SPECIAL ISSUE ARTICLE

CYBERCRIME AND CYBERSECURITY

Hydra: Lessons from the world's largest darknet market

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Abstract

Research Summary: We present a comprehensive description of Hydra, the largest darknet marketplace in the world until its shutdown in April 2022. We document the main features of Hydra such as dead-drop delivery, feedback and reputation system, escrow, and dispute resolution. Using data scraped from the platform, we quantitatively examine the scale and the structure of the marketplace. We find that it has been highly competitive, geographically covering at least 69% of the Russian population and trading a wide variety of drugs, while also allowing the wholesale trade of drugs and precursors. The dead-drop delivery system used on Hydra was expensive, as the courier costs comprised a substantial proportion of the sale price of drugs on Hydra. We contribute to the research on drug cryptomarkets by studying an unprecedentedly large non-Western marketplace that existed substantially longer than any other known darknet market.

Policy Implications: The phenomenon of Hydra shows that shut-down policies applied to darknet marketplaces have a large effect and implicitly shape the whole drug market. Without these policies, a pervasive digitalization of the drug trade can occur. The major cost of allowing marketplaces to grow is the probable increase in the

> consumption of illegal drugs due to convenience for consumers and facilitated cooperation between suppliers. This cost must be weighed against the potential benefits, including a higher quality of drugs, a decrease in potential violence, and the incentives for a large marketplace to self-regulate. The case of Hydra also suggests the relevance of financial regulation to limit the growth of darknet marketplaces.

With the establishment of the Silk Road in 2011, drug cryptomarkets emerged as a novel means of the drug trade (Christin, 2013). Since then, the number of anonymous online drug markets has expanded and online trade has become a common way to buy and sell illegal drugs (United Nations Office on Drugs and Crime, 2021). A multitude of studies have examined the organization of drug cryptomarkets (Aldridge et al., 2018), including the coordination between buyers and sellers (Bakken et al., 2018) and methods to maintain marketplace trust such as reviews, ratings, and escrow services (Barratt & Aldridge, 2016; Morselli et al., 2017; Munksgaard & Tzanetakis, 2022; Przepiorka et al., 2017). The research has also evaluated how parties in cryptomarkets avoid risks related to law enforcement (Aldridge & Askew, 2017; Hutchings & Holt, 2017) and specifically the effects of law enforcement shutdowns of individual marketplaces. One important finding from these studies is the resiliency of the online drug trade to law enforcement interventions with the closure of major vendors and marketplaces merely causing participants to migrate to alternate vendors/platforms (Décary-Hétu & Giommoni, 2017; Ladegaard, 2019; Ouellet et al., 2022). This has contributed to the debate on the effectiveness of the primarily coercive responses from law enforcement, such as prosecuting sellers and marketplace administrators and shutting down marketplaces. Given the finite resources allocated to combating illegal drug use, there is inherently a policy trade-off. Hence, some scholars argue for dealing with illegal drug use through the lens of harm reduction instead of criminalization and law enforcement, continuing a debate that began prior to the onset of the online drug trade (Curtis & Wendel, 2007; Hunt et al., 2011). However, in assessing the impact of darknet market shutdowns, the literature has focused on the Western experience. Such a narrow focus without an appropriate counterfactual of what would occur in the absence of these shutdown policies does not allow for a complete assessment of the effectiveness of these policies.

This study addresses this gap in the literature by focusing on a single yet dominant drug marketplace that existed for 7 years, was situated in Russia, did not have significant competing marketplaces, and was the largest drug cryptomarket in the world. Based on the available evidence from media investigations and other nonacademic sources, prior to its shutdown in April 2022,[1] the majority of the retail drug trade in Russia was conducted through Hydra,[2] the largest darknet marketplace in the world at the time. Unlike their Western counterparts, Russian drug enforcement appears not to have directly attempted to close Hydra, despite regular arrests of low-level market participants, for example, couriers (VICE, 2020b). As a result, Hydra existed for a substantially longer period than any other popular darknet marketplace, thus allowing it to grow significantly larger than any market that has ever operated in the United States or Western Europe. During its years of operation, the marketplace developed an ecosystem that allowed for anonymous communication between multiple segments of the drug market, from wholesalers[3] to

end consumers. While it only served the Russian-speaking world, the success of this marketplace provides useful insights into the future of the retail drug trade and the potential implications of allowing a darknet marketplace to grow and develop over several years.

Our paper describes Hydra in two ways. First, we provide a comprehensive account of the organization of the Hydra marketplace and the core services and mechanisms that contributed to its success. Operating on The Onion Router (Tor) network, Hydra facilitated the anonymity of market participants by using cryptocurrency for payments and dead-drops[4] for deliveries. At the same time, Hydra was a marketplace with active self-regulation, a system of advertisement for individual sellers/shops, and a feedback system of reviews and ratings for individual items and sellers. It also employed dispute resolution and special statuses, such as "trusted sellers." Finally, Hydra attempted to provide its own version of conventional harm reduction strategies. It selectively tested some of the drugs offered on the platform to ensure quality and provided telemedicine consultations for customers.[5]

Second, using listings and review data scraped from Hydra, we examine relative demand across drug types on the platform, the spatial and price variation of listings, and the composition and concentration of the drug market on the platform.[6] We observed over 417,000 unique dead-dropped drug packages throughout Russia in April 2020 and found that mephedrone (31%), cannabis (18%), amphetamine (13%), and alpha-PVP (12%) were the most popular drugs on the marketplace. Hydra operated in 1,129 different settlements (cities, towns, and countryside) in every region of Russia, providing potential instantaneous access[7] to illegal drugs for 69% of the Russian population. Larger cities had a higher concentration of sellers and drug listings. More expensive drugs were distributed predominantly in wealthier areas, in particular around business districts. We also analyze the market concentration using the Herfindahl–Hirschman index (HHI) and find that the online market of illegal drugs was extremely competitive, both in general as well as at the level of individual drug types and regions. We estimate a model to disentangle the distribution cost from the sale price of drugs sold on Hydra. We find that the dead-drop system is a costly type of delivery; for some drugs, the distribution cost accounts for more than 50% of the price of the median dead-drop. Finally, we turn to reviews, which anecdotally were important for customers on Hydra. We analyze the text of reviews and find that the language used by reviewers reflects multiple dimensions of customer experience, while ratings left by users are usually less informative and skewed toward the highest possible value of 10. Our findings suggest that it is the text of reviews that is likely to matter.

We then turn to analyzing the implications of our findings for public policy. Hydra had been a dominant darknet marketplace operating in Russia from its emergence in 2015 until 2022 and developed into a sophisticated platform. A crucial effect of the shutdown policies exercised by most governments is that no large marketplace similar to Hydra emerged in those countries. Hence, Hydra allows us to better understand the benefits of these policies by serving as a counterfactual for what could occur in their absence. We use our analysis of Hydra to highlight several key components of the policy trade-off behind shutdowns. On the one hand, an established marketplace has incentives to self-regulate and presents an environment in which sellers have incentives to sustain a good reputation. This might increase the quality of drugs and the welfare of customers. In addition, compared to in-person trade, online marketplaces are associated with reduced violence. On the other hand, a large online drug marketplace is likely to increase both the demand for and supply of drugs due to convenience and decreased risks for customers as well as the facilitation of communication and trade between market agents on the supply side. Once participants have shifted their transactions online, it appears that they readily migrate to new platforms.

In Section 1, we provide an overview of the current research on drug cryptomarkets, situate Hydra within the context of this research, and review the history of the online drug trade in Russia.

In Section 2, we provide a narrative description of the marketplace organization, drawing from Hydra rules, screenshots, and interviews. We introduce the results of our quantitative analysis based on the listings and reviews from the platform in Section 3. Section 4 briefly describes the consequences of the shutdown of Hydra. Section 5 summarizes the policy implications that we draw from our study. Section 6 concludes our analysis.

1 | BACKGROUND

1.1 | Drug cryptomarkets

Starting with Silk Road in 2011, the number of drug cryptomarkets has rapidly increased (Christin, 2013), with an estimated 118 cryptomarkets in 2019 specializing in black-market goods (United Nations Office on Drugs and Crime, 2021). Cryptomarkets are now an important source of narcotics for personal use and social supply (Coomber et al., 2016; Demant et al., 2018). Online drug markets attempt to circumvent law enforcement by conducting their operations on the darknet while relying on cryptocurrencies such as Bitcoin to conduct transactions.

The required anonymity of drug cryptomarkets poses a coordination problem for sellers, buyers, and the marketplace administration. The research shows that drug cryptomarkets employ a formalized set of rules of conduct and centralized administration to address this problem (Bakken et al., 2018). The issue of trust is one important aspect of the coordination problem; how can customers be sure that they will get a quality product for their money given that they cannot rely on consumer protections or contract law in the case of a low-quality product or scam? Borrowing from the existing legal online marketplaces, drug cryptomarkets often employ a reputation system based on reviews and ratings of sellers (Przepiorka et al., 2017). Additionally, some cryptomarkets employ escrow services maintained by the administration, which helps to resolve disputes between sellers and buyers and increases confidence in transactions (Morselli et al., 2017; Munksgaard & Tzanetakis, 2022). However, given that several darknet marketplaces have engaged in so-called "exit scams" (Barratt & Aldridge, 2016),[8] the customers of drug cryptomarkets are highly sensitive to the information about the stability of marketplaces (Howell et al., 2022).

The virtual nature of drug cryptomarkets has resulted in market participants not needing to physically meet (Aldridge et al., 2018). This shift can substantially decrease drug-related violence between competing sellers, which occurs due to the territorialism seen in the wholesale/broker market (Aldridge & Décary-Hétu, 2014). Customers of drug cryptomarkets also report greater subjective safety compared to other forms of drug distribution (Barratt et al., 2016; Morselli et al., 2017). This follows trends seen in offline drug markets, where the increased use of mobile phones for coordinating drug transactions since the early 2000s resulted in the less visible nature of these transactions, which reduced the associated risks of violence (Curtis & Wendel, 2007; May & Hough, 2004). Additionally, some drug cryptomarkets promoted harm reduction through forums where users can discuss harm reduction strategies concerning the choice of drugs and best practices for consumption (Bancroft, 2017). One qualitative study that specifically focused on the changes in drug use patterns due to the proliferation of online drug markets found a nuanced effect on drug use. With the increased subjective availability of drugs, drug users tend to consume drugs more frequently during the initial "honeymoon period" yet reduce their use afterward, buy smaller quantities, and generally engage in a more controlled consumption of illegal substances (Barratt et al., 2016).

Following a long-standing tradition of mostly coercive responses to drug use (Hunt et al., 2011), the law enforcement response has focused on various ways to disrupt the drug cryptomarkets, predominantly by prosecuting the major vendors and marketplace owners and shutting down cryptomarkets. Hutchings and Holt (2017) outline the main strategies to disrupt stolen data from darknet marketplaces, which could also be appropriate for drug marketplaces. Following the situational crime prevention perspective, these strategies focus on increasing transaction costs. These include "lemonizing" the marketplace: reducing the overall degree of trust by utilizing law enforcement agents who can infiltrate the marketplace and either post fake reviews with low ratings or pretend to be a seller. Other strategies focus on traditional law enforcement responses, such as tougher bank payments regulation, prosecution of dealers and customers, and censoring websites through domain de-registration.

However, online trade of illegal goods and particularly drugs is remarkably resilient to law enforcement interventions and closures. Ouellet et al. (2022) examine the aftermath of the closure of DarkMarket, an illicit marketplace specialized in data products in 2021, and argue that darknet marketplaces are highly connected: once a major marketplace is shut down, the sellers rapidly migrate to similar marketplaces, resulting in a high degree of substitutability between marketplaces. Similarly, Ladegaard (2019) documents crime displacement and market resiliency after the shutdown of a major MDMA (3,4-Methylenedioxymethamheptamine, also known as ecstasy) vendor who operated on numerous markets, including Silk Road 2, Evolution, and Agora. The study also shows that in the aftermath of Operation Onymous in November 2014, the number of operating cryptomarkets was reduced from 19 to 12, but the trade volume among these quickly recovered and exceeded the pre-intervention levels 6 months after the operation. In their evaluation of the effects of Operation Onymous, Décary-Hétu and Giommoni (2017) show that the participants of cryptomarkets quickly adapted and that drug prices were not affected.

