Market structures of crypto markets

An analysis into the underlying market structure of
online crypto market The Real Deal

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Abstract - Crypto markets are digital markets that are used to trade illegal goods. This makes analyzing these markets from an economic perspective interesting, but research on this remains remarkably underdeveloped. Therefore, this study assesses the following research question: *What is the impact of the crypto market's suppliers, products, and prices on the underlying market structure?* The main hypothesis for this question is: due to the difference in suppliers, products and prices on the market, all three levels of competitiveness – *monopoly*, *competition* and *super competition* – can be distinguished in crypto markets. Through a data analysis from crypto market The Real Deal can be concluded that this hypothesis is partly true; distinct suppliers can indicate different levels of competitiveness, but the average price level cannot. A key discussion point for this study is that these results are strongly influence by the categorization of products in the dataset, which includes some ambiguous categories.

1. Introduction

"Crypto markets are digital platforms that use anonymizing software (e.g. Tor) and cryptocurrencies (e.g. Bitcoin) to facilitate trade of goods and services, most notably illicit drugs" (Barratt, Ferris, & Winstock, 2015:1). Due to the facilitation of the market through the internet, the availability of these illegal products are seen as cybercrimes (Martin, 2013). This makes that law enforcement actively tries to combat the presence of these markets through surveillance, hacking and other forms of interdiction (Buxton & Bingham, 2015). Next to law enforcement, academic researchers are also showing interest in these markets, because their popularity and importance is growing in recent years. (Schrager, 2015). However, an economic perspective on these markets seems to lack – no studies are found that specifically assess e.g. the market structures of these crypto markets, therefore this research paper tries to address this by conducting a case study with data from one crypto market: The Real Deal.

1.1 Context

This research paper is written in the light of the course *Economics of Cyber Security* at the Delft University of Technology. In this course a specific security issue is analyzed from various perspectives. The security issue that is used during the group assignments was: *the availability of cybercrime-related products on crypto market The Real Deal*. This report will assess this problem for a different perspective; this report will assess how the availability of these products influences the market structure of these crypto markets. This is interesting, because very little research has been done into the market structure from an economic perspective. Nonetheless, there are some research papers that slightly address this topic: Buxton & Bingham (2015) state that the most popular crypto market, Silk Road 1.0 – which was terminated in 2013 – had a nearly monopoly position. However, since its closure hundreds of other crypto markets have emerged (Schrager, 2015). Schrager (2015) refers to UN data that states that the drug market in general does not function efficiently. One reason stated for that is the information asymmetry – you don't know the quality of the product. With crypto markets, this problem becomes even bigger, because the lack of personal contact is one of the key characteristics of these markets (Martin, 2013).

1.2 Structure of report

In the following sections the market structure of crypto market The Real Deal will be analyzed. First a comprehensive literature review will be conducted in section 2 in which a summary will be provided of existing research concerning crypto markets and their market structure from an economic perspective, if available. Next to that, the research objective will be stated, together with the research question and a hypothesis in section 3. In section 4 the research design will be discussed. The results of the research will be presented in section 5. The last two sections, section 6 and section 7, will consist of the limitations of this research and a conclusion.

2. Literature Review

In order to analyze the market structure of crypto markets it is important to assess how these markets have been formally defined in literature. Martin (2013:356) define these market as *"an online forum where goods and services are exchanged between parties who use digital encryption to conceal their identities"*. To make this more clear, the author has identified six characteristics that are shared among such markets (Martin, 2013:356):

1. Based on the TOR network;
2. cryptonyms are used to conceal the identity of the user;
3. despite the digital nature, traditional postal services are used to deliver goods;
4. third-parties are used for hosting and administration;
5. decentralized exchange networks are used;
6. encrypted electronic currencies are used (e.g. Bitcoin).

Next to that, it is interesting to assess what perspective other previous researchers in this field have taken. One view on crypto markets is provided by Barratt et al. (2015) who have assessed what the implications are of such markets. Their research was mainly focused on the safety of participants on these market. The researchers argue that due to the digital nature of these markets – in general – systemic violence is reduced, mainly because there is no personal contact between the parties that trade and the market operator can help to overcome disputes by acting as a neutral third party. (Barratt et al., 2015; Buxton & Bingham, 2015).

