Analysis of the supply on crypto markets

Defining the market structures on crypto market the Real Deal by looking at suppliers

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Abstract
Crypto markets can be defined as online markets were mostly illegal products are being sold, such as drugs. This research aims to offer insights into the market structures of such markets in order to make a less dichotomous comparison between conventional (drug) markets and crypto markets. A dataset of the Real Deal market will be used for this analysis. The market structure theorem is used to classify the markets, where markets can be defined as either monopoly, oligopoly or perfect competition market. The analysis showed that most markets on the Real Deal are of the perfect competition type, while some of them are an oligopoly and only one is a monopoly. Further research could focus on comparison of several other crypto markets.

1. Introduction

Crypto markets (also known as darknet markets) are online markets that are located on the darkweb. Just like any other online market, these markets allow users to sell or buy products. Since these markets are located on the darkweb, all of transactions are anonymously. Therefore, it is more likely that illegal products are being traded on these websites. This creates security issues for several actors, such as police task units, who's objective it is to keep the public order safe and secure.

1.1. Previous assignments

This research is performed as part of the Economics of Cyber Security course of the TU Delft. It continues and builds on three prior developed assignments of project group 6. The security issue stated in the previous assignments of the project group defined the existence of crypto markets as the security issue for two actors: the police task unit and the software company. Previous assignments where mostly focused on the supply of so-called cybercrime assets. These assets were defined as assets that were used for on-line cyber criminality. Examples of such cybercrime assets are hacked accounts, spam and zero-day exploits. These assets can form a security issue for the software company since these assets exploit vulnerabilities in the software of the software company. It formed a security issue for the police-task unit since these assets can be used by online criminals to steal for example personal data via the available asset hacked accounts. Assuming that the overall objective of the police task unit is to have a safe and stable public order, these kind of activities could form a threat this safe and stable public order and. Therefore, the existence of the crypto market can be seen as security issue for the police task unit.

1.2. Focus of this paper

This paper tries to view the crypto markets in a broader perspective by not only focussing on the cybercrime assets, but by also by looking the other assets that are available in these markets, such as drugs. What are the security issues that arise by looking with this broader perspective? Do these drug marketplaces influence the security issue for the police task unit? More on this will be elaborated on later in this paper.

1.3. Structure of this paper

The paper starts off with a comprehensive literature review in section 2. This is followed by a description of the research objective and research questions in section 3. In section 4, the methodology will be explained. In section 5, the result of the analysis will be presented and interpreted. Next, in section 6, the limitations of this research will be discussed. Finally, the research is concluded in section 7.

2. Literature review

2.1. Definition of Crypto markets

According to Rhumorbarbe, Staehli, Broséus, Rossy, & Esseiva (2016), the darknet is a set of networks within the internet. The darknet is built on peer-to-peer technologies and are accessible via 'Tor' browsers (Bancroft & Scott Reid, 2015). All of the processes on these networks are encrypted via the PGP (Pretty Good Privacy) cryptography. This allows users of the darknets to operate anonymously. The anonymous darknet has led to the creation of darknet markets or crypto markets. Crypto markets are online websites where illegal services on products are being traded. Currencies on these markets are peer-to-peer currencies such as Bitcoins, Litecoins, Dogecoins and Darkcoins (Bancroft & Scott Reid, 2015). These type of currencies allow for anonymous transactions between the market suppliers and the buyers and. Therefore, this makes it difficult to trace these suppliers and buyers.

One of the first crypto markets was the Silk Road market. This market was shut down in 2013. After the shutdown, several other markets were founded, such as the Agora market (Rhumorbarbe et al., 2016). The markets have evolved in sophisticated places where feedback systems are implemented to ensure the quality of goods. Also, escrow systems are implemented in these markets. An escrow system is a system which ensures that the supplier receives the bitcoins, after the buyer has received his product.

