Crime, Law and Social Change
https://doi.org/10.1007/s10611-023-10106-w

Online and offline determinants of drug trafficking across countries via cryptomarkets

Luca Giommoni[1] · David Décary-Hétu[2] · Giulia Berlusconi[3] · Andréanne Bergeron[2]

Accepted: 21 June 2023

Abstract
Drug cryptomarkets are a significant development in the recent history of illicit drug markets. Dealers and buyers can now finalize transactions with people they have never met, who could be located anywhere across the globe. What factors shape the geography of international drug trafficking via these cryptomarkets? In our current study, we test the determinants of drug trafficking through cryptomarkets by using a mix of social network analysis and a new dataset composed of self-reported transactions. Our findings contribute to existing research by demonstrating that a country's level of technological advancement increases the probability of forming trafficking connections on cryptomarkets. Additionally, we found that a country's capacity to police cryptomarkets reduces the number of trafficking connections with other countries. We also observed that trafficking on cryptomarkets is more likely to occur between countries that are geographically close. In summary, our study highlights the need to consider both online and offline factors in research on cryptomarkets.

Keywords Drug cryptomarkets · Social network analysis · Drug trafficking · Cybercrime

Introduction

Silk Road's inception in February 2011 ushered in a novel era in illicit drug transactions. In the past, individuals who sought illicit drugs had to meet dealers in person to finalize transactions. Cryptomarkets, however, heralded a shift in this convention.

✉ Luca Giommoni
giommonil@cardiff.ac.uk

[1] School of Social Sciences, Cardiff University, Glamorgan Building, King Edward VII Avenue, Cardiff CF10 3WT, UK

[2] School of Criminology, Université de Montréal, Montréal, Québec, Canada

[3] Department of Sociology, University of Surrey, Guildford, UK

Published online: 02 July 2023

These anonymous online markets, accessible exclusively via the darknet (Aldridge, 2019), enabled the purchase of both illicit drugs and other commodities, licit or not, without requiring personal contact with transaction partners. As a result, drug dealers could extend their businesses, dealing with people unknown to them and receiving anonymous cryptocurrency payments (Ouellet et al., 2022).

This shift in drug dealing paradigms posed significant challenges to law enforcement authorities, given cryptomarkets' potential to reshape the structure and scale of drug trafficking. Ordinarily, illicit drugs traverse multiple international borders before reaching their final consumers. Cryptomarkets, on the contrary, provide the means to streamline supply chains by sourcing directly from drug-producing countries, bypassing intermediaries. This model has the potential to boost the global reach of drug traffickers and heighten their profits.

However, current evidence suggests that cryptomarkets haven't significantly disrupted traditional drug trafficking routes. Most cryptomarket vendors operate from consumer countries like the United Kingdom, EU countries, USA, Canada, and Australia. This pattern extends to buyers and revenue as well. Only a handful of transactions occur directly between producer countries, such as Afghanistan for heroin and Colombia for cocaine, and destination or consumer countries (Kruithof et al., 2016). Furthermore, cryptomarkets represent only a small fraction of the overall illicit drug market (Kruithof et al., 2016).

Despite some understanding of the geographic dispersion of cryptomarkets, the driving forces behind international trafficking on these platforms remain unclear. What factors influence a participant's decision to buy from or sell to another country on cryptomarkets? And more broadly, what shapes the geography of international drug trafficking via cryptomarkets?

This article will attempt to answer these questions through social network analysis techniques and a new dataset of self-reported cryptomarket transactions. It aims to contribute to existing literature by: (1) exploring the impact of both offline (like geographic distance) and online variables (like technological development) on trafficking between countries on cryptomarkets, and (2) proposing that a country's ability to regulate cryptomarkets can dissuade the establishment of online drug trafficking channels.

In the following sections, we will delve into relevant literature, formulate and test hypotheses assessing the relative influence of offline and online factors on drug trafficking via cryptomarkets. We will then introduce our novel crowdsourcing methodology and proceed to discuss the results. Our findings imply that countries involved in drug trafficking are not randomly connected; local factors indeed affect the movement of drugs from one country to another via cryptomarkets.

Online drug trafficking flows

Cryptomarkets, accessible solely via the darknet, are anonymous online marketplaces (Aldridge & Décary-Hétu, 2014). Ross Ulbricht inaugurated the first such market in 2011, driven by a libertarian ethos. He envisaged these cryptomarkets as open platforms for vendors to list their products and services (Barratt, 2012). Buyers could browse these listings, select their preferred product, and place an order. Transactions were conducted in bitcoin, and all connections were protected by the darknet, ensuring the anonymity of all parties (Martin et al., 2020).

Given the intensely competitive nature of cryptomarkets, vendors are required to disclose substantial information as part of their business. With few discernible differences between vendors selling similar products like cocaine (EMCDDA, 2023), they share information regarding their location, experience, and the quality of their products and services. Conversely, buyers on cryptomarkets have minimal incentives to reveal personal information as it would compromise their anonymity.

Initially, cryptomarkets were heralded as revolutionary criminal innovations (Aldridge & Décary-Hétu, 2014), posing a potential threat to traditional illicit drug markets (Barratt, 2012; Martin, 2014). For the first time, drug buyers could order any drug of their choice whenever they wished (Barratt et al., 2016a). This suggested a shift in the international illicit drug trafficking network, bridging the gap between buyers and producers.

However, the first analysis of a cryptomarket by Christin (2013) challenged this theory. He found that the most active countries distributing illicit drugs on cryptomarkets, namely the United States, the United Kingdom, the Netherlands, Canada, and Germany, were more commonly known as consumer or transit countries rather than producers (UNODC, 2021). Consistently, these countries, along with Australia and other European nations, have been reported as the principal origins of all illicit drugs sold on cryptomarkets (Demant et al., 2018; Kruithof et al., 2016; Munksgaard et al., 2021). In many instances, cryptomarkets act as the final link in the distribution chain of illicit drugs (Duxbury & Haynie, 2018). Thus, drug traffickers typically import illicit drugs in bulk before redistributing them to buyers via cryptomarkets.

Norbutas' study (2018) supports this, revealing that cryptomarket buyers often purchase from multiple vendors within their own country. In the case of international transactions, buyers usually prefer vendors from the same continent. Demant et al. (2018) drew similar conclusions, noting a propensity for national purchases over international ones.

Risk factors potentially explain this behavior. Décary-Hétu et al. (2016) found international drug shipments to be riskier, and a vendor's circumstances significantly influenced their decision to operate internationally. Factors such as the volume of drugs sold, perceived law enforcement efficiency, and national demand could determine a vendor's willingness to risk exporting illicit drugs via cryptomarkets. For example, vendors in countries with stringent border law enforcement like Finland, Australia, the United States, and Canada are often reluctant to ship internationally (Kruithof et al., 2016). However, the origin of the drugs could also affect their online sales. Countries like Germany, Canada, and the Netherlands, known for producing synthetic drugs like ecstasy, MDMA, and amphetamines (UNODC, 2022; EMCDDA, 2023), seem to favor international exports over domestic sales (Broséus et al., 2017).

Over the past decade, several studies have investigated international drug trafficking, its structure, and the various factors shaping offline trafficking routes. For instance, Boivin (2014a) determined that drug trafficking typically follows specific routes and countries usually have a limited number of trading partners. Meanwhile, Chandra et al. (2011) discovered different countries playing key roles in the distribution of cocaine and heroin in Europe. This reflects the multifaceted nature of illicit drug markets and their ability to adapt to internal and external shocks. Utilizing various network techniques, Giommoni et al. (2017) found that geographical proximity and intense migration flows increased the likelihood of drug exchanges between countries. Interestingly, the risk of interception and arrest did not deter traffickers from exporting illicit drugs.

Our understanding of the factors influencing international drug trafficking via cryptomarkets remains limited. Previous research largely focuses on the concentration of sales, sellers, or buyers within countries instead of cross-border trafficking (Broséus et al., 2017; Christin, 2013; Demant et al., 2018; Dittus et al., 2018; Kruithof et al., 2016; Morelato et al., 2018; Soska & Christin, 2015). This methodology can highlight active countries within the cryptomarket ecosystem but provides little insight into why some countries export to or import from others. Cryptomarket data also tend to be inadequate for tracking trafficking flows (Broséus et al., 2017; Dittus et al., 2018; Morelato et al., 2018), with nearly 40% of sellers claiming to ship 'worldwide,' which hampers precise mapping of trafficking routes (Broséus et al., 2017).

