Price Formation of Illicit Drugs on Dark Web Marketplaces

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ABSTRACT

A large portion of the internet or world wide web is not indexed by search machines, this is called the deep web. A smaller portion of this deep web, only accessible using anonymization software (e.g. Tor), is called the dark web. Websites in the deep- and dark-web can only be directly accessed through their URL. The dark web is used for various pursuits, both legal - such as human rights activism - and illegal. The latter being the most prevalent, with content such as child pornography or the sharing of malicious services such as DDoS-tools. The focus of this research will be on another - and perhaps the most prevalent - part of the illegal activities on the dark web, namely drug trafficking.
In this research, the dark web's illicit drug markets and their 'offline' counterparts will be compared. Specific differences between 'offline' and 'online' markets will be investigated and summarized along with other benefits and services the dark web might offer, next to this a price comparison will be made to finally examine whether these possible factors alter the price formation.

Keywords

Dark web, illegal, drugs, services, price analysis, marketplaces

1. INTRODUCTION

Parts of the dark web are being used as a distribution and supply management platform in the illicit drug trade, in 2016 drugs accounted for roughly 80% of all items on sale on the dark web [3].
Not only are these drugs illegal, their impact on society is also quite substantial. In a Belgian study by Lievens et al. [20] it was concluded that in the year 2012 the direct and indirect cost of addictive substances amounted to about 1,19% of the GDP and 515.000 human life years lost.
The impact of illicit drugs on society and the people in contact with it is substantial enough to warrant action to disrupt the distribution, trade and supply of these drugs. The 'offline' illegal drug market has been the target of law enforcement and government authority interdiction for decades. Illegal drug trafficking on the dark net and the attempted obstruction of this by law enforcement is more of a matter of the recent decade, with the most known marketplace - the Silk Road - launching in 2011 and finally being taken down in 2014 [38].
The online drug market is relatively small compared to the overall drug market, but growing. In The Netherlands the percentage of drugs purchased online increased from 1,4% to 4,1% from 2013 to 2015 as shown by 2017 Trimbos Institute research [35]. Although already notable and cause for action this percentage has most probably risen further since then.

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1.1 Research Problem

The focus of this research is to clarify whether differences exist between 'offline' and 'online' illegal drug prices and to give reasons for the existence or nonexistence of these differences on different dark web markets, to present more insight into the workings and benefits of the dark net as a platform for drug trade.
The insights provided should give an idea to the extent and usage of the dark web as a platform for drug sales and why some might prefer it to the more traditional 'offline' counterpart, even if prices differ. Furthermore, this research could be used in law enforcement to determine the efficacy of used strategies to tackle the dark web illicit drug trade, by comparing price fluctuations as a gauge for supply or network problems without the unknown variables of differences between the 'offline' and different 'online' marketplaces.

1.1.1 Research Question

To address the research problem the following research question will be used:
Does the use of various dark web marketplaces and services lead to differences in the pricing of illicit drugs online, compared to each other and their 'offline' counterparts?

To help formulate and better analyse the response to this question it will be divided into sub-questions, these will all take an aspect of the research question into account.

1. What factors into the determination of the price of illegal drugs sold though the 'offline' market?
2. How does usage of dark web marketplaces affect distributors and retailers of illegal drugs so that it could be cause for differences in price?
3. In what ways do consumers benefit from using dark web marketplaces as their source of illegal drugs and how do these marketplaces differ on the consumer side?
4. How do prices of 'offline' bought illegal drugs compare to prices of drugs purchased on the dark web?

1.2 Methodology

To answer these questions individual research has been conducted into the subject(s) of each question. The research of the first three question composes of literature research. This literature was found through a method of querying the *Google Scholar* and *Scopus* academic search engines and snowball sampling from already examined literature. This literature was then examined and - if deemed useful to the question - excerpts were collected along with references to the source. After the collection process these excerpts were compared, further examined, rephrased or connected and added to the paper accordingly. The usefulness of a piece of literature was graded on: the perception of helpfulness in leading to a proper answer to the research question being examined; or possible connections to already collected literature.

Below are listed example queries used to search for literature on the first three subject respectively, these contain most of the common keywords used, but are not limited to the full scope of the queries used for each subject.

- `(illicit OR illegal) AND drugs AND (supply-chain OR "supply chain")`
- `marketplace AND darkweb AND (distributor OR retailer) AND (sell* OR sale*)`
- `(("dark web" OR "dark net") AND (customer* OR consumer* ) AND (illicit OR illegal) AND drugs)`

Lastly, to answer the fourth research question empirical research took place. A dataset containing price information of dark web marketplace listings was examined and further calculations were applied to this dataset. This dataset was then compared to already collected data on prices in the 'offline' setting.

2. PRICING IN 'OFFLINE' MARKETS

In this section further gained insights related to the first research question will be examined. These insights have been obtained by conducting reviews of different literature related to the price and supply-chain of drugs in an 'offline' setting. For this examination we will go through the respective sections of the supply-chain one by one, to determine how factors in these sections play a role in the price formation. Figure 5.1 in the RAND framework for drug-related crime, as presented by Kilmer and Hoorens was used as a basis for this division into supply-chain sections [17]. These sections will be: production, transportation, sales (divided into wholesale and retail) and additionally the 'enforcement tax'. The last being a concept to be explained in its respective section.

2.1 Production

At the top of the supply chain of illicit drugs are the producers (e.g.methamphetamine producers) and/or cultivators (e.g. opium poppy farmers). These are both separately or in combination responsible for the production of the drug itself.

Specifically for the production-side two cost determining components have to be accounted for - as outlined by Reuter and Kleimann: (a) the cost of producing and transporting the good and (b) the 'normal' profits (or rather 'expected' profits) which can be seen as the return on investment [29]. The cost of producing can be better examined by dividing it into two parts, namely: cost of inputs & cost of transportation, as mentioned by Kilmer and Hoorens [17], and the 'enforcement tax'.

Transportation will be touched upon in a sub-section of its own. The normative profits would be added during a sale, hence they will be treated there. The enforcement tax will also be examined in its own section, as this affects multiple layers of the supply-chain and is not exclusive to production. This leaves the cost of producing the drug itself and more specifically the cost of inputs to examine. Furthermore we assume there to be more costs, such as to uphold or increase reputation/trust (marketing) which is proven to be a concern later in this paper, or to fend off other potential (harmful) competitors or other drug market related entities, proven to be quite a problem according to Reuter [26].

The production of drugs requires input resources, these could be seen as the cultivated land for the drug to grow on, or items needed in production (e.g. hydrochloric acid for methamphetamine). The prices for buying or facilitating these input resources factor into the production cost. Kilmer and Hoorens assume there to be a scarcity in these inputs that might make it difficult to scale up production to increase total output without having to pay more per input unit [17]. This scarcity might be assumed to be impacted by locality, i.e. some regions or places having less access to specific kinds of resources, leading one to have to purchase the goods elsewhere or purchase them at a higher rate.