2.2. Prior research on crypto markets

In the paper of Barratt, Ferris, & Winstock (2015) is stated that various aspects of crypto markets have been investigated in the academic literature. One of the aspects that is being researched, is the reduced likelihood of violence of crypto markets. Some authors argue that crypto markets can reduce the likelihood of violence since a different set of skills are required to successfully succeed as a supplier. An example of such a skill are good writing skills (Aldridge & Décary-Hétu, 2015). Therefore, suppliers may come from a different population compared to the suppliers from the conventional markets. Andreas & Wallman (2009) state that these type of suppliers quicker resort to violence for dispute resolution, since violence might be more normative and there is a lack of alternative options. A second reason for the reduced likelihood of violence could be the implementation of customer feedback systems. These systems require suppliers to provide good customer service to their buyers. The third reason for reduced violence could be the absence of any physical personal contact between suppliers and sellers, which makes physical violence difficult to enact (Barratt et al., 2015).

2.3. The openness of crypto markets

Barratt et al. (2015) state that current literature on crypto markets fails to provide a complete and full comparison between conventional drug markets and crypto markets, because it does not take into account the different market structures of crypto markets. The authors state that there is instead a dichotomous comparison between online and offline trading, without a reference to other structures ranging between fully open and fully closed market structures. Also in the paper of Rhumorbarbe et al. (2016) is stated that current literature fails to identify the number of suppliers that are active, and what market structures there exists on these crypto markets. Therefore, this papers aims to provide more knowledge and insights on what market

structures there exists on crypto markets, to be able to make a less dichotomous comparison between online and offline trading. In the following section the theorem of market structures of traditional economics will be explained, which will be used as methodology for this analysis.

2.4. Market structures economics

To structure the classification of markets, the market structure theory of economics will be used to classify the different markets on the crypto market. A brief literature study is performed to be able to identify the different type of market structures.

2.4.1. Monopoly

In a monopoly, there is only one supplier who offers a product on the market. Monopoly markets have a lack of competition, and the supplier can set the price of the good well above the marginal cost of the good which results in a high monopoly profit. The monopoly market is characterized by high barriers, i.e. it is very difficult for other suppliers to enter the market. These barriers are strong enough to prevent any potential supplier from entering the market (Binger and Hoffman, 1998). Furthermore, there exists price discrimination in such markets, which means that the supplier can change the price and quality of the product according to his preferences. The price level of goods is normally higher in monopoly markets, since the monopoly supplier does not have to worry about losing buyers to competitors if they price if perceived as too high by the buyers. Therefore, the prices in monopoly market are often higher than in perfect competition markets (Bradley, 1991).

2.4.2. Oligopoly

In an oligopoly, there is a small group of suppliers (often referred to as oligopolists) which offer the product to the buyers. There exists some competition on these markets between the limited number of suppliers, however, this is still limited compared to the perfect competition. Similar to the monopoly market, suppliers can decide to set the price instead of 'taking' the price that is determined by competition (Perloff, 2008). Therefore, this normally results also in higher prices as compared to the perfect competition markets. Just like the monopoly markets, the entry and exit barriers are high, so it is difficult for new suppliers to enter an oligopoly market (Hirschey, 2000).

2.4.3. Perfect competition.

Perfect competition markets are characterized by a large number of suppliers. There are no entry or exit barriers on these kind of markets. Furthermore, the market power of the suppliers is too little to set the price. Instead, suppliers have to take the price that is determined by competition and market conditions (Binger & Hoffman, 1998).

3. Research objective

3.1. Objective

Given the knowledge gap as defined by Barratt et al. (2015), this paper tries to identify the different market structures on a crypto market, by looking at the amount of suppliers that are active in the various markets on the crypto market and by looking at the average price of goods on these markets. So, the objective of this research can be defined as follows:

"This research aims to identify the number of suppliers on the different markets and the distribution of the average price of goods, with the objective to identify market structures on crypto markets. The overarching objective of this research is to add to the current research on crypto markets."

3.2. Research question

This research objective can be reached by answering the following research question:
1. "What are the different market structures in crypto markets?"
2. "How are the average prices of products distributed in these markets?"

3.3. Research hypothesis

The first research question is of exploratory nature. This research question is necessary to define if there exists different type of market structures. Therefore, there is no hypothesis defined for this research question. To answer the second research questions, hypotheses are defined:
H0: There is no significant difference between the average prices of goods between a monopoly, oligopoly and perfect competition market structure.
H1: There is a significant difference between the average prices of goods between a monopoly, oligopoly and perfect competition market structure.