Moreover, the majority of these studies are descriptive, offering limited explanation of the various factors shaping trafficking routes on cryptomarkets (Broséus et al., 2017; Christin, 2013; Demant et al., 2018; Dittus et al., 2018; Kruithof et al., 2016; Morelato et al., 2018; Soska & Christin, 2015). An exception is Norbutas' study (2018), which explored the structure of the now-defunct cryptomarket Abraxas, highlighting the geographic constraints of drug transactions. However, his analysis, conducted seven years ago, focused solely on geographic distance and neglected other influential factors. The unanswered questions include whether countries with more advanced communication and information infrastructures are more likely to engage in international drug trafficking on cryptomarkets, or whether the level of cryptomarket law enforcement deters international trading. In general, what online factors, besides geographic distance, impact the formation of drug trafficking routes on cryptomarkets? These queries remain largely unaddressed and require further empirical exploration.

The current study

In this study, we aim to examine the factors influencing drug trafficking via cryptomarkets. This constitutes the first investigation into how both online and offline elements shape drug trafficking routes via these cryptomarkets. Although previous research identified geography as a significant determinant of drug trafficking (Broséus et al., 2017; Demant et al., 2018; Dittus et al., 2018; Norbutas, 2018), the role of online and offline factors in creating drug trafficking links between nations has not yet been explored. From previous research, we formulate the following hypotheses:

Hypothesis 1[H1]: A country's technological advancement level has a positive correlation with the formation of drug trafficking routes via cryptomarkets.

Cryptomarkets do not operate in isolation. They require specific technological infrastructures (Martin, 2014). Participants need access to a reliable internet connection and bitcoins for drug transactions (Aldridge & Décary-Hétu, 2016a). Furthermore, they need resources to acquire the knowledge needed to operate efficiently on cryptomarkets. While some countries have these resources readily available, others do not. We hypothesize that countries with a more developed digital infrastructure – an online factor – are more likely to innovate in their drug trafficking and form drug trafficking connections with other nations. A country with a significant role in offline trafficking might have strong economic incentives to join cryptomarkets but might struggle to access them if high-speed connections and cryptocurrencies are scarce. Conversely, countries with highly developed technological infrastructures might easily participate in drug trafficking via cryptomarkets, even with a minimal economic return. Previous studies have demonstrated the positive impact of internet penetration on innovation development (Xiong et al., 2022) and international tourism expenditures (Lorente-Bayona et al., 2021). We anticipate the same for online drug trafficking.

Hypothesis 2[H2]: The farther two countries are from each other, the less likely they are to trade drugs on cryptomarkets.

The influence of geographic distance on legitimate and illicit trade is well-documented (Caulkins & Bond, 2012; Disdier & Head, 2008; Paoli & Reuter, 2008; Reuter, 2014). Distance augments transportation costs and the risk of interception and arrest. Although cryptomarkets primarily operate online, geographic distance – an offline factor – also affects them for similar reasons. Norbutas (2018, p. 98) concluded in his analysis of the cryptomarket Abraxas that "buyers might be more willing to order domestically to avoid increased risks of package interception, potential arrest, and long shipping times." We, therefore, anticipate that geographic proximity plays a role in establishing drug trafficking routes via cryptomarkets.

Hypothesis 3[H3]: Sharing a common language increases the likelihood that two countries will trade drugs via cryptomarkets.

Language – an offline factor – can aid drug trafficking in two ways. Firstly, cultural affinity – such as speaking the same language – has been shown to reduce uncertainties by providing non-economic factors for buyers and sellers to trust each other. This principle applies to legal goods (Prashantham et al., 2015; Rauch & Trindade, 2002; Sgrignoli et al., 2015), and even more so to drug markets, where participants cannot rely on legal authorities to enforce agreements and are perpetually at risk of arrest (Paoli, 2002). Thus, language diminishes uncertainties between the two parties of a deal (Combes et al., 2005; Kleemans & Van de Bunt, 1999; Paoli & Reuter, 2008). Secondly, buyers and sellers must be able to read and write in the same language to understand the terms of a deal. For example, all other factors being equal, the USA is more likely to trade with the UK than with Brazil, given the larger English-speaking population in the former.

Hypothesis 4[H4]: A country's ability to police cryptomarkets negatively correlates with the formation of drug trafficking routes.

In theory, the primary costs for drug dealers are those imposed by enforcement authorities, such as arrest, imprisonment, seizures, and confiscation (Caulkins & Reuter, 2010; Kuziemko & Levitt, 2004; Reuter & Kleiman, 1986). The higher the level of enforcement in a country, the less appealing it becomes to cryptomarket participants, as this increases their punishment risk. Although various theories suggest this, evidence shows that the intensity of enforcement – an offline factor – does not impact the formation of trafficking routes (Berlusconi et al., 2017; Boivin, 2014b; Giommoni et al., 2017). Previous research found that perceived law enforcement effectiveness reduces international shipping of listings (Décary-Hétu et al., 2016). Effective law enforcement tactics might increase border inspections and disrupt the delivery of drugs purchased online. Therefore, we assume that enforcement and control levels can deter participants from trafficking drugs internationally on cryptomarkets due to the multi-faceted and somewhat disruptive nature of police operations against cryptomarkets (Décary-Hétu & Giommoni, 2017; Martin et al., 2020; Soska & Christin, 2015). A cybercrime report by Chainalysis (2021) suggests that, except for Russia, cryptomarkets have indeed experienced some disruption, as their size and scope have not significantly increased since 2018.

Methodology

Data

The data for this study were sourced from the crowd-sourcing project DrugRoutes, which we launched online on January 1, 2020. DrugRoutes was an online platform that gathered transaction data directly from individuals who had bought or sold drugs on cryptomarkets. The website, accessible via the clear web or the darknet, allowed users to anonymously share information regarding their latest cryptomarket transactions. The data gathered included the specific type of illicit drug involved, the quantity traded, the transaction amount, the transaction date, the countries of origin and destination, and confirmation of parcel receipt. To encourage participation, DrugRoutes openly shared the collected data, enabling cryptomarket users to identify the most popular routes. Consistent with previous studies (Barratt et al., 2016b; Martin et al., 2019), our methodology aimed to create a safe space for cryptomarket participants to contribute information for research purposes.

Every submission to the project underwent moderation by the authors to filter out potential spam. Submissions deemed too deviant from the prevalent cryptomarket prices per unit at the time were labeled as spam and excluded from the dataset. The research team cross-referenced the price per unit from multiple listings on several cryptomarkets and calculated an average. A transaction price from the same origin country that deviated more than one standard deviation from the mean was regarded as spam and removed from the dataset. We also removed multiple submissions made within seconds of each other as potential spam. While DrugRoutes was one of the few crowd-sourcing initiatives collecting information on illicit drug transactions (for example, see Government of Canada, 2022), it stands out as the only one incorporating successful delivery of illicit drugs. The research team advertised the crowd-sourcing platform on approximately 140 darkweb platforms, and the consent form and contact information were readily available on the website.

In total, we collected 1,364 submissions between 2020 and 2022, all of which were confirmed to be authentic and genuine. Below, we present some descriptive statistics to demonstrate the nature and characteristics of the collected sample. Figure 1 highlights the top fifteen buyer countries, while Fig. 2 displays the percentage of international transactions for these same countries. In line with several other studies, the United States is the primary buyer country (Aldridge & Décary-Hétu, 2014; Christin, 2013; Soska & Christin, 2015), followed by three European nations (Germany, France, and the United Kingdom), and then Canada and Australia. Figure 2 complements Fig. 1 by indicating which countries are more open to sourcing drugs internationally and which prefer to make purchases within national borders. Turkey, India, and Belgium concentrate most of their purchases internationally, while Russia, the USA, and Canada mainly fulfill their online drug demands domestically.