Despite the growing abundance of drug cryptomarket studies, there are several considerable knowledge gaps in the literature. First, most of the studies focus on cryptomarkets popular in Western countries, such as the United States, Canada, countries of Western Europe, and Oceania (Décary-Hétu et al., 2018; Martin et al., 2018). However, the use of darknet markets for drug trade is a global issue. In particular, it has substantially increased in recent years in India (International Narcotics Control Board, 2021) and a number of Southeast Asian countries, including Indonesia, Thailand, and Vietnam (United Nations Office on Drugs and Crime, 2020). It is important to understand the specifics of drug cryptomarkets in other countries, given that a large part of the world population lives there. Our paper does this by studying the dominant darknet marketplace in Russia, which also operated in several post-Soviet countries. We will argue that despite differences in political systems, drug policy, and the resulting organization of illicit drug markets, the experiences and responses of non-Western countries to drug cryptomarkets can still provide important insights for policies in the Western world as well.

Second, the majority of studied drug cryptomarkets employ legal post services to deliver packages. While technological innovations have attempted to provide anonymity on darknet markets and thus reduce the legal risks, delivery has remained a weak point, with law enforcement targeting the interception of packages containing narcotics. Users of Western darknet markets have employed several methods to reduce risks related to mail delivery. For example, among the methods used were choosing a delivery location far from home or work and rotating these locations, trying not to use post services that require a signature, and even using purchasers' real names so that the mail would look less suspicious to law enforcement (Aldridge & Askew, 2017). Another potential way to deliver drugs, which so far does not appear to have been implemented in Western countries on a large scale, is dead-drop delivery (Aldridge & Askew, 2017). This method is

substantially faster, as it does not involve the large delay in receiving drugs that is associated with mail delivery. We provide a detailed description of a drug cryptomarket mainly operating through dead-drops, which have the potential of becoming popular in other countries as they allow delivery to occur quickly and without relying on legal delivery services.

Third, most drug cryptomarkets have a lifespan of less than a year due to police shutdowns or exit scams (Zambiasi, 2022), with new markets quickly replacing those which are taken down (Bhaskar et al., 2019; Soska & Christin, 2015). However, concluding that this means shutdowns have no impact neglects an important effect of shutdowns: they prevent the emergence of a large marketplace dominating the market. This paper provides details of the counterfactual experience of what may occur if a darknet marketplace is given scope to develop. This counterfactual should provide policy makers with greater insight into the potential implications of changing the current policy of indiscriminately shutting down these markets whenever they become popular.

1.2 | Hydra: The largest darknet marketplace

Prior to the digitalization of the drug trade, Russia had experienced several significant trends in illegal drug consumption: a large increase in heroin use in the 1990s (Paoli, 2002), a wave of popularity of desomorphine in the 2000s (Zheluk et al., 2014), and a very high rate of human immunodeficiency virus (HIV) from injection drug use (Fairbairn et al., 2016). The official drug policy in Russia focuses on criminalization (Lilja, 2021), and there is limited availability of harm reduction services in the country (Harm Reduction International, 2022). For example, the Russian government has progressively tightened regulations on publishing information related to illicit drug use on the Internet (Zheluk et al., 2014). In the last decade, the Russian drug market went through a steady increase in the level of darknet sales of drugs. The first large marketplace that operated in Russia was RAMP (WIRED, 2014), which opened in 2012. In addition to RAMP, several darknet forums were also used for trading drugs, among which the most popular ones were Rutor, LegalRC, and WayAWay. In 2015, LegalRC and WayAWay partnered to popularize a new marketplace, Hydra, which competed with RAMP until the latter was shut down by the Russian police in September 2017 (VICE, 2020b). After that, Hydra had the opportunity to grow without any substantial competition.[9] This dominant position was actively maintained by Hydra through restrictions such as forcing sellers not to operate on competing platforms (see Section 2.2). The role of Hydra in the Russian drug market was partially admitted by the government when the marketplace was discussed during hearings in the lower house of the Russian parliament in 2019 (Lenta, 2019). We are not aware of attempts by Russian law enforcement to shut down the marketplace. The closure of Hydra happened due to the intervention of the United States and German governments, which we discuss in more detail in Section 4.

Being allowed to exist for 7 years, Hydra was able to grow and reach an unprecedented size of operations. The U.S. Government estimated that Hydra facilitated more than USD 5 billion in illicit transactions from January 2016 to March 2022 with approximately 80% of all darknet market cryptocurrency transactions in 2021 occurring on Hydra (United States v. Pavlov, 2022). Similarly, Chainalysis (2021) estimates the share of Hydra in the worldwide darknet market revenue in 2020 to be 75%. Hydra's scale meant that it had a substantial impact on the overall cryptocurrency market, with transactions by consumers using Hydra constituting a significant share of the revenue for some cryptocurrency exchanges (United States District Court, 2023; Reuters, 2022).

In particular, the U.S. Department of Justice (United States v. Pavlov, 2022) referred to Hydra as "the largest and longest-running darknet market in the world." To provide additional evidence for

Hydra's status as the largest darknet market, we list in Table 1 estimates of total revenue obtained by various studies assessing the size of the major darknet marketplaces. The table shows that the available estimates for Hydra exceed the estimates for other marketplaces almost by an order of magnitude. We conclude that Hydra was the largest marketplace that had ever existed at the time this article was written.

However, there are no comprehensive surveys of drug use in Russia that would allow us to properly estimate the market share of Hydra relative to traditional street trade. To situate our quantitative analysis, we conducted a set of interviews with activists from harm reduction organizations and investigative journalists who studied Hydra (which we describe in detail in Section 2). Our informants confirmed that Hydra was a common way to buy narcotics in Russia and was likely the most popular way in densely populated regions such as Moscow and Saint Petersburg. Additionally, informants suggested that there were other online venues to buy drugs in Russia, particularly individual shops operating via Telegram groups and bots. However, these were less popular and focused on selling drugs locally in specific cities and districts. Also, a small proportion of the drug trade continued offline, particularly amongst marijuana growers and economically disadvantaged opiate users who did not have access to the Internet. Overall, all informants suggested that Hydra was the most popular way to illegally buy drugs, at least in Moscow, Saint Petersburg, and other large Russian cities.

The stark difference between Hydra and its counterparts that operate in Western countries is the length of time it was able to continuously operate without intervention from law enforcement. Hydra operated for 7 years and was the dominant darknet market in Russia for much of this time. Relative to other popular darknet markets, which rarely survived even a single year from inception, Hydra had the opportunity to evolve to dominate the Russian drug market in an unprecedented way. As a part of this, it developed a sophisticated organization and structure, established a set of rules and regulations for sellers and buyers, introduced quality assurance mechanisms, and provided an escrow service.

Similar to other illicit marketplaces, Hydra also facilitated the sale of other illegal and gray-market goods (forged passports, counterfeit documents, counterfeit money, SIM cards, etc.) and services (graphic design for the new shops on Hydra, use of private-access databases to find personal information about individuals). However, our informants suggested that these accounted for a substantially smaller proportion of transactions than drugs. This suggests that Hydra was primarily a drug market, which is also the case for many Western marketplaces (United Nations Office on Drugs and Crime, 2021). The scope of illegal business was limited by the platform itself, which explicitly forbade selling guns, poisons, contract killing, explosives, government secrets, and pornography. In addition, drugs considered particularly dangerous, such as fentanyl and its derivatives, were also banned.

One specific feature that distinguished Hydra from popular darknet markets in the United States and Europe was the delivery method. The majority of darknet markets use mail orders, with suppliers relying on either the post or legal couriers to send the disguised drugs. While mail delivery had previously also been popular in Russia, the introduction of a bill in 2014 requiring the postal service to inspect packages for illicit substances made this method of delivery less attractive (Saidashev & Meylakhs, 2021). As a result, Hydra, similar to its Russian predecessor RAMP, operated via a dead-drop system (see Section 2.3 for more details). Couriers employed by vendors would hide drugs throughout the city prior to transactions taking place. The vendor would then list the type, quantity, approximate location, and price of the drugs on the Hydra website.

TABLE 1 Estimates of annual revenue obtained in previous studies.

Marketplace	Active period	Source	Measurement period	Yearly revenue
Silk Road	January 2011–October 2013	Aldridge and Décary-Hétu (2014)	September 2013	$90 million
		Soska and Christin (2015)	June 2013–August 2013	$105 million
Silk Road 2.0	November 2013–November 2014	Demant et al. (2018)	February 2014–November 2014	$97 million
		Christin (2022)	November 2013–October 2014	$94 million
		Bhaskar et al. (2019)	January 2014–September 2014	$130 million
Agora	December 2013–August 2015	Demant et al. (2018)	February 2014–April 2015	$36 million
		Bhaskar et al. (2019)	January 2014–February 2015	$121 million
		Hiramoto and Tsuchiya (2020)	December 2013–August 2015	$126 million
AlphaBay	December 2014–July 2017	Christin (2017)	March 2015–May 2017	$99 million
		Tzanetakis (2018a)	September 2015–August 2016	$94 million
Dream	November 2013–August 2018	Zhou et al. (2020)	October 2018–March 2019	$168 million
		Christin (2022)	July 2017–August 2018	$187 million
Hydra	2015–April 2022	U.S. Department of the Treasury (2022)	2020	$1300 million
		Chainalysis (2023b)	2021	$1700 million

Note: We annualize the numbers when the authors present daily estimates or estimates of sales over a particular period. For Aldridge and Décary-Hétu (2014), estimates are from p.15. For Soska and Christin (2015), estimates are from p.40. For Demant et al. (2018), estimates are from p.54. For Christin (2022), estimates can be found at https://arima.cylab.cmu.edu/markets/viewecosystem.php. For Bhaskar et al. (2019), estimates are from their Table 8. For Hiramoto and Tsuchiya (2020), estimates are from p.6. For Christin (2017), estimates are from p.12. For Tzanetakis (2018a), estimates are from p.179. For Zhou et al. (2020), estimates are from p.266.
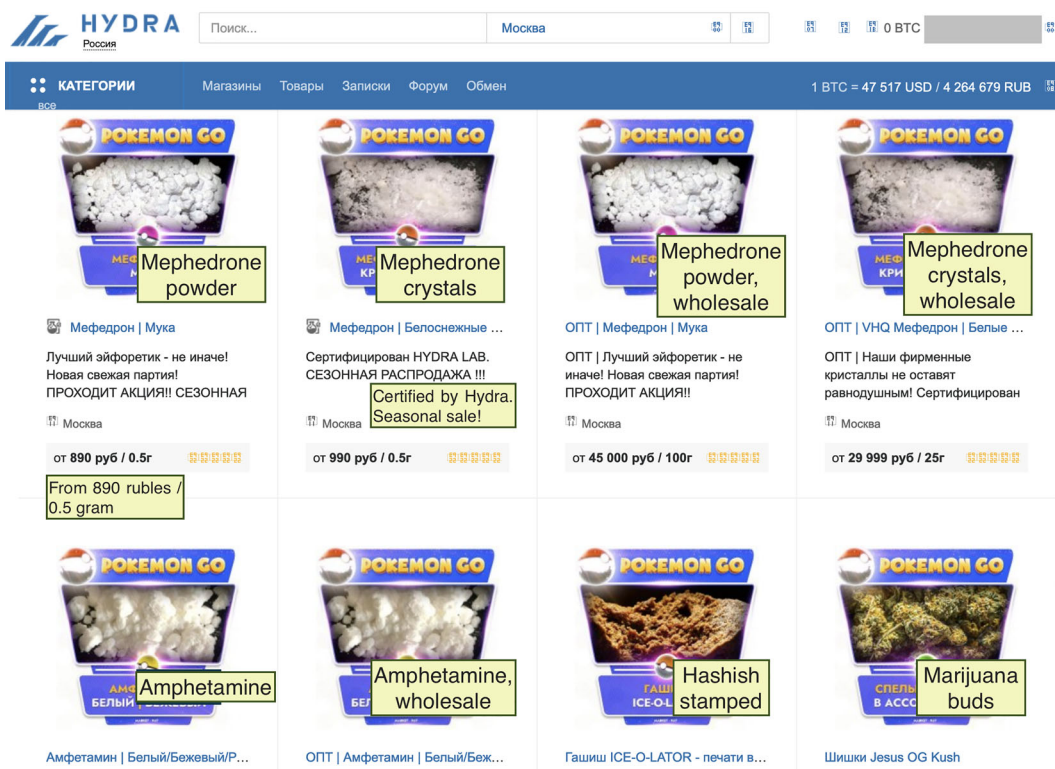
FIGURE 1 The page of a Hydra vendor listing the types of drugs they sell in Moscow, 2022. [Color figure can be viewed at wileyonlinelibrary.com]