Related to this, the authors argue that these crypto markets are viewed as a combination of open and closed markets, they are a hybrid of each. This means that they have characteristics of open markets – any seller can access the market, without prior introduction to the seller, but also characteristics of closed markets – deals are made in less open spaces and parties decide to meet on beforehand (Barratt et al., 2015). Due to this combination of openness and closeness, the researchers argue that much violence that is usually related to drug trade is reduced. Another consequence is that, unlike street drugs, customers are buying from several suppliers, they are less 'connected' to their supplier and easily switch to others. This lack of loyalty can give an indication of the market structure of these crypto markets; there is competition between suppliers (Barratt et al., 2015).

In order to explore what market structure this might indicate, it is interesting to assess what researchers have concluded about market structures of digital markets from a more general economic perspective. Smith, Bailey, & Brynjolfsson (2000) have published an extensive paper about the characteristics of electronic markets. Due to the focus on e-commerce, the paper is very applicable for crypto markets, since this is also an online marketplace. The authors argue that efficiency in internet marketplaces can be measured on four dimensions:

1. Price levels: efficiency occurs when prices are set to the retailer's marginal costs.

2. Pricy elasticity: efficiency occurs when consumers are sensitive to small changes in prices, as long as substitute suppliers exist.
3. Menu costs: the costs that are due to price changes are argued to be as high as a simple alteration of a value in a database. In efficient markets price changes occur more often.
4. Price dispersion: efficiency occurs when there is low price dispersion, prices for the same goods are more or less the same.

For more 'basic' economy theory, the researcher refer to state-of-the art economic papers from theorists that explained these theories. One of these papers is by Salop (1979), who distinguishes three market structures that are related to three regions on the demand curve: the *monopoly*, *competitive* and *super competitive* region. The author defines the monopoly as: *"prices in which the brand's entire market consist of consumers for whom the surplus of no other brand exceeds the surplus of the homogeneous outside good"* (Salop, 1979:143). With this, the author means that that there are only one or two suppliers for the product. The competitive region is defined as: *"those prices in which customers are attracted who would otherwise purchase some other differentiated brand"* (Salop, 1979:143). At last, there is the super competitive region, which is defined as: *"those prices in which all the customers of the closest neighboring brand are captured"* (Salop, 1979:143). The three regions are illustrated in Figure 1 – Typical demand curve *(Salop, 1979)*Figure 1.

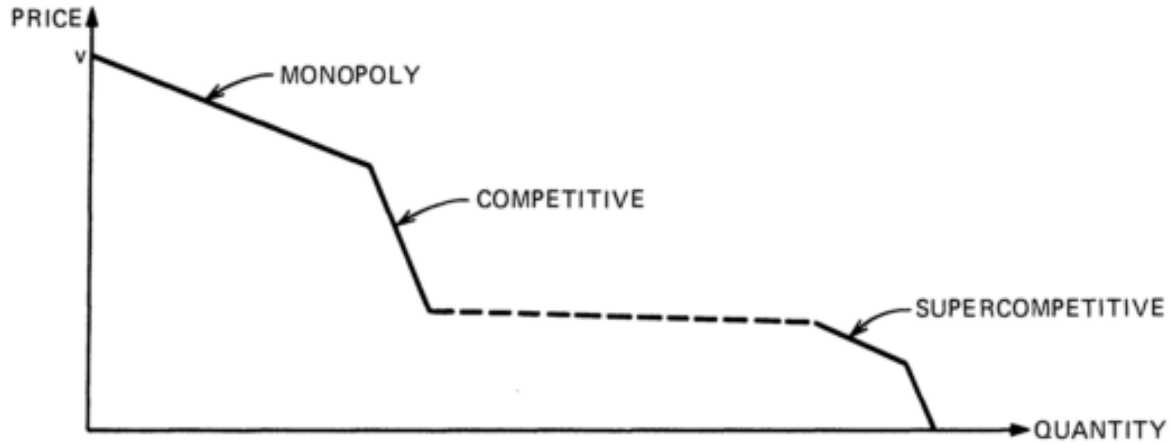

Figure 1 – Typical demand curve (Salop, 1979)