Figure 3 broadens the scope of what we observed for the top buying countries, offering insight into the most prominent selling countries. Firstly, there are noteworthy differences between the two lists. Although the United States tops both rankings, several countries featured in Fig. 1 are absent from Fig. 3, including the Netherlands, Mexico, Colombia, and Afghanistan. Figure 4 can assist us in understanding the roles these countries play in international trafficking via cryptomarkets. Countries like the United States, Australia, Italy, and Russia primarily cater to domestic markets, whereas the Netherlands, Mexico, Colombia, and Afghanistan focus at least 75% of their sales on international transactions. This

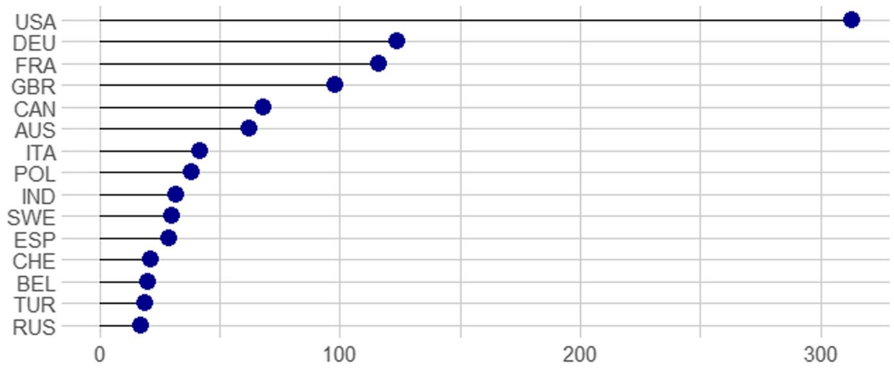

Fig. 1 Top 15 buyer countries. National and international transactions

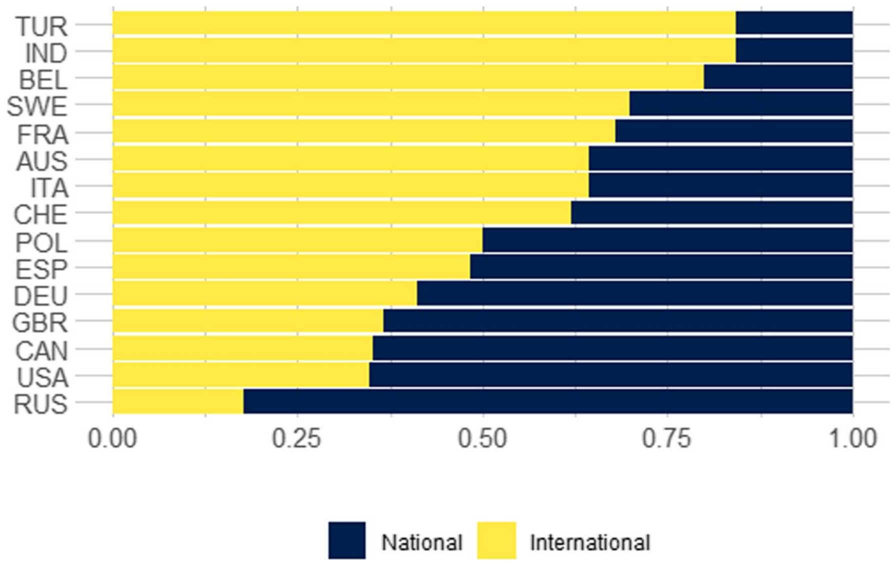

Fig. 2 National V International transactions for the top 15 buyer countries (%)

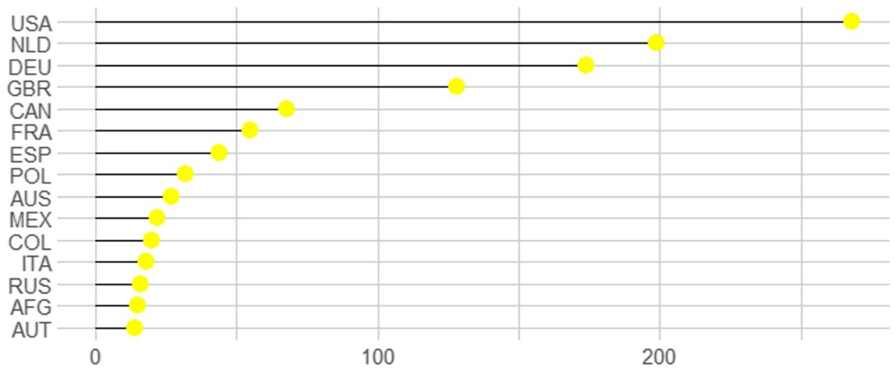

Fig. 3 Top 15 seller countries. National and international transactions

corroborates literature on offline drug trafficking that designates these countries as either producers (Afghanistan and Colombia) or transit points before drugs reach their final destinations (UNODC, 2021).

As this paper is exclusively concerned with international transactions, the subsequent analyses will omit data that pertain strictly to domestic trade. Table 1 presents the total number of international transactions recorded on DrugRoutes, differentiated by substance type. Cannabis is the most traded drug, accounting for over a quarter of transactions, followed by cocaine and LSD. MDMA and amphetamines constitute 8% and 6% of all transactions, respectively. Notably, the

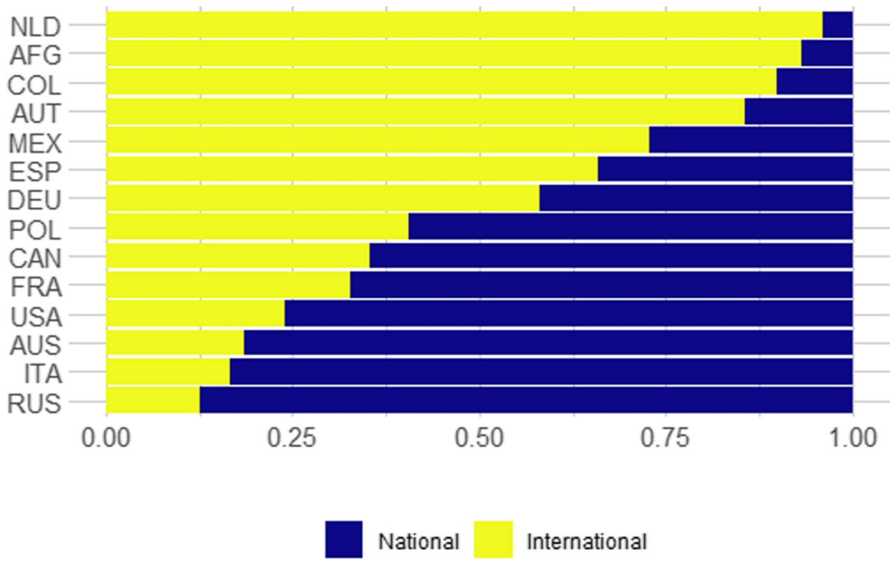

Fig. 4 National V International transactions for the top 15 seller countries (%)

Table 1 International transactions per type of drugs in DrugRoutes

Drug	Count	%	Cumulative %
Cannabis	207	28%	28%
Cocaine	146	20%	48%
LSD	63	9%	57%
MDMA	56	8%	65%
Amphetamine	41	6%	70%
Others	41	6%	76%
Methamphetamine	36	5%	81%
Ecstasy	31	4%	85%
Heroin & other opioids	30	4%	89%
Hallucinogens	26	4%	93%
Prescription drugs	24	3%	96%
Benzodiazepines	20	3%	99%
Ketamine	10	1%	100%
Total	731	100%	100%

five most popular substances account for 70% of all transactions, with the remaining nine substances representing the remaining 30%. This distribution aligns with previous research based on the analysis of cryptomarket webometrics (Aldridge & Décary-Hétu, 2014), lending credence to the reliability of our data in mapping online drug trafficking routes.

Dependent variable

This study views drug trafficking on cryptomarkets as a network of relationships between countries. This perspective aligns with previous literature analyzing drug trafficking across nations (Aziani et al., 2021; Bichler & Jimenez, 2022; Boivin, 2014b), and recent studies investigating the geographic structure of drug trafficking on cryptomarkets (Broséus et al., 2017; Norbutas, 2018).

We utilize data from DrugRoutes to identify relationships between countries. DrugRoutes solicited information from cryptomarket participants about their home country and the country with which they most recently transacted. Consequently, we establish a link from Germany to Spain if a participant based in Germany reports purchasing drugs from a dealer in Spain, or if a Spanish drug dealer declares having shipped drugs to Germany. Using this method, we identified a total of 731 different transactions involving 372 dyads across 42 pairs of countries.

The network of drugs trafficked via cryptomarkets is characterized by two distinctive features. First, we only consider a connection if at least two submissions are reported for a pair of countries. For example, we dismissed the connection between Albania and Ireland since we have only one observation following this route. These connections are more likely to be random or sporadic links between countries and, therefore, are not included in our analysis. The final network is predicated on a total of 100 exchanges between any two countries.

Secondly, we do not differentiate between substances. For example, a connection between Spain and Germany for cannabis is regarded in the same way as a connection between France and Germany for cocaine. Given that we have only a few transactions for most substances, creating individual networks for each illicit drug type would result in very small networks. As a result, we opted to group all drug types together to avoid information loss. More crucially, we anticipate the independent variables to exert a similar effect on cryptomarket transactions, irrespective of the drug type. This approach also enables us to compare our findings to previous studies that do not differentiate between substances (Broséus et al., 2017; Morelato et al., 2018; Norbutas, 2018).

