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TITOLO DELLA TESI: DARK NET MARKET CRIMINAL ACTIVITIES AND CRYPTOCURRENCIES: COMPARATIVE LAW AND ECONOMIC ANALYSIS

TESI PRESENTATA DA: KATSIARYNA BAHAMAZAVA

CO-SUPERVISORI: FABIO PRIVILEGGI, EVA RAFFAELLA DESANA

COORDINATORE DEL DOTTORATO: GIOVANNI BATTISTA RAMELLO

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Contents

Introduction

Understanding the functionality of illegal markets on the Dark Net is crucial to minimize their harmful effects on societies in a continuously evolving technological world. Dark Net, by its inherent characteristics, is a complex phenomenon combining numerous advanced technologies and tools such as encryptions, cryptocurrencies, and multi-signatures. The borderless nature of Dark Net Markets (DNMs) and cryptocurrencies, together with numerous anonymizing techniques, have brought additional challenges to policymakers. In addition, COVID-19 has reshaped illegal trade favoring online markets. DNMs appear to play a more prominent role in delivering drugs without face-to-face interactions (EMCDDA and Europol, 2020).

The dissertation, in its three distinct chapters, uses empirical and theoretical approaches to study the Dark Net illegal drug trade from different perspectives.

First chapter, "The shift of Dark Net illegal drug trade preferences in cryptocurrency: the question of traceability and deterrence," shows that the Law Enforcement's ability to trace Bitcoin's transactions (announced in 2015) did not have a deterrent effect on illegal drug trade on DNMs. To study DNM drug users' preferences in cryptocurrency, Natural Language Processing techniques, topic modeling, and Sentiment analysis were employed to the online forum dedicated to DNM illegal drug trades. More specifically, the CorEx model and VADER analyzer were applied to 219,414 posts and comments to perform the text analysis over the period of eight years. From the performed analysis, it appears that DNM drug users have shifted to a new anonymity-centered cryptocurrency – Monero, as early as a new privacy feature has been introduced. Bitcoin's traceability announcement probably pushed the DNM drug users to search for new and innovative ways to buy narcotics online instead of deterring them.

Second chapter, "The comparative analysis of regulations in the Italian Republic and the Russian Federation against crypto laundering techniques," studies specific cryptocurrency laundering techniques that could be used to launder proceeds from the illegal DNM drug trade. This chapter compares anti-money laundering regulations in the Italian Republic and the Russian Federation to understand how successful are these culturally, socially, and economically diverse countries in combating money laundering. This chapter presents a case study to understand if the Italian and the Russian regulations are capable of preventing money laundering through one of the most popular online wallets in 2020. Topic modeling in an unsupervised manner was applied to online forum consisting of 196,546 entries (in 2020) to

identify that the Cake cryptocurrency wallet is one of the most popular and widely used. In light of the current regulatory frameworks, it appears that the Cake wallet is not regulated neither by Italian legislation nor by Russian regulatory body.

Third chapter, "A Cournot equilibrium between Dark Net Market and Street market," contributes to the economic analysis of illegal drug trade in the Street market and DNM.
For the sake of simplicity, it is assumed that there is a continuum of consumers with unitary demand for one drug. Their demand price varies from one market to the other according to the risks they bear in accessing it. The lower risk of violence in the DNM implies that, ceteris paribus, the good delivered there is deemed higher quality. Vendors compete à la Cournot in quantity in their "home" market, selling homogeneous goods. However, the other market exerts a vertical competitive threat. The two markets are intertwined, and we model the case in which both are simultaneously in equilibrium. A numerical simulation illustrates the mechanics of the model together with possible policy implications.

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The shift of Dark Net illegal drug trade preferences in cryptocurrency: the question of traceability and deterrence

1 Introduction

Dark Net markets (DNMs), also known as cryptomarkets, are collections of Dark Net (DarkWeb) websites that function similarly to other online platforms facilitating trades, such as eBay or Amazon (EMCDDA and Europol, 2017). Users' anonymity is the main feature distinguishing DNMs from traditional e-commerce platforms. Only cryptocurrencies are accepted as a payment method on Dark Net Markets to enhance anonymity. DNM administrators build trust between participants by introducing review, dispute, and escrow systems, along with sanctions for scammers (Demant et al., 2018).

According to Europol, approximately 1 billion USD was spent on DNMs in 2018 (Europol, 2019). While drugs is the number one category offered on DNMs, which accounts for 62% of the deals, the remaining sales consist of fraud and counterfeit, guides and tutorials, hacking and malware, firearms and explosives, along with other illegal activities (EMCDDA and Europol, 2017).

Customers choose to buy illegal goods and services on DNMs because of perceived anonymity, protection, and higher quality (Caudevilla et al., 2016) of goods sold. Also, during the COVID-19 lockdowns, the "usual" places (streets and clubs) have been inaccessible; hence, the access to the products became an issue, which spiked the DNMs' attractiveness (UNODC, 2020).

This paper assumes that apprehending criminals on the Dark Web is challenging due to the following reasons:

1) limited amount of research compared to the conventional drug sale markets,

2) continually evolving technologies that DNMs are based on,

3) involvement of multiple jurisdictions, not always supporting each other and/or working together.

Let us examine the first reason of a fairly new phenomenon with a limited amount of research. American R.W. Ulbricht created the first DNM "Silk Road" in 2011, which functioned until 2013 (U.S. Department of Justice, 2014). At the same time, the traditional illegal drug trade possibly appeared as early as narcotics were outlawed. Being a unique phenomenon, the DNM requires time to be recognized, researched, and analyzed (EMCDDA and Europol, 2017).

The second issue with the difficulty of apprehending DNM's illegal activities is the continuously evolving technology used by DNM participants. For instance, "Silk Road" only controlled specific Bitcoin addresses to manage sales. However, in recent years, the DNM platforms started utilizing escrows,[1] PGPs,[2] and numerous cryptocurrency wallets with anonymous ex-

[1]Escrow is the use of a neutral third party that holds the money until the vendor delivers the good.

[2]Pretty Good Privacy is the encryption technique used to code the shipping address before sending it to the vendor.

changes.

Finally, the third reason is that sometimes buyers and vendors are in different locations during their transactions. The absence of physical links impedes investigations and requires collaboration between countries. This kind of deep cooperation between jurisdictions with different political and economic regimes is not always possible. One of the few successful illustrations of coordinated actions was the seize of European DNM "ItalianMafiaBrussels" with Romanian members who sent drugs primarily to the U.S. and Canada (EMCDDA and Europol, 2019). Another more recent international cooperation is an operation, "Dark HunTor," that spanned three continents, lasted ten months, and resulted in 150 arrests worldwide (U.S. Department of Justice, 2021). These operations are examples of how much effort and how many countries are needed to cooperate in shutting down DNMs.

Considering the complications of the three reasons mentioned above, the presumed weakest link in the whole scheme is the transition from the online world to the real one or vice versa. We are interested in studying the drug trade preferences of new or potential users. As they use ClearNet forums as the starting point, we choose to explore those forums. On ClearNet forums, beginners ask questions about accessing DarkNet, cryptocurrency usage, specific markets, and reasons to buy drugs on DNMs. In contrast, on the DarkNet forums, there are people who already understand the whole process of buying DNM's illegal products. Therefore, it is beneficial to analyze ClearNet forums since they provide information on the new DNM users, their motivations, and their challenges.

Bitcoin is the first successful cryptocurrency, and it is still the most popular one among the general public. However, as it became known in recent years, the data in the bitcoin blockchain is traceable, and anyone with proper

tools and expertise can analyze it. This traceability feature makes it possible to identify DNM participants. In 2015, for the first time, the FBI announced ("traceability announcement") (Greenberg, 2015) the usage of blockchain analysis to trace Bitcoins back to the R.W. Ulbricht (founder of "Silk Road") personal wallet. Even if the user utilized mixers, it became possible to disentangle the output. More recents cases of the law enforcement agencies tracing DNM participants are the operations "Dark HunTor" (U.S. Department of Justice, 2021), "DarkMarket" (Europol, 2021), and the shutdown operation of "Wall Street Market" (U.S. Department of Justice, 2019). For example, in the last case, it is explicitly explained how the traceability feature of Bitcoin was utilised to trace back the administrators of "Wall Street Market". Overall, law enforcement agencies have apprehended at least one hundred individual DarkNet vendors since 2013 (Ladegaard, 2019a). Therefore, we assume that Bitcoin is not a preferred cryptocurrency for DarkNet drug users anymore.

To discover whether DarkNet drug users found a substitute for the traceable Bitcoin, Natural Language Processing (NLP) techniques are utilized. Topic models are used to infer latent topics from unstructured text in different domains. It is also quite intuitive to analyze the forum's posts and comments by using topic models in our case. The topic model connects documents and words through variables (L'huillier et al., 2011). The topic itself is defined as a distribution of words with a document constructed as a mixture of topics (Curiskis et al., 2020). One of the most popular techniques of unsupervised topic modeling, Latent Dirichlet Allocation (LDA), was applied to DarkNet forums to explore their topics evolution in 2016 - 2017 (Tavabi et al., 2019). The Anchored Correlation Explanation model was implemented to perform supervised topic modeling for revealing cryptocurrency

manipulations (Nizzoli et al., 2020).

The principal objective of this paper is to apply topic modeling and sentiment analysis to study the behavior of new or potential Dark Net drug users over time. The extracted topic models and their corresponding sentiment over a period of time would help us examine the deterrent effect of Bitcoin traceability announcement as mentioned in the hypothesis. Since cryptocurrency is the only payment method on DarkNet, we expect to observe the influence and consequence of this announcement in the evolution of preferred cryptocurrency.

The ClearNet forums' information was inspected to study DarkNet drug users' behavioral shift in cryptocurrency. Several studies have already utilized ClearNet forums to determine the effect of DNM busts (Porter, 2018), to detect anomalies signaling the advent of disturbing events (Shah et al., 2019), to determine critical players on specific DNM (Hazel Kwon, K. and Shao, Chun, 2020). Some authors (Cho, S. Y. and Wright, J., 2019) compared topics discussed on DarkNet and ClearNet forums showing that the same topics were discussed on both forums. However, on DarkNet, users also talked about additional topics related to security.

The Correlation Explanation (CorEx)(see section 2) model in an unsupervised manner was used instead of LDA since it minimizes the starting assumptions and human intervention in general (Gallagher et al., 2017).

To test the hypothesis that Bitcoin is not the preferred cryptocurrency anymore, we are going to answer the following research questions (RQ):

RQ1: What was the most recommended cryptocurrency by forum users for buying drugs from DNMs? Cryptocurrency usage is one of the few links between buyers and sellers on DarkNet. Potentially, it is possible to influence an illegal online drug sale through cryptocurrency regulation. Our goal is to

understand the evolution of the preferred cryptocurrency for DarkNet sales and the reasons for this evolution.

RQ2: How did the Bitcoin traceability announcement (2015) and Monero's privacy update (2017) influence the topics' evolution over time? Understanding the drug users' reaction through the ClearNet forum's posts would shed light on the deterrent effect of the traceability announcement and the privacy update if any.

RQ3: What were the most popular topics discussed by the new drug buyers on the forum? The answer to this question would provide a better understanding of the challenges faced by the new drug users while buying drugs from the DarkNet. This information could help in designing new policies against illegal drug sales.

To investigate the evolution of sentiment toward Bitcoin among DarkNet drug users, sentiment analysis, more precisely the VADER tool (Hutto, C. and Gilbert, E., 2014), was used. We computed the aggregated sentiment score for each of the extracted topics related to cryptocurrency.

In contrast with previous research, this paper considers the change of cryptocurrency preferences of DNM drug users as the determinant of perceived traceability.

The major contribution of this paper is the analysis and study of the English-speaking ClearNet forum data from 2012 - 2019 through temporal topic models and sentiment analysis to explore the behavioral shift of Dark-Web drug users. Previous works were restricted to yearly studies of topic models for specific forums. In this paper, we went beyond that and performed an exhaustive study of inferring topic models from the ClearNet forum over a period of eight years.

2 Methodology

2.1 Data collection

On ClearNet, some forums exist where experienced and new DNM users interact. One of the biggest is r/darknet (Reddit, 2021). The data from such open forums yields more benefits for research than the DarkNet forums because we are interested in new users' analysis. These ClearNet public platforms operate as a gateway and a guide to the DarkNet. The particular interest for researching them is to perform quantitative analysis since beginners on these forums ask questions about DNMs' functionality, updates, payments, and security.

The public subreddit r/darknet was chosen for this research project because of its size (179,000 registered members) and the length of time it has been in operation (it was created on December 26, 2009).

We utilized the Reddit Scrapper (Agarwal, 2020) to obtain the r/darknet data from the open archive (Pushshift.io, 2021). The data was collected from January 1, 2012 to December 31, 2019. The overall number of posts and comments used in the paper is 219,414.

2.2 Text analysis

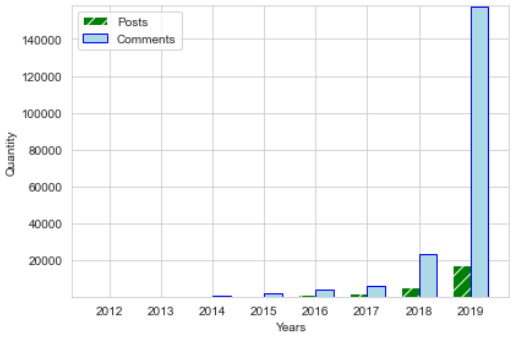
To analyze the behavioral shift of the r/darknet forum participants, we used topic models and sentiment analysis. Topic models extract latent topics from a corpus of text. Since we had an unstructured dataset over eight years, we applied the temporal topic model (CorEx). Furthermore, we utilized the sentiment analysis tool, VADER, to study the evolution of sentiment of different topics over a period of time.

2.2.1 CorEx

The usual temporal topic model's approach examines documents over time with different topics where a topic is a probability distribution over the words (Sohrabi et al., 2018). We used a Correlation Explanation (CorEx) model, which does not assume any specific mechanism of how topics emerged (Gallagher et al., 2017). CorEx discovers independent latent factors that explain correlations between observed variables. In this model, X is a group of words, and Y is a topic to be learned. The Total Correlation is zero only when there is no dependence between variables X and Y.

The data was divided into sixteen datasets as we had eight years of posts and comments. Before applying CorEx, the text was cleaned by lemmatization (Spacy.io, 2021), removing stop words, lowercasing, removing punctuation, deleting NaN values, and erasing bot entries. We defined the stop words like pronouns, swear words, and auxiliary verbs.

The number of the topics for each dataset was chosen in such a way as to explain 70% of all entries since extra topics contributed insignificant correlation to the learned models. We normalized all the data due to differences in the number of posts and comments in each year (Figure 1).



Year	Posts	Comments
2012	65	110
2013	65	171
2014	207	458
2015	718	1588
2016	1358	3633
2017	2009	5630
2018	5510	23093
2019	16952	157847

Figure 1: Quantity of posts and comments over 2012 - 2019

We utilized the comments dataset to answer the first research question since we are interested in the other users' recommendations but not in their questions.

In order to answer the second research question, we examined the posts dataset because we wanted to understand which topics were interesting for DNM users.

To answer the third research question, we needed to identify the forum's new users. The manual analysis of the forum indicated that the new users identified themselves as "newbie," "noob," "new," "beginner," or "n00b." We developed a program (using flashtext (Flashtext, 2018)) to retrieve the aforementioned keywords' posts.. After obtaining the datasets only with new users' posts, we applied CorEx to identify prevalent topics.

2.2.2 VADER

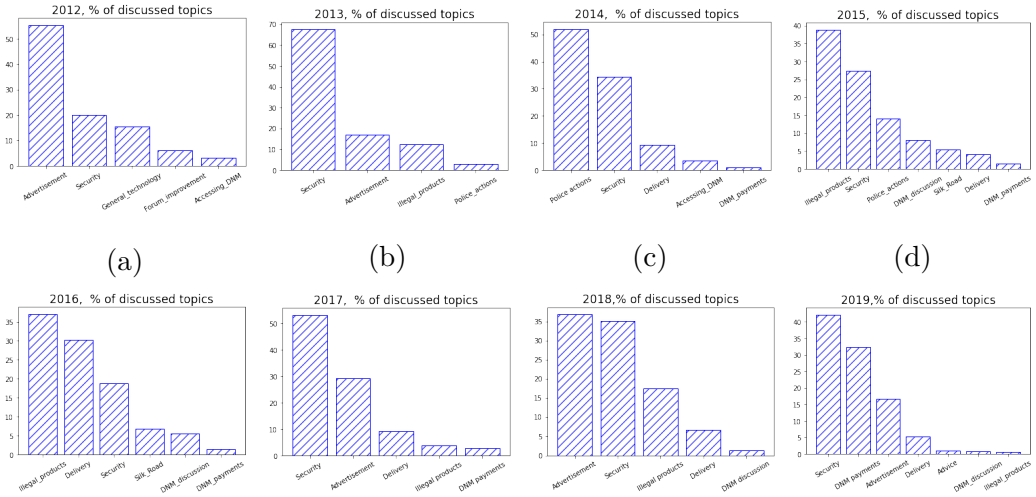
The study of Bitcoin's and Monero's sentiment over a period of time would help us check the validity of our hypothesis. We chose the VADER model since it is easily available and was successfully applied to tweets and Facebook posts to analyze anti-vaccine movements (Garay et al., 2019) and a proprietary dataset to research customer sentiment (Borg, A. and Boldt, M., 2020), among other things. Before using VADER, we expanded its lexicon with domain-specific (DarkNet) words, for example, "untraceable," "anonymous," and "legit."