2 | MARKETPLACE ORGANIZATION

2.1 | Methods

Unless stated otherwise, we base our qualitative description of the marketplace on three sources of information. First, we have access to a set of screenshots from the website, which illustrate the core functionality of the marketplace. Second, we studied the pages with the "rules" of Hydra and the manuals for customers and sellers. These pages were available[10] on the Hydra website and provided extensive information about the operation of the marketplace (see Figure 1).[11] Third, we rely on four interviews with activists from harm reduction organizations and investigative journalists who studied Hydra to validate this information. To situate our quantitative findings and better understand the context of the online and offline drug trade in Russia, we conducted a series of interviews with experts in the field of drug use in Russia. One informant was a member of a nongovernment (NGO) organization specializing in harm reduction situated in Russia, while the remaining three were investigative journalists from Russia who published materials on the illegal drug trade. To find the informants, we began by contacting the authors of the media publications on the online drug trade in Russia. After the interviews, we asked if they could provide us with contacts to other potential topic experts.

The interviews were conducted over video calls from March 2022 to May 2022 by two of the study coauthors in Russian, and each interview lasted 1–2 hours. We did not record interviews

due to concerns over the sensitive nature of the content. However, each of the interviewers took notes during the interview. After each interview, we discussed the new information and added the relevant context to this paper. The interviews were semi-structured. Before each interview, we prepared a list of questions which addressed several topics, such as the overall structure of the drug market in Russia, the popularity of Hydra for the drug trade, and the mechanisms and different aspects of Hydra. Some of the questions were formulated as follows: How do people usually obtain narcotics in Russia? How popular is the online drug trade, particularly Hydra, compared to the offline market, such as the street-level drug trade? Which drugs are the most popular in Russia? How do subpopulations of people who buy drugs vary depending on the type of drug sold? What is the organizational structure of Hydra and sellers in the marketplace? Depending on the informant's background and the flow of the interview, we would ask follow-up questions. Together, these interviews helped us gather additional background knowledge about the illegal drug trade and the role of Hydra. We also acknowledge that the background of some of the informants might have influenced their stance and opinions on the drug market in the country. Because the interviews were solely used to situate our findings from the quantitative analysis, we leave the critical analysis outside of the scope of this paper. However, as we base some of the implications of the study on the information from interviews, we want to highlight that this approach introduces certain limitations to our analysis.

2.2 | Customers

Similar to other popular darknet markets, Hydra was accessible on the Tor network via the use of the Tor Browser. After creating an anonymous[12] profile, a user could browse the website and filter available goods by drug type, shops, geography, price, and desired volume. For many product listings, there were reviews by other customers who provided feedback on the quality of the product and their experience.

Once a customer decided on the desired product, payment was made via Bitcoin. Customers generally had two options for depositing Bitcoin on the platform.[13] One was to externally purchase Bitcoin, which could then be transferred to the address provided by the marketplace. Another option was to use a QIWI wallet, a payment service provided by the Russian financial company QIWI. As the company has ATM-like terminals throughout Russia, a customer can simply deposit cash to exchange it for Bitcoin using one of many crypto exchange services operating on Hydra. Given that no identification is required for the use of the terminals, this way of depositing money provided sufficient anonymity for buyers. To the best of our knowledge, these terminals were crucial to the popularity of Hydra as they made it substantially simpler to anonymously obtain cryptocurrency. This is supported by the fact that the user guide on the website of Hydra had several pages with detailed instructions about how to use QIWI terminals for payment.[14] Once the purchase was made, Hydra provided an escrow service holding the funds in an escrow account until the transaction was confirmed as having been successfully completed.

After payment, the customer received detailed information on the location of the dead-drop, including photos and GPS coordinates. Thus, there would be no physical contact between the seller and the buyer. Moreover, the communication between them was isolated by the website on the Tor network. The financial transaction was anonymous, provided the customer used Bitcoin or directly deposited cash to a QIWI terminal.

The main channel of communication between the buyer and seller occurred through the chat system on the Hydra website. While it is possible that market participants could use other means

of communication, the marketplace aggressively prohibited this. In particular, the rules of the platform prescribe large penalties (up to 2 Bitcoins, BTC) for sellers attempting to establish connections with buyers outside of Hydra and rewards for buyers exposing such attempts.

2.3 | Delivery

In contrast to most darknet markets, Hydra mostly operated through a system of *dead-drops*; the drugs were hidden in advance and buyers could see the type, quantity, and approximate location on the platform (VICE, 2020b). After payment, the customer was given the exact details necessary to collect the item. There were four methods used to hide packages: "magnet," "dig," "snow dig," or "hiding."[15] The first involved attaching a magnet to the package and then sticking it to an object, such as the inner surface of a rain gutter. The second and third methods were burying the package in a suitable location, such as a park or public garden, in either soil or snow, respectively. Finally, the package could simply be hidden somewhere it was unlikely to be accidentally found (such as the attic in multifamily housing).

Additionally, instead of dead-dropping, some goods could be mailed after purchase, similar to other darknet markets, although this was primarily used for drugs such as LSD that are particularly difficult for law enforcement to intercept.[16] Finally, many goods were also available for preorder, which meant that they were not hidden prior to the transaction but were instead deposited after payment. Preorders were primarily used either for wholesale transactions or for exotic drugs.

As the communication between Hydra administrators, vendors, couriers, and customers was remote and anonymized, the marketplace served to mitigate many of the legal risks involved in drug transactions. However, placing and retrieving the dead-drop did expose couriers and consumers to the risk of detection by law enforcement (VICE, 2020b). Activities such as digging in parks or searching the yards of multifamily houses became indications that someone was likely retrieving drugs.

2.4 | Sellers

Similar to other darknet marketplaces, Hydra allowed sellers to register and list a variety of drugs for sale. However, there are two features of the functionality that Hydra provided for sellers that were specific to the marketplace. First, the functionality was tailored to the delivery system that the marketplace used; Hydra has automated the assignment of dead-drops to couriers and the management of dead-drops. Second, the interface of the marketplace allowed several users to work for the shop. The marketplace allowed three types of workers: administrators, operators, and couriers. Administrators could assign roles to other workers, change the profile and the settings of a store, and conduct financial transactions. Operators served as midlevel management, for example, responding to disputes and requests of customers. Finally, couriers delivered drugs.

2.5 | Marketplace services

In this section, we describe the main services and features that the platform provided to users.

2.5.1 | Reviews and ratings

Previous studies have highlighted the crucial role of reputation on darknet marketplaces (Janetos & Tilly, 2017). Hydra allowed for two channels of buyers' feedback: ratings and reviews. Every time a buyer made a purchase, they were given 24 hours to leave feedback.[17]

The simplest information that potential buyers could use to evaluate the seller and item is the average rating. Hydra allowed for ratings between 0 and 10. On Hydra, users could see the average rating for the seller and the average rating for each of the items it sells. Like AlphaBay (Červenỳ & van Ours, 2019) and SilkRoad (Bhaskar et al., 2019), most of the ratings on Hydra were very high. The average rating is close to 10, and the share of orders with a rating below 10 is just 4% (we present the detailed analysis of reviews and ratings later in Section 3.6). This may partly be explained by the fact that if the user did not post a rating during the 24-hour period, the marketplace automatically assigned a rating of 10 to the order. It may also be due to the effects of reputation inflation, where raters begin leaving higher ratings despite not being satisfied (Filippas et al., 2022). This is supported by the fact that we observe numerous instances where a user expressed negative sentiment in the review text despite leaving a rating of 10/10, which is in line with the findings of Filippas et al. (2022) that review text is less sensitive to "inflation" than numerical ratings. (See Table C.1 in Appendix C for examples of such reviews on Hydra.)

The second component of the reputation system was reviews. According to the Hydra users we interviewed, reviews were an important factor in choosing between vendors. A typical review is a short message expressing satisfaction with a purchase. However, reviews often contain additional information: perceived quality of the drug, problems with the collection process, and missing items. Reviews could only be left after purchase to mitigate the risk of distortions due to fake reviews left by competitors. (See Figure 2 for an example of reviews posted on Hydra.)

2.5.2 | Dispute resolution

Hydra allowed buyers to initiate disputes. A typical dispute was related either to issues with the collection process or with the item purchased. Collection issues were typically related to situations where the drug was missing from the specified location or the collection was too difficult either for safety or access reasons. Problems with the item itself were generally due to either the quantity or quality being below what was advertised on the platform.

Disputes started with communication between the buyer and the seller through the internal messaging system. Typical outcomes were a refund, a replacement by providing information about another dead-drop, or a discount for a future purchase. If the dispute could not be resolved by the buyer and seller themselves, one of the platform moderators read the messages and decided how to resolve the dispute. The moderators were more likely to resolve a dispute in favor of the buyer if she or he had a long history of purchases without a high share of disputes. Thus, the system of disputes incentivized users to maintain an account instead of registering new ones.

2.5.3 | Quality testing

Hydra also employed methods to try and ensure products sold on the platform were of high quality. The administrators regularly published information on audits they claimed had been conducted

FIGURE 2 Example review page for a drug listing on Hydra. [Color figure can be viewed at wileyonlinelibrary.com]

on some of the items listed for sale. This testing covered only a small subset of listed items within a given month. For example, only 47 test results were published in June 2021. Among them, 15 were supposedly done in Moscow and 32 were in Saint Petersburg. In other months, tests were also listed for several other cities. The administration of Hydra claimed that vendors/items with a higher proportion of negative reviews or disputes were prioritized for selection. The tests were claimed to be blind, with the specialist not knowing the name of the seller. The test results were made public and posted to the marketplace forum. These results include an overview of the collection experience, a description of the packaging, the quantity relative to the advertised amount, and the results of chemical testing. In particular, for drugs distributed as powder it was reported whether the purity met the listed standard (e.g., very high quality, VHQ or high quality, HQ). As well as providing buyers with additional information about vendors, which could be used alongside reviews to reduce the information asymmetry present in an anonymous online marketplace, it should have served to directly incentivize sellers to maintain high standards given the risk of fines for failing the weight/quality tests.

2.5.4 | Special statuses

Another feature of Hydra was that it allowed merchants to obtain two special statuses that helped to differentiate them from other sellers and improve business processes, similar to some of the Western cryptomarkets which adopted status rankings (Munksgaard & Tzanetakis, 2022).

Trusted sellers

The status of a "trusted seller" could be purchased if the following two requirements were satisfied: the seller had more than 1,000 sales overall and had a dispute rate below 7%. The status increased perceived reliability from the point of view of buyers. It also improved its position in search results. In addition, trusted sellers could make decisions in the dispute procedure before Hydra's moderators reviewed it.[18] Finally, trusted sellers were allowed to have franchisees, that is, small partners who produce synthetic drugs or grow marijuana and partner with the seller using Hydra as the mediator.

Certified producers

For sellers of synthetic drugs, the marketplace allowed sellers to obtain the status of a certified producer. This status could increase sales by signaling the relative safety of the items purchased, with buyers also able to filter search outputs only to show certified producers.

This feature of the marketplace required a substantial degree of involvement by marketplace employees. Based on the description on the website, Hydra was supposed to check the whole production cycle: the chemical reagents bought and used, the equipment, and the qualifications of the workers. The marketplace also claimed to test the final product in its lab. It is not clear from the description whether the Hydra employees conducting these tests physically visited the production facilities. The platform stated that Hydra required photos of the production facility and detailed information regarding it (e.g., the reagents purchased) as part of the application for this status.