2.2 Transportation

In his paper about risks, prices and positions with respect to illegal drug trafficking in the world-economy Boivin points to an excerpt from Reuters and Greenfield that states that "the value of illegal drugs increases almost exponentially after production, while price increases are more modest for legal commodities". He explains this further by comparing the price of a kilo of cocaine in Bolivia, where it costs around $1.000, to its price in the USA, Australia or France, where the same amount costs $100.000. [5, 28].

Since illegal drugs are not sold through markets that follow the general laws of supply and demand, where entities have perfect information (Moeller and Sandberg [21]), it is hard to imagine these price differences could exist out of producer cooperation and unfair competition through price agreements made between different producers.

A more logical explanation is that transportation is partially - if not fully - responsible for this large increase in cost. Naturally transportation of any good costs money on its own, but Boivin mentions to different aspects in the transportation of illicit substances, which might play parts in these price differences [5].

- The volume of trade should be lower between distant countries because of higher transport costs, which in turn also raises the price in the destination country.
- The price markups in for countries on the route to a large potential market are lower, this could be explained because supply greatly exceeds demand in transit countries.

The latter could for example be the case in countries that serve as the gateway to Europe, for example Spain, Portugal and Turkey as shown by Farrel et al. The prices would then become more expensive the further "inland" [12]. Hence it would be more beneficial to buy illicit drugs from suppliers based in these transit countries, given that one has access to them.

It is further stated that the increase in price is mainly because of the risk taken during transportation and the losses incurred to mitigate these risks, rather than the price of

the transport itself. Boivin states "Longer journeys involve higher risks of being detected at some point; it takes more time to cover longer distance. Scholars have also suggested that distance is closely related to means of transportation and that different means are associated with specific risks" drawing upon earlier literature by Farrel et. al and Reuter and Kleimann [12, 29]. This is also a practical example of 'enforcement tax'.

2.3 Sales

Another essential process in the illicit drug supply-chain involves sales. This sales subsection will be divided into wholesale and retail sales, the latter being the last action between entities in the supply-chain - to the consumer. Below both types will be further examined to advance our understanding of how these affect the price formation.

2.3.1 Wholesale

Wholesale is "the selling of goods in large amounts at low prices to shops and businesses, rather than the selling of goods in shops to customers" [8]. This often means selling from distributor to retailer, but could naturally include a larger distributor selling to a smaller one. Moeller and Sandberg state, drawing upon previous sources, that drug distribution occurs in social networks of known partners to reduce law enforcement interdiction. Moreover: "the price formation in drug distribution is embedded in social networks". According to Moeller and Sandberg, power in these network relationships also gives room for credit provision, stability improvement and gives way to price fixing. While social networks are important in the legal economy, they are indispensable in the illegal economy because of the absence of official marketplaces [21].

Interesting perhaps is another wholesale-distribution reference made by Moeller and Sandberg, from another research article by Gallet stating that above the street level on two transaction are priced the same. Giving further proof to the previous statement that there is no official market (at least 'offline') [14].

Reflecting upon the credit provision, referring to a book by Reuter from 1983 [25] and an article by Stigliz and Weiss [30], Moeller and Sandberg state that because of the cost of making and collecting loans the credit prices are higher than if a buyer were to purchase using cash. Although when this is the case the creditor still recognizes the other party's entitlement to make money and that party's ability to repay the loan. It can be assumed that this done as it it beneficial to the preservation of the 'trusted' buyer, preventing the seller from having to find another - possibly untrustworthy - buyer. This could however also mean that drug prices could fluctuate based on whether a person in the supply-chain has made use of credit and upped their prices as a result to make up for the loan.

Next to how the social context might factor into the price determination at a wholesale level, it should also be mentioned that the price per unit is often proportional to the size of the transaction raised to a negative power and discounts in general are more substantial within sales of illicit drugs [9]. This means that discounts are applied in transactions for large quantities of drugs, this factors into the price determination as the buyer would have a lower cost price. As an example: the price per gram of an illicit drug to a distributor could cost a certain amount, whilst a tenfold of the same drug to another distributor (given other circumstances are similar) could cost much less per gram, leading to differences in the price down the line. This might be associated to risk and enforcement tax. Practically there's a higher risk and more cost associated with storing larger quantities than smaller quantities. This will be touched upon later.

2.3.2 Retail

The retail level is the final level in the illicit drug supply-chain, it is here that the final price is determined, as this is where it is last sold. The first concrete thing we should take into account when examining retail prices (applicable to wholesale as well) is that we cannot assign a value to a transaction by plainly multiplying the quantity and amount of grams, to come to a price per gram. Ideally one would examine the prices from a so called 'Purity Adjusted Price', which takes into account the actual percentage of illicit drug in the sold substance; as given by Caulkins [9]. Purity is not standardized and substances purchased from different dealers might contain different percentages of drug and dilluents. Caulkins cites previous work by himself and Reuter from 2004, which states that the variation in drug quality (purity) is enormous in comparison to legal markets [27].

Because of this reason, illicit drugs can be described as an "experience good". The customers (sometimes even the retailer) often do not know the exact purity at moment of purchase.
Non-standardized transaction sizes along with traditional pricing basically mean: that the customer's price really only changes with respect to the actual pure drugs bought for their money as a percentage of the purchased item [9]. The consumer would have to 'experience' the good by consuming it to actually determine the quality.

Related is a situation described by Moeller and Sandberg [21]. Where a dealer sells higher quality drugs for a lower price to grow goodwill and trust. Showing that these are still important factors on the street level. As they state "price formation is not purely an economic endeavor". They expand further on this by saying that status and trust are important in the price formation. Especially without warranties or product standards. So that reputation becomes a safeguard for the quality of the drugs as well as the reliability of the dealer.

According to Hughes et al. changes in consumption can be the result of changes in price, for both addicted or non-addicted people, and with respect to different kinds of illicit drugs [16]. This also seems to be the main point of focus for law enforcement interdiction. Kilmer and Hoorens have stated that the purity of drugs at the wholesale level is relatively invariant, but not so much at retail level. This could be because of law enforcement interdiction forcing the retailers to extend their stock. A practical example of this, also outlined by Kilmer and Hoorens, described that in 1995 the US Drug Enforcement Agency shut down major methamphetamine production operations. Leading to increases of prices from $100 to $1.200 per pure gram [17].

2.4 Enforcement Tax

Boivin states: "Illegal drug prices are extremely high, compared to similar goods. There is, however, considerable variation in value depending on place, market level and type of drugs. A prominent framework for the study of illegal drugs is the "risks and prices" model (Reuter & Kleimann, 1986)" [5, 29].
Reuter and Kleimann summarize this as "Illicit drugs are expensive because criminalization 'taxes' all aspects of distribution". This is also concept that is mentioned in the publication by Kilmer and Hoorens, where they further

explain it as: " 'Enforcement tax' is the extra cost that comes to producers and sellers to remain undetected by law enforcement" [17].