We applied VADER on topics obtained with the CorEx model. To receive the normalized results, we utilized the compound (i.e., aggregated) score instead of just positive and negative scores (Hutto, C. and Gilbert, E., 2014).

3 Results and Discussion

This section presents the results of our research and discusses possible implications.

Figure 2 demonstrates the evolution of major topics in the posts dataset for all users from 2012 to 2019. As we can see, in 2012, the popularity of the "Advertisement" topic was much higher than other discussions. In 2013, not only the most discussed topic changed to "Security," but new themes such as "Illegal products" and "Police actions" arose. In 2014, two prominent discussions were "Police actions" and "Security," and new topics such as "Delivery" and "DNM payments" emerged. "Illegal products" was the main topic in 2015 and 2016. Users discussed mainly "Security" and "Advertisement" in 2017 and 2018. In 2019, "Security" and "DNM payments" topics were the most popular discussions (Figure 2).



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 2: Posts topics evolution of all users

Figure 2 presents the evolution of the main topics of the posts dataset on

the ClearNet forum. Unsurprisingly, users argued extensively about security issues ("Security") almost every year. One of the possible reasons for the "Security" topic's spike in 2013 could be the "Silk Road" shut down by the FBI. The subsequent spikes of this topic were in 2017 and 2019. The possible reasons for this change are presented in subsubsection 3.2.1. The analysis of the cryptocurrencies' discussion is demonstrated in subsection 3.1. In subsection 3.3, we compared the topics discussed by new users and all users.

3.1 RQ1: What was the most recommended cryptocurrency by forum users for buying drugs from DNMs?

To answer this question, we utilized the comments dataset. While users ask for recommendations in posts, the recommendations themselves could be found only in the comments dataset. We can see that from 2017 (Figure 3), in comments, forum users are more interested in discussing the "Monero"[3]topic than "Bitcoin" (see topics with the related terms in A). Since in the realm of DarkNet, the cryptocurrency is of interest only as a payment method and not, for example, as an investment opportunity, we hypothesized that these comments were answers to the question of which cryptocurrency is best to use for buying drugs on DarkNet.

As presented in Figure 3, in 2016, CorEx did not reveal any mentioning of the "Monero" topic. After 2017, "Monero" started to appear in forum discussions. In 2017, Monero Network was upgraded by introducing RingCT (Monero, 2017) transactions. This upgrade made it impossible to deduce the transaction amount from the Monero blockchain, which is not true for Bitcoin. Therefore, Monero became untraceable, which potentially, made

[3]Monero is a P2P cryptocurrency focusing on private and censorship-resistant transactions (Houben and Snyers, 2018)).

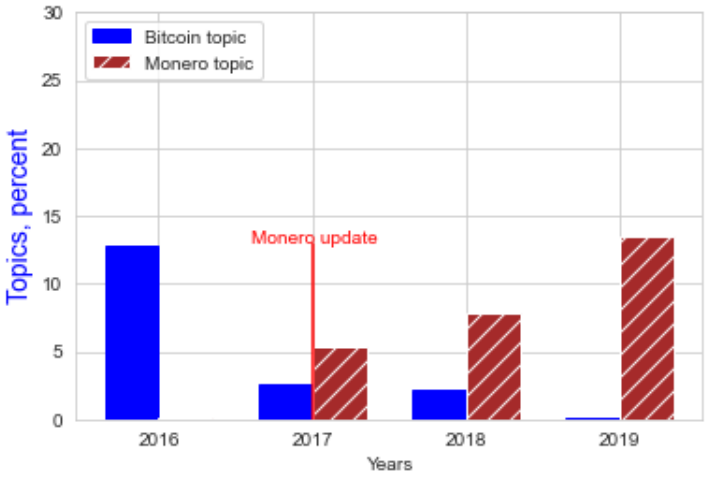


Figure 3: Evolution of "Bitcoin" and "Monero" topics in comments dataset.

it preferred cryptocurrency for the DarkNet illegal trade. The performed analysis suggests that the DNM users recommended using Monero instead of Bitcoin from 2017, as shown in Figure 3.

We applied VADER to analyze the evolution of the forum users' sentiments towards cryptocurrency-related topics. From the topic modeling, we know that only two cryptocurrencies: Bitcoin and Monero, were discussed. Starting from 2017, the change in sentiment in both cryptocurrencies was traced to test our hypothesis of shifting preferences. The sentiment analysis was performed from 2017 as this was the year when the topic "Monero" appeared in our study.

Figure 4 indicates that the sentiments on both cryptocurrencies have changed. More precisely, Monero sentiments displayed a positive trend while Bitcoin's sentiments were in decreasing tendency. This analysis suggests that perceptions toward Bitcoin have changed.

According to our research on the comments' dataset over the period 2012-2019, Monero was the most recommended cryptocurrency by forum users for

buying drugs from DNMs. These results are consistent with the expert's opinion (Financial Times, 2021) that cybercriminals (not just DarkNet drug users) shifted from Bitcoin towards Monero due to its privacy features. Moreover, the fact that the U.S. Internal Revenue Service offered remuneration (SAM, 2020) for developing Monero's tracing tool confirmed Monero's growing importance. However, this result should be confirmed by future research.

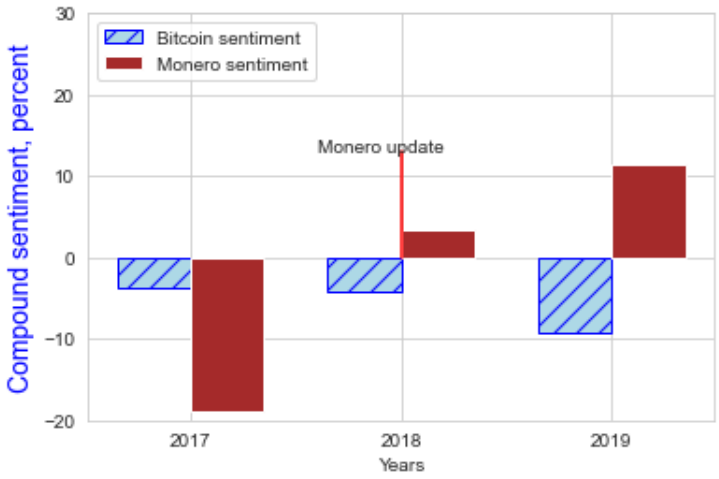


Figure 4: Sentiment analysis of "Bitcoin" and "Monero" topics in comments dataset.

3.2 RQ2: How did the Bitcoin traceability announcement (2015) and Monero's privacy update (2017) influence topics' evolution over time?

The topics' change after Monero's privacy improvement and the Bitcoin traceability announcement are examined in this subsection. We want to explore how these two events influenced topics' evolution in the posts dataset.

It is known that the deterrent effect of increased probability of apprehension is more significant than of increased severity of punishment (Fader, 2016). Perhaps, the motivation behind the traceability announcement was to show the improved skills in incarcerating criminals on the DarkNet (i.e., the increased probability of apprehension) (U.S. Department of Justice, 2015)

3.2.1 "Security" topic

The "Security" (see a topic with the related terms in Appendix A) topic was one of the most popular topics from 2013 to 2019. This topic is directly correlated with Monero's privacy update and the traceability announcement (Figure 2). The "Security" topic was the most discussed one in 2013. As seen from Figure 5, in 2012, the "Security" topic occupied only 20% of all topics. In 2013, the percentage was 67.7%, probably due to shut down of the "Silk Road" DNM. Afterward, the interest in this topic declined until the news of the Monero privacy upgrade. Even the traceability announcement did not change the trend. The graph shows that the percentage of the "Security" topic decreased from 34.3% in 2014 to 27.4% in 2015. Probably, DNM drug users did not have a better alternative to Bitcoin. Possible ways to make Bitcoin more anonymous had not changed for years. DNM drug users did not have any choice but to take the risk associated with Bitcoin's traceability. After the Monero privacy upgrade in 2017, the percentage increased from 18.9% in 2016 to 53.18% in 2017. The "Security" topic again gained popularity. The next spike was in 2019, probably due to takedowns of two DNMs, "Dream Market" and "Wall Street Market." The data suggests that the traceability announcement did not influence the "Security" topic evolution, but the Monero major privacy upgrade did. After this event, security-related discussions revived. This behavior could be explained by the

drug offenders' "restrictive deterrence" theory. The theory states that actual or anticipated sanctions instead of deterring drug offenders make them adopt a more innovative strategy to reduce the risk of apprehension (Fader, 2016).

3.2.2 "Illegal products" topic

Another considered topic is "Illegal products" (see a topic with the related terms in Appendix A). We chose this topic as it reflects Dark Net drug users' interests in general. This subsection presents how the two major announcements influenced the "Illegal products" topic.

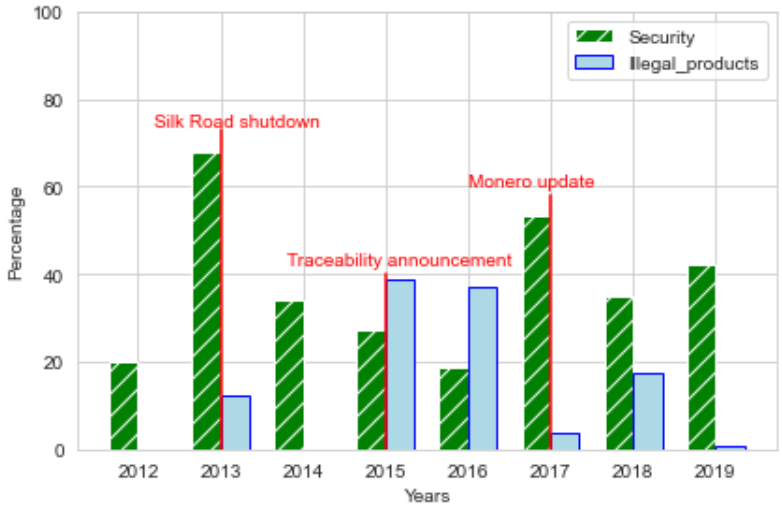


Figure 5: Evolution of "Security", "Illegal products" topics in posts dataset

Analyzing the "Illegal products" topic evolution, we observed that the traceability announcement impacted it. Right after the announcement, in 2015 and 2016, "Illegal products" was the most discussed topic on the forum. It seems that this announcement worked as an advertisement for the Dark Net markets. More people became aware of DNM's existence and wondered which illegal products they could buy there. Also, in 2018, we observed another spike in the "Illegal products" topic. Perhaps, this spike

was a consequence of media reports due to takedowns of "Alphabay" and "Hansa" DNMs (Greenberg, 2018). According to our research, traceability announcement acted as an advertisement and did not change the attitude toward DNMs. Monero's privacy update was discussed on the forum and gave another tool for avoiding surveillance. Our results are in line with other research (Ladegaard, 2018), which showed traceability announcement had no visible deterrent effect on DarkWeb business but increased trade.

3.3 RQ3: What were the most popular topics discussed by *new* drug buyers on the forum?

We have used both the new users' datasets and all users' datasets for analysis in this subsection. Section 2.2 explained the identification method of new users from the forum. To explore the influence of the traceability announcement on new users, we decided to consider "Security" and "DNM discussion" topics. New users were interested in "Security" during the first two years of analysis. Then, another spike was in 2017 at the time of the Monero privacy update and in 2019 during the two DNM shutdowns. The evolution of new users' "Security" topic followed the same trend as for all users. However, new users were less interested in the "Security" topic than all users in general. Probably, it was due to the common knowledge that first-time purchases, especially in small quantities, would not lead to sanctions. The second most popular topic, "DNM discussion," was related to the Dark Net market functionalities (see a topic with the related terms in Appendix B). As seen from Figure 6, after the FBI announcement, in 2015, the "DNM discussion" percentage spiked in the new users' dataset. The subsequent spikes were at the time of media reports about DNM shutdowns. In contrast with all users' datasets, new users had more intense discussions about

DNM functionality. This observation reassures the advertisement effect of traceability announcement.

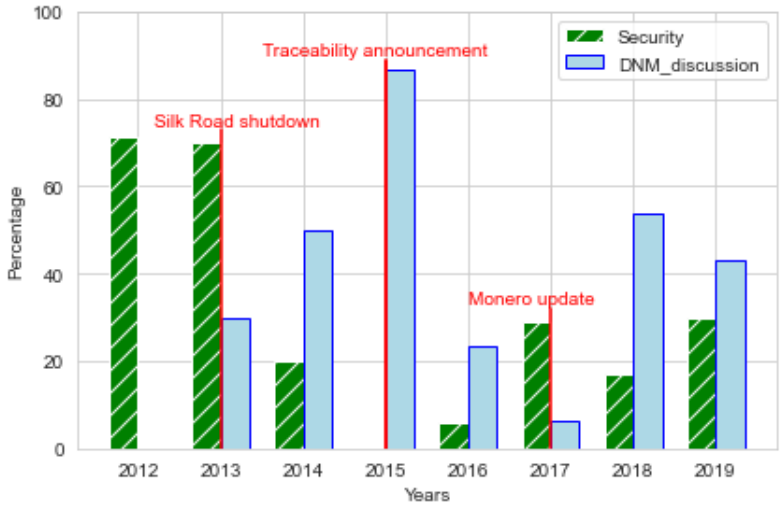


Figure 6: Evolution of "Security", "DNM discussion" topics in new users posts dataset

The most popular topics in the new users' datasets were "Security" and "DNM discussion." The "Security" topic followed the same trend in both datasets but was discussed more profoundly in all users' datasets. At the same time, new users were more interested in the "DNM discussion" topic than all users.

From the performed analysis of the period 2012-2019, it appears that DNM drug users had shifted to a new cryptocurrency called Monero. This conclusion is consistent with the other research that showed that DNM drug users are constantly trying to improve their anonymity, and they are capable of employing new technology (Lorenzo-Dus and Di Cristofaro, 2018). According to a self-selected online review of almost 4000 respondents, 38% had completed a university degree. The founder of the "Silk Road" had a master's degree in material science and engineering, while the founder of the "Silk

Road - 2" had a SpaceX internship. This point and the users' demographic suggest that DNM participants are competent in utilizing technology to continue the illegal online drug trade. Moreover, DNM users are willing to help each other with pieces of advice "to battle against structures that prevent people from partaking in relational and voluntary transactions" (Ladegaard, 2019b). However, the results should be confirmed by future research.

4 Limitations

In the present study, we examined the posts and comments of users who presumably buy drugs from the Dark Net regularly. Although these users wrote that they acquire drugs on DNMs, we did not have access to the actual transactions on Dark Net to confirm their purchases. Therefore, the major limitation is the possible discrepancies between users' words on the forum and the actions on the Dark Net.

5 Conclusion and Future applications

Motivated by the increasing popularity of DNMs, we studied the switch in cryptocurrency preferences in the illegal drug trade for eight years and the influence of real-world events on DarkWeb users' discussions. ClearNet forum on Reddit was chosen for performed analysis since it gave the perspective on the issues by the experienced and new users.

From the application of the temporal topic modeling and sentiment analysis on posts and comments of the period 2012-2019, it appears that the cryptocurrency's preferences for the DNM deals were changed. Still, these results should be confirmed by the analysis of the subsequent 2020-2021 years.

We examined the influence of the traceability announcement and Monero privacy upgrade on the topic's evolution of DNM drug users. Consistent with the other research, our paper showed that the traceability announcement did not influence users in an anticipated way. This announcement acted as an advertisement for new users. It pushed users to search for a new way to purchase drugs on DNM, confirming the restrictive deterrence theory of drug offenders. Bitcoin's utilization was probably a forced choice in the absence of an alternative. As soon as the Monero privacy update was implemented, the shift from Bitcoin to Monero had begun. For now, Monero is untraceable. However, it is probably only a matter of time and effort before it changes since some governmental agencies have already proposed bounty for developing Monero's tracing tool. In the beginning, it was thought that Bitcoin was also untraceable. Due to the blockchain nature, transactions are immutable. This means that when tracing solutions are found, it will be possible to go back and find all the participant's trades on the DarkNet. Still, as we saw with Bitcoin, this will only lead to new and innovative ways to buy narcotics online.

One of the possible paths in future work could be to consider forums in other languages to compare the differences in cryptocurrencies perception of DNM drug users in localized markets.