These insight from the economic perspective on online markets have been applied to crypto markets by Broséus et al. (2016) who have analyzed the structure and organization of distribution networks of eight crypto markets. They were mainly focused on drug trade and use Silk Road as one of the examples to argue that these markets were quite competitive: *"Just before its closure, more than 1000 vendors were active on Silk Road and annual sales were estimated at 89.7 million USD"* They add that there is a lot of demand for these markets: *"At the time of writing, about 20 crypto markets are active. This illustrates the strong demand for this kind of marketplace as well as the growing importance of crypto markets in the trafficking*

of illicit products." (Broséus et al., 2016:8). For the analysis of the structure of these markets, they have assessed the following:

1. Vendor names: to explore how many suppliers are active on the market. They conclude that most suppliers focus only on one market, but sometimes also other markets are used to sell the products. This indicates competition between markets (Broséus et al., 2016).
2. PGP keys: these keys are used by the online community to uniquely identify a user. This can give better insight in the number of (unique) suppliers on the markets.

By getting insight into the suppliers on these markets, the researchers reveal who the key suppliers are and how these key suppliers are behaving. These suppliers are diversifying their offerings on various markets to gain more revenue, which indicates that these markets are competitive (Broséus et al., 2016). The authors also add to this that de market structure can differ per product sold; some products might have a high number of suppliers, whereas other products only have one or a few suppliers.

3. Research Question, Objective and Hypothesis

As stated in section 1, this paper has the objective to assess the market structure of crypto markets. As a case study for this paper, data from crypto market The Real Deal will be used to analyze the structure of the market in terms of products sold, suppliers and price of the products. This dataset contains the following variables: *Date, Description, URL, Price, User, Reviews* and *Product*. Data is collected over a period of 2.5 months in which the crypto market has been scraped 23 times. Due to the dynamics of the market, some products were available for all these days, whereas other products were only available for a fraction of these days. There are various products being sold on the crypto market, such as cybercrime assets (0-day exploits, SPAM, accounts), Credit Cards and various types of drugs.

Based on the literature review in section 2, the data will be used to find an answer to the following research question:

> *What is the impact of the crypto market's suppliers, products, and prices on the underlying market structure?*

Looking back on the findings in literature, especially the research by Smith et al. (2000) and Broséus et al. (2016) seem applicable to guide the data analysis; to derive the market structure of crypto market The Real Deal. Smith et al. (2000) argue that particularly the price can be used as an indicator for this. Unfortunately it is not possible to derive the marginal costs, the menu costs and the price dispersion from the dataset. However, the average price level of products can be derived to indicate the level of competitiveness.

Next to that, Broséus et al. (2016) argue that crypto markets are subject to competition, the distinction as defined by Salop (1979) will be used for this: *monopoly, competition* and *super competition.* Broséus et al. (2016) state that the number of suppliers that are active on the market give an indication of the market structure – a high number of sellers indicate competition, whereas a low number of suppliers indicate a monopoly, this can also differ per product on the market. Therefore, the following main hypothesis is stated:

> Due to the difference in suppliers, products and prices on the market, all three levels of competitiveness – *monopoly, competition* and *super competition* – can be distinguished in crypto markets.

To test this main hypothesis, the following aspects will be assessed

1. The number of suppliers over the product categories – a difference in distinct suppliers indicates a categorization based on competitiveness of the product category is possible.
    a. *Hypothesis: the number of distinct suppliers for the products are different over the three categories*
2. The average prices of products – a difference is prices between the three categories, indicates a difference in market structure
    a. *Hypothesis: the average prices are different over the three categories*

4. Methodology (Research Design)

As stated before, in order to find an answer to the research question, a quantitative case study will be performed using data from crypto market The Real Deal. This is applicable for exploring and explaining a topic in its own context (Saunders, Lewis, & Thornhill, 2009; Yin, 2009). In section 3 is explained that the following variables can be found in the data set: *Date, Description, URL, Price, User, Reviews* and *Product.* Based on the hypotheses, the focus will mainly be on variables *Price, Product* and *User* (supplier).