Independent variables

This study employs both nodal and relational attributes data to decipher the factors that influence the geographic arrangement of drug trafficking through cryptomarkets. Nodal attributes represent unique characteristics of the countries comprising the network, such as a country's gross domestic product (GDP) per capita or its population size. On the other hand, relational attributes provide insights about the connections between any two countries within the network, like the distance between Spain and Germany. Table 2 presents all variables used in this analysis, detailing the source, reference period, the nature of the variable (i.e., nodal or relational attribute), and relevant descriptive statistics.

Table 2 Independent variables

Nodal attribute	Source	Dimension	Period	Min	Max	Mean	St. Dev
Information and Communication Development (ICT) index	International Telecommunications Union (ITU) of the United Nations	Information Technology Infrastructure	2017	1.95	8.74	6.77	1.76
Global Cybersecurity Index	International Telecommunications Union (ITU) of the United Nations	Enforcement of cryptomarkets	2020	5.20	100	83.07	23.73
Relational attributes	Source		Period	Network size	Edge count	Density	Mean
Geographic distance (1,000 km)	CEPII	Geographical Proximity	NA	42	1722	-	6.31
Language spoken by at least 9% of the population	CEPII	Social proximity	2000–2008	42	208	0.24	-

We utilized the Information and Communication Development (ICT) index as a country-level indicator of technological progress to verify our initial hypothesis. This empirically derived index comprises three weighted sub-indices (infrastructure access, intensity, skills) and facilitates cross-national comparisons (ITU, 2020).

We examined the impact of geographic proximity (*H2*) and social proximity (*H3*) using two matrices; one calculating the geographic distance between countries, and another evaluating the prevalence of a language spoken by a minimum of 9% of the population in any pair of countries. Both variables were sourced from the Centre d'Études Prospectives et d'Informations Internationales (CEPII) and have been previously employed in several studies to measure social and geographic proximity (Favarin & Aziani, 2020; Giommoni et al., 2017).

We operationalized a country's capacity to olice cryptomarkets (*H4*) using the Global Cybersecurity Index (GCI) developed by the International Telecommunications Union (ITU) of the United Nations. The GCI assesses each country's developmental stage in five areas: legal measures, technical measures, organizational measures, capacity development, and cooperation. Our decision to use this index was motivated by three factors. First, since cryptomarkets operate online, it seemed logical to employ a variable examining a country's online resilience, rather than conventional offline law enforcement metrics (e.g., number of police forces or arrests). Many interventions against cryptomarkets involve specialized cybercrime policing units such as the Netherlands National High Tech Crime Unit or the Dark Web Intelligence, Collection, and Exploitation team within the British National Crime Agency. Second, proxies indicating the level of enforcement across countries are notoriously deficient and lack comparability (Aebi & Linde, 2015; Kilmer et al., 2015). Third, several countries examined in this analysis neither collect nor report any data related to cybercrime.

Method

Exponential Random Graph Models (ERGMs) were employed to ascertain the factors influencing the geographic arrangement of drug trafficking through cryptomarkets. ERGMs comprise a category of statistical models applicable to relational data, evaluating the likelihood of a connection between two countries in the network based on the individual country attributes (e.g., their ICT index) and attributes of country pairs (e.g., geographical distance between two countries). Unlike traditional statistical models, ERGMs don't assume observation independence, thereby allowing for testing or controlling network attributes such as the propensity towards centralization (Lusher et al., 2013; Robins et al., 2007).

Besides the independent variables previously discussed, one of the models incorporates two controls to compensate for outdegree centralization and reciprocity. The latter accounts for the likelihood of reciprocal connections between any two given countries, while we employed the GWODEGREE parameter to control for a country's probability of establishing a new outgoing tie based on the number of existing ties with other countries (Hunter, 2007). All network analyses were conducted utilizing the Statnet suite of packages for R (Butts, 2008; Handcock et al., 2018; R Core Team, 2021). The model encompassing parameters for centralization and reciprocity employed Markov Chain Monte Carlo simulation methods to approximate the maximum likelihood (Hunter et al., 2008). Appendix 2 features goodness-of-fit plots that compare observed networks with simulated ones, evaluating the overall fit of the models discussed in the "Results" section below.

Ethics

This study was approved by the Social Science Research Ethics Committee at Cardiff University (SREC/3197), underscoring our commitment to ethical considerations. The research was guided by two fundamental principles: (1) the process of data collection and analysis should not expose any party involved to potential harm, and (2) no personally identifying information would be collected or disclosed at any stage of the research. Although DrugRoutes was accessible on both the clear and dark web, we did not gather any sensitive data such as IP addresses or geolocation of submissions. It's also crucial to clarify that while the platform disseminated information about prevalent drug trafficking routes on the dark web, it didn't indicate the routes least likely to be intercepted. Our objective was to illuminate the operations of cryptomarkets, not to furnish guidance on successful strategies for online drug trafficking.

Results

Table 3 provides descriptive statistics of the drug trafficking network through cryptomarkets, with Fig. 5 offering a visual depiction of the network. Comprising 42 countries and 100 links, the network represents close to 6% of all possible links. This observation aligns well with prior studies indicating that offline drug trafficking has a low density and tends to concentrate along specific routes (Boivin, 2013, 2014a; Giommoni et al., 2017).

Despite the sparse density, countries usually obtain illicit drugs from multiple sources, as on average, each country imports from more than two nations and conducts trade with nearly five countries. However, the number of connections is not evenly distributed, as demonstrated in Fig. 6. While most countries export to one or a few countries, a handful export to numerous others. This suggests that, akin to

Table 3 Network statistics

Measures	Statistics
Size	42
Edge count	100
Density	0.06
Mean Degree	4.76
Mean In-degree	2.38
In-degree Centralization	0.36
Out-degree Centralization	0.49
Reciprocity	0.26

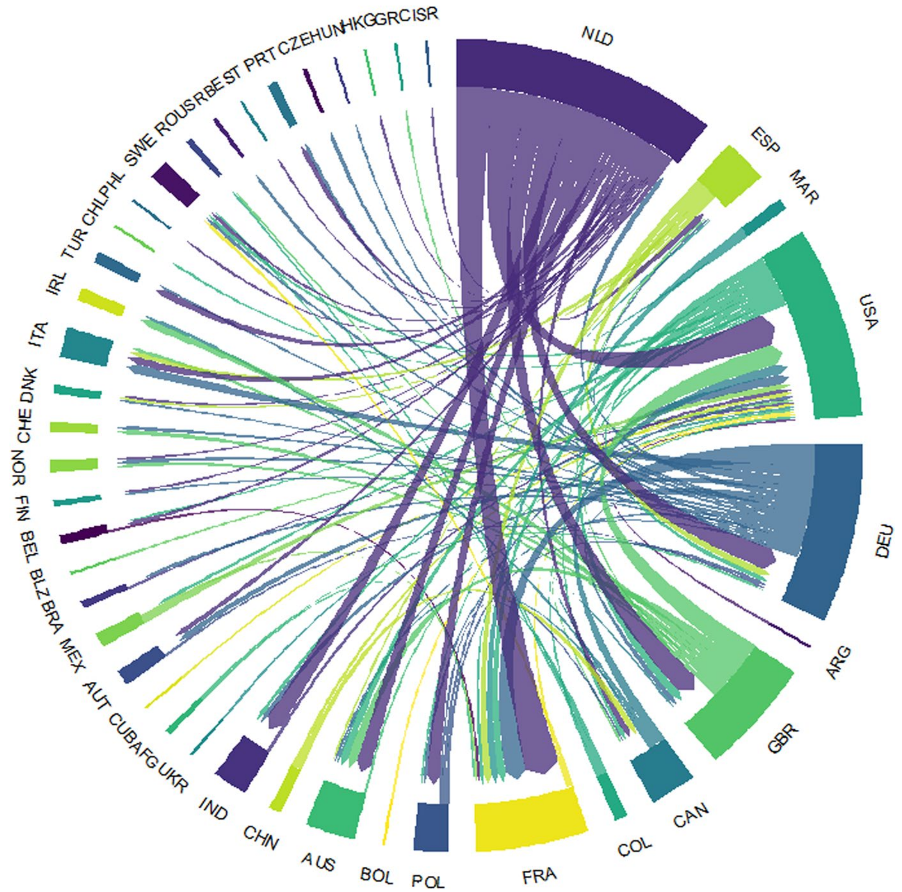

Fig. 5 Trafficking network via cryptomarkets

offline drug trafficking, some countries play a central role in trafficking via cryptomarkets. Germany (20), the Netherlands (20), and the USA (15) stand out due to the number of outgoing ties with other countries. This is not entirely unexpected – prior studies have revealed that the USA dominates cryptomarket transactions (Aldridge & Décary-Hétu, 2016b; Christin, 2013), while Germany and the Netherlands are known for their key roles as redistribution centers for heroin, cocaine, and cannabis within Europe (Aziani et al., 2021; Lahaie et al., 2015; Paoli & Reuter, 2008).