During the entire process of production, transportation and sales the entity handling the illicit drug is at risk. Mostly because of the illegality of its actions, but possibly also by threat of rival entities. As mentioned before; mitigating the threat from rival organisations would surely factor into the cost, but arguably the more important cost throughout the supply-chain is the cost to prevent law enforcement interdiction: 'enforcement tax'.

During the production process there is a risk to exposure. Drug labs or plantations could be discovered, or participants could be busted buying suspicious quantities of input items from legal businesses - e.g. a hardware store reporting unusual amounts of possible methamphetamine input resources bought. It is highly likely that to circumvent this risk extra costs are made. One could - in case of the given example - think of people going to stores outside their locality or purchasing smaller (non report-worthy) amounts from multiple stores. Other situations can also be thought about, but we could assume generally risk avoidance increases (labour) cost.

On the subject of transportation, according to Boivin: "drug prices increase more sharply when drugs are headed to countries where law enforcement imposes higher costs on traffickers". This could be seen as a higher risk of successful law enforcement interdiction and therefore higher prices, as the trafficker would have to pay extra costs to avoid this. Boivin states that the corruption level in a country, measurable through the Corruption Perception Index (CPI) as given by the 'Transparency Index' [31] along with the number of police officers in a country per one thousand inhabitants gives a good indication of the this risk [5]. This is because the more law enforcement cannot simply be bribed, the higher the need for concealment and hence the cost for the transporters. Bribery in in this sense also frequently mentioned by Kilmer and Hoorens [17]. The CPI also seems to negatively correlate to the gross national product per capita adjusted for the purchasing power parity , which might be part of the reason some drugs are generally more expensive in countries better positioned in the legitimate world-economy [5]. Farrel then expands this by saying that if one drug is a higher price, than as a general rule, the other drugs are also of a higher price [12].

Sales prices, more specifically cheaper prices in deals for larger quantities of drugs, (quantity discounts) as mentioned before, might find a basis in "inventory cost".
Moeller and Sandberg explain this as the costs being higher because of the criminalization of storing these drugs. Several dealers they had interviewed said that they saw inventory as a major concern and its 'maintenance' costs should be considered when making deals.
One always questions whether or not an offer is worth the price, or if one would rather wait and sit on their high-risk wares until a better offer comes along. Often though, they would sell out as soon as possible to prevent being caught with large amounts [21]. The dealer's network also plays a large role, as a less secure network would put higher risk for a dealer's exposure - increasing the risk of getting caught with possibly larger more punishable quantities. Therefore the dealer might choose to only sell to close relations or friends, keeping a lower stock, as described by Moeller and Sandberg [21].

3. DISTRIBUTORS AND RETAILERS ON THE DARK WEB

In this section the motivation for and differences in usage of the dark web by distributors and retailers of illicit drugs (vendors), in contrast to the 'offline', will be examined; conforming to the second research question. To do this the section will be divided into two sections. One section describing utilization of the dark web and dark web marketplaces, also called cryptomarkets, with respect to these vendors. The other section describing differences between the use of dark web marketplaces versus the 'offline' that affect these vendors.

3.1 Vendors on dark web marketplaces

Dark web marketplaces, also known as cryptomarkets, can be used for the sale of a multitude of products ranging from firearms to counterfeit documents. In this paper the focus is on illicit drugs. Cryptomarkets for illicit drugs can be divided into two categories. One being shops for a single vendor, often selling a narrow range of drug types, and the other being an actual marketplace with numerous vendors to the likes of eBay and Amazon, where customers can search for products and compare these and their vendors [2]. In this research the primary focus will be on the latter category, below some aspects of these marketplaces will be further examined.

On these marketplaces the vendor benefits from increased anonymity, because of the use of the dark web (accessible through Tor routing) and crypto-currencies for payment. Tor routing would prevent the user from being tracked to a location. The use of crypto-currencies enables anonymous transactions, where a third party cannot find further details on the buyer or seller [19, 10].

Cryptomarkets are not exclusive, but can also be used in an integrated fashion in the drug supply-chain, as Barratt and Aldridge [4] state: "drugs flow into and out of cryptomarkets into broader social and commercial drug supply chains".
Demant et al. similarly conclude that cryptomarkets can play a role in shortening the supply-chains specifically for drugs such as MDMA. Again shown in the results of their conducted research stating that "Our results suggest that cryptomarkets can complement traditional drug trafficking at the international level" [11].

The argument could thus be made; that a vendor is not necessarily dependent on customers who are sufficiently digitally literate to access cryptomarkets. They could restock and sell portions of their stock through the dark web; and sell the remainder to 'offline' entities. This is also concluded by Aldridge and Décary-Hétu stating that "Wholesale activity on cryptomarkets may serve to increase the diffusion of new drugs – and wider range of drugs – in offline drug markets, thereby indirectly serving drug users who are not cryptomarket customers themselves" [2].

An important paper defining characteristics of sellers (and buyers) is one by Tzanetakis [32]. In this paper she describes her analysis of 'AlphaBay' - a leading cryptomarket at the time of her research (shut down in 2017). On this website (and other cryptomarkets) a vendor is often able to define where they would ship their product, through their profile or in their listings. According to Tzanetakis shipping domestically or regionally has a lower risk of interception than shipping globally, often leaving the decision to vendors to choose between lower risk, fewer customers and therefore lower profit or higher risk, higher profit. In this paper Tzanetakis concludes that vendors were split about

50/50 on this decision. Although she stated that "drug distribution on cryptomarkets is conducted at a regional rather than global level".

In the same paper Tzanetakis describes that her research also led her to conclude that "none of the traditional cultivation countries had a relevant share as a country of origin or destination" [32]. From which could be assumed that producers of drugs of an agricultural nature do not sell their product through these dark web marketplaces. This could be related to the with nonavailability of digital infrastructure and insufficient digital literacy in these countries.

Tzanetakis [32] describes another feature on the dark web marketplaces that facilitates vendors in this paper: the use of a review and feedback systems. These systems are similar to ones to be found on the websites of legitimate e-commerce businesses on the internet, allowing customers to rate the vendors and the products they sell. These reputation systems are crucial in expanding and attracting more customers, according to the interviewees (vendors) in the study by Munksgaard and Martin [23]. Tzanetakis again explains - drawing upon a study by Van Hout and Bingham on vendors on Silk Road 1 - that in order to accomplish higher ratings vendors would run their business and communicate in a professional manner, give customers slightly more than they bought with quick delivery times and provide a good service and pricing amongst other things [32, 37].

One of the participants of this mentioned study by Van Hout and Bingham stated "Silk Road is all about the quality - you sell bunk gear, you will get burnt on the forum and your feedback so you lose sales". According to the study - in line with the professional approach described above: the quality of product is guaranteed through the use of laboratory work, researching the product personally, peer feedback, using good suppliers. Worth mentioning is that next to the quality standards; the use of 'freebies' - given to long term customers - is used to boost the relation between seller and customer even more is also not uncommon [37].