2.5.5 | Professional education

Hydra also hosted a page called "School of Couriers," where it sold a few online courses for couriers and services for resolving employer–employee disputes for shops. Based on the reviews, the training sold by Hydra was credited with reducing the risks associated with depositing dead-drops. Hydra also provided consulting services for aspiring producers. The services were stated to range from helping with the purchase of precursors and equipment to the education of production facility workers.

2.5.6 | Medical help

Hydra provided free telemedicine consultations for people who use drugs. In particular, the platform actively advertised employment for medical professionals for this service. The consultations occurred either through the chatbot in the Telegram messaging service, the website messenger, or on the platform's forum. While we cannot evaluate the popularity or efficacy of Hydra's telemedicine services, the attempt to provide and advertise them represents a novel innovation in harm reduction on darknet marketplaces.

2.6 | Business model

There were several key sources of revenue for the platform. First, Hydra charged sellers a monthly fee and commission from all transactions on the marketplace. Second, Hydra auctioned

off positions on the main page of the website. Third, Hydra sold special statuses to larger sellers on the market.

Platform fees
Hydra charged sellers for operating on the platform. As of March 19, 2022, the price the marketplace charged for starting a new shop was roughly USD 300. Additionally, Hydra also charged "rent" of USD 100 each month. This price had not changed since 2019 when it was reported by Proekt (2019).

Sales commission
Hydra charged a sales commission that varied by drug type and value. For sales below 200,000 rubles (≈ USD 2,700), the fee was generally 5% of the purchase price. The commission was higher for certain drugs and could be as high as 10%.

Front page
The sellers could pay for one of the 20 positions on the main page of the website. These positions were distributed through a monthly auction, with the highest bidder getting the first position, the second highest bidder getting the second position, etc. The bids could be observed by store owners. Proekt (2019) reports that by the time the article was written, the cost of the positions on the main page was on the order of magnitude of tens of thousands of USD per month.

Fines
Hydra could also charge a seller a penalty if they broke the rules of the platform. The size of the penalties ranged from 25,000 rubles (approximately USD 340,[19] which was the penalty for hiding dead-drops too close to each other) to several hundreds of thousands of rubles. The largest penalties were related to maintaining the monopoly position of the marketplace. As was discussed in Section 2.2, stores could be penalized for inviting clients to buy drugs outside of the platform or register on other marketplaces.

Special statuses
The status of a "trusted seller" cost USD 1,000 per month. The status of a "certified producer" required sellers to share an additional 3% of all sales with the platform.

3 | MARKETPLACE ANALYSIS

3.1 | Data

For our quantitative analysis, we use two complementary data sets. The first data set is a set of drug listings scraped from the Hydra website. The data set contains daily snapshots of drug listings on Hydra from April 1, 2020 to May 2, 2020. For each listing, we observe the characteristics related to the product and its delivery method. The former includes the type of drug, amount, price, name and title of the listing, and the name and ID of the seller. Information on delivery includes whether the listing is a preorder or an instantaneous listing, and whether the order is mailed. For instantaneous listings, we observe the type of hiding and the approximate location of dead-drops. In total, the data set contains 31,035,506 listings. These data were purchased from an independent data collector, who also provided data for several journalist investigations (Knife

Media, 2020; Proekt, 2019). Scraped listings from Hydra have also been used in studies of drug use, and opiate listings were shown to be significantly correlated with fatal drug overdoses (Vlassov et al., 2021).

The second data set we use is provided by a data provider established in Pennsylvania, USA. This firm continuously collects data from the world's largest darknet marketplaces. Details about the project can be found in Soska and Christin (2015) and Christin (2022). This data set allows us to see a large subset of the reviews left on the platform. For each review, we observe the item for which it was left, the vendor, the nickname of the buyer, the time of the review, and the associated numerical rating that the buyer has given. We exclude all reviews that were left for job postings or nondrug products sold on Hydra. After removing duplicated reviews,[20] we end up with 325,740 unique reviews that were left on the marketplace from January 2019 to February 2022. Our sample only covers a fraction of all reviews as the firm providing the data was not able to scrape all pages of the website because of technical difficulties. As coverage of scraping fluctuated significantly across days, we do not use these data for quantifying how many and what drugs were sold on Hydra. We only use this data set for analysis of the reputation system on Hydra, and our conclusions do not rely on the ability to observe all reviews on the marketplace.

3.2 | Drugs sold

Table 2 shows the composition of dead-drop listings on Hydra in April 2020. The original data set contains 31,035,506 listings. As instantaneous listings were already hidden and ready for pickup at the time of listing, sellers have already in effect committed to selling these listings. In contrast, a seller could list several different quantities of the same drug for preorder/mail-order to provide options for consumers. However, it is not clear that they could fill these listings if many traded in a short period. Hence, we believe instantaneous listings are more directly linked to traded quantities and we focus our analysis just on instantaneous listings. Removing all preorders and mail-based listings leaves us with 2.8 million dead-drop listings. However, listings for the same package will appear multiple times in our data set as they were listed each day until purchased. Thus, in Table 2 we remove duplicate listings at the drug-vendor-quantity-location level. We end up with approximately 417,000 unique dead-dropped drug listings during April of 2022.[21] The majority of the drug listings are for either stimulants or euphoretics.

We can see that the most popular drugs on the platform are mephedrone (31%), cannabis (18%), amphetamine (13%), and alpha-PVP (12%). Our finding that mephedrone has the largest number of listings on Hydra confirms existing evidence of its extreme popularity in Russia (VICE, 2020a).

Note that one listing on the website can represent several dead-dropped packages with the same characteristics hidden in the same general location. Therefore, this table likely underestimates the actual number of drug packets hidden throughout Russia. Proekt (2019) suggests that the true number might be as much as five times higher. Hence, ≈417,000 is a conservative lower bound of the number of drug packages lying hidden in Russia during April 2020. In comparison, Bhaskar et al. (2019) observe fewer than 25,000 drug listings at the peak of major Western darknet market-places such as Silk Road, Silk Road 2.0, Evolution, and Agora. However, because the definition of a listing is substantially different on Hydra compared to most other darknet markets, a more meaningful comparison may be the number of sellers on the platform. Using this metric, Hydra still appears to have been substantially larger than the major Western darknet marketplaces as we observe 4907 unique sellers on the platform in our single month of data compared to the 2604 sellers on Agora observed by Bhaskar et al. (2019) over a much longer period from December of 2013 to August of 2015.[22] Given the finding of Soska and Christin (2015) that darknet sellers are on

TABLE 2 Unique listings of dead-drops on Hydra. Bold rows show summaries by the drug group. Normal rows show drug types within each group.

Drug	Numbers	Percentage
Group: Stimulants	**304,045**	**72.8**
Mephedrone	131,341	31.5
Amphetamine	55,916	13.4
Alpha-PVP	52,297	12.5
MDMA (ecstasy)	40,937	9.8
Cocaine	20,538	4.9
Methamphetamine	2,969	0.7
Other	47	0.1
Group: Cannabis	**76,067**	**18.2**
Marijuana buds	36,260	8.7
Hashish	34,801	8.3
Marijuana leaves	3,253	0.8
Marijuana oil and extracts	1,319	0.3
Other	434	0.1
Group: Psychedelics	**16,253**	**3.9**
LSD	5,709	1.4
NBOME	3,189	0.8
Mushrooms	3,052	0.7
Sodium oxybate	2,818	0.7
Dissociatives	573	0.1
2C-*	452	0.1
Other	460	0.1
Group: Opiates	**9,645**	**2.3**
Methadone	6,113	1.5
Heroin	3,326	0.8
Other	206	0.1
Group: Synthetic cannabis	**6,309**	**1.5**
Hard mix	4,814	1.2
Soft mix	934	0.2
Cannabinoids	561	0.1
Group: Quasilegal and RX drugs	**3,842**	**0.9**
Group: Precursors (DIY)	**796**	**0.2**
Group: Other	**448**	**0.1**
Total	**417,405**	**100**

Note: Total number of unique listings for each drug type over the period from April 1 - May 2 2020. Data is restricted to instantaneous dead-drop listings on Hydra.

TABLE 3 Summary statistics for select drug types on Hydra.

	Alpha-PVP	Amphetamines	Cocaine	Ecstasy	Hashish	Marijuana	Mephedrone	Heroin
Numbers of sellers	1513	1621	639	1299	1505	1655	2481	145
Numbers of cities/towns	741	589	352	516	494	482	721	185
Median price (United States\$ per gram/unit)	31	13	127	9	24	22	21	59
Average price (United States\$ per gram/unit)	35	15	126	13	26	24	23	65
Average daily number of listings	9484	16,810	5535	14,103	5439	4438	24,045	1158
Average daily total quantity listed (grams/units)	59,131	368,501	17,520	344,627	78,727	33,192	385,097	6022
Average daily total value of listings	837,594	4,786,341	1,603,401	1,642,807	1,311,500	493,021	4,441,260	208,269
Median quantity (grams/units per listing)	1	2	1	3	2	2	2	1
Average quantity (grams/units per listing)	6.24	21.92	3.17	24.44	14.47	7.48	16.02	5.20
Average daily number of wholesale listings	115	311	237	267	186	75	646	16
Proportion of listings wholesale (instantaneous orders)	0.01	0.02	0.04	0.02	0.03	0.02	0.03	0.01
Proportion of listings wholesale (all orders)	0.51	0.28	0.41	0.41	0.48	0.28	0.55	0.16

Note: Summary statistics for select drug types. Data is restricted to instantaneous dead-drop listings on Hydra except where specified otherwise. "Wholesale" is defined as any listing with a price above $1000.

average active for just 220 days, this comparison likely underestimates the extent of the difference in size between Hydra and the major Western marketplaces. We conclude that the comparison of listings and sellers also supports the statement that Hydra was the largest darknet marketplace in the world (see Section 1.2).

Table 3 shows summary statistics for select drug types on Hydra. Consistent with studies on Western cryptomarkets (Tzanetakis, 2018a), we see that heroin was a small proportion of this market. While it was allowed to be sold on Hydra, our interview informants have suggested that heroin was an exception among other drugs, and the majority of the heroin trade in Russia occurs through more informal methods such as bots on Telegram or offline and on the streets. The remaining drug types were widely available, many being sold in around 500 different cities and towns. Unlike most other darknet marketplaces, a large proportion of listings on Hydra appear to have been intended for redistribution. Demant et al. (2018) estimate that just 2.1% of transactions on Agora and The Silk Road 2.0 were wholesale transactions, defined by having a value above USD 1000, with the remainder appearing to be for either personal consumption or social distribution. Using this definition, we find that for the categories listed in Table 3, the proportion of wholesale listings varies from ≈ 50% for Alpha-PVP to ≈ 15% for heroin. Restricting our data to instantaneous orders (i.e., excluding preorders), we find that the proportion of wholesale listings drops to 1–5% for the categories in Table 3. Hence we conclude that the majority of these business-to-business transactions occurred through preorders, and this inference is corroborated by several of our informants.
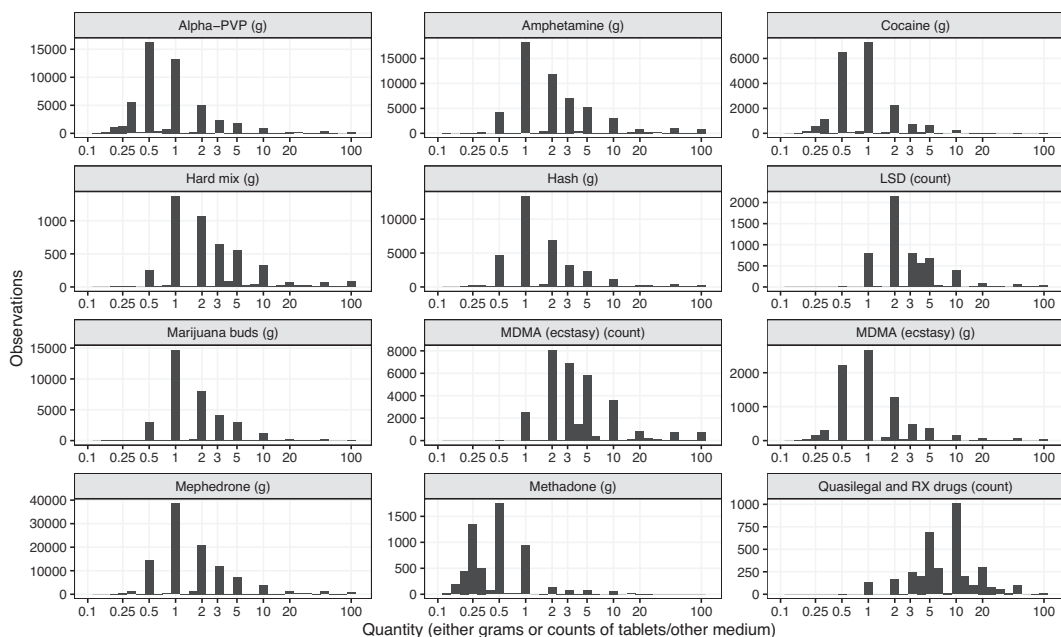
FIGURE 3 Histograms of quantity distribution for most frequent drugs in unique instantaneous listings.
Note: Quantity is represented either in grams (g) or counts.