The distribution of incoming ties is more evenly spread than that of outgoing ties (in-degree centralisation stands at 0.36, while out-degree centralisation is at 0.49), with forty-one countries having between zero and nine connections. With seventeen incoming ties, the USA emerges as a clear outlier. This can be explained by both online and offline factors. Firstly, as noted earlier, the USA accounts for a significant majority of illicit drug transactions on cryptomarkets. Secondly, with a population exceeding 300 million, it is one of the world's primary consumer markets for illicit drugs.

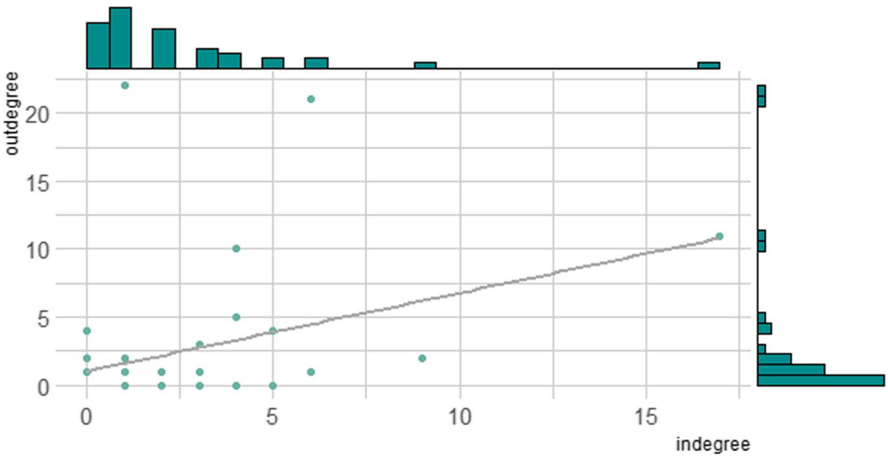

Fig. 6 Scatterplot between indegree and outdegree along with their distribution

Reciprocity offers further valuable insights into the network. It reveals that 26% of connections are reciprocated, meaning that in a quarter of the cases, Country A imports from Country B, and conversely, Country B imports from Country A. This feature characterises drug trafficking via cryptomarkets, a phenomenon less common in offline drug markets. Offline trafficking generally follows a single direction - for instance, the UK imports from the Netherlands, but the Netherlands does not reciprocate. However, this dynamic occurs within cryptomarkets, albeit on a small scale. Cryptomarkets can broaden geographic and informal networks by offering alternative paths to traditional routes. For example, even though illicit drugs usually move from the Netherlands to the UK, Dutch-based buyers might find a better deal in the UK. It's also possible that reciprocity is an artifact of the drugs traded on cryptomarkets. As most transactions involve cannabis, which is produced in almost every country, drug trafficking is less tied to a single direction and more open to reciprocal exchanges.

Table 4 details the estimates and standard errors from ERGMs of drug trafficking via cryptomarkets. Model 1 includes all variables operationalising our four hypotheses. Most of these variables are significantly associated with the dependent variable, and their direction aligns with our predictions. The exceptions are the ICT index for exporter countries and common language. While the ICT index standard errors are relatively small and close to the significance threshold of 0.05, the standard errors for common language are considerably larger.

Model 2 is the final model, incorporating structural effects to manage the impact of exporters and mutual connections. This model reveals that social proximity, defined by the existence of a language spoken by at least 9% of the population in any pair of countries, is significantly associated with traditional trafficking but doesn't explain cryptomarket trafficking. Two reasons can account for this variance.

First, cryptomarkets replace social proximity with a collection of deliberately crafted mechanisms aimed at fostering trust among participants (Martin et al., 2019; Munksgaard, 2021). The question of how a buyer can trust a seller on cryptomarkets arises — how can

Table 4 Estimates and standard errors from ERGMs of the drug trafficking via cryptomarkets

Parameter	Model 1		Model 2	
	Estimate	Std. Error	Estimate	Std. Error
Edges	-1.444*	0.023	-2.302***	0.001
ICT Importer	0.271**	0.007	0.255*	0.015
ICT Exporter	0.165	0.083	0.035	0.624
GCI Importer	-0.016*	0.023	-0.006	0.452
GCI Exporter	-0.035***	0.000	-0.020***	0.001
Distance	-0.058*	0.014	-0.041*	0.045
Common language	0.323	0.259	0.270	0.256
Exporter effect			-3.297***	0.001
Mutual			2.257***	0.001
AIC	702.7		643.8	

* $p < .05$; ** $p < .01$; *** $p < .001$

they ascertain the seller will not abscond with their money? The answer lies in the transparency of past transactions, feedback from prior buyers, and a series of strategies that allow buyers to form informed judgments about a vendor's trustworthiness and reliability (Tzanetakis et al., 2016). Cryptomarkets have engineered mechanisms to identify reliable partners and mitigate deceitfulness, rendering social proximity unnecessary.

Second, there are active cryptomarkets in various languages at any given time. Participants have access to online markets in any language, and they do not need to learn or use another language to buy drugs online. However, proficiency in English, or at least the ability to read and write in English, is a requirement for participating in certain cryptomarkets. Hence, the ecosystem's diversity reduces the significance of language.

This study, for the first time, underscores the role that a country's information technology infrastructure plays in facilitating drug trafficking transactions on cryptomarkets. Digital restrictions are as crucial as offline restrictions and account significantly for importing countries. To sell or buy drugs online, participants need access to a high-speed internet connection, the Tor browser or an alternative anonymous network like I2P, and the capability to set up an anonymous Bitcoin wallet (Basheer, 2022). Usually, these are not enough; participants in cryptomarkets often need to take extra steps to increase their anonymity, such as setting up encrypted emails, encrypting all communications, and using a VPN (Horton-Eddison et al., 2021).

In some countries, these technologies are readily available, contributing to digital skills being more widespread among the population. However, this might not be the case in other countries that could potentially benefit from joining cryptomarkets. For example, Colombian dealers could reap substantial profits from selling on cryptomarkets, as the domestic wholesale price for a kilogram of cocaine is about $1,500, while it is $45,000 in the UK (UNODC, 2021). But the internet penetration in Colombia is 65%, with a significant proportion of those without internet access likely residing in more rural areas where cocaine production is more concentrated. By contrast, internet penetration in the UK is 95%. This disparity helps illuminate — albeit incompletely — why the UK has a more central role in drug cryptomarket trafficking than Colombia.

The degree of a country's cybersecurity commitment inversely impacts the likelihood of outgoing trafficking connections with other nations. In essence, the more equipped a country is to combat cybercrime, the fewer outgoing connections it has. This observation is contrary to much of the empirical research on drug law enforcement and some studies on policing cryptomarkets. Research on international drug trafficking drivers reveals that stringent law enforcement actions do not deter a country from establishing trafficking connections (Aziani et al., 2021; Berlusconi et al., 2017; Giommoni et al., 2017). Likewise, police operations' impact on cryptomarkets is often minimal. The majority of studies concur that cryptomarket participants tend to adjust to law enforcement interventions by implementing extra security measures or shifting to other markets (Décary-Hétu & Giommoni, 2017; Ladegaard, 2018, 2019; van Wegberg & Verburgh, 2018). Police successes, at best, are fleeting and diminish over time.

There are a few reasons why a more advanced cybersecurity infrastructure might make drug trafficking via cryptomarkets less attractive. Firstly, the Global Cybersecurity Index evaluates a country's readiness to confront cybercrime. Individual police operations may yield limited success, but the overall cybersecurity infrastructure could deter people from exporting illicit drugs via cryptomarkets. This might seem counterintuitive, but it aligns with traditional drug trafficking. Most police operations are deemed limited in duration and scope, but illicit drugs remain less accessible and costlier than if legalized (Kleiman, 2009; Pollack & Reuter, 2014). The mere existence of drug law enforcement influences drug markets. The second reason is more technical, relating to how we measure levels of enforcement. The GCI is a composite indicator accounting for different aspects of cybersecurity, such as organizational measures, capacity development, and cooperation. There is not a comparable measure for a country's ability to counter international drug trafficking, leading most studies to resort to questionable proxies like the number of police officers per capita (Giommoni et al., 2017). We posit that the GCI provides a more robust and comprehensive indicator of enforcement against cybercrime, including cryptomarkets.