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A Appendix

Topic 2012	Terms
Security	privacy, app, encrypt, download, alternative, use, idea, propose
Advertisement	search, information,control,internet,distance, pay, profit, integrate
General technology	state, read,edit,copy,system,fire, filter, lose
Forum improvement	interface, list,file, connect, dns, agency,wireless,community
Accessing DNM	scene, networking, mark, linux, government, byzantium, dark, start
Topic 2013	Terms
Advertisement	involve,network,wiki,work,node,store,untrusted,medium
Security	traffic,vpn,isp,monitor,capture,force,open,connect
Illegal products	waste,list,hidden,device,exist,child,porn,request
Police actions	alternative,android,seize,encryption,direction,darkplan,group,government
Topic 2014	Terms
Police actions	law,user,turn,content,remove,street,follow,enforcement
Security	escrow,prevent,vote,love,party,international,feature,encrypt
Delivery	product,deliver,package,problem,talk,ship,process,personal
Accessing DNM	use,download,find,answer,search,information,access,source
DNMs payments	deposit,communicate,provide,stay,fact,experience,sort,transaction
Topic 2015	Terms
Security	safety,secure,service,basis,aspect,rate,remember,talk
Illegal products	red,hidden,gun,pin,view,bank,military,xanax
Police actions	knowledge,change,intelligence,obtain,paper,policy,contain,dose
DNM discussion	product,pure,listing,stealth,create,score,include,rating
"Silk Road"	road,silk,country,safe,compare,insight,purchase,hell
Delivery	order,receive,package,box,noob,work,public,system
DNM payments	pay,bitcoin,prescription,consider,drug,money,government,buy

Table 1: Topic for 2012, 2013, 2014, 2015

Topic 2016	Terms
Delivery	version,pack,content,carding,sell,jabber,title,cause
Illegal products	passport,card,driver,license,credit,counterfeit,register,guarantee
Security	answer,rule,view,direct,stop,leave,attack,encryption
"Silk Road"	come,grow,effect,case,hear,silk,road,past
DNM discussion	customer,list,drop,reason,reply,clean,purity,request
DNM payments	wallet,bitcoin,dnstatsnet,invite,search,exchange,tumbler,electrum

Table 2: Topics for 2016

Topic 2017	Terms
Advertisement	stripe,pin,proper,cause,blank,defrauding,score,carding
Police actions	information,notice,value,feature,takedown,law,activity,project
Security	use,pgp,tail,noob,vpn,access,email,computer
DNM discussion	customer,strain,country,choose,charge,hand,claim,purity
Illegal products	license,driver,passport,ssn,server,onion,document,testing
Delivery	receive,ship,private,burn,xtc,sample,perform,cop
Mixing Bitcoin	bitcoin,send,wallet,purchase,tumble,safe,anonymous,address
Topic 2018	Terms
Delivery	send, come,receive,ask,product,change,address,customer
Illegal products	driver,license,passport,scan,number,novelty,establish,tracking
Advertisement	digital,handle,chargeback,gtour,bankdrop,dash,handbook,guide
Security	vpn,tail,laptop,phone,download,access,setup,window
DNM payments	decide,noob,brick,talk,value,stop,ethereum,knowledge
DNM discussion	use,know,information,pay,create,marketplace,require,user
Topic 2019	Terms
Security	tail,use,pgp,tor,key,vpn,electrum,download
DNM payments	bitcoin,wallet,send,transfer,deposit,coinbase,transaction,monero
Advertisement	contact,biometric,affordable,lab,watsapp,test,room,certificate
Delivery	order,address,receive,open,ask,wait,check,ampxb
Advice	talk,ban,continue,community,apply,related,world,result
Illegal products	passport,xanax,banknote,counterfeit,duplicate,diploma,fake,ielts
DNM discussion	buy,drug,price,quality,weed,mdma,pill,risk

Table 3: Topics for 2017, 2018, 2019

Topic 2016	Terms
Bitcoin	tor,vendor,know,bitcoin,address,tail,review,consider,transfer,spend,run,log,end,catch
Topic 2017	Terms
Bitcoin	use,tor,bitcoin,address,noob,tail,access,public,user,vpn,pgp,cash
Monero	search,monero,password,spam,home,idea,prepaid,success,sort,project
Topic 2018	Terms
Bitcoin	use,order,vendor,buy,dark,bitcoin,address,send,account,market,product,noob
Monero	fee,monero,prove,bulk,atm,claim,step,rule,mention,ensure,platform
Topic 2019	Terms
Bitcoin	use,vendor,order,send,market,drug,buy,bitcoin,address,dark
Monero	tail,pgp,key,monero,log,electrum,save,file,encryption,proof

Table 4: Bitcoin and Monero topics in comments datasets for 2016, 2017, 2018, 2019

B Appendix

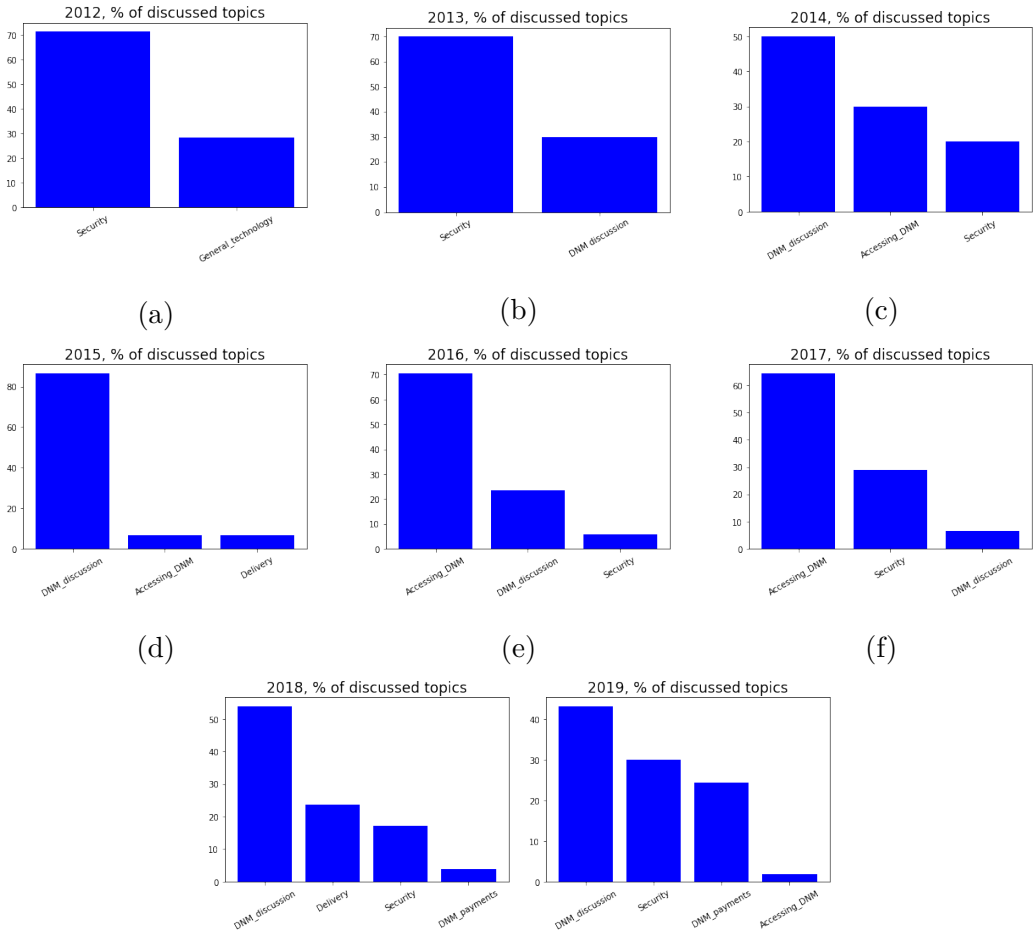


Figure 7: New users posts topics evolution

The comparative analysis of regulations in the Italian Republic and the Russian Federation against crypto laundering techniques

1 Introduction

Advances in modern technologies introduce new opportunities for businesses and people while providing challenges for regulators. One of the main challenges is the use of digital innovations to commit crimes. Money laundering, a crime by itself, is often used to trace another illegal activity, otherwise, undiscovered. Therefore, it is possible to use crypto laundering schemes to investigate other crimes like the illegal drug trade on DarkNet, which otherwise is difficult to scrutinize. However, the borderless nature of cryptocurrencies and all blockchain-based technologies bring another layer of complexity for regulators. Notwithstanding the progress made in cryptocurrency regulations, criminals are one step ahead in utilizing newer technologies.

The Italian Republic and the Russian Federation both follow the same international guidelines in their fight against crypto laundering. Italian laws are based on custodianship, and all custodial platforms must comply with AML/CFT regulations. Russian laws govern all crypto-related activity regardless of custodianship solely based on whether platforms are using Russian

infrastructure and/or locations. We will show in a case study the use of non-custodial wallet in view of anti-money laundering regulations of the Italian Republic and Russian Federation.

Consider Internet consisting of layers, "surface[1]" layer or ClearNet, and "deep[2]" layer (Deep Web). The DarkWeb[3] (Dark Net) is the deepest layer of the Deep Web. There are few different ways to reach the Dark Net, and the most common way is through The Onion Router[4] (TOR). People use TOR as a browser to anonymously reach the DarkNet. In August 2020, TOR had at least 2,171,353 daily accesses worldwide (TOR team, 2020). DarkNet hosts web sites known as DarkNetMarkets (DNMs). DNMs operate like usual e-commerce businesses such as eBay and Amazon, with enhanced anonymity. DNMs are widely popular platforms, and users spent approximately 1 billion USD in 2018 on these markets (Europol, 2019).

Based on DNMs' perceived anonymity, protection, and convenience, customers choose to buy illegal goods and services there (UNODC, 2020). All DNM users are interested in concealing the origin of their cryptocurrency. Transactions done in crypto are written in the corresponding blockchain, which means that it is possible to trace the origin of the payment using specific techniques. Buyers are interested in obscuring their connection with cryptocurrency intended for DNM trades, sellers need to "clean" profit obtained from illegal activity on DNMs, and platform owners seek to conceal

[1]"Surface" Web - everyday part of the Internet accessible by search engines as Google (Weimann, 2016).

[2]"Deep" Web is everything not discoverable with search engines, including password-protected sites and encrypted networks (Shillito, 2019).

[3]Dark Web is a portion of the Deep Web that contains intentionally concealed content (Shillito, 2019).

[4]TOR is a free network designed to anonymise your real Internet Protocol address by routing your traffic through many servers of the TOR network (Europol, 2017).

the origin of fees they earned from DNM vendors.

Money laundering is defined by UN Vienna 1988 Convention (article 3.1):

"the conversion or transfer of property, knowing that such property is derived from any offence(s), for the purpose of concealing or disguising the illicit origin of the property or of assisting any person who is involved in such offence(s) to evade the legal consequences of his actions" (UNODC, 2021). Member countries, among which are the Italian Republic and the Russian Federation, adopted measures to criminalize money laundering offences.

One of the measures to combat international money laundering is membership in FATF. "The Financial Action Task Force (FATF) is an intergovernmental body established in 1989 by the Ministers of its Member jurisdictions" (FATF, 2021). FATF was organized to set standards and advance the effective application of "legal, regulatory and operational measures for combating money laundering, terrorist financing and the financing of proliferation, and other related threats to the integrity of the international financial system" (ibid).

Due to the proliferation of new technologies, innovative methods to conceal the origin of cryptocurrencies have appeared. These methods consist of the use of crypto-exchanges, non-custodial wallet-mixers, Decentralized Finance (DeFi) projects, and Non-Fungible Token (NFT) platforms.

Crypto exchanges are entities or persons who offer exchange services for cryptocurrency users, usually for a fee (Houben and Snyers, 2018).

Wallet-mixer (tumbler) is a service that enables customers, for a fee, to send cryptocurrency to designated recipients in a manner that was designed to conceal and obfuscate the original owner (or the source) of the cryptocurrency (U.S. Department of Justice, 2020).

Decentralized Finance project (DeFi) is a common term that incorpo-

rates decentralization, blockchain, smart contracts[5], disintermediation, open banking (Zetzsche et al., 2020).

Non-Fungible token (NFT) "represents a one-of-a-kind digital asset which has been securitised by the backing of cryptography and thus allows the owner to claim their creation" (NFTically, 2021). In other terms, NFT is proof of ownership of any digital artwork.

The paper's main objective is to consider new opportunities for money laundering which offer cryptocurrency-related projects and the challenges for regulators to combat them.

Due to the novelty of such phenomena as cryptocurrency (the first successful cryptocurrency, Bitcoin, was created in 2008), DNMs (first DNM "Silk Road" was created in 2011), DeFi (2018 (Russo, 2020)), and NFT (2014 (The New York Times Magazine, 2021)) the paper hypothesizes that anti-money laundering regulations are not fully equipped to cover crypto laundering schemes. To check the hypothesis, the following research questions (RQ) were asked:

1) How do Italian and Russian regulators address the crypto laundering techniques? What are the aforementioned crypto laundering techniques?

2) What are the differences in those regulations?

3) What was the most recommended crypto laundering method by DarkNet forum users, and how does it relate to the laws of the Italian Republic

[5]"Smart-contract is an algorithm that is characterized by the presence of the following elements: 1) there is an agreement that defines a set of promises that are declined in a set of clauses; 2) the agreement is written in digital form, through a program or software that incorporates these clauses; and 3) the agreement is formalized by a protocol that established how the parties must process the qualitative and quantitative information of the contract, thereby allowing the parties to satisfy the contractual terms" (Gola et al., 2019). For more on smart-contract's regulatory issues, see (Grundmann and Hacker, 2017).

and Russian Federation?

To answer the first research question, the functional method (Van Hoecke, 2011) of comparative legal research was used. This method was chosen since it concentrates on similarities/differences of rules' results (social or legal) rather than the pure legal approach. Furthermore, the existing laws related to crypto laundering were examined with the evaluative research type.

For the second research question, the laws related to crypto laundering were examined from an economic point of view.

To answer the third research question, we utilized the unsupervised machine learning approach. We applied Natural Language Processing (NLP) techniques and topic models to reveal the most popular method for exchanging and manipulating cryptocurrency. Then, we consider the revealed method through the prism of anti-money laundering laws and regulations in the Italian Republic and the Russian Federation.

The main contributions of this paper:

1) Consideration of non-custodial wallet projects and NFT platforms through the lens of money laundering opportunities,

2) Comparison of Italian and Russian anti-money laundering regulations related to cryptocurrency,

3) Empirical analysis of the preferred method of trading/exchanging cryptocurrency for Dark Net illegal trade using machine learning techniques,

4) The assessment of how Italian and Russian regulations address these money laundering methods.

The paper has the following sections. Section 2 is the literature review. Section 3 provides the stylized facts of the aforementioned crypto laundering techniques. In Section 4, the analysis of Financial Action Task Force (FATF) recommendations against crypto laundering techniques is presented.

Section 5 examines specific laws confronting laundering cryptocurrency in the Italian Republic. Then, Section 6 reviews the legislation in the Russian Federation addressing crypto laundering. Next, in Section 7 provides a comparative analysis of Russian and Italian regulations against laundering techniques. Section 8 demonstrates the case study using the unsupervised machine learning approach. Section 9 provides the limitation of the case study, and Section 10 concludes.

2 Literature review

B. Walker-Munro analyzed the problem of criminal law regulators in adapting to technological change (Walker-Munro, 2020). The author considered how new technologies (DarkWeb) exacerbated the old problem (the supply of illicit drugs). Furthermore, he showed how cyber-systemics could be attractive for criminal law regulators in times of technological disruption.

I. Adeleke et al. applied the Systematic Quantitative Assessment Technique to analyze the cryptocurrency scholarship (Adeleke et al., 2019). The authors found that most papers focused on problems of cryptocurrency regulation without providing any recommendations.

D. Bryans compared Bitcoin to other currency systems and showed the potential for money laundering using bitcoin blockchain (Bryans, 2014). Unfortunately, Bitcoin is thought to be untraceable at the time of writing, which is not true.

V. Dyntu and O.Dykyi analyzed the challenges and opportunities that the Fourth Industrial Revolution brought to law regulators through such a new phenomenon as the digital economy (Dyntu and Dykyi, 2018). The authors examined how Bitcoin could facilitate money laundering.

T.A. Frick reviewed the international development in lieu of money laundering through cryptocurrency (Frick, 2019). Furthermore, he compared the E.U. developments with the Swiss approach. Out of the author's analysis, the Swiss approach to anti-money laundering in the case of cryptocurrency usage was more effective.

M. Campbell-Verduyn argued that Bitcoin and other cryptocurrencies posed a more theoretical threat to be used in money laundering schemes than actual (Campbell-Verduyn, 2018). Furthermore, the author considered the possibilities that cryptocurrency could give to combat money laundering globally.

V.A.Kinsburskaya compared the FATF recommendations and Russian regulation related to cryptocurrency usage (Kinsburskaya V.A., 2019). The author analyzed criminal cases (mostly related to illegal drug trade) where cryptocurrencies were utilized and proposed strengthening control over the transactions where cryptocurrency is exchanged for fiat money.

L. Haffke et al. considered the shortcomings of the 5th AML EU Directive (Haffke et al., 2020). The authors gave an overview of possible cryptocurrency-related services and presented the hypothetical money laundering scenario with cryptocurrency. They showed that the 5th AML EU Directive created an ambiguity with the "virtual currencies" definition covering only currency tokens. From this uncertainty follows that only cryptocurrency exchanges trading currency tokens are regulated. Moreover, providers engaged in trading solely cryptocurrency are not covered by the 5th AML EU Directive. However, if these providers "safeguard private cryptographic keys on behalf of its customers," they are regulated by the Directive. Wallet providers who do not store their customers' private keys are out of the scope of Directive. The authors argued that all wallet providers, irrespective

of safeguarding private keys, should be out of the scope of AML law since they are, in essence, private transaction providers. "As a private transaction in cash or in vouchers is not subject to AML law, a private transaction in virtual currencies should neither be."

R. Barone and Masciandaro D. compared money laundering through usury and cryptocurrency using initial coin offering (ICO) (Barone and Masciandaro, 2019). After the calibration of the proposed model, the authors stated that money laundering through ICO was not economically profitable.

F. Di Vizio explained the difficulties which faced regulators with the advance of cryptocurrency usage (Di Vizio, 2018). Furthermore, the author presented the evolution of anti-money laundering regulations related to cryptocurrency in Italy. Moreover, he considered the changes that brought the 5th AML EU Directive, 2018 FATF recommendations, and Italian Legislative Decree 125/2019 compared to previous publications. The author explained the laundering opportunities which Bitcoin and ICO could bring to criminals.