4. Methodology

4.1. Dataset

The dataset that will be used for this analysis is data scraped from the crypto market the Real Deal by (Branwen et al., 2015). The dataset consists of 7668 rows and the following columns; *data* (which is from the date of scraping the data), *description,* (description of the product), *price, username* (name of the supplier), *reviews* (number of reviews a product received) and *product category*. The *product category* column will be used to define the different markets, where for example product type 'cannabis' can be classified as one marketplace, and where the different type of cannabis can be defined as the different type of products that are available on that market. The *username* variable will be used to identify the number of suppliers per market, where a market is equal to the *product category* variable. The *price* will be used to determine the average price.

4.2. Data cleaning

The raw data file as received needed to be cleaned up in order to make it ready for the data analyses. Microsoft Excel was used for the data cleaning. First, several aspects needed to be removed such as the 'BTC' (BTC stands for the currency Bitcoin) string in front of the price, several comma's and dots that were not in place, and some rows which were incomplete or contained the wrong type of data. Second, two columns were removed that did not provide any relevant data, which were the *URL* column and the *Review* column. The *Review* column would have been useful if it contained ratings about certain products. However, the *Review* column only contained data about the number of reviews a certain product received. Most of the products were not reviewed; of the total of 7668 rows only 148 rows contained data about the number of reviews. Third, duplicates were removed. After the data cleaning was finished, the file contained 4563 rows and the following columns; *date*, *product description*, *price* (in Bitcoin), *user* and *product category.*

4.3. Data exploration

After the data was cleaned up, the dataset was explored. The dataset contains 37 markets, such as the 'MDMA' market or the 'Source code' market and there are 84 unique suppliers active on the Real Deal market. The biggest market is by far the 'Pharmacy' market, as can be seen in figure 1. It consists of around 25% of the products available on the market. The most active suppliers are displayed in figure 2. This figure shows that three of the suppliers are most active compared to the other ones, of the name 'idealpills', 'littlebruce' and 'AllDutch'. It looks like these suppliers have some kind of oligopoly position on the total market the Real Deal.

However, the objective of this research is to identify the different market structures within certain markets, so data about the total marketplace is not going to be analys

