPS. Another study, investigating wholesale activity on cryptomarkets, found that wholesale transactions were especially concentrated in China. According to the authors, this may be related to the role of China in the production of these substances [18].

Regarding NPS in general, or more specifically synthetic cannabinoids, China has always been suspected of being the place where these products are synthesised since the first appearance of "spice" products in 2004 [35–38]. It was also suggested that some substances are sent to Europe, or even North America, and then reconditioned for retail shipping [36]. On the clear web, China was also mentioned as the country of origin of websites offering MT-45, an opioid-like substance often referred to as a NPS [39]. However, this was not investigated further, for example by performing controlled purchases. Meyers and al. [40] also noted the accessibility of purchasing synthetic cathinones (a major class of NPS) on the clear web. They highlighted the United States, together with Germany and the United Kingdom, as the three main countries where retailing websites were hosted. Concerning NPS shipments confiscated at borders, cathinones seizures in 2009 in New Zealand mostly originated from the United Kingdom or directly from China [41]. In Australia, in the period 2013–2014, NPS in kilogram quantities came primarily from China [42]. Thus, although based on only one cryptomarket, the results obtained through our study support various assumptions regarding the position of China within the NPS market.

4. General discussion and conclusion

Through the analysis of a dataset containing information about 4171 vendors and 92,980 sale proposals, this study aimed first at investigating the type and proportions of products offered for sale on *Evolution*, a popular darknet marketplace in 2014–2015. Then, this article studied the trafficking flows and geographical
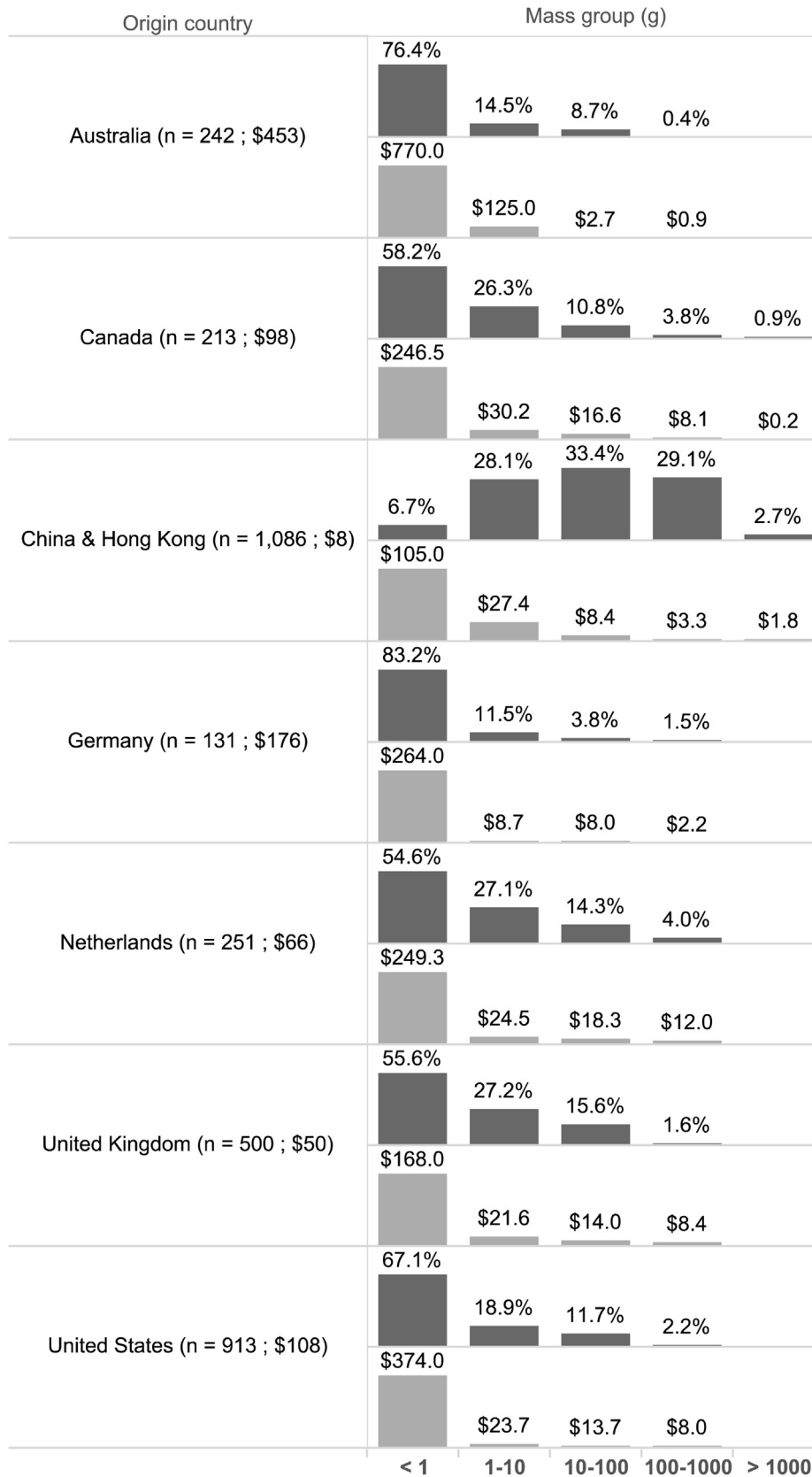
Fig. 9. Proportions of NPS listings (%) and median prices per gram (USD) according to the shipping country and the quantity proposed. The global median price per gram is mentioned into brackets along with the number of listings for each shipping country. Only the main shipping countries proposing NPS are represented.