Riverditi, M. and Cossavella, G. discussed still controversial nature of bitcoin and its regulation in Italy (Riverditi and Cossavella, 2021). The authors showed that cryptocurrency exchanges should be registered in "Organismo degli Agenti e dei Mediatori" and obliged to profile their customers. They considered the phenomenon of money laundering and the possible usage of FinTech for laundering solutions.

3 Stylized facts of crypto laundering techniques

The money laundering process is usually decomposed into three steps: placement, layering, and integration (Ardizzi et al., 2014).

During the first stage, ill-gotten funds are introduced into the financial system. Crypto exchanges and non-custodial wallet-mixers are used during this step. Still, there are two more steps to be accomplished to protect the identities. Step two is the layering stage. The layering stage's goal is to conceal the origin of "dirty" money. This step usually involves the use of another round of crypto mixers. The third step is the integration step. During the integration step, the aim is to reintroduce the "cleaned" funds into the formal economy. This step involves the use of crypto laundering techniques, such as crypto exchanges, various DeFi projects, and NFT platforms. Below are these crypto-laundering techniques in more detail.

3.1 Cryptocurrency Custodial Exchanges

Since the cryptocurrency-related industry is still evolving, the number of exchanges is constantly fluctuating; in September 2021, there were around three hundred exchanges (CoinMarketCap, 2021). Different types of crypto exchanges exist. This paper examines two types of exchanges: centralized (custodial) and peer-to-peer (non-custodial). Centralized custodial exchanges are "platforms that enable users to buy and sell cryptocurrencies against payment of a fee[6]." These exchanges require full disclosure of the origin of the funds and identifying information. Therefore, these kinds of centralized exchanges are not suitable for crypto laundering (stage one and two), but they are suitable for stage 3 (reintroduction of the funds in the formal economy).

[6]Art. 2(3) lit g Directive 2015/849/EU

3.2 Cryptocurrency Non-Custodial Peer-To-Peer Exchanges

Non-custodial peer-to-peer exchanges provide a platform maintained and operated by software with no central point of authority, facilitating deals among users by connecting them to one another (Houben and Snyers, 2018) without leaving the platform. These kinds of non-custodial exchanges can be used for stages one and two of the money laundering process. Even though they also can be utilized for stage three, but it will not provide the desired result of cleaned funds.

It is worth mentioning that the use of crypto exchanges has always been a popular crypto-laundering method. Since 2019, the share of illicitly received bitcoins has increased from 30% to 85% (Chainalysis, 2021).

3.3 Non-Custodial Wallet-Mixer

Another category of the popular crypto-laundering method is the use of mixers. Mixers are non-custodial cryptocurrency wallets with the additional function of "mixing" cryptocurrency to conceal the exact origin. A crypto wallet is a service that stores and safeguards cryptocurrency on behalf of customers (Gola et al., 2019). In September 2021, there were at least 84 wallets that differed in functionalities and fees (CryptoWisser, 2021). The main difference of non-custodial wallets, as opposed to custodial form, is the existence of a natural or legal person who takes custody of other people's crypto keys. According to Article 3 (19) Directive 2015/849, a custodial wallet is "an entity that provides services to safeguard private cryptographic keys on behalf of its customers, to hold, store and transfer virtual currencies." That means that full personal disclosure has to be provided to the custodial wallet

platform. Based on that, only non-custodial wallets are suitable for money laundering schemes. These non-custodial wallets are suitable for stages one and two of the crypto laundering process.

3.4 Decentralized Finance (DeFi) Projects

The newest technique to launder money is Decentralized Finance (DeFi) projects. These DeFi projects are released through decentralized applications (dApps). Today, most of the DeFi projects run on the Ethereum blockchain. These platforms offer the ability to trade, option for lending, borrowing, or investing in crypto-related products automatically. It is said to be a "global, open alternative to the current financial system" (Ethereum, 2021). DeFi is a multi-facet phenomenon that democratizes the financial and financing worlds. However, it opens a grave possibility to launder money quickly and automatically. As an example, a hacker transferred $1 million to "Uniswap" after stealing $200 million from the crypto exchange "KuCoin" (Decrypt, 2020). DeFi platforms are suitable for the whole scheme money laundering process (stage 1-3) but best they are used for stage three - reintroduction cleaned funds into the formal economy.

3.5 Non-Fungible Token (NFT) Platforms

NFT is currently another blockchain-related boom. NFT works as proof of ownership of digital arts in many forms and formats, including images, videos, and music. NFT and their corresponding ownerships are registered in the blockchain, manifesting digital scarcity and uniqueness (Kraken, 2021). Even though the NFT trade is written in the blockchain, involved parties can stay anonymous while using non-custodial wallets. Since NFT can have an agreed value, criminals with ill-gotten cryptocurrencies could use these

non-fungible tokes for money laundering purposes, the same as regular art pieces in the real world. NFT platforms are trendy. In September 2021, there were at least sixty-nine NFT platforms (SourceForge, 2021). For the first half of 2021, NFT achieved over $927 million in sales (Kraken, 2021). NFT platforms are suitable for stages two and three of the crypto laundering process.

4 Financial action task force (FATF) intergovernmental recommendations

FATF defines a virtual asset as "a digital representation of value that can be digitally traded, or transferred, and can be used for payments or investment purposes" (FATF, 2021). Cryptocurrencies, DeFi products, and NFT tokens fall under this definition.

FATF also defines virtual asset service providers (VASPs). VASP "means any natural or legal person...conducts one or more of the following activities or operations for or on behalf of another natural or legal person:

1)Exchange between virtual assets and fiat currencies;

2)Exchange between one or more forms of virtual assets;

3)Transfer of virtual assets;

4)Safekeeping and/or administration of virtual assets or instruments enabling control over virtual assets; and

5)Participation in and provision of financial services related to an issuer's offer and/or sale of a virtual asset" (ibid.).

VASPs are required to be licensed or registered at a minimum in the jurisdiction where they are created (FATF, 2021). In addition, VASP should be supervised or monitored by a competent authority. Based on FATF recom-

mendations, VASPs are required to conduct Customer Due Diligence (CDD) when the transaction's threshold is above USD/EUR 1,000 (FATF, 2021). "Countries should ensure that originating VASPs obtain, and hold required and accurate originator information and required beneficiary information on virtual asset transfers, submit the above information to the beneficiary VASP or financial institution immediately and securely" (ibid).

As seen from the definition of VASPs, all platforms, including DeFi projects and NFT platforms that have a focal point of authority, should be registered and conduct AML/CFT and CDD policies. There is a problem in conducting the AML/CFT and CDD policies based on platforms having or not the central point of authority and custodianship over clients' private information. The non-custodial platforms, where the operators cannot oversee the transactions, do not collect AML/CFT and CDD information.

The following sections look in detail at how Italian regulations and Russian laws address these crypto laundering issues.

5 Italian regulations against crypto laundering

All Member States must follow and transpose the European Union Directives into their national laws in the European Union. These Directives can be furthered in their scopes in the countries' local decrees (laws). Various directives cover money laundering in European Union.

According to Directive (E.U.) 2015/849 of 20 May 2015 (4AML), art.1, par.3, "the following conduct, when committed intentionally, shall be regarded as money laundering:

a)the conversion or transfer of property, knowing that such property is

derived from criminal activity or from an act of participation in such activity, for the purpose of concealing or disguising the illicit origin of the property or of assisting any person who is involved in the commission of such an activity to evade the legal consequences of that person's action;

b)the concealment or disguise of the true nature, source, location, disposition, movement, rights with respect to, or ownership of, property, knowing that such property is derived from criminal activity or from an act of participation in such an activity;

c)the acquisition, possession or use of property, knowing, at time of receipt, that such property was derived from criminal activity or from an act of participation in such an activity;

d)Participation in, association to commit, attempts to commit and aiding, abetting, facilitating and counselling the commission of any of the actions referred to in points a, b and c."

In the Italian Republic, AML/CFT[7] legislation is represented by Decree n. 231 and 109 of 2007 (UIF, 2020) with recent amendments Decree n. 124, 125, and 157 of 2019. Furthermore, Directive (E.U.) 2015/849 of 20 May 2015 (4AML) was transposed into Italian law through Legislative Decree n. 90/2017 of 25 May 2017.

Legislative Decree n. 90/2017 of 25 May 2017 established the definition of virtual currency, highlighting its use as a medium of exchange (F. Vizio, 2019). Art. 5, par. I of this Decree categorized entities providing services related to cryptocurrency - as non-financial operators. These entities must comply with AML/CFT policy and must be registered with "Organismo degli Agenti e dei Mediatori" (Riverditi and Cossavella, 2021). Nevertheless, this Decree was only limited to regulating exchanges between fiat (regular)

[7]CFT - Countering Terrorist Financing

currency and cryptocurrency. This Decree did not mention nor regulate any services provided by custodial wallet platforms.

On 30 May 2018, new and the most recent, European Directive 2018/843 was passed into law. This Directive represents the fifth Anti-Money Laundering European Directive (5AMLD). According to the 5AMLD, entities that provide exchange services between "virtual currencies" and fiat currencies (art. 1, par. g) and custodial wallet providers (art 1, h) must follow AML/CFT policies. This Directive defined virtual currencies as "a digital representation of value that is not issued or guaranteed by a central bank or public authority, is not necessarily attached to a legally established currency and does not possess a legal status of currency or money but is accepted by natural or legal persons as a means of exchange and which can be transferred, stored and traded electronically." Again, it is evident that exchanges trading only cryptocurrency are not included in supervised entities. Also, some DeFi projects and all NFT products being considered not virtual currency are not covered by 5AMLD. However, in the "Proposal for a regulation of the European Parliament and of the Council on the Markets in Crypto-assets" of 24.09.2020, the exchange of crypto-assets for other crypto-assets is included in the definition of "crypto-asset service" (Title 1, Article 3(9)). According to this Proposal, all crypto-asset services providers must be legal persons, have a registered office in a Member State of the Union, and must be authorized by a competent authority (Title 5, Article 53(1)). If this Proposal comes into force, exchanges trading only cryptocurrency will be included in supervised entities.

On 4 October 2019, 5AMLD was transposed into the Italian legal system through the Legislative Decree 125/2019 (Gazzeta ufficiale, 2019). This Decree furthers the 5AMLD's scope even more: Legislative Decree n. 125/2019

incorporates entities dealing with a digital representation of value, including cryptocurrencies. It covers entities participating in issuing, offering, transferring, and clearing cryptocurrencies (art. 1, par. f). Crypto exchanges, custodial wallets, and DeFi projects fall into this category and must comply with the AML/CFT requirements. According to art.5, par. 1b, custodial crypto platforms are obliged to create a reporting system and communicate potentially suspicious transactions. As we can see, custodial crypto exchanges, custodial wallet providers, and custodial DeFi projects are covered by the latest Decree.

There is an issue in Decree 125/2019 with recognizing NFT transactions. By definition, NFT transactions are not considered to involve fiat with cryptocurrency. NFT is not a cryptocurrency by itself because it does not act as a medium of exchange but only as proof of ownership. Therefore, it does not fall into the scope of regulation. The only time NFT platforms would be considered for AML/CFT requirements is when the NFT platform is custodial, but NFT products by themselves do not fall under the scope of the current regulation.

Non-custodial exchanges also do not fall under the scope of Legislative Decree n. 125. The owners of such platforms do not have custody of the users' information, funds, and private keys. In other words, a non- custodial exchange is a peer-to-peer platform that automatically connects users for an exchange. The non-custodial exchange operates by finding suitable counterparts for the transaction. It means that the cryptocurrency is in the user's wallet until the transaction happens. After the transaction occurs, the cryptocurrency is transferred directly to the other user's wallet. The algorithm is written in such a way that users are matched automatically and instantly. The exchange platforms' owners do not get custody of any funds and are not

engaged in any exchange per se. Consequently, these platforms are not in the scope of Legislative Decree n. 125/2019.

Crypto wallets and wallet-mixers could be in custodial and non-custodial forms. According to Legislative Decree n. 125/2019, art. 1, par. g, custodial wallets, which could be mixers, are obliged to follow AML/CFT regulation, and the same does not apply for non-custodial wallets. These non-custodial wallets are being used as the solutions for tumbling cryptocurrencies, i.e., hiding the origin of the funds, therefore, performing the first stage of money laundering. For example, the Wasabi wallet utilized the CoinJoin technique to enhance privacy to camouflage transactions. Cake wallet uses private in-wallet exchanges, therefore, hiding the origin of the funds. These non-custodial wallets are providing the platforms for stage one of the money laundering operations. These non-custodial wallets are not breaking any laws since they are not required to follow AML/ CFT and CDD policy.

To summarize, the Italian regulation successfully confronts crypto laundering through custodial, centralized exchanges, custodial DeFi and NFT platforms, and custodial wallet-mixers. Still, crypto laundering through decentralized non-custodial platforms and NFTs is possible.

6 Russian regulations against crypto laundering

In the Russian Federation, Federal laws are passed in the Parliament (Duma), then approved by Federal Council, and signed by President.

In 2001, Federal Law n. 115-FZ/2001 went into effect, which defined money laundering as follows:

"..bringing a legal appearance to the possession, use or disposal of amounts

of money or other property received as the result of committing an offence" (Legislationline, 2021). This law obliges providers of investment platforms[8], financial platforms[9], and information systems issuing digital financial assets and exchange providers of digital currency[10], i.e., cryptocurrency, to comply with AML/CFT regulation.

This regulation with amendments covers exchange platforms, DeFi projects, non-fungible tokens (NFTs), and crypto exchange-wallets. Also, it is worth mentioning that Russian Federation only regulates entities and persons within its authority. Any company or natural person registered, located in, or citizen of the Russian Federation falls under its jurisdiction. Any person or entity utilizing the service within the territory of the Russian Federation, using Russian domain names (.ru, .rf) falls under its jurisdiction.

Russia defines crypto exchange as an exchange between any crypto and/or any fiat currencies. Decentralized Finance projects are defined as financial platforms that issue "digital financial assets." NFT platforms are considered as an investment platform issuing "utilitarian digital rights." Wallet providers that only hold cryptocurrency without additional services are not defined or regulated, while wallets providing exchange services are regulated as crypto exchanges. It is also worth mentioning that Russian legislation does not distinguish between custodial and non-custodial service providers. All platforms under Russian regulations being custodial or non-custodial, are obliged to exercise AML/CFT procedures.

According to Federal Law n. 259-FZ of 31.07.2020, "Digital currency is a set of electronic data (digital code or designation) contained in the information system that is offered and/or may be accepted as:

[8]Amended by Federal Law n. 259-FZ of 02.08.2019.

[9]Amended by Federal Law n. 212-FZ of 20.07.2020.

[10]Amended by Federal Law n. 259-FZ of 31.07.2020

1)A mean of payment that is not the official unit of currency of the Russian Federation, a unit of currency of a foreign country or an international unit of account or currency; and/or

2)An investment in respect of which no person is responsible towards the owners of such electronic data, except for operations and information systems nodes (that are only responsible to ensure the consistency of the issuance of such electronic data and making (amending) entries in such information subject to the rules thereof)" (Buzko and Krasnov, 2021).

According to Federal Law n. 259-FZ of 31.07.2020 art.14, par.2, Russian jurisdiction is applied when cryptocurrency "is deemed issued or exchanged in Russian Federation, if the process involves the use of the Russian information infrastructure objects, including Russian domain names and network addresses or technical infrastructure located in Russian Federation" (Buzko and Krasnov, 2021).

Russian Federation does not distinguish whether the exchange has custodianship. The laws must be followed irrespective of exchanges' type (custodial or non-custodial), the providers must follow AML/CFT policy. If the exchange process takes place not on Russian infrastructures or domains, this exchange is not obliged to comply with AML/CFT rules.

DeFi projects are regulated in Russian Federation as financial platforms. According to Federal Law n.211-FZ of 20.07.2020 art. 2, par.1, "financial platform - information system which provides interaction of the financial organizations or issuers with consumers of financial services by means of the Internet for the purpose of possibility of making of financial transactions and access to which is provided by the operator of financial platform" (CIS-legislation, 2021). Financial platforms' providers should be legal entities.

DeFi projects use digital financial assets (DFA). According to Federal

Law n. 259-FZ of 31.07.2020 art.1, par.2, digital financial assets (DFA) "are a subset of digital rights that are set forth by the decision on the issue of respective DFAs and may include:

1)Monetary claims

2)Ability to exercise rights attaching to issuable securities;

3)Interest in the capital of a non-public joint stock company; and

4)Right to require transfer of issuable securities" (Debevoise and Plimpton, 2021).

DFAs should be issued through a distributed ledger-based information system. As clear from the definition, the DeFi platforms that provide lending, borrowing, and investing services through usage of their tokens, utilize digital financial assets. Therefore, in the case of any DeFi platforms (custodial or non-custodial), their respective administrators should exercise AML/CFT policy.