Cryptomarkets often provide an escrow service and options for dispute arbitration. Where an independent entities mediate in a problems, to support both the vendors and buyers and secure transactions until both sides are satisfied [4]. These escrow services could be useful in mitigating violence or other hostility, a plus point not only for vendors.

According to the interview studies conducted by Munksgaard & Martin [23], and Van Hout & Bingham [37]: the motivation to become a dark web marketplace vendors seems to primarily come forth out of the ability to make large amounts of money using the supportive anonymous infrastructure, which would ensure more security and mitigate risks otherwise taken in the offline setting - regardless of commission fees (estimated to have been between 3 and 8,5% for Silk Road 1).

The Munksgaard & Martin study also points out that the majority of interviewed vendors had previously dealt illicit drugs in an 'offline' setting, having now switched to the dark web fully or partially. Furthermore the vendors also enjoyed the autonomy, other social and cultural elements of the marketplaces and "fulfilment of ethical-political convictions" [23].

Van Hout and Bingham note that aspiring Silk Road vendors would have had to go through an authentication process, often involving the payment of a refundable bond of $500 or by buying new vendor accounts at auction, probably to insure their integrity. The decision to start a vendor account - for the majority of vendors interviewed in their study - would also have occurred after a couple of weeks of deliberating and interacting with other members on the website [37].

3.2 Differences for Distributors and Retailers

Now that a general idea regarding the workings of distributors and vendors on cryptomarkets has been outlined, a closer look at the notable differences between cryptomarkets and the 'offline' setting will be taken in this section.

Perhaps the most important difference is that the vendor in the 'offline' setting is limited to time and space. This means that a vendor has a select number of customers he can meet with and sell to given his area of operation and limited time. Drawing upon previous work by Reuter; Aldridge and Décary-Hétu state that because of this limitation vendors are unable to expand their customer base. This limitation is - however - surpassed by the use of cryptomarkets, as meetings and contacts are not necessarily restricted to the confines of space and time [25, 2]. The vendor does not need to deliver the product themselves, but can often ship it through the use of traditional postal services, be it with some restrictions or adaptation [32].

Along with limitations in terms of space and time, Aldridge and Décary-Hétu also point out that the local competition can be a negative factor in expansion [2]. In terms of local competition, the illicit drug industry is known to be violent. For a lot of the vendors interviewed in the study by Munksgaard and Martin the reduction of violence was a large benefit to the online drug trade [23].

However, other forms of harm might be done to an entity on the dark web. Barratt and Aldridge [4] (citing Tzanetakis [33]) state that 'doxxing' ((threatening to) expose someone's personal information), blackmail, theft, fraud or cyber-bullying might be commonly practised.

Aldridge and Décary-Hétu also point out that limitations to expanding might include other risks, such as the risk of exposure to law enforcement. This is also one of the common aspects mentioned in the Munksgaard and Martin study [23], where vendors answered that they associated risk from law enforcement more with the physical dimensions and that usage of the dark web reduced this very risk. As mentioned before, this risk is reduced by the fact that vendors, when dealing with unknown customers, are protected by the anonymity the dark web offers (Tor / cryptocurrency) and therefore have less chance of exposure [2].

Next to surpassed limitations, vendors on the dark web also benefit from other features. Tzanetakis and Aldridge & Décary-Hétu emphasize as an example the aforementioned escrow-service. This service, which allows for dispute resolution, can be used to avoid conflicts and possibly violence. [32, 2]
The respondents in the Munksgaard and Martin study specified how the manner of transactional conduct were a large motivation for using the dark web to sell [23].

The ability to put yourself on the market publicly as a vendor was also deemed beneficial. Advertising could be done as the marketplaces - as mentioned before - offer the same structure as sites such as eBay. Where a vendor can make a listing advertising their product, also increasing transparency [32]. In this setting the vendors again bene-

fit from the anonymity the dark web offers, as well as the ability for customers to rate the vendor and/or product. Through this latter feature the vendors are able to gain reputation and trust with unknown customers [2, 32]. The vendors in the study conducted by Munksgaard and Martin even made sure of the safe arrival of their package and the proper concealment and packaging of their product. This was done as seizures and displaced packages could cause negative reviews by customers, resulting in short term as well as long term loss [23].

4. CONSUMER ASPECTS TO THE DARK WEB DRUG MARKET

In the following section insight will be provided into customer practises on, and motivation for, using the dark web, what benefits consumers gain from using the dark web to buy drugs, and how this all differs from the 'offline'.

To purchase illegal drugs through the dark web a consumer would have to familiarize themselves with the dark web and cryptocurrency beforehand, this is - according to the participants in a 2013 study on the Silk Road by Van Hout and Bingham - relatively difficult and time consuming. This would - along with the set up of false postal addresses - also be a deterrence for novel drug users to use Silk Road, according to some participants of this same study [36]. It seems assumable that this statement could be extended to the use of most dark web cyptomarkets.

However, after surpassing the initial barrier - that is the required setup, benefits seem plentiful. The benefits that are most often mentioned are the cheaper price the dark web offers and the quality difference, which is supposedly of a much highers standard when purchasing from reputable dark web vendors [37, 34, 36].
The 2013 Van Hout & Bingham study states that the participants voiced concern with respect to poor drug quality in their locality. The dark web enabled them to come into contact with fellow consumers, possibly ones who had already bought certain products before, to attain more info about specific vendors, drugs or other aspects of the marketplaces. Moreover, participants in the study describe reading 'trip reports' (a journal about another user's experience of the drug) to gauge whether or not this drug could be something for them. They could also use the reputation system as validation of a vendor's integrity and the product's quality - as already mentioned before - but also mentioned by Paoli et al. [24].

Furthermore Van Hout & Bingham present that the use of online forum discussions, about product experiences was also not uncommon [36]. These, together with other facilitated features would - according to the participants - allow a possible buyer to make an informed decision. Cambini states that by increasing information availability, same as for non-dark web markets, does indeed reduce search cost and enables the consumers to find the best option [7].

The 2013 Van Hout & Bingham study furthermore states that next to quality benefits participants also expressed concern with regard to their own safety when buying drugs on the street. The use of the dark web, same as previously stated for vendors, offers a layer of protection to consumers. Two of the main reasons described for the use of the 'Silk Road' involved personal safety and anonymous transactions [36].

Safety is further ensured by the non-existent personal interaction between vendors and buyers, with - as stated before - the dark web utilizing the traditional postal services, along with often fake postal addresses. Postal or parcel services were, however, recognized as the weakest link in the chain in a study by Aldridge and Askew. Packages still had relatively high chances of being intercepted, depending on factors such as the packaging technique, whether or not the transfer was international or the quantity sent [1]. To circumvent this vendors are adapting a 'dead drop' system. This entails a package of drugs being dropped or perhaps buried in certain locations by a 'dropman'. After the purchase the buyer would get information as to where to find the package. This is described in detail by Paoli et al. [24]. It is assumable that this will be more extensively adopted in the future, as it removes the high risk associated with the use of traditional postal services.