Both models also indicate that trafficking is likelier between geographically proximate countries. Mirroring trends in legal trade and offline trafficking, geographic distance escalates the costs associated with drug trafficking via cryptomarkets (Caulkins & Bond, 2012; Disdier & Head, 2008; Favarin & Aziani, 2020). Long-haul deliveries require more ingenious methods of drug concealment, incur lengthier shipping times, and may increase the risk of interception (Décary-Hétu et al., 2016; Norbutas, 2018). Despite dealers' profit-driven motives, their main objective is to evade arrest (Caulkins & Reuter, 2010; Pollack & Reuter, 2014). Geographic distance amplifies this risk and can discourage dealers from engaging in long-distance transactions.

Finally, the significant and negative direction of the exporter effect indicates that a country's likelihood of forming a new outgoing tie decreases as its existing ties increase. This implies that the number of countries with cryptomarket consumers is limited and that certain countries may have nearly saturated at least their regional market once they attain a certain size. The reciprocity variable, being positive and significant, suggests a tendency towards mutual ties in the network. This might indicate that cryptomarket participants are conscious of the relative safety of transactions on cryptomarkets. If drugs can be successfully transported in one direction, consumers might be more inclined to order drugs internationally in the opposite direction, particularly if less.

Conclusions

This study presents compelling insights into the mechanics of drug trafficking within cryptomarkets. It challenges conventional notions of social proximity, demonstrating that shared language or traditional relationships are less relevant in these digital platforms. Instead, the establishment of trust-based mechanisms and multilingual capacities are more integral to interactions in cryptomarkets.

Furthermore, it highlights the significant role of a country's digital infrastructure and its IT capabilities in shaping its involvement in online drug trafficking. The level of internet penetration, availability of digital anonymity tools, and population's digital literacy can affect the scale and nature of a country's participation in these cryptomarkets.

The study also underlines the unexpected effects of strong cybersecurity infrastructure. Contrary to the conventional enforcement approach, which often fails to deter trafficking, advanced cybersecurity measures seem to reduce a country's involvement in the online drug trade. This finding could reshape our understanding of effective strategies to combat online drug trafficking.

Geographical proximity remains a critical factor, even in digital markets (Décary-Hétu et al., 2016; Norbutas, 2018). The risks and costs associated with longer shipping distances can deter dealers from international transactions, reflecting the influence of physical logistics on online trade. Overall, these findings suggest that cryptomarkets operate under different dynamics than traditional markets and need unique strategies for intervention and control.

This paper provides key methodological advancements in studying online drug trading. By harnessing crowd-sourced data, we haveve managed to explore this field more deeply than ever before. While cryptomarkets tend to provide elusive details about buyer locations, our platform has proven successful in gathering and examining data on trafficking routes. As a result, we now have an unparalleled glimpse into the pathways of drug movement across international borders through the dark web.

Yet, this innovative approach is not without its challenges. The data collection process led to an unrandomized sample, due to a self-selection bias among participants. With no concrete understanding of why some users shared information and others did not, our findings could potentially be skewed. However, such biases are common in research involving illicit activities like drug trading. To ensure the accuracy of our findings, we implemented stringent checks to remove spam, outliers, and infrequent connections between countries.

Moving forward, fostering stronger relationships with participants in illicit drug markets is crucial for the success of crowd-sourcing platforms. Although launching and maintaining such platforms like DrugRoutes requires significant effort and resources, they offer a unique opportunity to gain a deeper understanding of criminal behaviour and to prevent crime in our increasingly digital society. It provides a fresh, innovative approach amidst a growing array of diverse methods for studying and comprehending online drug markets (Barratt & Maddox, 2016; Munksgaard & Martin, 2020).

Appendix 1

Table 5 List of countries and their centrality scores

Country	Degree	Indegree	Outdegree	Betweenness	Closeness
AFG	2	0	2	0.00	0.43
ARG	1	0	1	0.00	0.40
AUS	7	6	1	1.42	0.54
AUT	3	2	1	0.00	0.44
BEL	3	2	1	0.00	0.48
BLZ	1	0	1	0.00	0.40
BOL	1	0	1	0.00	0.40
BRA	2	1	1	0.00	0.47
CAN	9	5	4	14.00	0.51
CHE	2	2	0	0.00	0.43
CHL	1	1	0	0.00	0.40
CHN	2	0	2	0.00	0.41
COL	4	0	4	0.00	0.43
CUB	1	0	1	0.00	0.40
CZE	1	1	0	0.00	0.41
DEU	27	6	21	375.13	0.68
DNK	3	3	0	0.00	0.45
ESP	9	4	5	30.83	0.51
EST	1	1	0	0.00	0.41
FIN	2	2	0	0.00	0.44
FRA	11	9	2	45.12	0.55
GBR	14	4	10	89.20	0.59
GRC	1	1	0	0.00	0.37
HKG	1	1	0	0.00	0.41
HUN	1	1	0	0.00	0.41
IND	4	3	1	0.00	0.49
IRL	2	2	0	0.00	0.38
ISR	1	1	0	0.00	0.41
ITA	4	4	0	0.00	0.47
MAR	2	0	2	0.00	0.38
MEX	3	1	2	0.00	0.42
NLD	23	1	22	90.45	0.68
NOR	3	3	0	0.00	0.46
PHL	1	1	0	0.00	0.41
POL	6	3	3	0.87	0.51
PRT	2	2	0	0.00	0.44
ROU	2	2	0	0.00	0.39
SRB	1	1	0	0.00	0.41
SWE	5	5	0	0.00	0.52
TUR	2	2	0	0.00	0.44
UKR	1	0	1	0.00	0.40
USA	28	17	11	458.98	0.66