NFT platforms are considered investment platforms that trade "utilitarian digital rights." According to Federal Law n. 259-FZ of 02.08.2019 art.2, par.1, an "investment platform is the information system on the Internet used for the conclusion by means of information technologies and technical means of this information system of agreements of investment, access to which is provided by the operator of investment platform" (CIS-legislation, 2020). On these investment platforms, users can trade "utilitarian digital rights" (Mograbyan A., 2021): "demand the transfer of things or exclusive rights to use them, as well as demand the performance of work and (or) the provision of services." It means that all NFT platforms are considered investment platforms. It also means that non-fungible tokens are, in fact, tradable/ exchangeable utilitarian digital rights products. According to this legislation, all NFT platforms and legal entities and natural persons adminis-

trating NFT platforms should exercise AML/CFT policy. Yet again, Russian laws do not distinguish between custodial and non-custodial platforms. All platforms, regardless of their custodianship, must comply with AML/CFT procedures if they fall under the jurisdiction of the Russian Federation.

Russian law does not regulate wallet providers as separate entities. Wallets and wallet platforms that provide exchange services are considered as an exchange. Wallets and wallet platforms that only provide the software for storing cryptocurrency are not regulated. Therefore, they are not required to comply with any AML/CFT policy.

It is evident that anti-money laundering regulations in Russian Federation do not differentiate between custodial and non-custodial platforms. All entities involved in the crypto business (such as crypto exchanges, DeFi projects, NFT platforms, and wallets/exchanges) under the jurisdiction of the Russian Federation must comply with the AML/CFT process.

7 Regulation's comparison

Despite significant differences in legal, socio-economic structure, historical and cultural uniqueness, combatting money laundering is a common objective for all governments. However, the approaches are different. The Italian and Russian legislators do not define cryptocurrency in the same manner, and this leads to even more differences in their anti-money laundering regulation related to cryptocurrency. The general economic definition of money is done through its three functions (Von Mises, 2013): medium of exchange, the standard of deferred payment, and store of value. Even though cryptocurrency is not money, it could operate similarly.

Italian legislation and Russian laws define cryptocurrency in a differ-

ent manner. Italian government considers cryptocurrency as a medium exchange and a store of value. As per Italian Legislative Decree n. 90/2017 of 25.05.2017 art. 1, par. Qq, cryptocurrency is a digital representation of value, not issued by any Central Bank or public authority, and used as a medium of exchange for goods and services and electronically transferred, archived, and traded. In contrast, the Russian government classifies cryptocurrency as a store of value only. According to Federal Law n. 259-FZ of 31.07.2020 art. 14, par.7, Russian legal entities and natural persons residing in Russian Federation for at least 183 days in consecutive 12 months cannot use cryptocurrency to purchase goods or services. Cryptocurrency can only be used as a store of value for investment purposes and to be exchanged for other cryptocurrencies, digital assets, and utilitarian digital rights. Therefore, in Italy, people can purchase goods and services, but in Russian Federation, cryptocurrency can only be used as a store of value, i.e., investment tool.

There are also major differences in how DeFi, NFT platforms, crypto exchanges, and crypto wallets are regulated. To summarize, the main difference is in what is being regulated. In the Italian Republic, only custodial platforms being DeFi, exchanges, and wallets are required to comply with AML/CFT policy. At the same time, Non-Fungible tokens (NFTs) are not being considered as a cryptocurrency, do not fall under the existing scheme of Italian regulations.

On the other hand, in the Russian Federation, all custodial and non-custodial platforms being crypto exchanges, DeFi, exchange-wallets, including NFTs, that fall under the authority of the Russian Federation, must exercise AML/CFT policy. Still, it is not clear why regular crypto wallets, that only store crypto, are excluded from the legal consideration in the Russian Federation so far.

Like the money laundering process, crypto laundering consists of three steps: placement, layering, and integration[11]. While Russian legislators focus on preventing crypto laundering through the first and the second stages, Italian laws concentrate on preventing crypto laundering through the second and third stages.

8 Case study

Let us look at one case of popular non-custodial wallets that Dark Net users in laundering funds are widely using. With this case, we can see how current laws and regulations within the Italian Republic and the Russian Federation are non-effective in stopping it. This is the case of Cake wallet, a legal and fully compliant with current laws crypto exchange wallet.

The information of the widely used Cake wallet was derived from the ClearNet forum that discussed all the cons and pros of illegal activities on the Dark Net.

ClearNet forums are gateways for new and potential Dark Net participants; therefore, we can utilize them to understand the motivations and challenges of these users. The public subreddit r/darknet was chosen for this research project because of its size (184,000 registered members) and the length of time it has been in operation (it was created on December 26, 2009).

We employed the Reddit Scrapper (Agarwal, 2020) to obtain the r/darknet data from the open archive (Pushshift.io, 2021). The data was collected from January 1, 2020, to December 31, 2020. We researched the comments dataset as we were interested in the recommended techniques for exchanging cryp-

[11]More in Section 3.

tocurrency, but not in the questions per se. The number of comments used for the paper is 196,546.

Aiming to understand the preferred methods of buying and exchanging cryptocurrency, we applied topic models on obtained text data. Then we considered if anti-money laundering regulations covered this method.

Several studies have already utilized ClearNet forums and topic models to determine the effect of DNM busts (Porter, 2018), to discover anomalies signaling the advent of disturbing events (Shah et al., 2019), to determine critical players on specific DNM (Hazel Kwon and Shao, 2020).

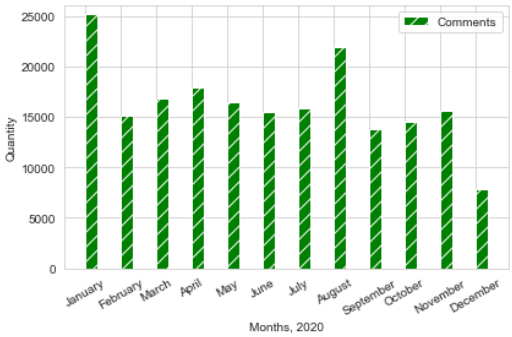
The usual topic model's approach examines documents over time with different topics, where a topic is a probability distribution over the words (Sohrabi et al., 2018). The utilization of the Correlation Explanation (CorEx) model allows minimizing starting assumptions and human intervention (Gallagher et al., 2017). CorEx discovers independent latent factors that explain correlations between observed variables. In this model, X is a group of words, and Y is a topic to be learned. The Total Correlation is zero only when there is no dependence between variables X and Y.

Before analyzing data with CorEx, we removed stop words and punctuation, lowercased data, deleted NaN values, bot entries, and lemmatized text (Spacy.io, 2021). We defined the stop words like pronouns, swear words, and auxiliary verbs. Moreover, we anonymized the data by removing usersâ€™ names, identification numbers, and metadata.

Applying the CorEx model in an unsupervised manner without anchor words allowed us to comprehend the most discussed topics every month for 2020.

We chose the topic's number in such a way as to explain 70% of all entries since extra topics contributed only insignificant correlation to the

learned models. The data was normalized due to differences in the number of comments per month (Figure 1).



Month	Comments
January	25168
February	15085
March	16850
April	17917
May	16425
June	15522
July	15894
August	21981
September	13810
October	14509
November	15569
December	7816

Figure 1: Quantity of comments over 2020

Among the most discussed topics in 2020 (Figure 2), we revealed the topic related to the usage of the non-custodial wallet "Cake" wallet (see Appendix A for "Cake" topics over 12 months of 2020).

Since in the realm of Dark Net, the wallets are of interest only as a method to purchase and exchange cryptocurrency in the most untraceable way, and not as the cheapest solution, we hypothesized that these comments were answers to the question of "which wallet is best to use for DarkNet users?" (Figure 3).

Figure 4 suggests that the discussion of "Cake" had an increasing trend with spikes in May and October 2020. Let us consider what Cake wallet is and why Dark Net users were recommending it. The Cake wallet is a non-custodial multicurrency wallet allowing to exchange cryptocurrency directly in the wallet (Cake Technologies LLC , 2021). Being open-source, the wallet allows changing the code according to the user's needs. Originally, the Cake wallet was created in 2018 as an open-source Monero wallet, then other

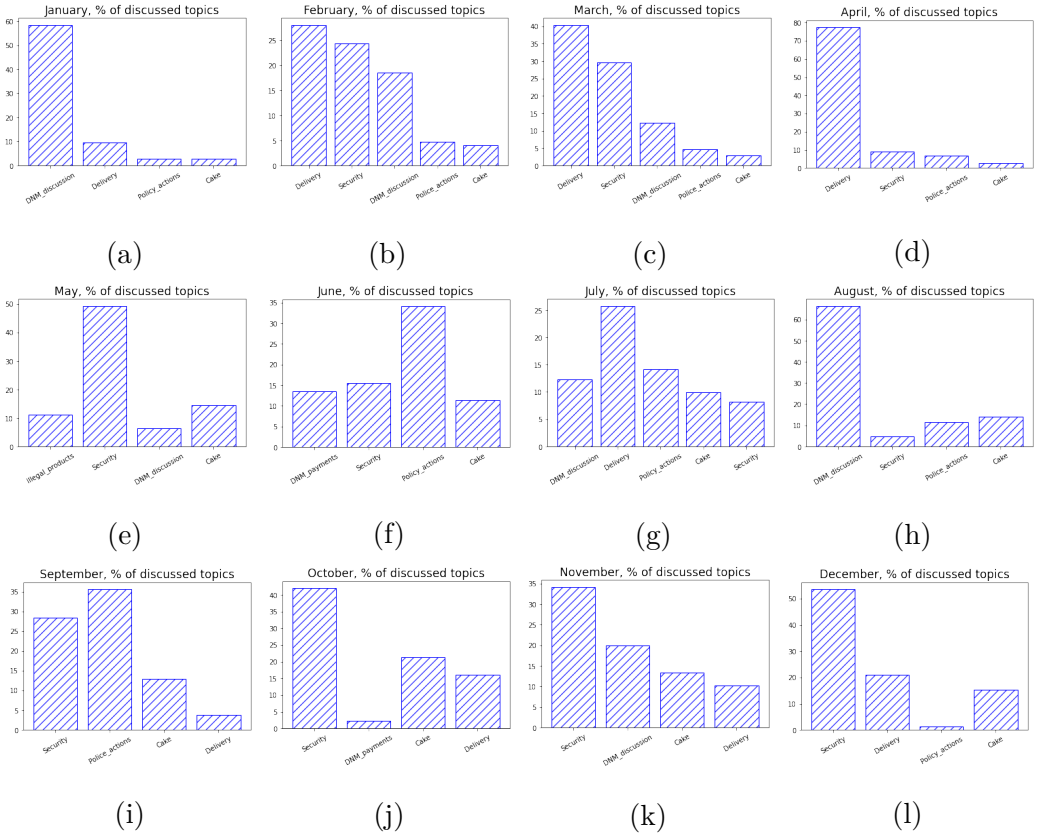


Figure 2: Comments' topics evolution in 2020

cryptocurrencies were added.

Let us consider the Cake wallet in the light of Italian anti-money laundering regulations. Since this wallet is non-custodial, existing decrees do not apply, which explains the wallet's popularity among this specific public.

Considering the Russian regulations, the Cake wallet platform does not have to exercise AML/CFT policies since it is not located in the Russian Federation, is not using Russian infrastructures, and does not hold Russian domain names. Furthermore, since the actual exchanges are performed outside of the scope of Russian jurisdiction, the platform does not have to provide AML/CFT functions even for Russian citizens utilizing its services.

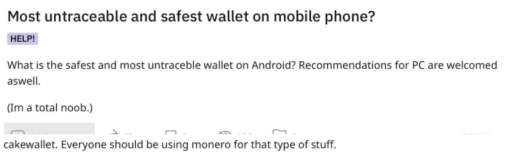


Figure 3: Example related to the best wallet for Dark Net.

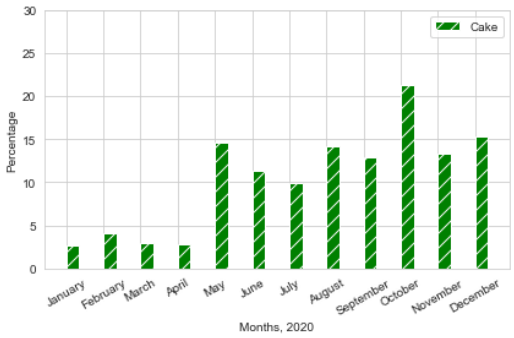


Figure 4: The evolution of “Cake" topic in 2020

It appears from the case study that current anti-money laundering laws are outdated and do not cover the activity that DarkNet illegal participants are currently using. The Cake wallet case showed us that only international cooperation and harmonization of anti-money laundering regulation could resolve the problem of money laundering related to cryptocurrency.

9 Limitations of the case study

In the present study, we examined users’ comments who presumably buy and sell drugs from the DNMs regularly. Although these users wrote that they used Cake wallet regularly, we do not have access to the actual transactions. Therefore, the major limitation is the possible discrepancies between users’ words on the forum and the actions.

10 Conclusion

The borderless nature of digital assets and cryptocurrencies creates vast complexity for regulators. Current laws to mandate and govern blockchain-

based technologies differ between countries, and these differences in interpretations and requirements allow criminals to be one step ahead. Even though international cooperation between such countries as the Italian Republic and the Russian Federation is done through FATF and other international organizations, these member countries fall behind on their ability to investigate and prevent crypto laundering. One possible solution could be digital law harmonization through an international cooperating body.

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A Appendix

Months 2020	Terms of the “Cake" topic
January	transfer,app,coinbase,atm,cake,finally,burner,suspicion,target,morphtoken
February	bitcoin,wallet,monero,tor,noob,vpn,fee,email,extra,cake
March	fee,transaction,atm,coinbase,cake,heroin,arrest,fully,pro,bounce
April	loss,exchange,single,yellow,kraken,mess,interest,cake,official,best
May	electrum,coinbase,fund,kraken,involve,cake,steal,escrow,reporting,content
June	weed,cake,pack,dose,virus,smoke,game,paper,hot,warning
July	monero,bitcoin,wallet,tail,cake,tor,directly,app,security,electrum
August	wallet,monero,bitcoin,government,law,state,cake,enforcement,directly,illegal
September	wallet,cake,transfer,bag,coinbase,kraken,link,electrum,shitty,color
October	pgp,fee,tail,ipsjip,transaction,bomb,cake,app,encryption,exact
November	send,wallet,package,cake,vpn,delivery,android,risk,feature,trouble
December	monero,wallet,bitcoin,tail,cake,buy,tor,fee,anonymous,coinbase

Table 1: “Cake" topic in 2020

A Cournot equilibrium between Dark Net Market and Street market

1 Introduction

This paper aims to study drug vendors' and consumers' behavior in a framework in which they can meet either on the web, in the so-called Dark Net Market (DNM from now on), or the Street Market. By Street Market we mean a representative local market in which drugs are traded, characterized by the fact that consumers can reach it on foot or at negligible transport costs.

As for the DNM, we resort to the Cournot oligopoly model, and for simplicity of treatment, we assume that identical vendors compete in quantity and sell a homogenous given drug (like, e.g., cocaine) online. The role of platforms is not explicitly modeled: it is assumed that the costs of services of platforms contribute to determining the costs borne by vendors in this market. While this is a limitation of our approach, the presence of many competing platforms operating in this field and the frequency of multihoming severely limit the market power of platforms.

We also model the Street market for the same drug type as a Cournot oligopoly since some competition also arises in the Street, at least at the borders of catchment areas. Moreover, the Cournot approach also allows for the possibility of having a unique vendor, thus encompassing the case of a monopolistic market as well. The

risk of violence on the Street is considered in our model as a feature that negatively affects the quality of the goods traded in the Street market. The drug sold in the DNM is thus perceived as higher quality since the risk incurred during the trade is lower, i.e., the two markets are vertically differentiated.

The whole drug market, consisting of DNM and Street, is described as a Cournot-type market, in which, however, competition between the two markets occurs in quality instead of quantity (Gabszewicz and Thisse, 1979). We adopt a short-term perspective and assume that suppliers in each market are identical, specialize in one market, cannot move to the other or operate in both, and cannot modify the riskiness of accessing their market.

As for consumers, it is assumed that there is a continuum of them, each demanding one unit of a given drug, with no substitute or complement. Their demand price varies from the DNM to the Street according to the riskiness of the environment.

Vendors in both markets compete in quantity within their home market and also face the vertical threat coming from the other market. We present the conditions characterizing an equilibrium in which both markets are active.

The recent literature in the field of drug markets has focussed on the moral hazard problems raised by the fact that drugs sold in the streets are experience goods whose quality can be assessed only after buying them (Galenianos and Gavazza, 2017). Other papers (Galenianos et al., 2012) concentrated on the search process that arises in the Street market. As for the DNM, it has been pointed out that customers' ratings signal the high quality of products delivered there. At the same time, the DNM continuing expansion shows that it is resilient to disruptive events or specific risks, such as exit scams (Bhaskar et al., 2019).

Our contribution aims at building a simple model describing the current scenario, characterized by the fact that information asymmetry is now less relevant

in the DNM. At the same time, there is a vertical differentiation between the DNM and the Street since the latter is perceived as being riskier than the DNM. We aim to describe both the internal functioning of each market and the interaction between them, and for the latter sake, we exploit the classical approach to vertical differentiation à la Gabszewicz and Thisse (Gabszewicz and Thisse, 1979). Notwithstanding the strong simplifying assumptions needed to render this approach manageable, our model provides a rich basic framework for analyzing policy interventions, which might target the relative riskiness of the two markets and/or the other parameters affecting the internal functioning of each of them.

The rest of the article is organized as follows. In Section 2, we introduce background information about the DNM drug trade. Section 3 presents the standard Cournot model in which suppliers compete in quantity, and the equilibrium which would arise if each market was the only active one. We introduce and study the global equilibrium in the two markets in section 4. Section 5 discusses illustrative example and policy implications, while the final section concludes.