specificities in the trafficking of the different types of products, in particular illicit drugs. Finally, NPS were especially studied to show how digital data can inform on the role of specific countries in the distribution chain of products.

The results illustrate that the trafficking on *Evolution* is mainly devoted to the trade of illicit drugs. These substances represent 46% of all listings and 57% of vendors offer for sale at least one product classified as illicit drugs. Nevertheless, a wide range of other illicit products or services are offered as well. In particular, sale proposals related to various fraud issues (carding, ID theft, counterfeit goods, etc.) represent almost a third of the total number of listings and close to half of vendors propose products classified in this category. The spatial analysis we performed showed that English-speaking countries (especially the United States but also the United Kingdom and Australia) and Western European countries (the Netherlands, Germany) dominate the market, which is in line with past and more recent studies carried out on other cryptomarkets [7,9,11,16,21]. The study of trafficking flows reveals the domestic (e.g. Australia) and international (e.g. the Netherlands, Germany and China) nature of the trade in some countries. The spatial analysis also shows the specialisation of vendors and which countries are at the forefront of the distribution of specific types of products. For instance, vendors from the Netherlands and Canada specialise in trafficking prescription and illicit drugs, Indian vendors in prescription drugs, Chinese vendors specialise in luxury goods and NPS, while vendors from the United States dominate in a wide range of product categories. The combination of our results and other sources of information shows that geographical trends in the trafficking of a specific type of illicit drugs tend to reflect the structure of the traditional market (e.g. prevalence data and role in the production of synthetic drugs). This may corroborate that sellers use cryptomarkets as a new distribution channel to sell all or part of their merchandise.

Nevertheless, the analysis of the number of vendors and sale proposals performed provides only information on the supply side of the market. To properly evaluate the role of countries on *Evolution*, as well as that of cryptomarkets in the distribution chain, it would be interesting to get an insight into the volume of sales of each country using the feedback left by past customers [2,7]. This would also better inform on the availability of products offered for sale [18]. Unfortunately, the way data on *Evolution* were collected did not make possible such analysis. The data collected online, and used by researchers to evaluate different aspects of the trade on crypto-markets – such as the vendor name, type of product, quantity, price, shipping country and destination(s) – are uncertain. Indeed, they depend on what the vendors state on their sale proposals and profiles. The only viable way to verify the accuracy of the online information is to purchase and evaluate a product [19,43]. However, incoherence between the stated online information and that of the physical product shipped by post could have a negative impact on the reputation of the seller and consequently on his revenue [9]. A previous study showed that sellers seem to describe accurately their sale proposals, in particular their origin country and products offered for sale [14]. Indeed, customers can easily verify the country of origin of the purchased product, when they received it by mail since it is stated on mail shipped internationally [9]. Thus, even if the possibility exists that sellers do not provide accurate information, it seems unlikely that they do so in regards to the shipping country and the products offered for sale [9,18,26]. In addition, the stated origin country tends to be accurate, as evidenced by studies based on *darknet* orders [19], seizures of postal parcels at the borders [44] and coherence between online information and knowledge regarding the offline market [9,10].