Finally, Figure 3 shows the weight/quantity distribution of several types of drugs. It is apparent that the most frequent quantities are 0.5, 1, 2, 3, and 5 g for most of the drugs. Quasi-legal and RX drugs, such as Xanax, are sold as tablets and, therefore, have higher quantities. Interestingly, methadone is rarely sold in weights above 1 gram.

3.3 | Geography

3.3.1 | Within-city dispersion

Given that our interviews mentioned that the convenience of the pick-up location was a key factor in differentiating between listings, the distribution of listings across the different neighborhoods of a city reflected the spatial distribution of demand. Figure 4 shows the share of three major drug categories as a proportion of all drug listings within each district of Moscow. As can be expected, cocaine is generally hidden in the city center around the business districts. At the same time, cheaper drugs, such as synthetics and marijuana, are proportionally much more popular in the outskirts. Similar patterns can be seen in other major cities throughout Russia. In Figure A.1 in Appendix A, we show this for the case of Saint Petersburg.

3.3.2 | Between-city dispersion

With Hydra operating in 1,129 settlements across every region in Russia, over 100 million people live in a settlement that had at least one dead-drop available for purchase on Hydra in April 2020.
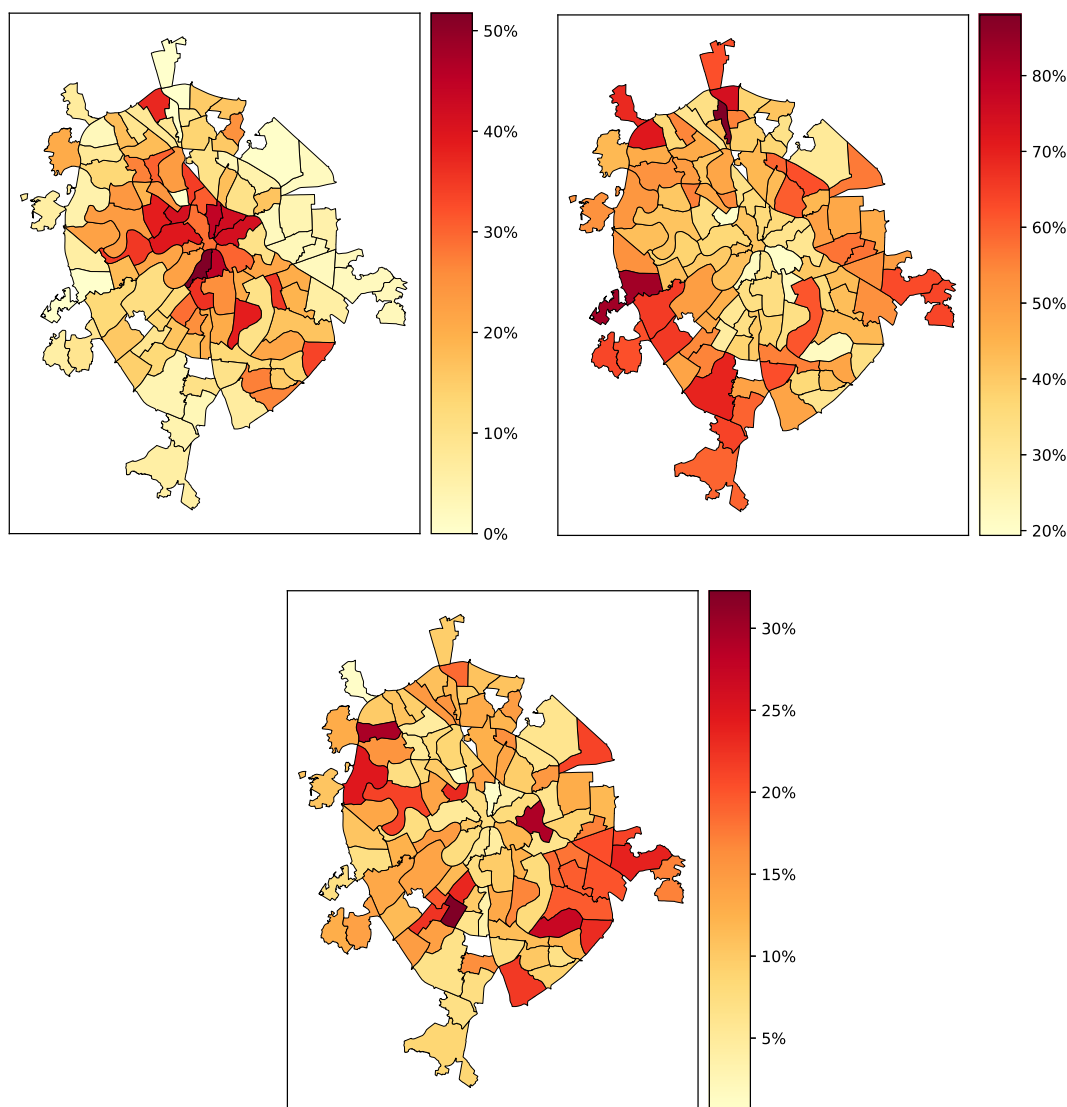
FIGURE 4   Spatial distribution of dead-drops in Moscow. [Color figure can be viewed at wileyonlinelibrary.com]

Note: Map of Moscow showing the proportion of listings of the given drug type as a proportion of the total number of drug listings in that neighborhood. Synthetics include methamphetamine, amphetamine, MDMA, alpha-PVP, MDPV, and mephedrone. Only municipal districts are included.

This means that of the 144 million inhabitants of Russia, 69% had access to drugs from Hydra in their city or village at the time when our data were collected.

Figure 5 shows the distribution of cities with at least one instantaneous listing from Hydra. We can see that the degree of presence of Hydra is positively correlated with population size. Moscow and Saint Petersburg, the two most populated cities in Russia, on average had 3 and 9 dead-drops per 100 residents, respectively. Among the less populated cities, Sochi stands out as one of the cities with the highest demand with 16 listings per 100 residents, likely related to its popularity as a resort location. Finally, many smaller satellite cities around Moscow (such as Aprelevka or Solnechnogorsk) have a particularly high number of listings per capita. These locations can be
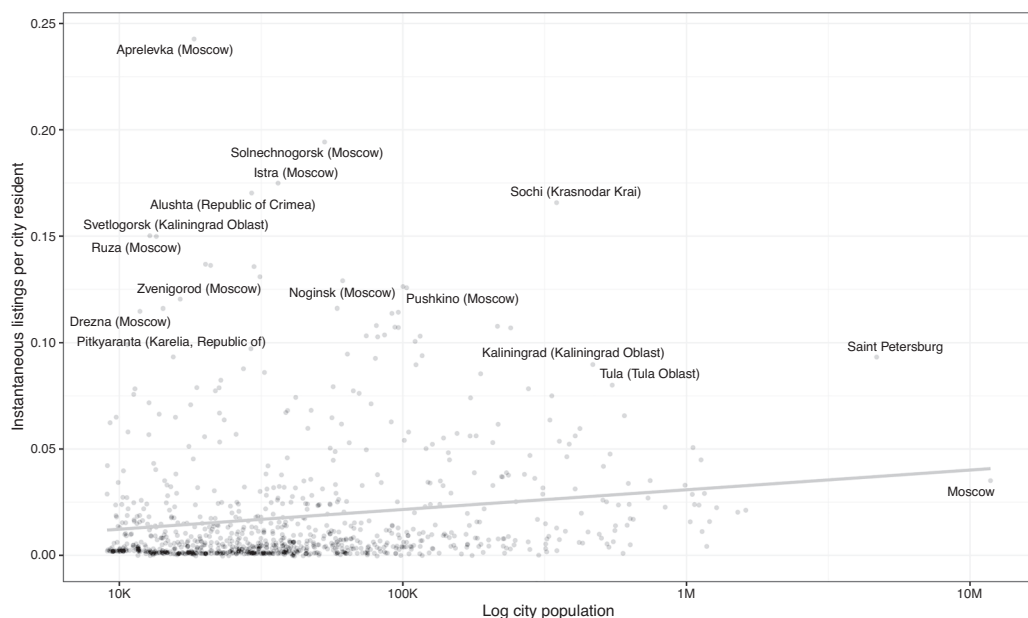
FIGURE 5   Instantaneous listings per resident in Russian cities.

Note: Only cities with a population >10K are included. The gray line shows the linear fit.

easily accessed by car or public transportation but have less policing and more parklands. Thus, they are likely to be convenient for hiding and picking up drugs and serving some consumers from Moscow.

3.3.3 | Distribution across regions

Figure 6 shows the distribution of activity on Hydra across regions. Several groups of regions seem to have more listings per capita than others. In particular, we observe a high density of listings in Moscow, the most populated city in the country, and its neighboring regions such as Moscow Oblast, Kaluga Oblast, Tula Oblast, and Yaroslavl Oblast. The map also supports the view that drugs are more accessible in regions adjacent to major ports. For example, the highest density of listings is observed in Saint Petersburg. Some other regions with a long border (e.g., the Republic of Karelia and Kaliningrad Oblast) also have high density. The regional coverage by Hydra also reflects the distribution of population and the degree of urbanization, with more people living in the European part of Russia and in the southern parts of Siberia (in particular, in Krasnoyarsk Krai). While Kamchatka Krai has a high density of Hydra listings as well, it is hard to draw any conclusions from this fact as population density is very low there.

3.4 | **Market concentration**

More than 4,500 shops operated on Hydra in April 2022. This number itself suggests a highly competitive market. To quantify the degree of competition, we analyzed the characteristics of

FIGURE 6 Density of listings in regions of Russia. [Color figure can be viewed at wileyonlinelibrary.com]

Note: The map shows daily listings per 1000 citizens across regions of Russia. The map includes several regions of the Russian Federation, also known as federal subjects, the boundaries of which are marked in black. We have labeled several regions discussed in the text: Moscow, Saint Petersburg, Moscow Oblast, Kaliningrad Oblast, Kaluga Oblast, Krasnoyarsk Krai, Kamchatka Krai, the Republic of Karelia, Tula Oblast, and Yaroslavl Oblast.

shops: the number of listings they usually had, how many cities and regions they operated in, the extent of specialization, and to what degree the market is concentrated in general. To calculate market shares we sum the prices of each listing and obtain an estimate of the volume of a single shop, which is the total cost of all the listings. We use this estimate to calculate the share of each shop as a proportion of the total sum of volumes.