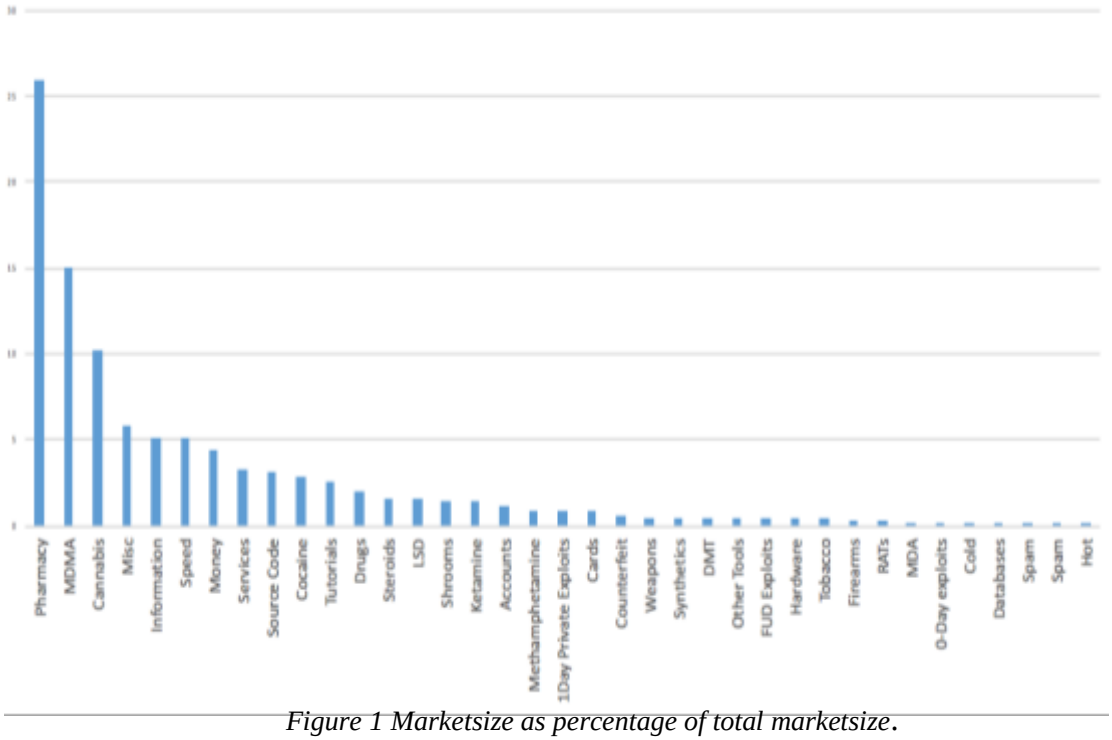

Figure 1 Marketsize as percentage of total marketsize.

zed in more detail.

4.4. Methodology for research question one.

To determine the market structures that exists on the Real Deal market, the number of suppliers per market will be analysed. Since the data is scraped on several dates not the absolute number of suppliers will be used, but the relative normalized number of suppliers compared the market

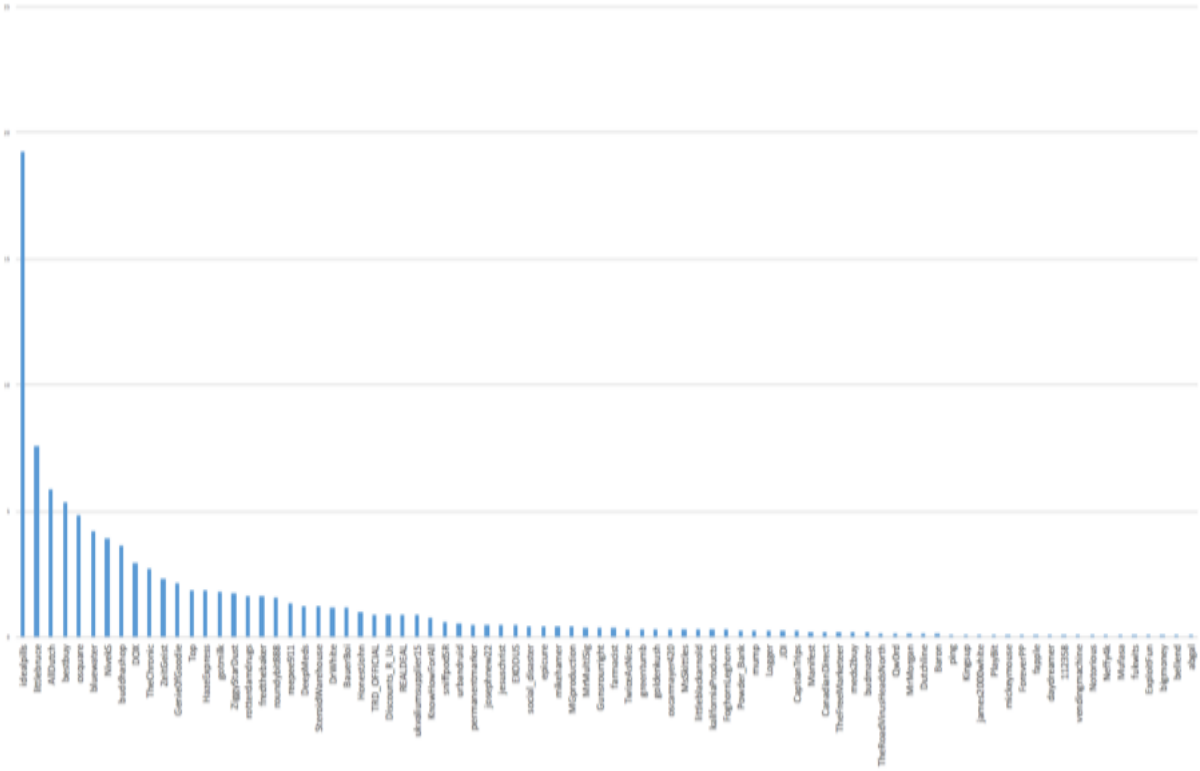

Figure 2 Number of products offered by suppliers as % of total number of offered products.