In conclusion, the analysis of cryptomarkets should be integrated in a more global approach that aims to improve the knowledge of illicit market structures and trafficking, which is in line with a forensic intelligence approach. Developing strategies to monitor Internet activities on cryptomarkets and on dedicated forums are powerful means to observe and detect global and specific trends for different categories of products on the illicit market. This research demonstrates the importance of analysing all the data available on a cryptomarket to inform on the structure (e.g. type and frequencies of products, number of vendors, shipping countries and destinations, etc.) and dynamics (e.g. trafficking flows, emerging substances, specific trends, etc.) of the trade as well as on the role of certain countries in the trafficking. In addition, our observations validate the hypothesis that the use of the shipping country statement truly inform on the origin of the products offered for sale. Performing a geographical analysis of trafficking on *darknet* marketplaces based on such statement can therefore be considered as appropriate. Since monitoring cryptomarkets may reveal country-specific trends, it could be seen as a new data source that would inform from a different perspective on the characteristics of the illicit market within the domestic context of particular countries. This would be particularly meaningful in the case of physical products such as (illicit) drugs. The knowledge obtained through this analysis could then be used at a tactical and operational level (e.g. to support specific operations) or at a strategic level (e.g. to obtain an understanding of the criminal activity) [45].

Appendix 1.

On *Evolution*, product categories are typically self-selected by vendors from an existing list when creating a sale proposal, which is a source of uncertainty. Indeed, category names administrators had chosen did not inform on the type of products that was actually proposed. For instance, most of the illicit drugs or medicines categories were not defined according to the chemical structure of the products but instead to their effects. Moreover, it was not rare that vendors misclassified their listings. Furthermore, categories that were defined by administrators were not necessarily coherent considering the diversity in the type of products they contained. Lastly, it was possible to merge in the same category several listings spread into different categories since they concerned the same type of fraud issue or illicit activity (see Figs. A1 and A2). Thus, sale proposals were semi-automatically classified according to a list of keywords that we defined after a thorough analysis of all the listing titles. The new classification was performed according to the type of products offered for sale or to the nature of the illicit activity involved and included three main categories, in particular "*Illicit drugs, drugs and paraphernalia*", "*Various fraud issues*" and "*Other*". In a few words, listings originally classified in "*Drugs*" were reorganised in a number of categories in "*Illicit drugs, drugs and paraphernalia*" according to the general type of licit or illicit drug or equipment offered. In particular, apart from the usual illicit drugs (e.g. cannabis, cocaine, opioids, ecstasy, LSD), the products known as new psychoactive substances (NPS) were distributed between three subcategories. The four major classes – phenethylamines, cathinones, piperazines and tryptamines [46] – were listed as "*NPS*". Their classification is based on the general chemical structure, shared by every substance of each category. Synthetic cannabinoids were classified separately since they may include herbal components and synthetic substances [47]. Substances not included in the two previous subcategories – due to a complex or anecdotal chemical characterization – were classified as "*NPS—Other*". It includes for example benzofurans (e.g. 5-APB, 6-EAPB) or aminoindane analogues (e.g. MDAI) (see Fig. A2). Ketamine was classified in "Other". In the "*Various fraud issues*" category, a significant proportion of the listings are part of the "*Fraud Related*" category. The latter mainly concerns listings on financial fraud and hacking services. In particular, most of the listings are related to *carding*. We also defined the "*Goods,*