Appendix 2

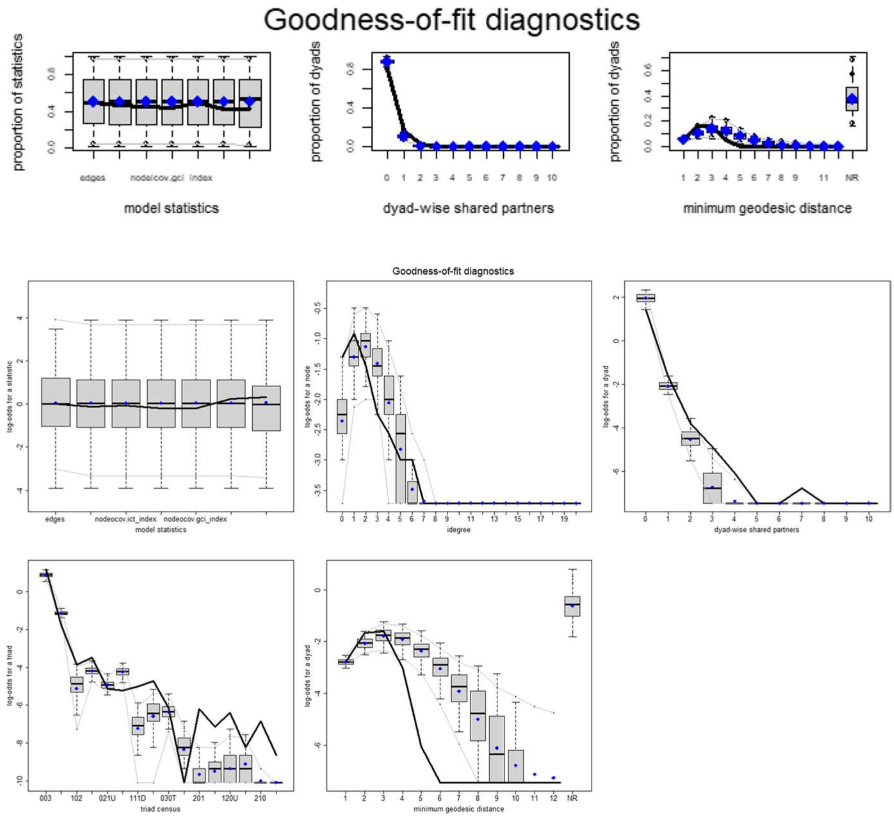

Fig. 7 Goodness of fit diagnostics for Model 1

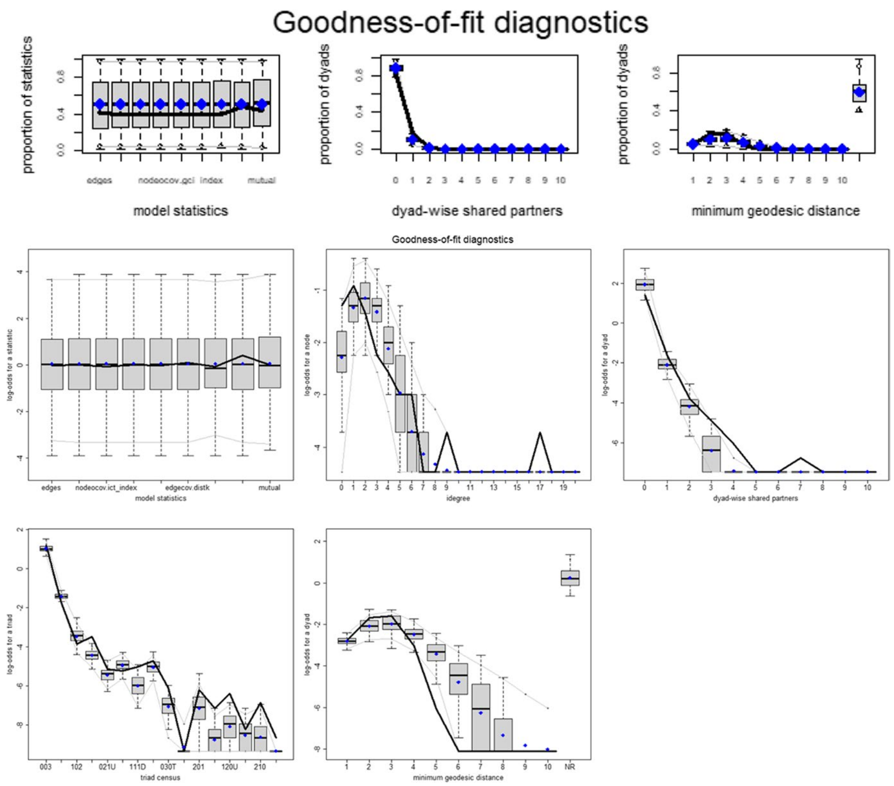

Fig. 8 Goodness of fit diagnostics for Model 2

Author contributions All authors contributed to the study conception and design. AB and DDH collected and cleaned and prepared the data. LG and GB performed all the analysis and wrote the first draft of the sections Introduction, The current study, Methodology and Results. AB and DDH drafted the literature review and conclusions. All authors read and approved the final manuscript.

Funding This work was supported by the Economic and Social Research Council under Grant ES/S008853/1.

Data availability Data supporting this study are openly available at https://doi.org/10.17035/d.2023.0267197475.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

Reference list

Aebi, M. F., & Linde, A. (2015). The epistemological obstacles in comparative criminology: A special issue introduction. *European Journal of Criminology, 12*(4), 381–385. https://doi.org/10.1177/1477370815595311

Aldridge, J. (2019). Does online anonymity boost illegal market trading? *Media Culture & Society*. https://doi.org/10.1177/0163443719842075

Aldridge, J., & Décary-Hétu, D. (2014). *Not an "Ebay for Drugs": The cryptomarket "Silk Road" as a paradigm shifting criminal innovation* (SSRN Scholarly Paper ID 2436643). Social Science Research Network. http://papers.ssrn.com/abstract=2436643

Aldridge, J., & Décary-Hétu, D. (2016a). Cryptomarkets and the future of illicit drug markets. *The Internet and Drug Markets*, (2016), 23–32.

Aldridge, J., & Décary-Hétu, D. (2016b). Hidden wholesale: The drug diffusing capacity of online drug cryptomarkets. *International Journal of Drug Policy*. https://doi.org/10.1016/j.drugpo.2016.04.020

Aziani, A., Berlusconi, G., & Giommoni, L. (2021). A quantitative application of enterprise and social embeddedness theories to the transnational trafficking of cocaine in Europe. *Deviant Behavior, 42*(2), 245–267.

Barratt, M. J. (2012). Silk road: Ebay for drugs. *Addiction, 107*(3), 683–683. https://doi.org/10.1111/j.1360-0443.2011.03709.x

Barratt, M. J., Ferris, J. A., & Winstock, A. R. (2016). Safer scoring? Cryptomarkets, social supply and drug market violence. *International Journal of Drug Policy*. https://doi.org/10.1016/j.drugpo.2016.04.019

Barratt, M. J., Lenton, S., Maddox, A., & Allen, M. (2016). What if you live on top of a bakery and you like cakes?'—Drug use and harm trajectories before, during and after the emergence of Silk Road. *International Journal of Drug Policy*. https://doi.org/10.1016/j.drugpo.2016.04.006

Barratt, M. J., & Maddox, A. (2016). Active engagement with stigmatised communities through digital ethnography. *Qualitative Research, 16*(6), 701–719. https://doi.org/10.1177/1468794116648766

Basheer, R. (2022). Cryptomarkets' phenomenon: A conceptualization approach. *Human Behavior and Emerging Technologies, 2022*, e6314913. https://doi.org/10.1155/2022/6314913

Berlusconi, G., Aziani, A., & Giommoni, L. (2017). The determinants of heroin flows in Europe: A latent space approach. *Social Networks, 51*, 104–117.

Bichler, G., & Jimenez, I. (2022). Drug smuggling seizures: The effects of reporting consistency and quality on the observed transnational structure. *Journal of Drug Issues*, 00220426221107550. https://doi.org/10.1177/00220426221107550

Boivin, R. (2013). Drug trafficking networks in the world economy. In C. Morselli (Ed.), *Crime and networks* (pp. 182–194). Routledge.

Boivin, R. (2014). Macrosocial network analysis: The case of transnational drug trafficking. In A. J. Masys (Ed.), *Networks and Network Analysis for Defence and Security* (pp. 49–61). Springer.

Boivin, R. (2014). Risks, prices, and positions: A social network analysis of illegal drug trafficking in the world-economy. *International Journal of Drug Policy, 25*(2), 235–243.

Broséus, J., Rhumorbarbe, D., Morelato, M., Staehli, L., & Rossy, Q. (2017). A geographical analysis of trafficking on a popular darknet market. *Forensic Science International, 277*, 88–102. https://doi.org/10.1016/j.forsciint.2017.05.021

Butts, C. T. (2008). Social network analysis: A methodological introduction. *Asian Journal of Social Psychology, 11*(1), 13–41.

Caulkins, J. P., & Bond, B. M. (2012). Marijuana price gradients implications for exports and export-generated tax revenue for California after legalization. *Journal of Drug Issues, 42*(1), 28–45.

Caulkins, J. P., & Reuter, P. H. (2010). How drug enforcement affects drug prices. *Crime and Justice, 39*(1), 213–271.

Chainalysis. (2021). *The Chainalysis 2021 Crypto Crime Report*. https://go.chainalysis.com/2021-Crypto-Crime-Report.html

Chandra, S., Barkell, M., & Steffen, K. (2011). Inferring cocaine flows across Europe: Evidence from price data. *Journal of Drug Policy Analysis, 4*(1), 1941–2851.

Christin, N. (2013). *Traveling the silk road: A measurment analysis of a large anonymous online marketplace*. Proceedings of the 22nd International Conference on World Wide Web.

Combes, P. P., Lafourcade, M., & Mayer, T. (2005). The trade-creating effects of business and social networks: Evidence from France. *Journal of International Economics, 66*(1), 1–29. https://doi.org/10.1016/j.jinteco.2004.07.003

Décary-Hétu, D., & Giommoni, L. (2017). Do police crackdowns disrupt drug cryptomarkets? A longitudinal analysis of the effects of Operation Onymous. *Crime Law and Social Change, 67*(1), 55–75. https://doi.org/10.1007/s10611-016-9644-4

Décary-Hétu, D., Paquet-Clouston, M., & Aldridge, J. (2016). Going international? Risk taking by cryptomarket drug vendors. *International Journal of Drug Policy*. https://doi.org/10.1016/j.drugpo.2016.06.003

Demant, J., Munksgaard, R., Décary-Hétu, D., & Aldridge, J. (2018). Going local on a global platform: A critical analysis of the transformative potential of cryptomarkets for organized illicit drug crime. *International Criminal Justice Review, 28*(3), 255–274. https://doi.org/10.1177/1057567718769719

Disdier, A. C., & Head, K. (2008). The Puzzling persistence of the distance effect on bilateral trade. *Review of Economics and Statistics, 90*(1), 37–48. https://doi.org/10.1162/rest.90.1.37

Dittus, M., Wright, J., & Graham, M. (2018). Platform criminalism: The last-mile geography of the darknet market supply chain. *ACM The Web Conference 2018*. https://ora.ox.ac.uk/objects/uuid:1ecd2466-4849-4383-b556-7c9c9e7ffef4

Duxbury, S. W., & Haynie, D. L. (2018). The network structure of opioid distribution on a darknet cryptomarket. *Journal of Quantitative Criminology, 34*(4), 921–941.