The statistical technique that will be used to analyze the data is a comparison of means. This will be done using an Analysis of Variance (ANOVA), in which two groups will be compared (Park, 2005). One important assumption to use the test is that samples are randomly drawn from normally distributed populations with unknown population means. The Central Limit Theorem states, however, that the distributions are approximately normal when N is large (Park, 2005). For this dataset, the N is 7595, so this is no issue.

The comparison of means will be undertaken in the following way. First, an overview will be created of the number of suppliers that are selling the various products in the markets. Based on this, the number of distinct suppliers for each product can be derived; this might indicate the difference of competitiveness in the market. Based on this, the several products will be

categorized based on their level of competitiveness. After that, the average price of the products in these categories can be assessed to analyze whether this differs over the categories.

5. Results

The results of the data analysis will be discussed for each hypothesis. First there is a short description of the findings and data structure, after which the relevant statistical output is presented.

5.1 Hypothesis 1: distinct suppliers

For the first hypothesis – *the number of distinct suppliers for the products are different over the three categories* – an overview is created in which the number of distinct suppliers for each product category is displayed, see Figure 2. In this figure, the values on the bars indicate the number of distinct suppliers, and the numbers next to the product categories indicate the size of that category. Based on this, the three categories are determined, see Table 3 in the Appendices for this categorization.