In addition, the aforementioned escrow-services, described by Barratt & Aldridge, Tzanetakis and Aldridge & Décary-Hétu [4, 32, 2] also benefit consumers. As they do not only help vendors in negating some trust, violence or transactional issues; but also protect the consumers against malicious vendors and help to resolve problems in a civilized manner.
Paoli et al. describe this as such "if an order is not received or the product is not as advertised, the buyer declines to finalise the purchase, and the vendor is not paid". This means the vendor has to make good on his advertised promise, deliver the product and is not simply able to take the money and disappear. The escrow service are sometimes even taken further, with the implementation of a 'scamwatch' team, consisting of administrators and members to tackle cases of vendors scamming customers [24].

Dark web cryptomarkets offer further dispute resolution. Both the vendors as well as the consumers have multiple means to resolve conflict, such as through the forums or secure private messaging. If no outcome is found, one can resort to the site administrators to settle the dispute, as they would have the final word in the matter. This is further explained by Morselli et al. in a paper on conflict management on illicit drug cryptomarkets [22].

According to Morselli et al. there are no formal regulations to conflict resolution and most of it can be characterized as 'policy in action'. Yet there are numerous mechanisms in place. It's more than assumable that these are enough to deter other kinds of violence or actions against a person.

Lastly another identified benefit seems to be that both the selection of drugs larger, as well as ease of access to certain kinds of drugs is increased; in comparison to if one were to pursue these kinds of products in the 'offline' setting. People are no longer restricted to their locality and the drug dealers they can meet, but are able to expand their search to a much broader range. This includes illicit drugs, but also what Koenraadt and Van de Ven describe as lifestyle drugs. These could be described as drugs one consumes to improve one's lifestyle, health or beauty. Sometimes unattainable or only attainable through a doctors prescription, extremer examples - somewhat unrelated to the research - could be anabolic steroids or weight loss drugs [18].

5. DIFFERENCES IN DRUG PRICES ONLINE AND OFFLINE

In this section a comparison of prices will be made to attempt to answer the fourth and last research question. In order to help answer this question; empirical research through data analysis has been performed on a dataset [39] composed of filtered data from the "Gwern Darknet Market Archives" [6], containing only drug related data. The "Gwern Darknet Market Archives" are probably the most

extensive dataset collected on dark web markets thus far. This filtered dataset was chosen due to the limited time available and the renown of its progenitor, which has already been used numerous times in other research before.

Environment
Python (a programming language) was used to further analyse the dataset and extract useful data due to its familiarity with the author and its widely known applicability in data analysis. For further support three different libraries were imported, namely:

- *re* - to specify and use '*Regular Expressions*' (*Regex* patterns) for data extraction.
- *pandas* - to format data into a specific easily manipulable structure called a '*DataFrame*'.
- *matplotlib* - to visualise the data in comprehensible graphs.

Analysis premeditation
The results of the dataset exploration will be mean prices per gram and - because of recognition of previously examined literature - purity adjusted prices per gram, both per drug-type and per drug-type per marketplace.
These will be compared between markets respectively and with the data of the 'offline' market from around the time of when the data was collected (2013-2015). For the latter the 2014 European drug report [13] will be used.

Because 'time of collection' was not available for each entry in the dataset, the year 2014 was used as an approximation, both in the drug report and for the used variables in the analysis.

5.1 Dataset Analysis

Importing the dataset
The dataset was downloaded as a csv-file, after which the *pandas* library could be used to read the data inside the csv-file into a DataFrame. The columns and rows inside the DataFrame were conform to the csv, but would be easier to manipulate and examine. The DataFrame's columns were then examined row by row.

Determining the drug-type
To determine the drug-type the title of the row (listing) was checked against a predefined list of drug-types and common names of these respective drug-types, such as for cocaine with '*coke*', '*cocaine*', '*coca*' and more. Not all alternative names were used, for example '*blow*' was excluded as it could be common in other listing descriptions and lead to false positives for cocaine. The drug-types included in this analysis are: *MDMA*, *heroin*, *weed*, *methamphetamine* (*meth*), *amphetamine* and *cocaine*. The full list of names used for these can be found in the code [15], in a structure that should be self-explanatory.

Extracting the amount
After the product was determined; an attempt was made to extract the amount of product and its unit using *Regex* patterns for both grams and milligrams. After they were found the amount and unit were both saved separately. Milligrams would later be divided to grams to simplify calculations and normalize the data. Amounts higher than 10 grams were also dropped out of the dataset, as this set would contain mainly distributor listings and would therefore skew the data to be compared to retail prices.

Finding the purity
Optionally also the purity was extracted from the title, using a *Regex* to look for a number (possibly separated by a space) preceding a percent sign, and saved as a number.

Calculating the price
In the next step the price was taken out of the price column and the currency was determined as either USD, GBP, EUR or AUD using some *Regex*-expressions. These currencies and amounts would all be transformed to Euro to simplify calculations and visualisations.
For this the average 2014 exchange rates given by: *www.exchangerates.org.uk* were used.

PPG / PAPPG
If any of the previous methods of determination (apart from the purity) had no result the row was skipped as it was deemed not to contain sufficient extract-able information.
Finally some calculations were done to determine both the price per gram (PPG) and purity adjusted price per gram (PAPPG) - the latter only in situations where purity could be determined.

First result
This resulted in a new normalized dataset of 2747 listings. This dataset contained: the type of drug, amount of drug, the unit (always grams), the price, the currency, the 'PPG', the 'PAPPG', listing origin country/region (could be empty) and the source marketplace - all prices being in Euro.

Removing outliers
From this resulting dataset the outliers were removed by dropping rows outside of the *5* to *95* percentile range for the 'PPG' per drug-type.
After this, using the mean and standard deviation for every drug-type's 'PPG' the z-score for that row according to the drug-type was determined by subtracting the mean 'PPG' for the row's drug-type from the row's 'PPG' and dividing this by the standard deviation. The rows with an absolute z-score over *1,5* were dropped.
These outlier removal methods resulted in 3090 and 2838 rows after successive execution respectively.

Final result
Lastly the data with outliers removed was used to determine (new) mean 'PPG' and 'PAPPG' per drug-type, and per drug-type and marketplace. For the 'PAPPG' only rows where previously the purity was able to be determined were taken into account.
These mean prices will be used in the following subsection, where they are compared against the average 'offline' prices as given by the European Drug Report [13].

Code download
The code is downloadable through Google Drive [15].

5.2 Data comparison

The European Drug Report [13] is an annual report that gives an overview of the drug situation and the developments caused by interdiction and other policies, including some data analysis. It presents a description of specific drugs along with a summary, which includes a representation of the average price and average potency of illicit drugs for that year. These are both represented on a scale including an inter-quartile range (IQR).
First the price per gram of the analysis will be compared to the prices in the report. After this the purity will also be taken in to account; along with the purities in the report.

5.2.1 Price per Gram

The drugs-types retrieved from the dark web dataset, as mentioned before, are: *MDMA*, *heroin*, *weed*, *methamphetamine* (*meth*), *amphetamine* and *cocaine*.