Category 1	Category 2	Category 3
Drugs	-	
	Benzos	
	Cannabis	-
		Concentrates
		Edibles
		Hash
		Other
		Seeds
		Synthetic
		Weed
	Disassociatives	-
		GHB
		Ketamine
		MXE
		Other
	Dissociatives	-
		GBL
		GHB
		Ketamine
		MXE
		Other
	Ecstasy	-
		MDA
		MDMA
		Other
		Pills
	Opioids	-
		Heroin
		Opium
		Other
	Other	
	Paraphernalia	
	Prescription	-
		Analgesics
		General Health
		Other
		Relaxants
		Sildenafil Citrate
		Stimulants
	Psychedelics	-
		2C
		4
		5
		DMT
		LSD
		Mescaline
		Mushrooms
		NB
		Other
		Salvia
		Truffles
	RCs	
	Steroids	-
		Stimulants
	Stimulants	-
		Cocaine
		Meth
		Other
		Speed
		Steroids
	Weight Loss	

Category 1	Category 2	Category 3
Counterfeits	-	
	Accessories	
	Apparel	
	Money	
	Other	
Custom Listings		
Digital Goods	-	
	E	
	Other	
	Software	
Drug Paraphernalia		
Electronics	-	
	SIM Cards	
Erotica		
Fraud Related	-	
	Accounts	-
		Bank Logins
		Other
		Paypal
	CC & CVV	
	Documents & Data	
	Dumps	
Guides & Tutorials	-	
	Drugs	
	Fraud	
	Hacking	
	Other	
	Security	
Jewellery		
Lab Supplies		
Miscellaneous		
Services	-	
	Hacking	
	IDs & Passports	
	Other	
	Paypal	
Weapons	-	
	Ammunition	
	Explosives	
	Guns	
	Melee	
	Other	

Fig. A1. Categories of products as created by administrators of *Evolution*.

currencies and precious metals" category, which especially contains "*Luxury goods*" (mostly watches followed by jewellery and perfumes) and "*Clothes and accessories*" (mainly glasses, shirts, jackets and bags). These two categories contain products with a high probability of forgeries, as will be discussed below. The "*Various fraud issues*" also includes sale proposals about material

ILLICIT DRUGS, DRUGS AND PARAPHERNALIA

Category 1	Category 2	Category 3
Illicit drugs	ATS	Amphetamine
		MDA
		Methamphetamine
	Cannabis	Cannabis concentrates
		Edibles & seeds
		Hashish
		Marijuana
	Cocaine	
	Ecstasy & MDMA	Ecstasy
		MDMA
		Other
	LSD and derivatives	
	NPS	Cathinones
		Opioids
		Phenethylamines
		Piperazines
		Tryptamines
	NPS - Other	
	NPS - Synthetic cannabinoid	
	Opioids	Heroin
		Opium
	Other	GHB and GBL
		Mushrooms
		Other
Lab supplies & Paraphernalia	Bags	
	Chemicals and others	
	Cutting agent	
	Electronics	
	Miscellaneous	
	Paraphernalia	
	Press machine	
	Other	
Performance and Image Enhancing Drugs		
Prescription drugs and medicines	Benzodiazepine	
	Codeine and methadone	
	Erectile dysfunction drugs	
	Miscellaneous	
	Morphine derivatives	
	Stimulants	
	Synthetic opioid	

VARIOUS FRAUD ISSUES

Category 1	Category 2	Category 3
Firearms & Weapons	Ammunition	
	Explosives	
	Guns	
	Melee	
	Other	
Fraud Related	Carding	Account (Bank, Paypal, Amazon)
		CC & CVV
		List
		Money laundering
		Shipping service
		Other
	Erotica	
	Hacking	Informatic
		Other
Goods, currencies and precious metals	Clothes & Accessories	Bag
		Belt
		Glasses
		Jacket
		Jeans
		Scarf
		Shirt
		Shoes
		Wallet
		Other
	Currencies	
	Electronic devices	
	Luxury goods	Jewellery
		Perfumes
		Watches
	Precious metals	Gold
		Silver
Guides & Tutorials	Illicit drugs	
	Fraud Related	
	ID Related	
	Firearms & Weapons	
	Other	
ID Related	ID	ID pack
		Other
	Identity theft	Account
		Fullz
		Other
	Various licenses and legitimation documents	Diplomas & Certificates
		License
		Report
		SSN
		Statements
		Other