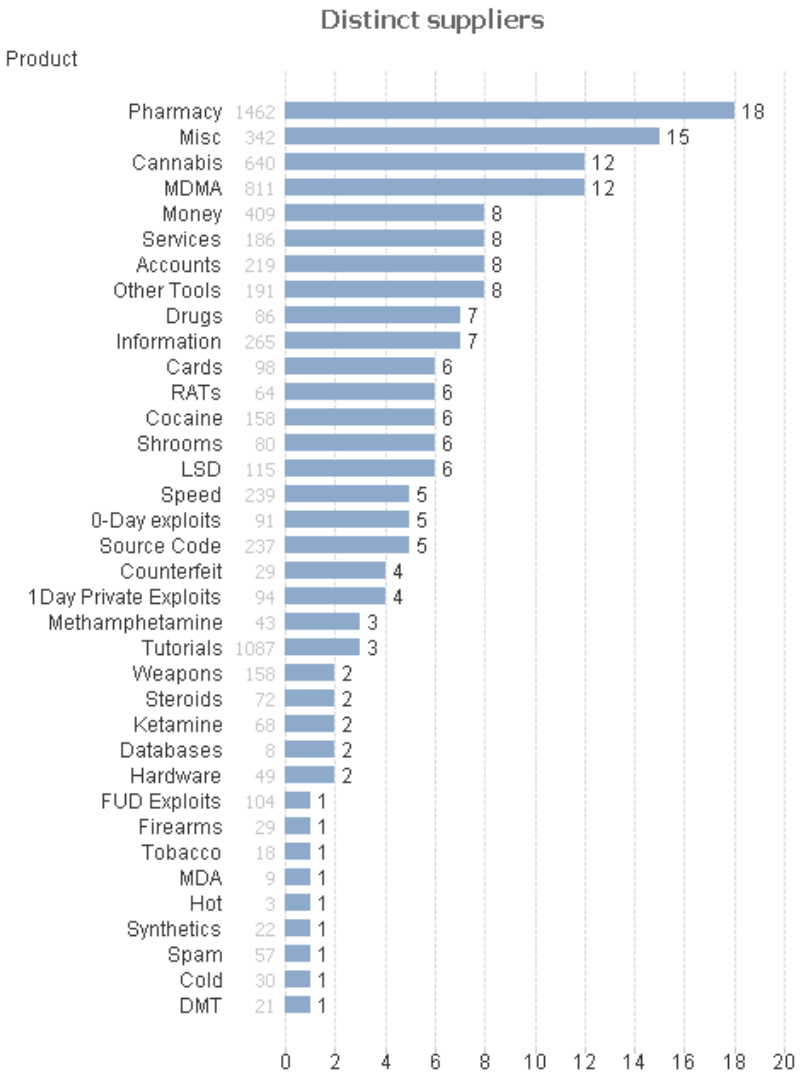

Figure 2 – Distinct suppliers for each product category

An ANOVA table is created to determine whether the difference between the means of the number of distinct suppliers per group are statistically significant. The result of the ANOVA is displayed in Table 1.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Monopoly	14	19	1,357143	0,247253
Competition	18	105	5,833333	2,735294
Super competition	4	57	14,25	8,25

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	540,5079	2	270,254	119,7672	7,43E-16	3,284918
Within Groups	74,46429	33	2,256494			
Total	614,9722	35				

Table 1 – ANOVA result for hypothesis 1

The null hypothesis for this test is: *there are no differences between the numbers of distinct suppliers for the three categories.* This hypothesis will be rejected when F > F crit. This is the case, 119,77 > 3,29. This means the three populations are not equal and the alternative hypothesis is accepted: *the number of distinct suppliers for the products are different over the three categories.* This is interesting, because this indicates that the main hypothesis might be true – all three levels of competitiveness can be distinguished in the market.

5.2 Hypothesis 2: average prices

For hypothesis 2 – *the average prices are different over the three categories* – the average prices of the products in each category are calculated. See Table 4 in the appendices for an overview of the average prices of each product category. A short summary is provided below:

Category	Monopoly	Competition	Super competition
Average price	11,61	7,67	1,41

An ANOVA table is created to determine whether the difference between the means of average prices per group are statistically significant. The result of the ANOVA is displayed in Table 2.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Monopoly	14	162,48	11,60571	556,9073
Competition	18	138	7,666667	470,1997
Super competition	4	5,62	1,405	0,6001

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	348,8923	2	174,4461	0,377862	0,688252	3,284918
Within Groups	15234,99	33	461,6664			
Total	15583,88	35				

Table 2 – ANOVA result for hypothesis 2

The null hypothesis for this test is: *there are no differences between the average prices for the three categories.* This hypothesis will be rejected when F > F crit. This is not the case, 0,38 < 3,29. This means the three populations are equal and the alternative hypothesis, *the average prices are different over the three categories* is rejected. Interestingly, the average prices are not significant enough to indicate a difference, even though this was expected based on the averages. This might be due to the high variance of the prices in the groups – even though the average indicates a significant difference, the variance is remarkably high, especially for the groups *monopoly* and *competition*.

6. Limitations

This section indicates the limitations of the study. These limitations are mainly based on the novelty of the research area and the quality of the dataset.

First of all, this study has the goal to analyze the market structure of crypto markets. In the literature review became apparent that this is a research area that is underdeveloped, this made if extremely difficult to come up with high quality research papers that were relevant for this topic. The papers that were found had mainly a specific focus, e.g. violence on drug markets or type of suppliers, and didn't discuss the market structures explicitly.

Next to that, the dataset that is used for the case study was obtained by scraping the crypto market The Real Deal. Consequently, the data was not clean and contained a lot of 'noise'. Products that are sold are categorized in the data set, but this is perhaps not always right. There are for example various types of drugs, but there is also a separate category for drugs. Next to that, there a big category called misc. – probably miscellaneous – in which various products are 'grouped'. Due to the high number of suppliers, this category was stated as *super competitive*, but future research should consider these vague categories in order to gain more valuable insights.

Another limitation of this study is that the prices of the products show a huge variance. Even though outliers have been removed, the statistical analysis indicated there is still a huge variance between the three groups. Consequently, the difference was not statistically significant. Future studies should assess the availability of outliers more critically and perhaps use a stricter threshold.