Ideally, we would estimate the market share of sellers using data on the number of transactions conducted on the platform. Unfortunately, in our data, we only observe listings and thus must use the number of listings to infer transactions. While Tzanetakis (2018a) estimated that only 69% of listings at the marketplace "AlphaBay" resulted in a transaction, we posit a strong correlation between instantaneous listings and transactions in the context of Hydra. Instantaneous listings represent drug packages that have already been hidden, retrieving such packages is costly, and there could be a potential loss if these packages are left for a long period without being sold. This vested interest in the already dead-dropped package among sellers on Hydra should mean that a higher share of listings results in a transaction. Thus we would consider 69% a lower bound for the proportion of listings that would have traded in our setting. Further, the discussion below is based on market shares, which should not be affected by any overestimation provided that the ratio of unsold listings is the same across shops. Nevertheless, this limitation does introduce additional uncertainty into our estimates.

To quantify the degree of market concentration on Hydra, we follow the approach in the literature (Paquet-Clouston et al., 2018) and calculate the HHI using the set of unique dead-drop listings in April 2020 (see the data description in Section 3.2) which were subset to omit wholesale listings and listings with artificially inflated prices.[23] Thus, we only include listings with a price lower than USD 1,000 (this removes 6,000 listings out of 417,000). HHI is a measure of market concentration ranging from ≈ 0 (perfect competition) to 1 (monopoly). A value below 0.15 is generally considered to suggest a competitive market. Overall, on Hydra we observe an HHI of 0.004, indicating a competitive market.

TABLE 4 Market concentration by most popular types of drugs.

Drug type	Numbers of sellers	Retail volume (USD)	Share of the total volume	Herfindahl–Hirschman index
Mephedrone	2649	6,169,398	0.27	0.007
Amphetamine	1733	2,982,659	0.13	0.009
Cocaine	670	2,855,486	0.12	0.028
MDMA (ecstasy)	1372	2,297,219	0.10	0.012
Alpha-PVP	1604	2,215,938	0.10	0.007
Hashish	1567	2,149,458	0.09	0.006
Marijuana buds	1735	2,005,045	0.09	0.004
Across all drugs	4676	22,936,026	1.00	0.004

Note: This table uses data on all unique retail (listing price < USD 1000) instantaneous listings listings in April 2020.

Looking in more detail at the characteristics of the largest and typical sellers on Hydra, the seller with the largest retail volume in the data, the shop "Prazdn1k" [Holiday] has 4,527 listings with a total value of USD 471,096, which is 2% of the whole retail volume on the platform in that month. The shop "Prazdn1k" was selling nine types of drugs, with the majority of their listings being mephedrone or cocaine, and operated in 34 regions and 54 cities.

The shop with the second largest volume, "PokemonGo," had the largest number of unique listings (5,416) with a total value of USD 406,577. It was active in 45 regions and 102 cities and sold eight different types of drugs, predominately mephedrone and amphetamine. All other sellers had market shares of 1% or less, with 30% of all shops having had less than 10 unique listings in total during the month we analyzed. The median seller on Hydra is relatively small: it worked in one or two cities, had just 10 listings per drug type, and sold one or two types of drugs.

We also separately calculate HHI for the most popular drugs and cities on Hydra. The markets for cocaine (HHI = 0.027) and mephedrone (HHI = 0.014) appear to have been the most concentrated markets on Hydra, yet in absolute terms, they are still competitive (Table 4). If we look at the sellers in each of the cities, we observe a negative correlation between the population of the city and the market concentration (Figure 7). In large cities, the HHI is low and the online drug market (judging by the Hydra data) is competitive. In smaller settlements, there is substantial variation in competitiveness and several appear to have been monopolies in terms of presence on Hydra.

3.5 | Price decomposition

Within a given store, pricing on Hydra tended to be nonlinear, with per-unit prices decreasing as order size increased. While part of this nonlinearity is driven by wholesale transactions in which dealers buy from larger suppliers, there were also fixed transaction costs imposed on suppliers as a result of the illegal nature of the market. A major component of this fixed cost is the dead-drop cost. Given the high risks faced by couriers in hiding drugs, compensation for these couriers is likely to represent a substantial proportion of the cost of a transaction, one which is relatively invariant to the number of drugs hidden. The dead-drop cost can be thought of as an example of illegality-related costs, which are usually understood through the risks and prices model (Munksgaard & Tzanetakis, 2022; Reuter & Kleiman, 1986). According to the model, the prices of illegal
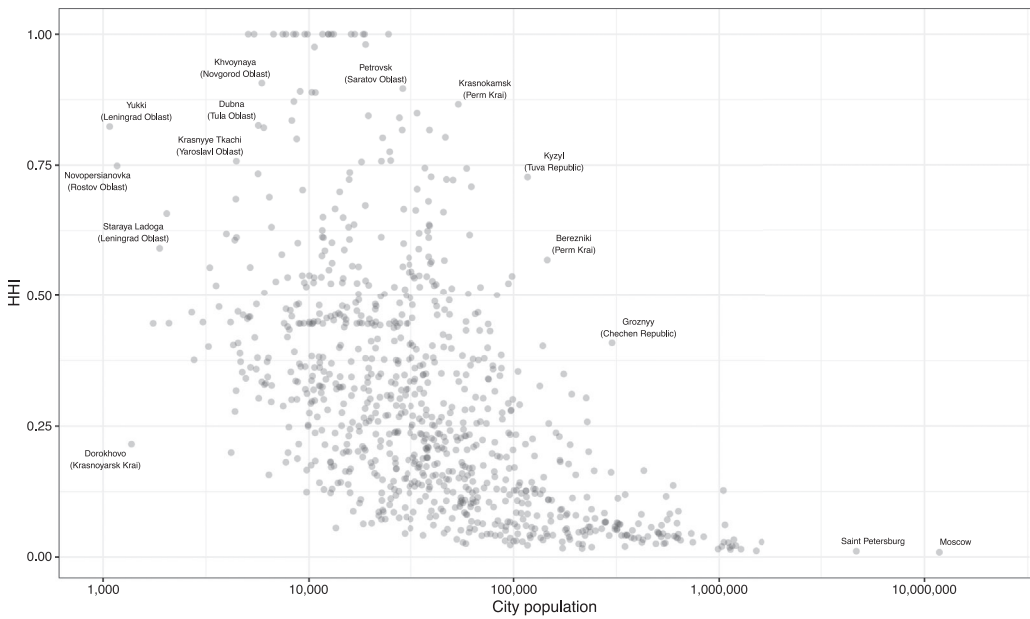
FIGURE 7   Market concentration in Russian cities, towns, and villages.

goods, especially narcotics, inherently include the risks related to law enforcement as well as the features of the internal social organization of the illegal market. Other costs that sellers are likely to incur include the cost of initial delivery of dead-drops to the courier[24] and the cost of managing the shop. To disentangle this, we use the following strategy.

In Section 3.4, we document a very high degree of competition between sellers on Hydra. In a competitive market, the price that sellers set should be equal to the total cost of supplying the goods. This includes the cost of raw materials, the time of participants, and compensation for the legal risk that participants take. These costs can be split between the cost of organizing delivery and the cost of purchasing or producing the drug. As Hydra was a large market for employment (see Sections 2.3 and 2.4), we expect the delivery cost to be approximately uniform across sellers. Further, if there is small product heterogeneity within each drug type and sellers produced the drug with similar technologies or purchased it on the same competitive market, then the per gram cost should be the same for each seller. Under these simplified assumptions, the price set by sellers should be given by the following formula:

$$price = DC + PGC \times weight, \tag{1}$$

where DC is the fixed delivery cost and PGC is the per-gram cost. Motivated by this simplified economic model, we run the below regression, allowing the fixed cost of dead-drops to vary depending on the drug type. That is, for each drug type, we estimate the regression

$$price_i = \alpha + \beta \times weight_i + \gamma_{s(i)} + \epsilon_i, \tag{2}$$

$$\sum_s \gamma_s = 0, \tag{3}$$

TABLE 5 Fixed cost and marginal cost.

| | (1) | (2) | (3) | (4) | (5) | (6) |
	Cocaine	**Buds**	**Hashish**	**Amphetamine**	**Mephedrone**	**Heroin**
Weight	97.50***	19.71***	17.72***	7.671***	13.24***	36.09***
	(0.101)	(0.0468)	(0.0532)	(0.0133)	(0.0224)	(0.108)
Constant	32.42***	13.75***	17.26***	17.16***	15.84***	14.02***
	(0.221)	(0.111)	(0.150)	(0.0793)	(0.0789)	(0.0971)
N	44,558	15,666	17,862	50,536	12,726	3151
R^2	0.955	0.921	0.864	0.868	0.965	0.973

Note: Standard errors in parentheses. Only retail listings with at least one review for the product are used. *p<0.10, **p<0.05, ***p<0.01.

where the sample consists of all listings i for this drug. We also include seller-level fixed effects $\gamma_{s(i)}$, where $s(i)$ is the seller selling listing i. We specify the fixed effects to sum to 0. In this model, α has the interpretation of the average fixed cost, which we expect to reflect the costs related to hiding a dead-drop. The per-gram costs of a particular drug are given by β. The seller-level fixed effects capture possible variation in costs and prices across sellers.[25] We restrict estimation to small retail listings.

The results for Moscow are shown in Table 5. Each column reports the results for a different drug type. For cocaine, the most expensive drug in Russia shown in column (1), we see that on average each additional gram of the drug increases the price of a listing by USD 97.5. For example, for marijuana buds and hash, shown in columns (2) and (3), we obtain much smaller marginal effects of weight: USD 19.7 and USD 17.7, respectively. The fixed cost of a listing of cocaine is on average USD 32.4, which we attribute primarily to the cost of having a courier perform the dead-drop. For marijuana buds, hash, amphetamine, mephedrone, and heroin, the fixed costs are close to each other and vary between USD 13.8 and USD 17.3. Figure B.1 in Appendix B shows that our estimates are close in magnitude to the piece rates that can be found in job postings for couriers on a marketplace that became popular after the shutdown of Hydra (see Section 4 for a detailed description of the aftermath of Hydra shutdown). Finally, the obtained R^2 is very high for all drugs, which provides some additional support for the chosen linear specification.

Table 5 reveals two properties of the fixed-cost components of prices on Hydra. First, the fixed effects in the regressions are different for different drugs. We believe that this reflects that delivery costs for different drugs are different (VICE, 2020b, provides anecdotal evidence for this). For example, cocaine dead-drops are the most expensive because they appear to be the most difficult to make for several reasons. First, cocaine is typically hidden in central areas (see Figure 4), where policing is more intense, and thus the risks for couriers are higher. Second, cocaine dead-drops can be expected to be of higher "quality": the cost of losing a dead-drop of cocaine is higher, and, hence, the packages should be hidden better. Finally, the risk of couriers absconding with drug packages appears to have been a significant concern for shops and the higher street value of cocaine packages makes them particularly susceptible. Hence, couriers were provided higher compensation per package to incentivize them not to steal the drugs.

The second property we observe is that the estimated fixed costs are high relative to the estimated per-gram costs. We can see that the dead-drop cost represents a substantial component of the cost of a small listing. For example, comparing these findings with the median quantities from Table 3, we find that for cocaine the cost of delivery comprises around one-third of the cost for the median dead-drop. For amphetamine, the delivery cost is more than half of the cost for the

TABLE 6   Distribution of user ratings on Hydra.

Rating score	Share
10	96.0%
8–9	1.3%
5–7	1.2%
1–4	0.7%
0	0.8%
Mean rating	9.8

median dead-drop. This suggests that, while the market has adapted, the Russian laws introducing more stringent scrutiny of posted packages have still somewhat served to inhibit the online drug trade by increasing prices and thus implicitly decreasing the quantity demanded.

3.6 | Reviews and ratings

Table 6 presents the distribution of ratings that users leave after purchases. Similar to what was documented for other darknet marketplaces (Bhaskar et al., 2019; Červený & van Ours, 2019), ratings on Hydra predominately took the maximum possible value.

Despite that, our informants consistently describe that reputation was important to Hydra, particularly for consumers choosing between vendors. We hypothesize that the review text was more important than the numerical rating. For example, the fourth review in Figure 2 is critical of the product, stating that "the quality is a little low" yet still rates the item 10/10.[26] In Table C.1 in Appendix C, we provide more instances of such reviews.