For each of these drug-types the mean price per gram was

determined, both over all marketplaces and per marketplace that had determinable listings. The overall mean price per drug-type is summarized in Table 1. Figure 4 in the appendix visualizes the mean price per gram over different marketplaces.

Drug-type	Mean PPG(€)	Mean PPG(€)*
Heroin	81.3007	153.416
Cannabis	9.65816	8.57
Meth	195.13	69.9518
Amphetamine	23.9934	7.23271
Cocaine	70.7971	69.7434
MDMA	96.0445	24.6096

Table 1. Mean Price Per Gram (PPG) of drug-types in the final dataset and the mean Price Per Gram of drug-types in this final dataset where the rows had known purity*.

For the aforementioned drug-types we find the following complete - and inter-quartile - ranges for prices per gram in the 2014 European Drug Report [13], presented in Figure 1 and Table 2 below. We can use the IQR to as an estimation of common 'offline' prices:

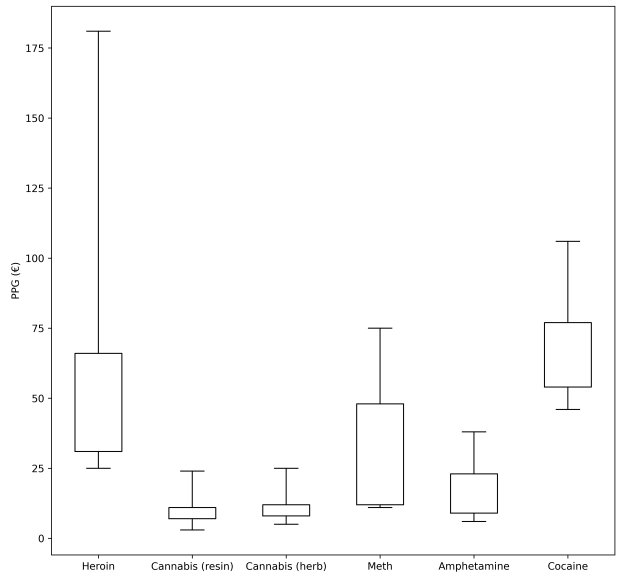

Figure 1. Price ranges and inter-quartile ranges per drug type (from the 2014 European Drug Report).

Drug-type	Total Range (€)	IQR (€)
Heroin	25 - 181	31 - 66
Cannabis (Resin)	3 - 24	7 - 11
Cannabis (Herb)	5 - 25	8 - 12
Meth	11 - 75	12 - 48
Amphetamine	6 - 38	9 - 23
Cocaine	46 - 106	54 - 77

Table 2. Price ranges and inter-quartile price ranges per drug-type as given by the 2014 European Drug Report.

MDMA has to be examined differently, as the European Drug Report includes it as the active component within Ecstasy. Where one Ecstasy tablet contains between 26 and 116 milligrams of *MDMA*, with an IQR between 57 and 102 milligrams. The price of such a tablet would lay between €2 and €17 with an inter-quartile range between €5 and €10.

Using these inter-quartile ranges we can roughly determine a range for the price for a gram of *MDMA*. On the low end of the IQR scale this would mean roughly €49 per gram, where on the high end this would mean around €175 per gram.

5.2.2 *Purity adjusted Price per Gram*

For each of the aforementioned drug-types the Purity adjusted Price per Gram has also been determined in Euro. These can be found in Table 3 below, or per marketplace in Figure 5 in the appendix.

Drug-type	Mean PAPPG dataset (€)
Heroin	170.078
Cannabis	26.4925
Methamphetamine	82.3118
Amphetamine	9.64979
Cocaine	121.298
MDMA	30.8278

Table 3. Mean Purity Adjusted Price Per Gram of drug-types from final dataset where purity could be determined.

The left-hand 'PPG' column of the first table (Table 1) seems to be heavily skewed, so the additional column provides the 'PPG' per drug-type where a purity could be determined. These seem to be more appropriate with respect to the calculated PAPPGs above (Table 3).

In the 2014 European Drug Report [13] we find purity ranges, as presented in Figure 2 and Table 4 below.

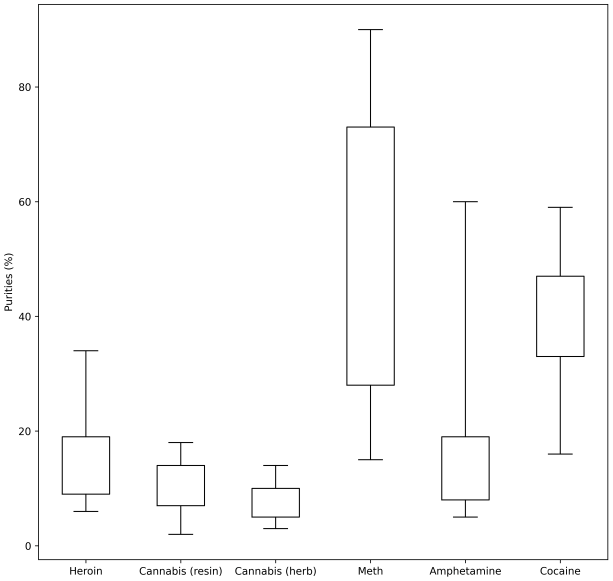

Figure 2. Purity ranges and inter-quartile Purity ranges per drug-type according to the 2014 European Drug Report

Drug-type	Total Range (%)	IQR (%)
Heroin	6 - 34	9 - 19
Cannabis (Resin)	2 - 18	7 - 14
Cannabis (Herb)	3 - 14	5 - 10
Meth	15 - 90	28 - 73
Amphetamine	5 - 60	8 - 19
Cocaine	16 - 59	33 - 47

Table 4. Full and inter-quartile Purity percentage ranges per drug-type (2014 European Drug Report).

It can be seen that the purities of the 'offline' market as given in Figure 2 and Table 4, are quite low compared to the mean purity per drug-type in the examined dataset, found in Table 5 below.

Drug-type	Mean Purity dataset (%)
Heroin	90.6
Cannabis	61
Methamphetamine	85.4118
Amphetamine	74
Cocaine	81.6197
MDMA	83.1399

Table 5. Mean purity per drug-types in the final dataset. Note that the purity mostly indicates the amount of active substance, for example 'THC' in cannabis.

5.2.3 *Conclusions from empirical research*

Looking at Figure 4 and especially Figure 5 (in the appendix). Although there seem to be some outliers, using for example the two bigger markets of the dataset (*Abraxas* and *Nucleus*) for a comparison. It can be concluded that there exists indeed a difference in pricing between cryptomarkets.

Next the comparison of the cryptomarkets prices with 'offline' prices. Strictly looking at the price ranges in Figure 1 and Table 2, and the rough calculation for *MDMA*; in comparison to the mean Price per Gram from the dataset in Table 1, it appears as if cryptomarkets are generally more expensive than buying drugs on the street. This is because of mean prices laying: at the higher end of the inter-quartile range, higher than the inter-quartile range, or even higher than the total range.