2 Background

The typical DNM functions as a traditional e-commerce business with many sellers competing for the consumer's attention. One of the most significant advantages of the DNM platform is a new and convenient way to order drugs. A person can browse drug listings from anywhere. The drug ordering process is temporally detached from its delivery process, creating an additional security buffer for users. There is no need anymore to meet with dealers. Third parties, such as postal services or delivery companies, handle drug shipments without even knowing it.

In contrast to the DNM, vendors and buyers are exposed on the Street. The violence and apprehensions are two major downsides of this exposure. While using

DNM, only dealers are susceptible to violence and arrests during meetings with wholesalers. End consumers never meet with sellers from the DNMs.

DNMs offer sellers a unique opportunity to enlarge their distribution channels worldwide. DNM vendors are not physically attached to any specific place like the Street dealers. On the Street market, the territory for drug sales is usually divided between criminal groups, which intermittently resort to violence to deter competitors.

In DNM trading, the decisive risk occurs at the level of delivery. To reduce the shipping and delivery risks, buyers and sellers share information about the best practices (Aldridge and Askew, 2017).

Aside from collecting information about "safe delivery" techniques, the DNM helps construct private and anonymous drug communities. There is no need to build an interpersonal relationship on the online platform like on the Street market, as the former offers a review system for both vendors and consumers. Moreover, through escrow system utilization, market administrators enforce contracts. Platform owners keep consumers' money in escrow until the delivery is confirmed. Even though the escrow system is designed to protect buyers and sellers, it tempts a platform owner to perform an exit scam with all the escrowed money in their possession.

To mitigate the platform's moral hazard problem, the usage of multi-signature[1] escrow schemes is advised. Still, this precaution measure is rarely used, possibly because of the additional fees to be paid (Bhaskar et al., 2019). Therefore, DNM drug sellers and consumers are exposed to the risk of losing money due to the platform's exit scam. However, the market proved to be quite resilient after episodes of scams (Bhaskar et al., 2019).

Accessing DNM for the first time could be challenging for new buyers. "Know-

[1]Multi-signature escrow means that money is released only when the seller, buyer, and platform put their signatures.

ing the right people" may be restated to knowing the right way on the internet (Leukfeldt, 2017). Still, the DNMs drug market is an open market, and everyone with a computer and an internet connection is welcomed. The "DarkNet Bible" exists to answer the most common questions and doubts.[2] Additionally, on ClearNet,[3] there are forums such as DarkNet on Reddit,[4] where DNM drug users can ask for advice or share information.

On the DNMs, consumers are not tied to specific dealers, and users can freely choose their suppliers from any part of the world. The entry barriers for suppliers on the DNMs are low. Vendors only need to register on the DNM and write product descriptions. The setup costs are modest, consisting of a vendor bond, which is about $200. Then, the vendor pays a fee of around 2-4% of each transaction (Aldridge et al., 2018). This leads to a simultaneous presence of vendors on multiple DNMs. A growing number of vendors and review systems increase the competition between the sellers and make vendors improve the product quality. On DNMs, while presenting their products, vendors should write the drug's composition and purity. If the description does not coincide with the actual product, it will mirror the reviews. The high quality of the drugs is one of the main reasons why consumers prefer DNMs (Caudevilla et al., 2016).

DNM is a relatively new phenomenon as the first one was created in 2011. Technologies used on DNM are constantly evolving. Nowadays, the biggest challenge for law enforcement agencies is the usage of untraceable cryptocurrency instead of Bitcoin. Therefore, the probability of apprehension is perceived to be lower on the DNM than on the Street: only 4.1% of drug users are concerned about being caught by law enforcement while buying drugs from DNM (Barratt et al., 2016).

[2]See `https://archive.is/yo4oF`, accessed 10.12.2021.

[3]ClearNet (Surface Web) is a everyday part of the Internet accessible by search engines as Google (Weimann, 2016).

[4]See `https://www.reddit.com/r/darknet/`, accessed 10.12.2021.

3 The model

Let us first of all model the functioning of each market in isolation, assuming that it is the only one active. Then we will consider the case in which both markets are active.

3.1 Demand functions

For simplicity, let us assume that all consumers are indexed over the interval $[0, 1]$; that is, any real number $x \in [0, 1]$ denotes a single customer belonging to a (continuous) infinite population of consumers. Moreover, again for simplicity, we assume that each consumer x is willing to purchase *one unit* of a homogeneous illicit good (e.g., cocaine), while only one market, i.e., either the DNM or the Street, is active. The same model, in which vendors compete in quantity, is used to describe both markets: of course, the relevant parameters for a calibration (such as the demand price, the number of firms, etc.) would differ from one market to the other.

In line with empirical evidence (Gallet, 2014), we assume that the inverse market demands are characterized by a constant elasticity in each market.They are denoted by $R_D(x)$ and $R_S(x)$ for the DNM and the Street respectively; for each $x \in [0, 1]$, $R_D(x)$ represents the inverse market demand in the DNM, while $R_S(x)$ represents the inverse market demand in the Street.

We characterize both markets with constant elasticity inverse demand functions:

$$R_D(x) = \theta_D x_D^{-\varepsilon_D} \qquad \text{and} \qquad R_S(x) = \theta_S x^{-\varepsilon_S}, \tag{1}$$

where θ_D and θ_S are positive constants and $-\varepsilon_D$, $-\varepsilon_S$ denote the (negative) con-

stant elasticities of the DNM and Street markets respectively, i.e.,

$$\frac{R'_D(x)\,x}{R_D(x)} \equiv -\varepsilon_D \qquad \text{and} \qquad \frac{R'_S(x)\,x}{R_S(x)} \equiv -\varepsilon_S \qquad \text{for all } x \in [0,1]\,.$$

We assume that $\theta_D = \theta_S = 1$ and $|\varepsilon_D| > |\varepsilon_S|$, which is equivalent of having (the absolute values of) the *elasticities of the direct demand curves*, $\frac{1}{|\varepsilon_D|}$ and $\frac{1}{|\varepsilon_S|}$, satisfying $\frac{1}{|\varepsilon_D|} < \frac{1}{|\varepsilon_S|}$ and having the inverse demand curves in the two markets such that $R_S(x) < R_D(x)$[5] for all $x \in [0,1)$ and $R_D(1) = R_S(1) = 1$.

3.2 Oligopoly with either the DNM or the Street market active

We study the two markets in parallel since the same standard Cournot competition model is used to describe the respective functioning.

There are n_D vendors in the DNM and n_S vendors in the Street market. The n_D vendors face the same marginal cost $c'_D(y)$ to provide any amount of the homogeneous drug $y \geq 0$ in the DNM, while the n_S vendors face the same marginal cost $c'_S(y)$ to provide any amount of the homogeneous drug $y \geq 0$ in the Street market. Vendors are all equal in each market and compete in quantity within their market, that is, in equilibrium, each vendor in the DNM sells $y_D = \frac{Y_D}{n_D}$ units of the drug, while each vendor in the Street market, if the latter is the only one active, sells $y_S = \frac{Y_S}{n_S}$ units of the drug, where Y_D and Y_S denote the total quantities offered in equilibrium in each market. Specifically, according to formula (16.4) on p. 290 in (Varian, 1992), the equilibrium conditions in each market, as long as it is the

[5]Our assumption of $R_S(x) < R_D(x)$ is consistent with empirical evidence (Rhumorbarbe et al., 2016). This assumption could be explained as follows. Drug users are willing to pay higher prices on the DNM in exchange to safer transactions, greater choice and more convenient process of buying drugs compared to the Street market.

only one active, are:[6]

$$R_D\left(Y_D\right)\left(1-\frac{\varepsilon_D}{n_D}\right)=c_D'\left(y_D\right)=c_D'\left(\frac{Y_D}{n_D}\right) \tag{2}$$

$$R_S\left(Y_S\right)\left(1-\frac{\varepsilon_S}{n_S}\right)=c_S'\left(y_S\right)=c_S'\left(\frac{Y_S}{n_S}\right). \tag{3}$$

Clearly, as both inverse demands $R_D\left(Y_D\right)$ and $R_S\left(Y_S\right)$ denote prices, the terms $R_D\left(Y_D\right)$ and $R_S\left(Y_S\right)$ are strictly positive; similarly, we assume that the cost structure in both markets increase in the quantity sold, i.e., $c_D'\left(y_D\right)$ and $c_S'\left(y_S\right)$ are strictly positive as well[7]. Hence, in order to be meaningful, conditions $\left(1-\frac{\varepsilon_D}{n_D}\right)>0$ and $\left(1-\frac{\varepsilon_S}{n_S}\right)>0$ in equations (2) and (3) must hold. As we do not want a priori rule out monopolistic markets, in line with the other research (Payne et al., 2020), we shall adopt the following assumption.

A. 1 *The elasticity parameters of the isoelastic inverse demand functions in (1) satisfy* $|\varepsilon_S|<|\varepsilon_D|<1$.

Assumption A.1, by requiring both inverse demands to be inelastic in the relevant domain $[0,1]$, allows for a single monopolistic seller in both markets to operate on the elastic part of the direct demand.

[6]Note that in equations (16.3) and (16.4) on p. 290 (Varian, 1992) the term ε denotes the (negative) elasticity of *direct demand*, while here we use ε_D and ε_S to denote the absolute value of the elasticity of the *inverse demands*; therefore, the expressions inside the brackets in the LHS contain the terms $-\frac{\varepsilon_D}{n_D}$ and $-\frac{\varepsilon_S}{n_S}$ instead of $\frac{1}{n_D\varepsilon_D}$ and $\frac{1}{n_S\varepsilon_S}$ as in Varian (1992).

[7]Indeed, on the DNM, cost increases due to shipping costs, and on the Street, dealers' cost increases due to payments for protection.

3.3 The inverse supply function

Conditions (2) and (3) imply that prices will settle in each market according respectively to (4) and (5):

$$R_D\left(Y_D\right) = \frac{c'_D\left(\frac{Y_D}{n_D}\right)}{1 - \frac{\varepsilon_D}{n_D}} \tag{4}$$

$$R_S\left(Y_S\right) = \frac{c'_S\left(\frac{Y_S}{n_S}\right)}{1 - \frac{\varepsilon_S}{n_S}}, \tag{5}$$

For different inverse demand functions the equilibrium quantities will differ; therefore, by considering all possible (constant elasticity) inverse demand functions it is possible to build the whole *inverse supply functions* L[8] for each market by taking the RHS terms in (4) and in (5) as functions of all the possible quantities Y:

$$L_D\left(n_D, \varepsilon_D, c'_D, Y\right) = \frac{c'_D\left(\frac{Y}{n_D}\right)}{1 - \frac{\varepsilon_D}{n_D}} \tag{6}$$

$$L_S\left(n_S, \varepsilon_S, c'_S, Y\right) = \frac{c'_S\left(\frac{Y}{n_S}\right)}{1 - \frac{\varepsilon_S}{n_S}}. \tag{7}$$

4 Towards a definition of global equilibrium

When both markets are active, consumers will choose the market which provides the best deal. This implies considering the *consumer surplus* (*rent*) $E_D : [0,1] \to \mathbb{R}_+$ and $E_S : [0,1] \to \mathbb{R}_+$ that consumers would get in each market, defined

[8] More properly these functions represent the *Locus of quantities offered in equilibrium in each market* (for a discussion of this topic, see (Klemperer and Meyer, 1989).

over the whole population $[0,1]$ of consumers as:

$$E_D(x) = R_D(x) - p_D^* \qquad \text{for the DNM,}$$
$$E_S(x) = R_S(x) - p_S^* \qquad \text{for the Street,}$$

where E_D and E_S denote the consumer surplus as functions of the consumers' index x in DNM and in the Street respectively, while $R_D(x)$ and $R_S(x)$ have the form in (1), and p_D^* and p_S^* denote the *prices that are actually being paid in equilibrium* in the DNM and in the Street market respectively. Prices p_D^* and p_S^* turn out to be complex objects that must be carefully discussed; for the moment let us consider them as abstract equilibrium prices in the two markets. Our key assumption is the following.

A. 2 *Whenever either* $E_D(x) \geq 0$ *or* $E_S(x) \geq 0$ *(that is, consumer* x *purchases at least in one of the two markets), the following hold:*

i) *consumer* $x \in [0,1]$ *purchases on the DNM if* $E_D(x) > E_S(x)$*,*

ii) *consumer* $x \in [0,1]$ *purchases on the Street if* $E_D(x) < E_S(x)$*,*

iii) *consumer* $x_m \in [0,1]$ *will be labelled as the* marginal consumer *(i.e., she is indifferent between DNM and the Street) if* $E_D(x_m) = E_S(x_m) \geq 0$*.*

Assuming that the inverse demand functions in the two markets have constant elasticity as in (1) which satisfy $\theta_D = \theta_S = 1$ and, according to Assumption A.1, $\varepsilon_D > \varepsilon_S$, consumers x close to the left endpoint 0 are eager to pay higher prices on the DNM than on the Street for one unit of the same drug. Independently of any assumption on the oligopolistic inverse supply functions provided by (6) and (7), we assume that consumers x close to the left endpoint 0 always prefer to purchase

on the DNM[9], that is $E_D(x) > E_S(x)$ for small values of x. As $\theta_D = \theta_S = 1$, $\varepsilon_D > \varepsilon_S$ implies that $R_D(x) > R_S(x)$ for all $x \in [0,1)$ and $R_D(1) = R_S(1) = 1$, necessarily R_D decreases faster than R_S. If we also assume that the inverse supply functions L_D and L_S have values sufficiently close in $Y = 0$, $L_D(0) \sim L_S(0)$, and that the former increases faster than the latter, one expects that there exists a (possibly unique) *marginal consumer* $x_m \in (0,1)$ which is indifferent between going to the DNM or to the Street market, i.e., such that $E_S(x_m) = E_D(x_m)$, and that all consumers $x \in (x_m, x_S^*] \subseteq (x_m, 1]$, where x_S^* is the consumer having reserve price equal to the equilibrium price p_S^* in the Street market, will go to the Street market; that is, $E_D(x) < E_S(x)$ for all $x \in (x_m, x_S^*]$. For simplicity let us assume that the marginal consumer x_m is unique.

4.1 The equilibrium in the Street market

Let $0 < x_m < x_S^*$; then in equilibrium each consumer indexed by $x \in [0, x_m)$ purchases one unit of drug, so that a total quantity given by

$$Y_D = x_m - 0 = x_m > 0 \tag{8}$$

is being sold by all the n_D vendors in the DNM. Conversely, each consumer indexed by $x \in (x_m, x_S^*]$ purchases one unit of drug, so that a total quantity given by

$$Y_S = x_S^* - x_m > 0 \tag{9}$$

is being sold by all the n_S vendors in the Street market. Specifically, (9) shows that the marginal consumer x_m is the first consumer entering the argument of the supply

[9]The intuition behind this assumption relies on the empirical evidence (Bancroft and Reid, 2016),(Moeller et al., 2021) of some customers ready to buy drugs only on DNM and to pay higher prices for the perceived lower risk and higher quality.

function $L_S(Y)$ in the Street, i.e., consumer x_m from the demand perspective corresponds to consumer $Y = 0$ from the supply perspective in the Street market, as clearly vendors cannot distinguish among consumers and are interested only in the quantity to be sold. Such an observation leads to the conclusion that, while in the DNM vendors in principle face the actual inverse demand function $R_D(x)$ (in the following we shall see that this is not exactly true), in the Street market vendors face the portion of the $R_S(x)$ demand starting from $x = x_m$. In other words, the actual inverse demand function faced by vendors in the Street is a new function obtained through a parallel shift of the original inverse demand function $R_S(x)$ towards the left by x_m; i.e., for any given x_m, the new inverse demand function is defined by

$$\hat{R}_S(x_m, x) = R_S(x_m + x) \qquad \text{for } (x_m, x) \in [0,1] \times [0, 1 - x_m], \tag{10}$$

Notice that $\hat{R}_S(x_m, \cdot)$ ceases to have constant elasticity, as its absolute value is given by

$$\hat{\varepsilon}_S(x_m, x) = \left| \frac{\frac{\partial}{\partial x}\hat{R}_S(x_m, x)\, x}{\hat{R}_S(x_m, x)} \right| = \left| \frac{R'_S(x_m + x)\, x}{R_S(x_m + x)} \right|.$$

Under our assumption in (1), it holds:

$$\hat{\varepsilon}_S(x_m, x) = \left| \frac{-\varepsilon_S (x_m + x)^{-\varepsilon_S - 1}\, x}{(x_m + x)^{-\varepsilon_S}} \right| = \varepsilon_S \frac{x}{x_m + x}, \tag{11}$$

which clearly depends on both x_m and x.

In order to define a global equilibrium across both markets we must consider that in the Street market the equilibrium must be determined as the intersection point between the "*horizontally shifted*" inverse demand function $\hat{R}_S(x_m, x)$ defined in (10) and, according to the Cournot equilibria discussed in Subsection 3.3,

the non-constant elasticity inverse supply function defined as

$$\hat{L}_S\left(x_m, x\right) = \frac{c_S'\left(\frac{x}{n_S}\right)}{1 - \frac{\hat{\varepsilon}_S(x_m, x)}{n_S}}, \tag{12}$$

where $\hat{\varepsilon}_S\left(x_m, x\right)$ is the elasticity defined in (11). As $\hat{R}_S\left(x_m, x\right)$ defined in (10) is the actual inverse demand function faced by vendors in the Street market, in order to guarantee a Cournot equilibrium their inverse supply function must be adapted as well according to (12).