OTHER

Category 1	Category 2	Category 3
Custom listings		
Miscellaneous	Alcohol	
	Service	Fraud Related
		Other
	Other	

Fig. A2. Classification of sale proposals performed by the authors.

related to identity theft such as false or stolen ID documents as well as data related to identity ("*ID Related*"). Moreover, a variety of electronic documents explaining how to perform some hacking or fraud related activities were listed as "*Guides & Tutorials*". To a lesser extent, a number of sale proposals concern "*Firearms & Weapons*", which is essentially constituted by the original "*Weapons*" category. Lastly, customers may request a specific listing from a vendor through private messaging [11]. A listing specifically designed for the customer will then be created, without necessarily stating the concerned product. They were classified in the "*Custom listings*" category if their title did not include any relevant keyword that may be used for classification in one aforementioned category (see Fig. A2).

Appendix 2.

Table B1
Shipping countries and destinations mentioned by vendors.

Information	Occurrence	Countries and regions mentioned
Shipping country	93	Afghanistan, Albania, Andorra, Argentina, Aruba, Australia, Austria, Azerbaijan, Bangladesh, Belgium, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cambodia, Canada, Cayman Islands, Central African Republic, Chile, China, Christmas Island, Colombia, Czech Republic, Denmark, Dominican Republic, Egypt, El Salvador, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guernsey, Hong Kong SAR China, Hungary, India, Ireland, Italy, Jamaica, Kenya, Latvia, Libya, Lithuania, Luxembourg, Malaysia, Mexico, Netherlands, Netherlands Antilles, New Zealand, North Korea, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Saint Kitts and Nevis, Sao Tome and Principe, Saudi Arabia, Serbia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Svalbard and Jan Mayen, Swaziland, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Timor-Leste, Togo, Uganda, Ukraine, United Kingdom, United States, Uruguay, Western Sahara, Worldwide, Yemen, Zimbabwe.
Shipping destination	164	Afghanistan, Albania, Algeria, American Samoa, Andorra, Angola, Anguilla, Antarctica, Antigua and Barbuda, Argentina, Armenia, Aruba, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Bouvet Island, Brazil, Brunei, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Canton and Enderbury Islands, Cape Verde, Cayman Islands, Central African Republic, Chad, Chile, China, Christmas Island, Cocos [Keeling] Islands, Colombia, Comoros, Congo—Brazzaville, Congo—Kinshasa, Cook Islands, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Dronning Maud Land, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Falkland Islands, Faroe Islands, Fiji, Finland, France, French Guiana, French Polynesia, Gabon, Gambia, Georgia, Germany, Ghana, Gibraltar, Greece, Greenland, Grenada, Guadeloupe, Guam, Guatemala, Guernsey, Hong Kong SAR China, Hungary, Iceland, India, Indonesia, Ireland, Isle of Man, Israel, Italy, Japan, Latvia, Lebanon, Lesotho, Liechtenstein, Lithuania, Luxembourg, Macau SAR China, Macedonia, Madagascar, Malaysia, Malta, Mauritius, Metropolitan France, Mexico, Moldova, Monaco, Montenegro, Morocco, Netherlands, Netherlands Antilles, New Zealand, North Korea, Norway, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Romania, Russia, Saint Lucia, San Marino, Sao Tome and Principe, Senegal, Serbia, Serbia and Montenegro, Singapore, Slovakia, Slovenia, Somalia, South Africa, South Korea, Spain, Sri Lanka, Svalbard and Jan Mayen, Swaziland, Sweden, Switzerland, Taiwan, Thailand, Trinidad and Tobago, Tunisia, Turkey, Tuvalu, Ukraine, United Kingdom, United States, Uruguay, Vatican City, Venezuela, Vietnam, Worldwide, Zimbabwe.

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