However when taking into account the drug-type's respective purity ranges, this is proven not to be true. Examining the purity in Figure 2 and Table 4 and the Purity Adjusted Prices per Gram from the dataset in Table 3, one can conclude that most drugs are actually on the cheaper side, This will be presented in the following Figure 3 and Table 6. These present both the purity adjusted (P.A.) price ranges (thus for 1 gram of actual active substance), besides the mean PAPPG calculated from the dataset.

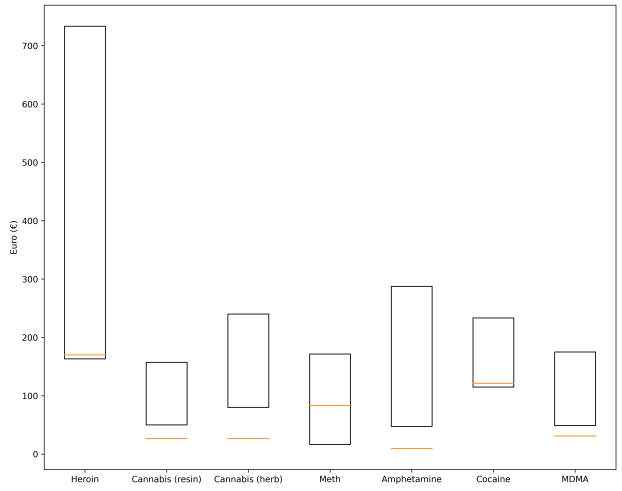

Figure 3. Adjusted 2014 European Drug Report ranges including purity, with the calculated PAPPGs in yellow. Ref. Table 6 for more information.

Drug-type	P.A. ranges (€)	Mean PAPPGs(€)
Heroin	163.16 - 733.33	170.08
Cannabis (Resin)	50.00 - 157.14	26.49
Cannabis (Herb)	80.00 - 240.00	26.49
Meth	16.44 - 171.43	82.31
Amphetamine	47.37 - 287.50	9.45
Cocaine	114.89 - 233.33	121.30

Table 6. Calculated ranges composed of *highest purity/lowest price - lowest purity/highest price* for the most ideal and least ideal pricing, all values rounded to two decimals. Next to rounded mean PAPPGs from the dataset.

Although no distinction could be made between cannabis resin and herb in the dataset, it is shown that the average price for cannabis generally lies lower than both variants listed in the European Drug Report. Furthermore all drug-types, apart from methamphetamine, seem to be below or on the very low side of the calculated ranges.
This shows that the prices are generally lower in 'online' markets in comparison to their 'offline' counterparts.

5.2.4 *Limitations in the research*

In the opinion of the researcher the provided knowledge is enough to present a proper conclusion to the research question, although the data is somewhat outdated. It would have been better to use more recent data, but finding data in an already normalized format, usable within the span of the research proved difficult.

Furthermore, had there been more time, extra effort could have been put into defining the methods of extraction and the '*Regex*'-patterns used to do so, to possibly include more rows in the final examined data.

It would have been better to examine more isolated markets - such as the Australian one - independently, as drug prices there are generally higher. Although assumed is that even if drug prices are generally higher a difference between 'online' and 'offline' would still present itself.

Lastly, the used comparison dataset was European, this might have led to some discrepancies. However, due the nature of other *important* consumer markets, such as the American and especially Australian, which generally have higher standard prices. It could be assumed that the 'offline' price ranges would have been higher, reinforcing our conclusion, as the ranges in in the table above would lie higher.

6. CONCLUSION

During the literature research into the first research question it became apparent that in the 'offline' setting the drug supply-chain and its participants are mainly restricted and adversely affected by risk, but also: their locality, access to resources, social networks and connections, the necessity to preserve contacts and the non-official market with non-standard prices and quality. The risk could be due to violence, but is mainly due to law enforcement interdiction. Because of this risk from law enforcement the producers and vendors in the supply-chain would add an 'Enforcement Tax' into the price formation. This tax, placed upon the price due to the illegality their product and/or actions, and could be added during all the described stages (production, transportation, sales) of the supply-chain.

This risk seems to be correlated to the 'Corruption Perception Index' given by the 'Transparency Index' [31], which is negatively correlated to the GDP. This might be part of

the reason that drugs are more expensive in countries with better positions in the legitimate world economy. These risk mark-up might however be slightly negated in transit/gateway countries - where drugs would pass; en route to larger markets - such as Portugal or Turkey, as there would be an overflow of supply and drugs are generally less expensive there.

Lastly, not only specific to the 'offline setting', it was found that illicit drugs are not simply to be compared by gram, but one needs to take into account its purity, to calculate purity adjusted prices. Especially in the 'offline' setting, where not two transactions are priced the same. This is because illicit drugs are sold in an environment without regulations, where vendors are able to dilute the product as they please, based upon supply and demand.

When researching literature pertaining to the second research question, as described in the third section, it became apparent that quite some of the restrictions and adverse effects of the 'offline' setting were offset by differences between the 'offline' and 'online' along with other features on the dark web. These include that locality, problems pertaining to that locality, and scarcity in that locality can be avoided by using the dark web to increase one's reach (access to resources), possibly even enabling entities to access other entities in countries where prices are substantially lower, such as the aforementioned transit countries. Furthermore usage of the dark web would allow vendors to access much more customers at once, no longer limited to the confines of time and space.

More counteracted restrictions or effects include that social networks are no longer necessary and another entity's trustworthiness can be determined easier. On the dark web one would be able to judge another entity's trustworthiness and reputation by using the reputation systems - similar to legitimate e-commerce websites. This environment allows for less dependence, as these systems would remove the necessity to keep social networks and preserve contacts - through for example credit systems. New contacts or trade possibilities could be found outside of one's current network. Furthermore, due to a more protected environment risk of violent interaction is mitigated. This is mainly because of the use of escrow-services or other (ever-expanding) market rules and regulations allow for disputes to be sorted through precedents set by policy-inaction.

Arguably the most important counteracted restriction for vendors, however, is that of the risk of law enforcement interdiction. Mainly due to the fact that one can remain anonymous whilst using the dark web and the numerous benefits these cryptomarkets provide. Anonymity is provided by the use of Tor, which prevents the user from being traced and the use of crypto-currencies enables means of currency transaction, where a third party cannot find further details on the buyer or seller. This would in turn reduce (risk of) possible law enforcement interdiction thus the 'enforcement tax'.

The cryptomarkets do not only provide facilitation for the vendors, but consumers also benefit from its usage as became apparent during the literature research into the third research question. The rating system could for example be used as a gauge of trustworthiness of a vendor (similar as between vendors). The dispute resolution system and rating system also protects consumers interests by keeping vendors accountable. Consumers are able to compare listings or interact with one another, discussing specific products or vendors. Due to this open nature the market becomes self-regulated leading to normalized prices for specific purity, as the vendors would no longer be able to dilute their product without repercussions.