4.2 The equilibrium in the DNM

Under the assumption that $x_m < x_S^*$ and because the (actual) excess demand function in the Street market, $E_S\left(x\right) = R_S\left(x\right) - p_S^*$, is strictly decreasing in x, necessarily $E_S\left(x_m\right) = R_S\left(x_m\right) - p_S^* > 0$ must hold, which, by definition of marginal consumer, in turn implies that $E_D\left(x_m\right) = R_D\left(x_m\right) - p_D^* > 0$ must hold as well. In other words, any definition of global equilibrium across the two markets must incorporate the property that the DNM market actually is in *disequilibrium*, at least according to the standard notion of equilibrium stating that supply must equal demand. However, no exception actually emerges if one considers that suppliers in the DNM are aware that consumers, beginning from the marginal one, would shift from the DNM to the Street as long as, notwithstanding the lower quality of the product delivered there, thanks to a lower enough price they would get a larger consumer rent. Under the threat posed by the other market, vendors in the DNM revise their profit maximization problem. The Cournot equilibrium in the DNM is reached when their revised assumption about the quantity demanded in their market is compatible with the equilibrium in both markets, so that the following condition is satisfied:

$$E_D(x_m) = R_D(x_m) - p_D^* = E_S(x_m) = R_S(x_m) - p_S^* > 0. \tag{13}$$

$E_D(x_m)$ is the minimum consumer rent that customers must obtain in the DNM in order to prevent them from shifting to the other market. To discuss the equilibrium when both markets are active we thus modify the inverse demand function $R_S(x)$ in the Street as shown in Subsection 4.1 and we change the original inverse demand function $R_D(x)$ by shifting it downward as in (13). Hence, the actual inverse demand function faced by vendors in the DNM is the new inverse demand function obtained through a rigid downward shift of the original inverse demand function $R_D(x)$ by a magnitude corresponding to the minimum consumer rent $E_D(x_m)$ in (13). Under the latter assumption, again, the new inverse demand function in the DNM ceases to have constant elasticity, as the new inverse demand function

$$\hat{R}_D(x_m, x) = R_D(x) - E_D(x_m), \tag{14}$$

which must be interpreted as a function of the only variable x, while $E_D(x_m)$ is a *constant* (it is the minimum consumer rent value in equilibrium), has elasticity given, in absolute value, by

$$\hat{\varepsilon}_D(x_m, x) = \left| \frac{\frac{\partial}{\partial x}\hat{R}_D(x_m, x)\, x}{\hat{R}_D(x_m, x)} \right| = \left| \frac{R'_D(x)\, x}{R_D(x) - E_D(x_m)} \right|.$$

As, according to the definition of Cournot equilibrium discussed in Subsection 3.2, we only need to consider the elasticity value on the marginal consumer x_m, we can define $\hat{\varepsilon}_D(x_m, x)|_{x=x_m} = \hat{\varepsilon}_D(x_m)$ as

$$\hat{\varepsilon}_D(x_m) = \left| \frac{R'_D(x_m)\, x_m}{R_D(x_m) - E_D(x_m)} \right|,$$

which, under the functional form in (1), becomes

$$\hat{\varepsilon}_D(x_m) = \left| \frac{-\varepsilon_D (x_m)^{-\varepsilon_D - 1} x_m}{(x_m)^{-\varepsilon_D} - E_D(x_m)} \right| = \varepsilon_D \frac{(x_m)^{-\varepsilon_D}}{(x_m)^{-\varepsilon_D} - E_D(x_m)}. \tag{15}$$

Therefore, once again the inverse supply in the DNM must be adapted because the oligopolistic vendors face an actual inverse demand function characterized by the elasticity defined in (15). According to the Cournot equilibria discussed in Subsection 3.3, such a non-constant elasticity inverse supply is pointwise defined on $x = x_m$ as

$$\hat{L}_D(x_m) = \frac{c'_D\left(\frac{x_m}{n_D}\right)}{1 - \frac{\hat{\varepsilon}_D(x_m)}{n_D}}, \tag{16}$$

where $\hat{\varepsilon}_D(x_m)$ is the elasticity defined in (15). It remains to determine the value of the minimum consumer rent $E_D(x_m)$ in (13). As it depends on everything at the same time[10] $E_D(x_m)$ is a key element in the following definition of global equilibrium across the markets, which is itself based on the definition of marginal consumer x_m as in Assumption A.2 (iii).

4.3 A definition of equilibrium across the two markets

The pivotal element on which the whole definition of a global equilibrium rests is the minimum consumer rent $E_D(x_m)$ [defined in (13)] enjoyed by the *marginal consumer* x_m [as specified in Assumption A.2(iii)], i.e.,

$$\hat{R}_D(x_m) = \hat{R}_D(x_m, x)\Big|_{x=x_m} = R_D(x_m) - E_D(x_m), \tag{17}$$

[10]Specifically, the downward shifted inverse demand function in the DNM, $\hat{R}_D(x_m, x)$ in (14), the inverse supply in the DNM, $\hat{L}_D(x_m)$ in (16), the value of the inverse demand function in the Street market corresponding to the marginal consumer x_m, $R_S(x_m)$, and the equilibrium price in the Street market, p_S^*, itself depending on the modified inverse demand and supply functions in the Street market, $\hat{R}_S(x_m, x)$ in (10) and $\hat{L}_S(x_m, x)$ in (12).

must hold in equilibrium.[11]

To clarify ideas we introduce an abstract definition of equilibrium.

Definition 1 *Consider a population of consumers indexed by* $x \in [0,1]$ *who have the opportunity to choose on whether to purchase one unit of a homogeneous illicit good either on the DNM or on the Street market. Each consumer* x *has a reservation price* $R_D(x)$ *if she purchases in the DNM and a reservation price* $R_S(x)$ *if she purchases in the Street market, and all consumers are ordered in the interval* $[0,1]$ *so that they have decreasing inverse reservation price functions* $R_D(x)$ *and* $R_S(x)$*. Let* $E_D(x, p_D) = R_D(x) - p_D$ *and* $E_S(x, p_S) = R_S(x) - p_S$ *be the consumer rent functions in the DNM and in the Street market respectively;* p_D *and* p_S *denote the prices that are actually being paid in each market and* $E_D(x, p_D) > E_S(x, p_S)$ *for values of* x *close to zero.*

We say that the two markets, the DNM and the Street, are in equilibrium if quantities $x_D^* > 0$ *and* $x_S^* > 0$ *and prices* $p_D^* > 0$ *and* $p_S^* > 0$ *exist such that the following conditions are satisfied:*

i) $E_D(x_D^*, p_D^*) = E_S(x_D^*, p_S^*) > 0$ *and*

ii) $E_S(x_S^*, p_S^*) = 0$.

Condition i) establishes the existence of a marginal consumer x_D^* who is indifferent between going to the DNM or to the Street market, as in both markets she earns the same (strictly positive) consumer surplus; condition ii) states that all consumers indexed to the right of x_D^*, i.e., $x \in (x_D^*, x_D^* + x_S^*]$, go to the Street market, where the price p_S^* satisfies the standard definition of equilibrium (supply equals demand), i.e., $R_S(x_S^*) = p_S^*$. Moreover, the DNM is in disequilibrium

[11] In fact, the whole definition of the downward shift $\hat{R}_D(x_m, x) = R_D(x) - E_D(x_m)$ of $R_D(x)$ in the DNM defined in (14) as a function of x is not required in our definition, only its value at the marginal consumer x_m, i.e., $\hat{R}_D(x_m)$ according to (17), suffices, as the whole equilibrium rests on the excess demand function $E_D(x_m)$ defined in (13).

according to the standard definition, as $R_D(x_D^*) > p_D^*$, where p_D^* is the price at which the illicit good is being sold in the DNM.[12]

The next proposition provides a characterization of the equilibrium introduced in Definition 1 when the supply structures in both markets are oligopolistic in the sense of Cournot according to the discussion in Subsection 3.2. We still make no assumptions on the demand structures other than the basic properties recalled in Definition 1, however we will assume that the there is one *unique* equilibrium.

Proposition 1 *Suppose that there are n_D identical vendors in the DNM, each facing the same marginal cost $c_D'\left(\frac{Y}{n_D}\right)$, and n_S identical vendors in the Street market, each facing the same marginal cost $c_S'\left(\frac{Y}{n_S}\right)$, where Y is the total quantity sold in each market. All vendors behave oligopolistically and they are eager to sell at Cournot-type equilibrium prices satisfying (6) and (7), that is,*

$$p_D = R_D(x) = L_D(x) = \frac{c_D'\left(\frac{x}{n_D}\right)}{1 - \frac{\varepsilon_D(x)}{n_D}}$$
$$p_S = R_S(x) = L_S(x) = \frac{c_S'\left(\frac{x}{n_S}\right)}{1 - \frac{\varepsilon_S(x)}{n_S}},$$

where $\varepsilon_D(x)$ and $\varepsilon_S(x)$ denote the absolute values of elasticities of the inverse demand functions $R_D(x)$ and $R_S(x)$ in the DNM and in the Street market respectively satisfying Assumption A.1.

Then, conditions i) and ii) of Definition 1 are equivalent to the following system of two equations in the unknowns x_m and x:

$$\begin{cases} R_D(x_m) - \hat{L}_D(x_m) = R_S(x_m) - \hat{L}_S(x_m, x) \\ \hat{R}_S(x_m, x) = \hat{L}_S(x_m, x), \end{cases} \tag{18}$$

[12]Clearly a similar approach could be applied to the opposite case, in which $E_D(x, p_D) < E_S(x, p_S)$ for values of x close to zero. In this alternative scenario, a suitable minimum consumer rent would be given to consumers in the Street.

where $\hat{L}_D(x_m)$ *is defined by (16) together with the elasticity* $\hat{\varepsilon}_D(x_m)$ *defined in (15),* $\hat{R}_S(x_m, x)$ *is defined by (10) and* $\hat{L}_S(x_m, x)$ *is defined by (12) together with the elasticity* $\hat{\varepsilon}_S(x_m, x)$ *defined in (11). The solution* (x_m^*, x_S^*) *of system (18) represents the total quantity sold in the DNM, corresponding to the* marginal consumer $x_m^* = x_D^*$*, and the total quantity sold in the Street,* x_S^**. The sum* $x = x_m^* + x_S^*$ *corresponds to the total quantity sold in both markets. The equilibrium prices are* $p_D^* = \hat{L}_D(x_m^*)$ *in the DNM and* $p_S^* = \hat{L}_S(x_m^*, x_S^*) = \hat{R}_S(x_m^*, x_S^*)$ *in the Street.*

For a proof see the Appendix.

For inverse demand functions having constant elasticities, i.e., given by (1), and affine marginal costs[13] faced by vendors, condition (18) in Proposition 1 can be further specified so to obtain a numerically computable equilibrium.

Corollary 1 *Assume that the inverse demand functions have constant elasticity and in both markets vendors face affine marginal costs; specifically, the inverse demand curves have the form* $R_D(x) = \theta_D x^{-\varepsilon_D}$ *and* $R_S(x) = \theta_S x^{-\varepsilon_S}$ *where* $\theta_D = \theta_S = 1$ *and* $\varepsilon_D, \varepsilon_S$ *satisfy Assumption A.1, while marginal costs are given by* $c_D'\left(\frac{x}{n_D}\right) = a_D + b_D\frac{x}{n_D}$ *and* $c_S'\left(\frac{x}{n_S}\right) = a_S + b_S\frac{x}{n_S}$*, with non-negative parameters* a_D, a_S, b_D, b_S*. Then, there exists one unique equilibrium characterized by the following specification of system (18):*

$$\begin{cases} \left(1 - \dfrac{\varepsilon_D}{n_D}\right)(x_m)^{-\varepsilon_D} - \dfrac{b_D}{n_D}x_m - a_D = (x_m)^{-\varepsilon_S} - \dfrac{a_S n_S + b_S x}{n_S - \varepsilon_S \dfrac{x}{x_m + x}} \\ (x_m + x)^{-\varepsilon_S} = \dfrac{a_S n_S + b_S x}{n_S - \varepsilon_S \dfrac{x}{x_m + x}} \end{cases} \tag{19}$$

For a proof see the Appendix.

[13] Affine marginal costs of the form $c'\left(\frac{x}{n}\right) = a + b\frac{x}{n}$ correspond to quadratic total costs of the form $c\left(\frac{x}{n}\right) = a\frac{x}{n} + \frac{b}{2}\left(\frac{x}{n}\right)^2 + d$, which are increasing and convex whenever $a, b > 0$.

Remark 1 *Note that the LHS in the first equation of system (19) contains exactly the two sides that would define the Cournot oligopolistic equilibrium for the marginal consumer x_m in the DNM according to equation (2): the inverse demand $R_D(x_m) = (x_m)^{-\varepsilon_D}$, multiplied by the term $\left(1 - \frac{\varepsilon_D}{n_D}\right)$,[14] and the vendors' marginal cost $c'_D\left(\frac{x_m}{n_D}\right) = a_D + b_D\frac{x_m}{n_D}$. However, such a Cournot equilibrium in the DNM requires these two terms to be equal; here, instead, the equilibrium in the DNM is characterized by a strictly positive minimum consumer rent $E_D(x_m) = \left(1 - \frac{\varepsilon_D}{n_D}\right) R_D(x_m) - c'_D\left(\frac{x_m}{n_D}\right) > 0$, so that $\left(1 - \frac{\varepsilon_D}{n_D}\right) R_D(x_m) \neq c'_D\left(\frac{x_m}{n_D}\right)$ and this market turns out to be in disequilibrium according to the standard concept.*

5 Illustrative example and policy implications

This chapter will provide just one of many possible scenarios to illustrate the mechanics of the model. Since our model shows two markets in equilibrium, we would like to study how policymakers can influence the markets to decrease the equilibrium number of sales. In line with other research, we believe that the arrival of DNM increases the number of drug users.[15] Therefore, shifting online drug dealers back to the streets or making them reconsider their online career path could make a difference in the war on drugs.

As previously stated, the drug market is expanding to a different domain, now present on the Street and online Dark Net market. This expansion has changed the nature of drug dealers and drug users. To succeed on the DNM, the platform's participants should have a specific level of digital literacy. This fact implies acquiring new knowledge by Street dealers or forming a new drug vendor type: the technology-educated dealer. According to an online survey of about 4000

[14]Note that the term $\left(1 - \frac{\varepsilon_D}{n_D}\right)$ is the reciprocal of the constant markup typical of an oligopolistic market with a constant elasticity inverse demand.

[15]A curious reader can turn to (Aldridge et al., 2018) to examine this issue more carefully.

individuals, 38% had completed a university degree. For example, the founder of the DNM "Silk Road" had a master's degree in material science and engineering, and the founder of the DNM "Silk Road-2" did his internship in SpaceX (Ladegaard, 2019). In our paper, we do not consider the knowledge path of drug dealers since it is a necessary condition to start online trading on DNM.

The goal of this chapter is not to analyze a drug dealership per se but consider the determinants of the illegal drug trade. Moreover, we analyze the ways of shifting DNM dealers back to the streets since it is more difficult to apprehend online criminals (Bahamazava and Nanda, 2022) than offline counterparts.

Let us consider two types of cocaine markets: Street market and DNM. The population of vendors is characterized by an affine marginal cost function in each market:

$$c'\left(\frac{x}{n}\right) = a + b\frac{x}{n}, \tag{20}$$

where, in our case, a represents delivery[16] costs that a vendor bears while selling drugs, b decomposes to b_i - insurance cost to avoid violence and b_s - scam cost[17] to avoid deception from other participants in the drug selling business, that is $b = b_i + b_s$, and n is a number of vendors in each market.

Let us specify affine marginal costs in the two markets as:

$$c'_S\left(\frac{x}{1}\right) = 0.6 + 20\left(\frac{x}{1}\right) \text{ and } c'_D\left(\frac{x}{15}\right) = 1 + 16\left(\frac{x}{15}\right). \tag{21}$$

We set n_S to 1 and n_D to 15 to stress the more competitive nature of the cocaine trade on the DNM. We assume that the delivery costs a are higher on the DNM than on the Street market since the DNM vendors send drugs to each end user while on the Street market delivery occurs only within drug cartel network. As

[16]Delivery was the most common risk identified by vendors (Aldridge and Askew, 2017).

[17]The increased occurrence of real or potential scams could disrupt the trust in the DNM ecosystem based on profit, ideology, and blockchain.

for the b costs, the insurance costs b_i are less on the DNM since vendors do not meet with the buyers. The scam costs are more substantial on the DNM market than on the Street market because of the involvement of potentially anonymous intermediaries (platform's administrators). We set $b_{Si} = 18$ and $b_{Ss} = 2$ on the Street market, while on the DNM, $b_{Di} = 2$ and $b_{Ds} = 14$[18].