size. For the market size, the total number of unique products offered in a specific market will be used. This leads to the following formula:

$$Density\ supplier\ per\ product = \frac{\#suppliers}{\#products}$$

A lower density indicates that there are more suppliers per product, while a higher density indicates that there are fewer suppliers per product. The formula divides the number of suppliers by the number of products to be able to compare the different market structures relatively, without the influence of duplicate products. This density will be used to classify a market as either a Monopoly, an Oligopoly or a perfect competition market. This will provide an answer to the first research question: *"What are the different market structures in crypto markets?"*

4.5. Methodology for research question two.

Next, the average prices of goods of the markets will be defined. To be able to define the differences of the average prices are significant, a comparison of means test will be used. The groups that will be used for this test are the Monopoly, Oligopoly and Perfect Competition groups, which are defined according to the notation in section 4.4. When the test is performed, the average prices will be analyzed to provide an answer to research question two: *"How are the average prices of products distributed in these markets?"*

5. Results

This section will first describe the results of the market structure analysis, followed by a description of the results of the average price analysis. Finally, the results will be interpreted and discussed.

5.1. The market structures

The results in this sections aim to provide an answer to research question one (*"What are the different market structures on crypto markets?"*). The table in figure 3 shows the results for the normalized number of suppliers per unique product. Guidelines are defined to make the classification of markets more formal. In figure 4 the guidelines are applied to figure 3.

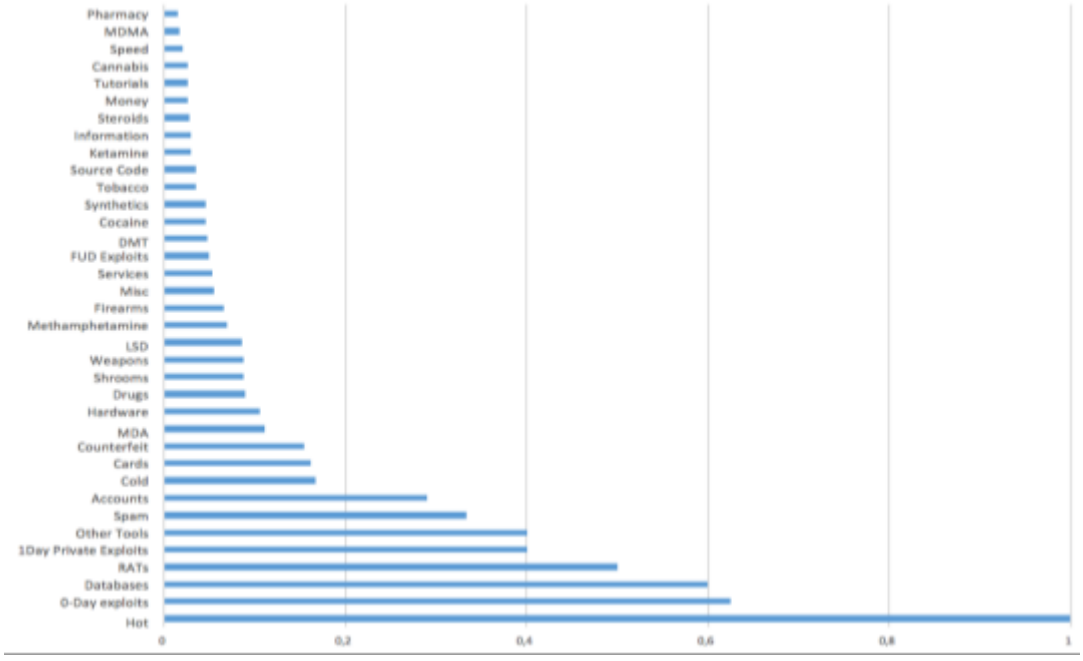

Figure 3 Density supplier per product.