In the fifth section an answer is presented to the last research question after empirical research was conducted, where a comparison between a dataset containing drug related listings from different cryptomarkets and 'offline' market data is made and further examined. A difference in prices between the 'offline' and 'online' and 'online' markets respectively is determined to exist, when both prices and purity are taken into account. Altogether the argument could most definitely be made that the services offered by cryptomarkets do indeed lead to differences in price between the 'online' and 'offline'. Though, even with the proof that there exist differences with regard to the pricing between cryptomarkets respectively and the 'offline', it cannot - with certainty - be said this is because of differences in offered services.

7. FUTURE WORK

Future work on this subject could consist of further examining the price differences between the 'online' and 'offline' or perhaps looking more closely at differences between certain cryptomarkets. For example had the research been given more time an attempt could have been made to retrieve the data at the moment of research, for a more actualized dataset. This could have been done either through an automated process; such as a crawler or by manually going onto the different cyptomarkets. This latter method would also allow the researcher to examine the different offered features and workings of the cyptomarkets firsthanded. Using more actual data; the question whether these aforementioned differences between 'online' and 'offline' are still so apparent (or even more different, perhaps because of new factors) could also be answered.

Next to drawing conclusions from this form of research, an interview study could also be conducted with both 'offline' as well as 'online' - or perhaps even hybrid - vendors/distributors to question what factors they weigh in to the formation of their prices.

Currently this research offers numerous possible reasons and differences that could lead to price formations, and proof for difference in prices; but cannot connect these without a doubt.

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APPENDIX

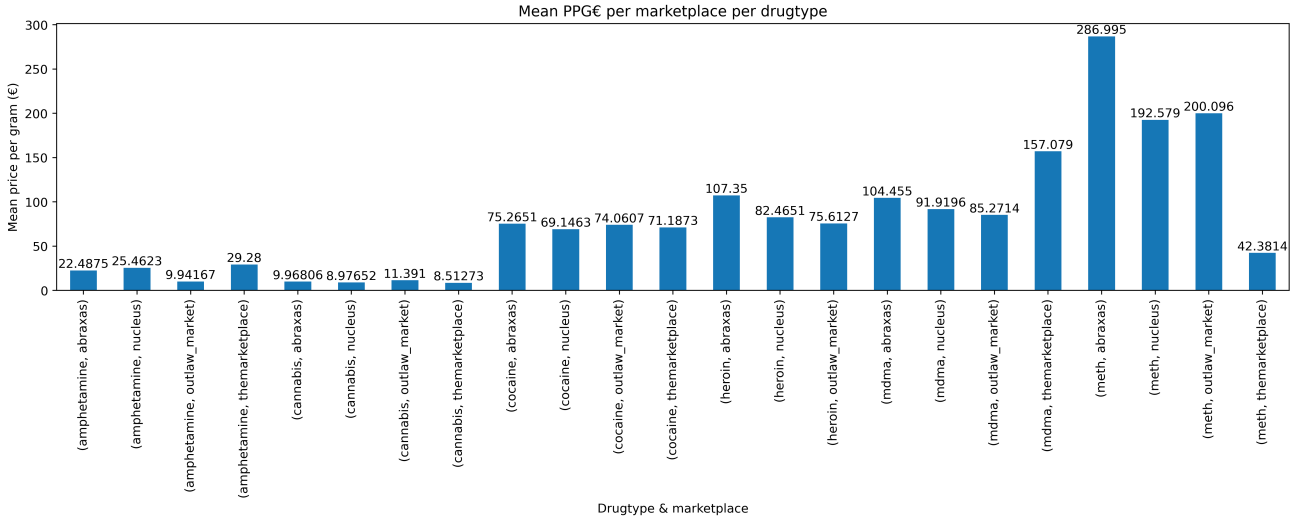

Figure 4. Mean PPG in Euro per drug-type per market (from analysed dataset [39] 2013-2015) [39]

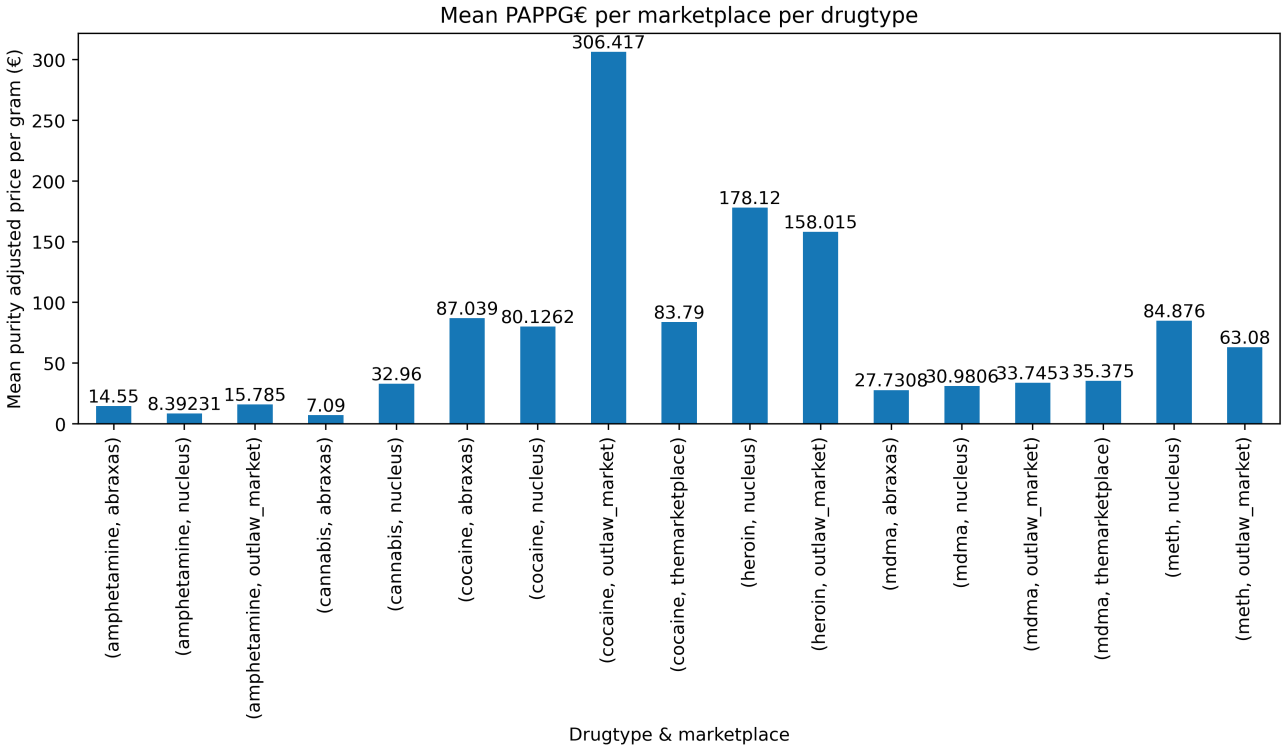

Figure 5. Mean PAPPG in Euro per drug-type per market (from analysed dataset 2013-2015) [39]