EMCDDA. (2023). *European drug report 2023: Trends and developments*. Lisbon: European Monitoring Centre for Drugs and Drug Addiction. https://www.emcdda.europa.eu/publications/european-drug-report/2023_en

Favarin, S., & Aziani, A. (2020). The global waste trafficking and its correlates. *Journal of Contemporary Criminal Justice, 36*(3), 351–383. https://doi.org/10.1177/1043986220939701

Giommoni, L., Aziani, A., & Berlusconi, G. (2017). How do illicit drugs move across countries? A network analysis of the heroin supply to Europe. *Journal of Drug Issues, 47*(2), 217–240. https://doi.org/10.1177/0022042616682426

Government of Canada. (2022). *StatsCannabis*. https://surveys-enquetes.statcan.gc.ca/cannabis/

Handcock, M. S., Hunter, D. R., Butts, C. T., Goodreau, S. M., Krivitsky, P. N., Bender-deMoll, S., & Morris, M. (2018). *Statnet: Software tools for the statistical analysis of network data* (2018.10) [Computer software]. The Statnet Project. www.statnet.org

Horton-Eddison, M., Shortis, P., Aldridge, J., & Caudevilla, F. (2021). *Drug cryptomarkets in the 2020s: Policy, enforcement, harm, and resilience*. Swansea: Global Drug Policy Observatory

Hunter, D. R. (2007). Curved exponential family models for social networks. *Social Networks, 29*(2), 216–230.

Hunter, D. R., Handcock, M. S., Butts, C. T., Goodreau, S. M., & Morris, M. (2008). ERGM: A package to fit, simulate and diagnose exponential-family models for networks. *Journal of Statistical Software*, *24*(3).

ITU. (2020). *The ICT Development Index (IDI): Conceptual framework and methodology*. https://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2017/methodology.aspx

Kilmer, B., Reuter, P. H., & Giommoni, L. (2015). What can be learned from cross-national comparisons of data on illegal drugs? *Crime and Justice, 44*(1), 227–296.

Kleemans, E., & Van de Bunt, H. G. (1999). The social embeddedness of organized crime. *Transnational Organized Crime, 5*(1), 19–36.

Kleiman, M. (2009). *When brute force fails: How to have less crime and less punishment*. Princeton University Press.

Kruithof, K., Aldridge, J., Décary-Hétu, D., Sim, M., Dujso, E., & Hoorens, S. (2016). *Internet-facilitated drugs trade* (pp. 21–32). RAND Corporation.

Kuziemko, I., & Levitt, S. D. (2004). An empirical analysis of imprisoning drug offenders. *Journal of Public Economics, 88*(9–10), 2043–2066.

Ladegaard, I. (2018). We know where you are, what you are doing and we will catch you: Testing deterrence theory in digital drug markets. *The British Journal of Criminology, 58*(2), 414–433. https://doi.org/10.1093/bjc/azx021

Ladegaard, I. (2019). Crime displacement in digital drug markets. *International Journal of Drug Policy, 63*, 113–121. https://doi.org/10.1016/j.drugpo.2018.09.013

Lahaie, E., Janssen, E., & Cadet-Taïrou, A. (2015). Determinants of heroin retail prices in metropolitan France: Discounts, purity and local markets. *Drug and Alcohol Review*. https://doi.org/10.1111/dar.12355

Lorente-Bayona, L. V., Gras-Gil, E., & del Rocío Moreno-Enguix, M. (2021). Internet penetration and international travel and tourism expenditure: The role of foreign exchange control. *Tourism Economics, 28*(8), 2050–2067.

Lusher, D., Koskinen, J., & Robins, G. (Eds.). (2013). *Exponential random graph models for social networks: Theory, methods, and applications*. Cambridge University Press.

Martin, J. (2014). *Drugs on the dark net: How cryptomarkets are transforming the global trade in illicit drugs*. Palgrave Pivot.

Martin, J., Cunliffe, J., & Munksgaard, R. (2019). *Cryptomarkets: A research companion*. Emerald Publishing Limited.

Martin, J., Munksgaard, R., Coomber, R., Demant, J., & Barratt, M. J. (2020). Selling drugs on darkweb cryptomarkets: Differentiated pathways, risks and rewards. *The British Journal of Criminology, 60*(3), 559–578. https://doi.org/10.1093/bjc/azz075

Morelato, M., Broséus, J., De Grazia, A., Tahtouh, M., Esseiva, P., & Roux, C. (2018). Forensic drug intelligence and the rise of cryptomarkets. Part II: Combination of data from the physical and virtual markets. *Forensic Science International, 288*, 201–210. https://doi.org/10.1016/j.forsciint.2018.05.002

Munksgaard, R. (2021). *Trust and exchange: The production of trust in illicit online drug markets*. https://papyrus.bib.umontreal.ca/xmlui/handle/1866/25234

Munksgaard, R., Décary-Hétu, D., Malm, A., & Nouvian, A. (2021). Distributing tobacco in the dark: Assessing the regional structure and shipping patterns of illicit tobacco in cryptomarkets. *Global Crime, 22*(1), 1–21. https://doi.org/10.1080/17440572.2020.1799787

Munksgaard, R., & Martin, J. (2020). How and why vendors sell on cryptomarkets. *Trends and Issues in Crime and Criminal Justice [Electronic Resource], 608*, 1–12. https://doi.org/10.3316/agispt.20201215041193

Norbutas, L. (2018). Offline constraints in online drug marketplaces: An exploratory analysis of a cryptomarket trade network. *International Journal of Drug Policy, 56*, 92–100. https://doi.org/10.1016/j.drugpo.2018.03.016

Ouellet, M., Décary-Hétu, D., & Bergeron, A. (2022). Cryptomarkets and the returns to criminal experience. *Global Crime, 23*(1), 65–80. https://doi.org/10.1080/17440572.2022.2028622

Paoli, L. (2002). The paradoxes of organized crime. *Crime Law and Social Change, 37*, 51–97.

Paoli, L., & Reuter, P. H. (2008). Drug trafficking and ethnic minorities in Western Europe. *European Journal of Criminology, 5*(1), 13–37.

Pollack, H. A., & Reuter, P. (2014). Does tougher enforcement make drugs more expensive? *Addiction, 109*(12), 1959–1966. https://doi.org/10.1111/add.12497

Prashantham, S., Dhanaraj, C., & Kumar, K. (2015). Ties that bind: Ethnic ties and new venture internationalization. *Long Range Planning, 48*(5), 317–333. https://doi.org/10.1016/j.lrp.2015.02.005

R Core Team. (2021). *R: A language and environment for statistical computing* (4.1.1) [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org

Rauch, J. E., & Trindade, V. (2002). Ethnic chinese networks in international trade. *The Review of Economics and Statistics, 84*(1), 116–130.

Reuter, P. H. (2014). The mobility of drug trafficking. In LSE (Ed.), *Ending the Drug Wars. Report of the LSE Expert Group on the Economics of Drug Policy*. The London School of Economics and Political Science.

Reuter, P. H., & Kleiman, M. A. R. (1986). Risks and prices: An economic analysis of drug enforcement. *Crime and Justice, 7*, 289–340.

Robins, G., Pattison, P., Kalish, Y., & Lusher, D. (2007). An introduction to Exponential Random Graph (p*) models for social networks. *Social Networks, 29*, 173–191.

Sgrignoli, P., Metulini, R., Schiavo, S., & Riccaboni, M. (2015). The relation between global migration and trade networks. *Physica A: Statistical Mechanics and its Applications, 417*, 245–260. https://doi.org/10.1016/j.physa.2014.09.037

Soska, K., & Christin, N. (2015). *Measuring the longitudinal evolution of the online anonymous marketplace ecosystem*. Proceedings of the 24th USENIX Security Symposium, Washington, D.C.

Tzanetakis, M., Kamphausen, G., Werse, B., & von Laufenberg, R. (2016). The transparency paradox. Building trust, resolving disputes and optimising logistics on conventional and online drugs markets. *International Journal of Drug Policy, 35*, 58–68. https://doi.org/10.1016/j.drugpo.2015.12.010

UNODC. (2021). *World Drug Report 2021*. United Nation Office on Drugs and Crime. https://www.unodc.org/unodc/en/data-and-analysis/wdr2021.html

UNODC. (2022). *World drug report 2022*. Vienna: United Nation Office on Drugs and Crime. https://www.unodc.org/unodc/data-and-analysis/world-drug-report-2022.html

van Wegberg, R. S., & Verburgh, T. (2018). Lost in the dream? Measuring the effects of operation bayonet on vendors migrating to dream market. *WebSci'18*. http://resolver.tudelft.nl/uuid:8c080055-37fb-4f53-a949-099110f91659

Xiong, F., Zang, L., & Gao, Y. (2022). Internet penetration as national innovation capacity: Worldwide evidence on the impact of ICTs on innovation development. *Information Technology for Development, 28*(1), 39–55. https://doi.org/10.1080/02681102.2021.1891853