The following guidelines are used:
-A market can be defined as a monopoly when the ratio of supplier per product is equal to 1. Marked yellow in figure 4.
-A market can be defined as an oligopoly when the ratio of supplier per product lies between 0,9 and 0,5, Marked green in figure 4.
-A market can be defined as an oligopoly when the ratio of supplier per product lies between 0,1 and 0,4. Marked red in figure 4.
Figure 4 indicates that there exists only one true monopoly, which is the *Hot* market. There are several markets which seem to be like oligopoly markets, and most of the markets show a relatively low number of suppliers per product, which indicates that these markets have the characteristics of a perfect competition market. Figure 4 shows that most of the markets related to cybercrime assets (such as the 'Databases' or 'RATS' markets) have a relatively low number of suppliers compared to the more drug related markets (such as the 'MDMA' or 'Speed' market). This indicates that these cybercrime markets have relatively higher entrance barriers compared to the drug markets. This might be caused by the easiness of obtaining the product as a supplier. The data shows that it seems to be more difficult to obtain products like zero-day exploits compared to obtaining products like mdma or cannabis. A reason for this might be the required skills to obtain these products. If one would acquire cybercrime assets, one would need certain IT skills in order to acquire these products, while for obtaining drugs additional skills are not necessary.

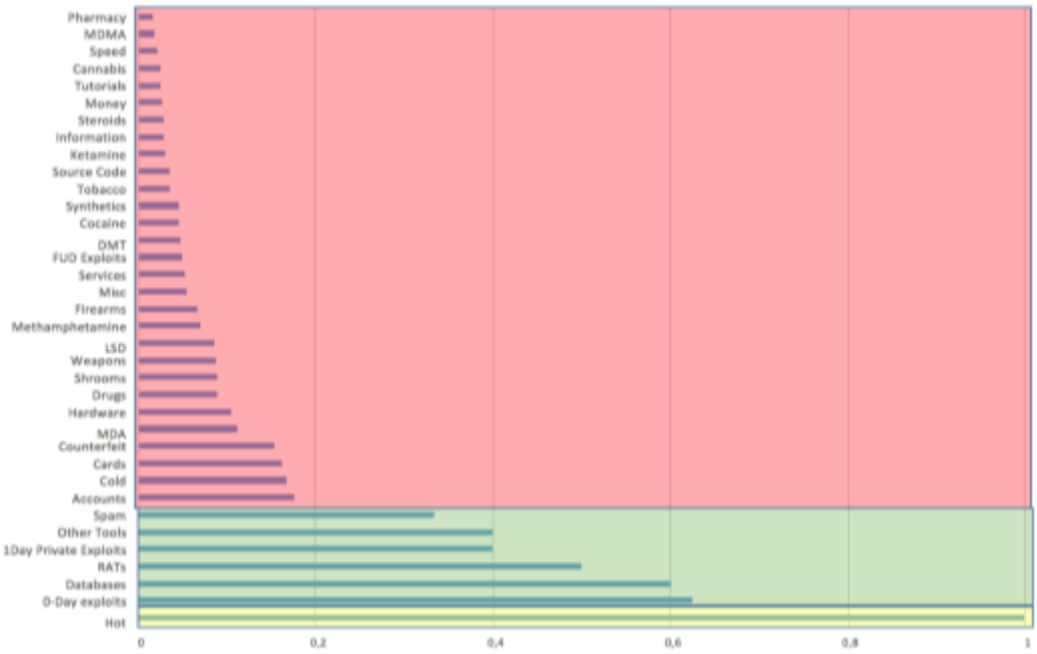

Figure 4 Classification of markets

5.2. The averages prices

In this section, the results of the statistical test will be displayed, with the objective to provide answers to research question two (*"How are the average prices distributed amongst these markets?"*). Only the means of the prices of the oligopoly and monopoly markets will be used in the statistical test, since there exists only one price in the monopoly market. Therefore, this data cannot be used in a statistical analysis. The statistical test that is used to compare the means of the oligopoly market and the perfect competition market is the independent t-Test with unequal variances. See table 1 for the results of this test.

	Oligopoly	Perfect competition
Mean	91.2792	2.1836
Variance	19545.2039	200.8847
Sample size	90	4561
df	89	
T-statistical data	6.0452	
P(T<=t) one-sided	1.7113E-08	
Critical area of T-test: one-sided	1.6621	
P(T<=t) two-sided	3.4226E-08	
Critical area of T-test: two-sided		1.9869

Table 1 Results independent t-Test with unequal variances

If the p value is lower than α=0.05, than H0 can be rejected and H1 can be accepted, if the p value is higher than α=0.05 than H0 can be accepted and H1 can be rejected. Table 1 shows that the p value is equal to 3.4226E-08, which means that H0 (there is no significant difference) can be rejected and H1 (there is a significant difference) can be accepted. In other words, the prices in oligopoly markets on the Real Deal are significantly higher than the prices of the perfect competition markets. This is conforming the theory as described in section 2.4.3.