At last, other aspects that are mentioned in the literature to indicate the market structure, such as the price dispersion and menu costs are not assessed in this study, due to limitation of the dataset – duration of observations is mainly the reason for this. A bigger dataset that analyzes the market over a longer period of time should be used in order to assess these aspects.

7. Conclusions

After conducting the research, the following can be concluded. First of all, the main research question that was stated is: *what is the impact of the crypto market's suppliers, products, and prices on the underlying market structure?*

The main hypothesis for this research question is stated as: due to the difference in suppliers, products and prices on the market, all three levels of competitiveness – *monopoly*, *competition* and *super competition* – can be distinguished in crypto markets.

There were two (sub) hypotheses stated to guide the data analysis:

1. The number of distinct suppliers for the products are different over the three categories
2. The average prices are different over the three categories

Based on the results in section 5, the following can be concluded: hypothesis 1 is accepted, but hypothesis 2 is rejected. This has the implication that the main hypothesis is only partly accepted: the three levels of competitiveness can be defined by the number of distinct suppliers, as argued by Broséus et al. (2016), but not by the differences in average price levels, as argued by Smith et al. (2000).

Using these findings, the main research question can be answered as follows: the market structure of crypto markets is impacted by the number of suppliers that offer a product. The difference in suppliers for products result in different levels of competitiveness that can be distinguished in the market. However, the price of the product has no significant impact on this distinction. As stated before, this supports the literature only partly, as the average prices were also stated to be an indicator for the market structure by Smith et al. (2000). However, as stated in section 6, these outcomes can be related to the data set that is used for this study.

Nonetheless, research on market structures of crypto markets from an economic perspective is lacking, thus the findings from this report can definitely be used by future researchers to build upon. Directions for future research are to assess why the difference average prices were rated as not statistically significant and whether other explanatory variables can be used to define the market structures of crypto markets.

Appendices

Monopoly		**Competition**		**Super competition**	
Ketamine	2	Accounts	8	Pharmacy	18
Databases	2	Other tools	8	Misc	15
Steroids	2	Services	8	Cannabis	12
Hardware	2	Money	8	MDMA	12
Weapons	2	Information	7		
DMT	1	Drugs	7		
Cold	1	Cards	6		
Synthetics	1	RATs	6		
Hot	1	Cocaine	6		
Firearms	1	Shrooms	6		
Spam	1	LSD	6		
FUD exploits	1	Speed	5		
MDA	1	Source Code	5		
Tobacco	1	0-Day exploits	5		
		Counterfeit	4		
		1Day Private Exploits	4		
		Methamphetamine	3		
		Tutorials	3		
Total Suppliers: 19		Total Suppliers: 105		Total Suppliers: 57	

Table 3 - Overview of categories and products

Category	**Product**	**AVG (price)**
Competition	0-Day exploits	28,67
Competition	1Day Private Exploits	90,33
Competition	Accounts	1,09
Competition	Cards	0,19
Competition	Cocaine	0,99
Competition	Counterfeit	0,65
Competition	Drugs	1,41
Competition	Information	0,11

Competition	LSD	0,35
Competition	Methamphetamine	0,61
Competition	Money	0,26
Competition	Other Tools	0,38
Competition	RATs	1,30
Competition	Services	4,58
Competition	Shrooms	0,22
Competition	Source Code	6,46
Competition	Speed	0,37
Competition	Tutorials	0,03
Monopoly	Cold	0,28
Monopoly	Databases	48,74
Monopoly	DMT	0,20
Monopoly	Firearms	11,32
Monopoly	FUD Exploits	2,05
Monopoly	Hardware	80,07
Monopoly	Hot	14,00
Monopoly	Ketamine	2,65
Monopoly	MDA	1,28
Monopoly	Spam	1,20
Monopoly	Steroids	0,11
Monopoly	Synthetics	0,13
Monopoly	Tobacco	0,18
Monopoly	Weapons	0,27
Super competition	Cannabis	2,33
Super competition	MDMA	0,95
Super competition	Misc	0,61
Super competition	Pharmacy	1,73

Table 4 Average price of products

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