Using (21), the equilibrium condition (19) becomes:

$$\begin{cases} \left(1 - \dfrac{0.90}{15}\right)(x_m)^{-0.90} - \dfrac{16}{15}x_m - 1 = (x_m)^{-0.84} - \dfrac{0.6 \cdot 1 + 20 \cdot x}{1 - 0.84\dfrac{x}{x_m + x}} \\ (x_m + x)^{-0.84} = \dfrac{0.6 \cdot 1 + 20 \cdot x}{1 - 0.84\dfrac{x}{x_m + x}} \end{cases} \tag{22}$$

where ε_S is equal to 0.84 and ε_D is equal to 0.90.[19] To solve the system of equations (22) numerically in Matlab software, we utilized the Newton-Raphson method (Figure 1). We decided to follow this approach since this numerical method is the best-known iteration approach to find a real or complex root of a differentiable function (Denis and Rose, 2006). In the code (Figure 1), F is the function in which we defined the system of equations (22), J is the function in which we defined the Jacobian matrix of the system (22), x_0 is our initial guess for x_m and x, toll is tolerance, and imax is the maximum number of iterations. In the following examples, functions f_1 to f_8 present contour plots of each of the two equations in the system (22) for different values of the parameters a_D and b_D.

We set the tolerance to 10^{-6}, and the max number of iterations - to 1000. Solving (22) for the interval $(0, 1)$, we obtain the solution (x_m, x), where x_m represents the equilibrium quantity sold on the DNM, while x denotes the equilibrium quantity sold on the Street market. In our example, (0.5263, 0.0448)

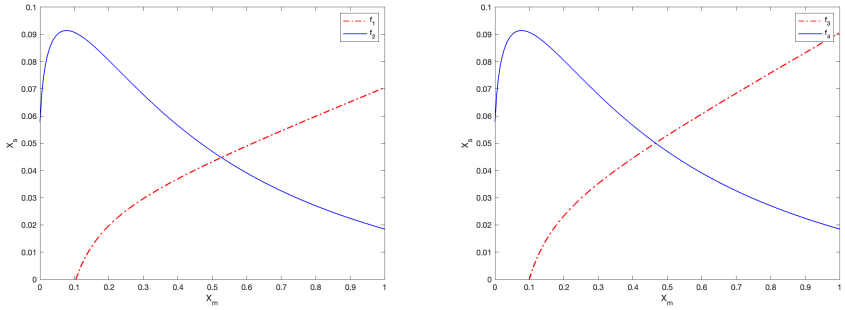
[18] Our example takes hypothetical values to illustrate the mechanics of the model.

[19] Consistent with empirical evidence (Payne et al., 2020) and our intuition discussed in Section 3.2 in the Footnote 5.

```
function [x,res,niter]=newtons(F,J,x0,toll,imax)
niter=0;
err=toll +1;
x=x0;
while err ≥ toll & niter < imax
JF=J(x);
FF=F(x);
Δ = -JF\FF;
x= x + Δ;
err =norm(Δ,inf);
niter=niter +1;
end
res=norm(F(x),inf);
if (niter==imax & err > toll)
fprintf(['\nll method doesnt converge in max',...
'number of iterations.The last iteration\n',...
'calculated has residual equal to %e.\n'],res);
else
fprintf(['\nll method converges in %i iterations ', ...
'with a residual equl to %e.\n'], niter, res)
end
```

FIGURE 1: Matlab software code for Newton-Raphson method

is a unique solution on the interval (0,1) (Figure 2a). The total number of cocaine sold on both markets is $x_m + x$, which is equal to 0.5711.



(A) $f_1 = 0$ and $f_2 = 0$ for initial equilibrium

(B) $f_3 = 0$ and $f_4 = 0$ after increasing scam costs

FIGURE 2

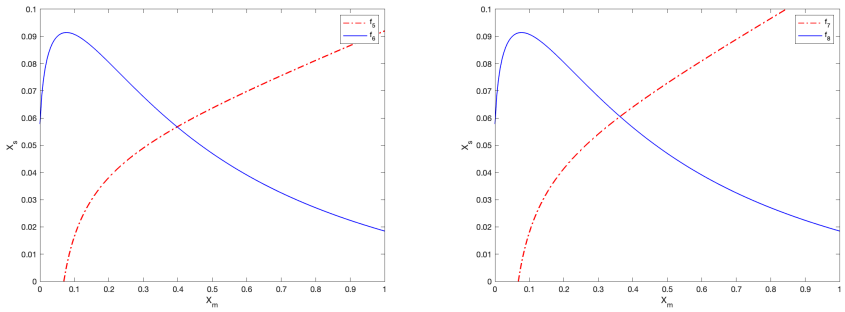
Increasing the scam cost b_{Ds} would deter occasional consumers from buying cocaine on the DNM and "shift" some of the usual buyers towards the Street market. Increasing scam costs by 50% (from 14 to 21) on DNM gives us a unique equilibrium solution (x_m, x) on the interval (0, 1) which is equal to (0.4656, 0.0501), respectively (Figure 2b). The new total number of cocaine sold on both markets is 0.5157. The 50% increase of scam costs would diminish the quantity of cocaine sold by 11.53% on DNM and decrease the total number by 9.7%. In the long term perspective (not considered in the model presented in the paper), increasing the scam cost b_{Ds} would increase the cost of doing drug business for DNM vendors shifting some sellers to the Street market or discouraging some of them to participate in the drug business at all.

The announcements related to DNM activities affected DNM's participants' behavior (Ladegaard, 2018); therefore, it is possible to influence the illegal drug trade through these announcements. Application of the proposed policy of increased scam cost would "shift" some vendors toward the Street market and deter occasional traders. Considering the starting presumption of the cocaine Street

market being easier to control than DNM by the law enforcement agencies, our example showed one of the possible ways of how to influence the illegal drug trade. The DNM sellers react to announcements related to DarkNet activity. More announcements could be made to create panic around the exit scam's scheme. The speculations announcing the "insider's information" about prepared exit scams schemes could increase costs in the cost and benefit analysis of doing business on DNMs. Vendors having the information about the possible exit scams on the specific DNMs would feel reluctant to continue their drug business as they risk losing not only cryptocurrencies linked to the trades but all the information about their customers and ongoing deals. Therefore, some of the sellers would cease their online drug business, perhaps shifting to the Street market. If it is easier to arrest criminals on the Street than on the DNM, our approach could be used to diminish the illegal drug trade.

Another proposed policy implication is to increase delivery costs a_D to "shift" DNM's vendors to the Street market or make them refrain from the drug business. Increasing delivery costs on DNM by 50% (from 1 to 1.50) would give us a unique solution (0.3979, 0.0568) on the interval (0,1) for equilibrium quantity sold on DNM and Street, respectively. Due to increased delivery costs by 50% on DNM, the quantity of cocaine sold on DNM would diminish by 24.4%, and the total cocaine quantity would decrease by 20.38% (Figure 3a).

For example, this policy could be introduced by announcing the possibility to trace DNM orders. Since ordinary postal services handle all the DNM purchases, it is feasible to trace them. With the possibility of being traced back, vendors would be forced to use different techniques while packaging to diminish the probability of orders being intercepted. This new packaging policy, in turn, would increase the cost of the DNM drug business. Due to increased costs of doing business and increased probability of being apprehended, some vendors would be



(A) Contour plot for $f_5 = 0$ and $f_6 = 0$ after rising delivery costs

(B) Contour plot for $f_7 = 0$ and $f_8 = 0$ after combined policy

FIGURE 3

reluctant to continue their online drug business. Some vendors, and according to the new equilibrium yielded by the new vendors' strategy, some consumers would return to the Street market, while occasional users would cease their online business. Note that this policy is more effective than the "increasing scam costs" policy in "shifting" drugs vendors from DNM to the Street market.

In the case of using both policies together, the unique solution would be (0.3628, 0.0606) for DNM and Street market, respectively (Figure 3b). The DNM cocaine sale would diminish by 31.07%, and the total quantity sold on both markets would decrease by 25.86%.

Our numerical example, consistent with other research (Martin et al., 2020), shows that some DNM vendors are reluctant to become Street dealers. Therefore, it is essential to research and explore the ways to influence DNM drug dealers. In this example, we consider delivery, insurance, and scam costs as factors affecting drug dealers' marginal cost function. We show that impacting these factors through media sources may shift or discourage selling drugs through DNM. We particularly stress the necessity of utilizing the Internet and social media for these announcements since we believe DNM drug dealers are more susceptible to these kinds of announcements than Street dealers.

6 Conclusion

In this paper, we modeled the internal functioning of two drug markets, namely, the Street and the DNM, and considered their interactions. Taking into account the relationship between the two markets seems of growing relevance in a framework that in recent years was characterized by the resilience and expansion of the DNM. Still, the Street market remains well active. Policy interventions in the field have been traditionally designed concerning the Street market, which, being active for a longer time, has been more thoroughly studied and has become more familiar to the police and the responsible authorities. The DNM has only recently attracted researchers' and public authorities' attention.

We stress the lower risk that buyers face in the DNM as a factor that translates into a higher perceived quality of supply therein. The Street market, however, can compete in terms of price, thus attracting the demand of consumers with a lower willingness to pay and inducing as a response a less than full exploitation of the quality advantage by vendors in the DNM. Our model provides a simple basic framework for describing the equilibrium in the two markets and for discussing policy interventions in the new scenario, in which both the old and the new forms of drug commerce are present.

DNM requires a different approach from Law Enforcement Agencies than the Street market for numerous reasons, including the diverse nature of drug dealers. Underlining the distinction between DNM and Street, we present possible determinants of the drug trade and ways to influence these determinants.

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Appendix

Proof of Proposition 1. Note that in the first equation of (18) the whole LHS and the first term in the RHS depend only on the marginal consumer x_m; only the second term in the RHS, in addition to depending on x_m, also depends on x. This is because the equilibrium point x_m is sufficient to define the Cournot equilibrium in the DNM as equality by the vendors' inverse supply $\hat{L}_D(x_m)$ defined in (16) and the downward shifted inverse demand curve $\hat{R}_D(x_m)$ defined in (17); otherwise, the RHS depends on the equilibrium price in the Street market, which, according to the second equation in (18), is defined as the intersection point between the *whole* leftward shifted inverse demand curve $\hat{R}_S(x_m, x)$ defined in (10) (by "whole" we mean that, in addition to depending on x_m, it also depends on the variable x over the whole interval $[0, 1]$) and the *whole* inverse supply $\hat{L}_S(x_m, x)$ defined in (12) (again, by "whole" we mean that, in addition to depending on x_m, it also depends on the variable x over the whole interval $[0, 1]$).

The first equation in (18) characterizes the marginal consumer x_m by equating the strictly positive minimum consumer rent $E_D(x_m)$ (the consumer surplus in the LHS) required to keep the marginal consumer in the DNM to the largest possible consumer surplus $E_S(x_m, x)$ (the RHS) earned in the Street market by the same marginal consumer. Both $E_D(x_m) = R_D(x_m) - \hat{L}_D(x_m)$ and

$E_S(x_m, x) = R_S(x_m) - \hat{L}_S(x_m, x) = \hat{R}_S(x_m, x) - \hat{L}_S(x_m, x)$ depend on the inverse supply value $\hat{L}_D(x_m)$ defined in (16) and the inverse supply function $\hat{L}_S(x_m, x)$ defined in (12), themselves depending on the elasticities of the inverse demand functions actually faced by the oligopolistic vendors in both markets, i.e., the value of the downward shifted inverse demand curve $\hat{R}_D(x_m)$ defined in (17) at x_m and the leftward shifted inverse demand curve $\hat{R}_S(x_m, x)$ defined in (10) respectively. For a given value of x_m, the second equation in (18) establishes the standard equilibrium in the Street market corresponding to the quantity x_S^* that equates the inverse demand function [the LHS, $\hat{R}_S(x_m, x)$] to the inverse supply [the RHS, $\hat{L}_S(x_m, x)$]. ■

Proof of Corollary 1. Clearly, $R_S(x_m) = (x_m)^{-\varepsilon_S}$ and $\hat{R}_S(x_m, x) = (x_m + x)^{-\varepsilon_S}$ according to definition (10). Under the assumption of affine marginal cost in the Street market, $c_S'\left(\frac{x}{n_S}\right) = a_S + b_S\frac{x}{n_S}$ and noting that, according to (11), the elasticity of the (leftward shifted) inverse demand curve in the Street market is $\hat{\varepsilon}_S(x_m, x) = \varepsilon_S\frac{x}{x_m+x}$, according to definition (12) $\hat{L}_S(x_m, x) = \frac{a_S n_S + b_S x}{n_S - \varepsilon_S\frac{x}{x_m+x}}$. Therefore, the RHS of the first equation and both sides in the second equation of (19) are equivalent to the corresponding sides in system (18).

The explicit form of the LHS in the first equation, corresponding to $E_D(x_m) = R_D(x_m) - \hat{L}_D(x_m) = (x_m)^{-\varepsilon_D} - \hat{L}_D(x_m)$ (the minimum consumer rent for consumers in the DNM) in the first equation in (18) is a bit trickier to obtain because of the expression of $\hat{L}_D(x_m)$ according to (16). Recall that the elasticity of the inverse demand function in the DNM is given by (15), so that, at the value $x = x_m$, it holds

$$\hat{\varepsilon}_D(x_m) = \varepsilon_D\frac{(x_m)^{-\varepsilon_D}}{(x_m)^{-\varepsilon_D} - E_D(x_m)}, \tag{23}$$

where, under the assumptions of constant elasticity inverse demand function, $R_D(x_m) = (x_m)^{-\varepsilon_D}$, and affine marginal cost in the DNM, $c_D'\left(\frac{x}{n_D}\right) = a_D + b_D\frac{x}{n_D}$,

the minimum consumer rent $E_D(x_m)$ defined in (13) after some algebra becomes:

$$E_D(x_m) = R_D(x_m) - \hat{L}_D(x_m) = (x_m)^{-\varepsilon_D} - \frac{c'_D\left(\frac{x_m}{n_D}\right)}{1 - \frac{\hat{\varepsilon}_D(x_m)}{n_D}} = (x_m)^{-\varepsilon_D} - \frac{a_D + b_D\frac{x_m}{n_D}}{1 - \frac{\hat{\varepsilon}_D(x_m)}{n_D}}$$
$$= (x_m)^{-\varepsilon_D} - \frac{a_D n_D + b_D x_m}{n_D - \hat{\varepsilon}_D(x_m)}.$$

Substituting the last expression into (23) yields

$$\hat{\varepsilon}_D(x_m) = \varepsilon_D \frac{(x_m)^{-\varepsilon_D}}{(x_m)^{-\varepsilon_D} - E_D(x_m)} = \varepsilon_D \frac{(x_m)^{-\varepsilon_D}}{(x_m)^{-\varepsilon_D} - (x_m)^{-\varepsilon_D} + \frac{a_D n_D + b_D x_m}{n_D - \hat{\varepsilon}_D(x_m)}}$$
$$= \varepsilon_D \frac{(x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m}\left[n_D - \hat{\varepsilon}_D(x_m)\right],$$

which is equivalent to

$$\left[1 + \frac{\varepsilon_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m}\right]\hat{\varepsilon}_D(x_m) = \frac{\varepsilon_D n_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m} \qquad \Longleftrightarrow \qquad \hat{\varepsilon}_D(x_m) = \frac{\frac{\varepsilon_D n_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m}}{1 + \frac{\varepsilon_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m}},$$

that is,

$$\hat{\varepsilon}_D(x_m) = \frac{\varepsilon_D n_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m + \varepsilon_D (x_m)^{-\varepsilon_D}}. \tag{24}$$

By replacing (24) into the definition of $\hat{L}_D(x_m)$ according to (16) we get

the second term in the LHS of (19):

$$\begin{aligned}
\hat{L}_D\left(x_m\right) &= \frac{c'_D\left(\frac{x_m}{n_D}\right)}{1-\frac{\hat{\varepsilon}_D(x_m)}{n_D}} = \frac{a_D n_D + b_D x_m}{n_D - \hat{\varepsilon}_D\left(x_m\right)} = \frac{a_D n_D + b_D x_m}{n_D - \frac{\varepsilon_D n_D (x_m)^{-\varepsilon_D}}{a_D n_D + b_D x_m + \varepsilon_D (x_m)^{-\varepsilon_D}}} \\
&= \frac{\left(a_D n_D + b_D x_m\right)\left[a_D n_D + b_D x_m + \varepsilon_D \left(x_m\right)^{-\varepsilon_D}\right]}{n_D\left(a_D n_D + b_D x_m\right) + \varepsilon_D n_D \left(x_m\right)^{-\varepsilon_D} - \varepsilon_D n_D \left(x_m\right)^{-\varepsilon_D}} \\
&= \frac{\left(a_D n_D + b_D x_m\right)\left[a_D n_D + b_D x_m + \varepsilon_D \left(x_m\right)^{-\varepsilon_D}\right]}{n_D\left(a_D n_D + b_D x_m\right)} \\
&= \frac{a_D n_D + b_D x_m + \varepsilon_D \left(x_m\right)^{-\varepsilon_D}}{n_D} \\
&= a_D + \frac{b_D}{n_D} x_m + \frac{\varepsilon_D}{n_D}\left(x_m\right)^{-\varepsilon_D}. \qquad (25)
\end{aligned}$$

Using the expression of $\hat{L}_D\left(x_m\right)$ in (25) in the LHS of the first equation in (19) we get

$$\begin{aligned}
E_D\left(x_m\right) &= R_D\left(x_m\right) - \hat{L}_D\left(x_m\right) = \left(x_m\right)^{-\varepsilon_D} - a_D - \frac{b_D}{n_D} x_m - \frac{\varepsilon_D}{n_D}\left(x_m\right)^{-\varepsilon_D} \\
&= \left(1 - \frac{\varepsilon_D}{n_D}\right)\left(x_m\right)^{-\varepsilon_D} - \frac{b_D}{n_D} x_m - a_D,
\end{aligned}$$

and the proof is complete. ■