5.3. Discussion on the results

The research objective of this analysis was to determine the openness of the crypto markets. This analysis showed that crypto markets are quite open; only one monopoly market was found. Drug-related markets have a relatively high number of suppliers and the products have relatively lower prices; therefore, these markets can be defined as the perfect competition markets. According to Binger & Hoffman (1998) this means that these markets have relatively low entrance barriers, so this might indicate that it is relatively easy to access drug markets as a drug supplier.

Barratt et al. (2015) argued that crypto drug markets might have a reduced likelihood of violence compared to conventional drug markets, since there is no physical between the supplier and buyer. However, these results show that the drug trafficking might increase, due to the accessibility of the crypto markets such as the Real Deal market. Crypto markets offer criminals new ways of doing business by offering a channel to transform local conventional markets for illegal drugs to online global markets (Aldridge & Décary-Hétu, 2015). This might lead to a lower likelihood of violence as stated by Barratt et al. (2015), the demand for drugs might increase and, therefore, it becomes more tempting to enlarge drugs production capacities and endangers public's health.

Buxton, Julia & Bingham (2015) argue that the growth of internet use and the growing specialization in online retail and distribution reinforce the argument that change is needed in the way drug control is enforced. This research substantiates this by showing that there is a relatively high number of suppliers active in these markets, and that the barriers of these markets are relatively low. Therefore, this research substantiates the security issue as stated in the introduction (section 1.2 of this report). The police task unit should still try to control the trade on the crypto markets. Although several authors agree that crypto markets reduce the likelihood of violence, drug suppliers have a new channel through which they could supply a large group of new customers of drugs.

6. Limitations and recommendations

This research has several limitations. This section describes these limitations and suggests further research which aims to improve these limitations.

First, the average prices of different products are now compared within the Real Deal market, which feels a bit like "comparing apples and oranges". It would be more accurate if prices of similar products between different crypto markets would have been analysed. Unfortunately, datasets of other crypto markets were not at available. This would really show if a product that is being sold on a monopoly market has a higher price compared to a similar product that is being sold on another market.

Second, the column *product category* is inconsistent. There exists a very broad 'drug' category, while there also exist more specific categories such as the 'cocaine' and 'MDMA' category.

Third, by using the density of supplier per product methodology only one monopoly was found, so the sample size was equal to one. Therefore, it was not possible to calculate the average price of the monopoly market.

Fourth, the average price calculation now consists of prices that are scraped on different dates. So the analysis consists now of a comparison of a variable that is measured at different times. This makes the analysis less accurate.

Lastly, the demand is not investigated in this research. The *hot* market is now defined as a monopoly market, but maybe this is just a product group that is relatively small compared to other product group because the demand for that product is very small. The small demand might be the reason that this market only consists of one supplier and one product.

Further research could focus on a comparison of average prices of similar products between different crypto markets. Another topic for further research could be an analysis of the average prices over time, or an analysis of the demand for products that are offered on crypto markets.

7. Conclusions

This research tried to fill the knowledge gap in literature about market structures on crypto markets. This knowledge can be used by further researchers to compare conventional markets to crypto markets in a less dichotomous way. The following research questions were defined to provide answers to fill the knowledge gap: *1. "What are the different market structures on crypto markets?"* and *2) "How are the average prices distributed amongst these markets?".* A data analysis on a dataset of the Real Deal was used to find answers to these questions. The results showed that most of the markets were of the perfect competition type, some of them were of the oligopoly type, and only one was of the monopoly type. The second question was used to deeper investigate the different type of market structures. According to economics, the price of monopoly and oligopoly markets should be higher than perfect competition markets. The result of this analysis was that the oligopoly markets had, on average, higher prices than the perfect competition markets, which is therefore confirming that these markets were of the oligopoly type. Unfortunately, it was not possible to determine the average price of the monopoly market.

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