To support this idea, we analyze the content of the text data. The average length of a review is 16.3 words. Table 7 presents words that were most widely used in reviews on Hydra. We can see that the language used by reviewers reflects the preferences of buyers on the platform. This supports our hypothesis that reviews were crucial for the system of reputation in the marketplace. In particular, a large set of words seems to be related to the delivery process, for example, "location," "touch" (this term is regularly used in reviews to state that it was possible to pick up the drug quickly), "find," "simple," and "quest." Other words seem to be used to discuss the product itself, for example, "quality" and "stuff." Finally, many words describe general satisfaction with the purchase: "thank you," "neat," "awesome," "super," "smooth," and so on.

To get more insight into how reviews could provide information about consumer experiences, we also separately analyze negative reviews. In the following, we restrict our analysis to reviews with the lowest possible rating of 0. The average length of negative reviews is much larger: 48.0 words. This suggests that users describe their negative experiences in more detail. Table 8 shows the most common words in negative reviews. We can identify two groups of words that were used with very high frequency. First, words like "dispute," "favor,"[27] "moderator," and "close" refer to the experience of consumers with the system of disputes (see Section 2.5.2). Second, words like "dead-drop," "location," and "not found" are related to the negative experience of picking up the dead-drop.

TABLE 7 Most frequent words in reviews on Hydra.

Word (translation)	Word (original)	Frequency
Thank you	спасибо	16.8%
Location	место	16.3%
Touch	касание	15.8%
Good	хорошо	14.0%
Quality	качество	13.2%
Shop	магазин	12.8%
Dead-drop	клад	11.2%
Stuff	стафф	9.5%
Pick up	забрать	7.3%
Find	найти	6.0%
Home	дом	5.9%
Awesome	отлично	5.7%
Take	брать	5.1%
Courier	кладмен	4.8%
Super	супер	4.2%
Simple	просто	4.2%
Smooth	ровный	4.1%
Quest	квест	4.0%
Weight	вес	4.0%
First	первый	3.6%

Note: The table excludes stopwords (in particular, words with general meaning, prepositions, and pronouns). All words are presented in their normal form. Frequency stands for the fraction of reviews in which a particular word occurs.

3.7 | Limitations of data

There are three major limitations of the listing data used in this analysis. First, the data set only covers April 2020, when COVID-19 lockdowns were first enacted in Russia. This likely affected both the demand and supply of drugs on Hydra, impacting the ability of couriers to hide drugs as well as the ability of consumers to collect dead-drops. The emerging studies on the effect of the COVID-19 pandemic on transactions in drug cryptomarkets suggest that the pandemic was associated with an increased rate of delivery failures in cryptomarkets (Bergeron et al., 2022). In addition, the study of online drug trade using Telegram in the Netherlands suggests heterogeneous effects of the pandemic on the popularity of different types of substances, with a decrease in the popularity of "party drugs" such as ecstasy, cocaine, and amphetamines, and an increase in the popularity of psychedelics (Blankers et al., 2021). While the relative popularity of drugs may have changed in this period, analysis by Flashpoint, Chainanalysis (2021) suggests that Hydra revenues actually decreased by only ≈ 10% in April 2020 relative to February 2020. Hence, we believe that our policy implications drawn from the size of Hydra remain valid despite the limited period of our scraped data.

A second limitation is that the short interval of time covered by the data set prohibits us from analyzing the development of the marketplace. We hope that future studies will access a longer panel data set to allow for the analysis of the evolution of the Hydra marketplace over time.

TABLE 8   Most frequent words in reviews with the lowest rating on Hydra.

Word (translation)	Word (original)	Frequency
Shop	магазин	51.0%
Dead-drop	клад	36.4%
Location	место	28.6%
Dispute	диспут	28.5%
Not found	ненаход	26.5%
Favor	польза	22.0%
Take	брать	18.7%
Moderator	модератор	17.7%
Close	закрыть	14.8%
Find	найти	14.6%

Note: The table excludes stopwords (in particular, words with general meaning, prepositions, and pronouns). All words are presented in their normal form. Frequency stands for the fraction of reviews in which a particular word occurs.

Finally, we used secondary data sources and cannot publicly provide the names of individuals and organizations who supplied the data due to the concerns over anonymity raised by these parties. We understand that this might further limit the potential external validity of our findings due to replication difficulties (Munksgaard et al., 2016).

4 | SHUTDOWN OF HYDRA

We provide a brief description of the shutdown, and how the landscape of the drug market has changed. These changes highlight the impact of Hydra on the Russian drug market and will have important implications for our policy analysis in Section 5.1.

The Hydra marketplace was shut down on April 5, 2022, when German police seized the servers hosting the marketplace in a joint operation with U.S. enforcement agencies (Bloomberg, 2022; Wall Street Journal, 2022). On the same day, the U.S. Treasury issued sanctions against the marketplace (U.S. Department of the Treasury, 2022) and the U.S. Department of Justice obtained an indictment against the alleged administrator of Hydra (United States v. Pavlov, 2022). We are not aware of any evidence that the Russian authorities were involved in the operation or were informed about it. The shutdown of Hydra by the two Western governments might be construed as a part of the increasing number of Western sanctions against Russia in 2022. We are not aware of any evidence that these two events are connected. Moreover, in its press release, the Federal Criminal Police Office of Germany stated that the corresponding investigation started in August 2021 (Bundeskriminalamt, 2022). Despite some market participants expressing expectations that Hydra would be brought back online, as of the time of writing, the marketplace has been inoperable for more than a year.

In the initial days after the shutdown, buyers and sellers attempted to trade using the two darknet forums that had been popular among Hydra users: LegalRC and RuTor (see also Section 1.2). In addition, sellers began actively using their own websites or bots on the Telegram messenger as a communication channel for selling drugs (Lenta, 2022).[28] Despite Telegram bots remaining popular, the demand for a centralized platform quickly led to the fast growth of previously small darknet marketplaces over the following weeks. Among the marketplaces that grew in

the wake of the Hydra shutdown, the largest at this moment are "OMG," "Blacksprut," "Mega," and "Solaris" (Chainalysis, 2023a; TRM Labs, 2022). Another marketplace that is popular now, "Kraken," opened in December 2022. Kraken presents itself as a successor of Hydra managed by people who were associated with the closed marketplace (Novaya Gazeta Europe, 2023).

According to media reports, there is intense competition between the new marketplaces. In particular, they are alleged to have engaged in multiple attempts to advertise themselves offline (VICE, 2023) or using social media (Novaya Gazeta Europe, 2023). Importantly, it has been reported that the competitive environment spurred a long series of large-scale hacker and distributed denial-of-service (DDOS) attacks to be organized by markets against their competitors (Lenta, 2022; Novaya Gazeta Europe, 2023; VICE, 2023). These attacks alongside the lower technical capacity of these platforms, have meant that they have struggled to support a large number of visitors, and they are considered to be much slower and less convenient than Hydra. The fact that individual marketplaces will regularly be inoperable forces market participants to operate in multiple marketplaces. This increases search costs for consumers, requiring that they spend time locating multiple marketplaces and suitable sellers on each marketplace. For sellers, this increases their administrative costs due to the additional management effort required to operate on multiple platforms.

The implications of the closure have extended beyond merely a reduction in "convenience." As mentioned in Section 2.5.1, the reputation mechanisms of darknet markets are an important feature that allows these markets to operate in a context that would otherwise give rise to significant moral hazard. However, in the new volatile environment, sellers have less incentive to sustain a positive reputation relative to when Hydra was the de facto monopolist. Reports of fake listings where drugs are not deposited are considered more common and concerns about drug quality have increased. These problems are exacerbated by the lower functionality of these platforms. For example, users report a lack of reliable moderation on these platforms, which, alongside the less reliable reputation/history of participants, inhibits the possibility of having disputes resolved satisfactorily (Lenta, 2022).

5 | DISCUSSION

5.1 | Shut-down policies

The case of Hydra demonstrates that a darknet marketplace that is allowed to grow without interruption can dominate the online market, reaching an extremely large size and high level of sophistication. Given the finite resources available to law enforcement, the decision of whether to attempt to shut down darknet markets requires an analysis of the overall impact of these shutdowns. We believe that the counterfactual of Hydra highlights the key costs of such an outcome and illustrates the trade-off that governments face when choosing whether to invest in shutting individual darknet marketplaces down. In this section, we outline the major arguments in favor and against shutting down drug cryptomarkets and augment them with the evidence we get from the analysis of Hydra. We start by listing the arguments supporting the shutdown of growing darknet marketplaces.

1. *Large marketplaces may increase demand for drugs.* We do not have any reliable evidence of the changes in drug use related to Hydra due to the unavailability of surveys or administrative data. However, we speculate that there are several mechanisms for an increase in consumption

that are present when a single large marketplace exists for a long time. In particular, the presence of a large darknet marketplace decreases many of the salient costs of consuming drugs. A single well-known platform decreases the search costs for consumers wishing to enter the market. This holds not just for consumers who were inexperienced in drug use but also those who wished to consume new drug types or consume drugs while away from home, given the wide variety of drug types (see Section 3.2) and cities (see Section 3.3) on the platform. In addition, Hydra was more convenient to use than smaller marketplaces, providing consumers with a well-developed website that was fast and reliable. This reliability was seen to decrease the risks consumers inherently face in an illegal market. The risk of an exit scam was low, thus reducing the possibility that users would lose funds deposited on the website. Meanwhile, the effect of marketplace-provided moderation in combination with a reputation system founded on a long history of operation reduced the risk of being scammed by a seller. These reductions in the salient costs of drug consumption relative to smaller markets should serve not only to encourage some consumers to switch from street trade to the large online market but also to encourage some potential consumers to switch from abstaining to consuming on the platform. This is partially corroborated by correlational evidence: the Russian Federal State Statistics Service reported an increasing number of overdose deaths in Russia in 2020 and 2021, with experts citing Hydra as a crucial factor (Meduza, 2022).

2. *Large marketplaces increase the supply of drugs.* We find that Hydra had a substantial number of wholesale drug listings (see Table 2). We also document that precursors were actively traded on Hydra. Finally, Hydra had job listings for individual producers, such as chemists to synthesize drugs and marijuana growers. This suggests that a large darknet marketplace facilitates communication between agents on the supply side of the drug market. This should have two effects. First, it should encourage entry into the market by lowering the fixed costs associated with establishing an operation to sell drugs. This is because it reduces search frictions in sourcing employees, precursors, and wholesale quantities of drugs. Second, greater transparency in the market for precursors and wholesale quantities should increase competition and thus lower input costs. In the context of the highly competitive market environment of Hydra seen in Section 3.4, these lower input costs should have been passed to consumers through lower prices. Hence, the greater competition among retail suppliers as well as in the wholesale market should have led to lower prices and an increase in overall traded quantities.

3. *Persistent impact of large markets.* After the shutdown of Hydra, several marketplaces quickly expanded their operations to fill the gap left by Hydra (see Section 4). This trend is similar to the experience in the Western world, where users migrated to substitute markets shortly after shutdowns (Bhaskar et al., 2019; Soska & Christin, 2015). However, this does not necessarily mean that shutdowns are ineffective. The Russian experience illustrates the lasting impact of allowing Hydra to grow, creating the foundation for a significant volume of online transactions. Although the current generation of Russian darknet markets is smaller than Hydra was at its peak, TRM Labs estimates that overall Bitcoin wallets associated with these new marketplaces received 24% more Bitcoin deposits in the 5 months after Hydra's shutdown than Hydra had received in the 5 months prior (TRM Labs, 2022).[29] Existing users of darknet markets, both buyers and sellers, have already paid the "fixed costs" of acquiring the knowledge necessary to operate on these platforms. These costs include understanding how to use TOR and Bitcoin in a way that maximizes anonymity, safe methods of locating markets in the darkweb, and in the case of sellers, the logistics involved in this new form of distribution. This means that a large proportion of participants can quickly migrate to new markets. Thus, if a large darknet market incentivizes potential users to learn to operate on these platforms (e.g., because of their per-

ceived reliability and convenience), these effects are persistent. Hence, allowing a marketplace to grow unchecked risks law enforcement losing the ability to shrink the size of the online drug trade in the future. This is underscored when considering the contrast to the Western experience where regular shutdowns of markets have prevented the online drug trade from becoming established, limiting the number of users available to migrate to new marketplaces following a shutdown. This is evidenced by the fact that TRM labs estimate that the four largest of the new Russian darknet markets which have grown following the demise of Hydra account for 80% of global darknet cryptocurrency transactions while the largest Western market–ASAP Market–accounts for just 7% (TRM Labs, 2022).

4. *Removal of dominant markets increases competition and promotes destructive attacks.* As described in Section 4, after the shutdown of Hydra, the emerging marketplaces have engaged in a sequence of DDOS attacks on each other as they vie for dominance. By shutting down Hydra, the resulting competition between new entrants itself serves to destabilize the online illegal drug trade without requiring the government to actively commit additional resources. The markets that developed in the aftermath of Hydra have actively worked to undermine each other. For example, one of these markets, Solaris, was temporarily shut down by hackers working for its competitor Kraken (VICE, 2023). In contrast, prior to the shutdown, the dominant position of Hydra appears to have given it the resources to protect itself from similar threats.

The reasons above highlight the strong negative effects of allowing a large dominant marketplace such as Hydra to exist. However, there are also important arguments against directing drug enforcement resources toward aggressively shutting down darknet marketplaces and instead allowing the development of a single dominant marketplace.

1. *Reputation system increases the quality of drugs.* In Sections 2.5.1 and 3.6, we describe the importance of available feedback for consumers choosing a vendor on Hydra. Previous studies have also highlighted the importance of reviews and reputation on darknet marketplaces (see Espinosa, 2019; Hardy & Norgaard, 2016; Aldridge et al., 2018; Bhaskar et al., 2019). The substantially longer history of Hydra resulting in a greater number of transactions suggests that reputation served as a substantially more informative signal on Hydra than other marketplaces. This allows consumers to better differentiate between sellers who sell purer drugs and those who may use dangerous adulterants. In addition, it would increase equilibrium quality beyond that of smaller marketplaces as the incentive to maintain a good reputation is stronger. Thus, a large monopolist marketplace can increase the quality of drugs, which in turn can improve health outcomes for consumers who otherwise would purchase drugs elsewhere. However, such an increase in the purity of drugs might also result in more overdose incidents, particularly in the case of opiates.

2. *Large marketplaces have incentives to self-regulate.* In Section 1.2, we report that Hydra forbade selling guns, poisons, contract killing, explosives, government secrets, and pornography. Importantly, it also forbade selling fentanyl and other drugs considered too dangerous. Hydra also claimed to audit the quality of drugs sold on the platform (see Section 2.5.3) and had representatives that supposedly provided medical consultations (see Section 2.5.6). This highlights that a large darknet marketplace has incentives to regulate participants on the platform and be concerned about its reputation. For example, a large marketplace has greater incentives to mitigate the risks of overdose or arrest for its users because it can expect to extract profits from them in the future (unlike a small marketplace operating in a fragmented market, which would observe only a small probability for a given user to return). Thus, a large marketplace to

some extent internalizes harm to its users. A reduced focus on shutdowns also incentivizes self-regulation in other ways, as illustrated by the rules of Hydra. When the government does not attempt to shut down all existing darknet marketplaces, marketplaces that primarily earn revenue through drugs benefit from prohibiting "socially reprehensible" goods such as contract killings, which would increase the attention of the police and the probability of a shutdown.

3. *Large marketplaces can be utilized for harm-reduction interventions*. A centralized marketplace is a convenient place for outreach programs to spread awareness among drug consumers. For example, Davitadze et al. (2020) describe an effort by an NGO to provide information about HIV and hepatitis C and advertise its harm reduction services on Hydra's forum. Interestingly, Hydra collaborated with the NGO and promoted this information on its Telegram channel. Similarly, Bancroft (2017) shows how a large marketplace can become a platform for drug consumers to share information about harm reduction. Barratt et al. (2016) present evidence of more controlled drug consumption within online drug marketplaces.

4. *On-line marketplaces may reduce violence*. At the moment, we have no quantitative evidence of the effect of Hydra on crime levels in Russia. However, prior research has shown that online marketplaces produce less violence than traditional street trade due to reduced face-to-face contact (Aldridge et al., 2018; Aldridge & Décary-Hétu, 2014). The scale of Hydra meant that it was able to facilitate supply-side transactions including recruitment and wholesale drug trade. Hence, the benefit of reduced violence should have extended up the supply chain and thus the benefits of reduced violence were likely stronger than in a situation where only retail trade is digitalized.

5. *On-line marketplaces increase the transparency of drug markets*. By its nature, the market for illicit drugs is extremely hard to observe by the government. An online marketplace can be scraped, and this data can be used to inform drug policy in the future. For example, this can help to track changes in the level of drug consumption in the country. It can also allow authorities to observe dangerous trends sooner such as consumers switching to substances associated with high risks.

Both the positive and negative effects of closing growing darknet marketplaces down can be substantially amplified because large marketplaces are likely to benefit from economies of scale. In other words, large marketplaces have the tendency to grow extremely large because they become more efficient. First, a large marketplace can invest more in the development and support of its website.[30] In Section 2.5, we demonstrate the level of sophistication of a large marketplace like Hydra. Second, the popularity of the market might grow even more when it increases the number of listings available. Our informants specifically mentioned that Hydra was growing quickly in a particular city after dead-drops became available in all neighborhoods of the city and drug consumers learned that they could always find a listing near them.

The example of Hydra shows new and important aspects of the trade-off faced by governments around the world in determining whether to pursue a policy of indiscriminately shutting down popular darknet marketplaces. In particular, we show that a large marketplace like Hydra can facilitate communication between drug producers and drug sellers while also lowering the non-monetary costs users face when choosing to purchase drugs. We also show the potential benefits of large darknet marketplaces that previously attracted little attention. Specifically, we show that Hydra had an efficient reputation system that could have positively affected the quality of the drugs and the related health outcomes of its customers, which was able to shift even wholesale drug trade online, thus potentially reducing much of the gang violence often associated with these transactions, and was self-regulating in several ways.

5.2 | Policy implications from Hydra's unique features

As a marketplace, Hydra was similar to Western drug cryptomarkets in terms of sociotechnical practices used to solve three major cooperation problems in online drug trade: valuation, competition, and cooperation (Tzanetakis, 2018b). At the same time, Hydra operated in an environment that had several distinctive features compared to the Global North: the country can be characterized by a punitive drug policy (Golichenko & Chu, 2018), lack of officially sanctioned harm reduction practices (Harm Reduction International, 2022), and strict control over mail delivery (Saidashev & Meylakhs, 2021). This, coupled with the geographical size, large population, and geopolitical position of the country, influenced the operation of the online drug trade in three major ways. We discuss these factors and their policy implications below.

Dead-drop delivery
As an informal institution, dead-drop delivery is similar to postal delivery as it does not require a physical meeting between transaction parties (Tzanetakis, 2018b). At the same time, dead-drops are an innovative way to circumvent the inherent risks related to the postage delivery of illegal drugs in Russia. It also has the advantage of being substantially faster. In a situation in which postage is associated with a high probability of law enforcement apprehension (Saidashev & Meylakhs, 2021), the online drug market in Russia adopted dead-drops as a dominant way to trade drugs. In response, Russian police seemed to focus on apprehending people involved in specific suspicious activity, such as planting hidden packages or looking for them in parks and other urban areas. Given the undesirability of "stop-and-frisk" policies in the United States, the use of this delivery method would present a difficult trade-off for law enforcement: specifically, a choice between relying on a controversial and potentially damaging policy or facing a reduced ability to intercept retail drug deliveries. Thus, our analysis confirms the view of Aldridge and Askew (2017) that governments in the Western world should pay close attention to this possibility.

Financial regulation
One element of the Russian context that appears to have significantly contributed to the popularity of Hydra was the ability to deposit money using QIWI terminals (see Section 2.2). This method of payment protected the anonymity of customers' financial accounts and lowered the technical barriers to participating in darknet markets. The literature has stressed the importance of financial regulation to limit darknet marketplaces (Hutchings & Holt, 2017). It is possible that while the regulation of cryptocurrency exchanges becomes stricter and cryptocurrency transactions become less anonymous, the role of alternative payment methods in the darknet drug trade will increase. The experience of Hydra shows that government regulation of money-sending services similar to QIWI is a crucial step in restricting the operations of drug cryptomarkets.

Harm reduction
In Sections 2.5.3 and 2.5.6, we describe how Hydra employed harm reduction methods: drug-related medical consultations and selective quality tests of drugs sold. These efforts by the platform highlight the high demand for harm reduction services in countries that currently employ punitive measures against drug consumers. This highlights the need for greater provision of harm reduction information by the governments in these countries which would ensure that drug users are able to access reliable and trustworthy information from medical experts. Given that there are small (if any) long-term deterrent effects of darknet marketplace shutdowns on crime

(Miller, 2020), this suggests that shifting the focus from the punitive/shutdown approach to online drug markets toward harm reduction might be a more effective government response. This is in line with existing evidence on interventions to disrupt drug supply in the pre-cryptomarkets era: "None of the prevention, treatment, or enforcement have demonstrated the ability to affect the extent of drug use and addiction; the best that government interventions can do is to reduce the damaging consequences" (Hunt et al., 2011, p. 225). In light of this, it has been suggested that a more effective use of drug enforcement funds may be to incentivize drug markets to operate in a manner that reduces the associated societal harm (Curtis & Wendel, 2007).

6 | CONCLUSION

This paper provides a unique quantitative overview of Hydra, an illegal darknet marketplace that was dominant in Russia during 2015–2022. Using two novel data sets of scraped data, including drug listings and consumer reviews on Hydra, we provide estimates of drug buying behavior online: the popularity of various drugs, their prices, volumes, and geographic distribution both between Russian cities and within districts of the two largest cities – Moscow and Saint Petersburg. We also provide evidence suggesting that until its closure in April 2022, the Hydra marketplace had been the dominant method of obtaining drugs in Russia.

Possibly the main feature that distinguished Hydra from darknet marketplaces in other countries and accounted for its market dominance was its age. Following the shutdown of RAMP in 2017, Hydra was allowed to develop and establish its market position over many years until its eventual shutdown in 2022. In contrast, of the 83 Western darknet marketplaces studied by Bhaskar et al. (2019), the original Silk Road was the longest surviving at 976 days of operation. This stability appears to have allowed Hydra to gain a market share far in excess of that achieved by darknet marketplaces in the West where the offline street trade still accounts for the vast majority of trade. Using cryptocurrency-based transactions, encrypted messaging, and no physical contact between buyers, sellers, and couriers, Hydra became the largest online illegal marketplace for drugs so far. It serves as an example of the potential evolution of the online drug market if a given darknet market is allowed to grow unchecked for several years.

This analysis has several limitations. First, we only use listing data from April 2020. This period was a peak of the COVID-19 pandemic which might have affected the composition and structure of the illicit drug market in Russia. Second, we are operating with a very short panel data set encompassing 1 month. Future studies can take advantage of a longer panel series and analyze seasonal and other temporal effects in prices, supply, and other indicators of the drug cryptomarkets, which can also result in more nuanced results with causal interpretation.

An additional limitation of the study is its reliance on media coverage and documents from international and government organizations to provide background information regarding the operation of Hydra and the situation following its closure. Because of the scarcity of published peer-reviewed studies of Hydra and, more generally, online illicit drug markets in Russia, we had to utilize other sources, such as journalistic investigations and state-affiliated documents. However, we acknowledge that these might be biased and limited in their views and positions by selective reporting, sensationalism, or specific political agendas.

We believe that the case of Hydra illustrates that there are many sides to the trade-off that governments face when they make the policy choice to shut down darknet marketplaces. Quantification of this trade-off is important for addressing the problem of drug abuse. We hope future research on illegal drug marketplaces will develop in this direction.

CONFLICT OF INTEREST

The authors confirm that they have no conflict of interest to declare.

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ENDNOTES

[1] On the April 5, 2022, German federal police announced that in a joint operation with U.S. enforcement agencies, they had seized Hydra's Germany-based servers and shut down the site (Bloomberg, 2022; Wall Street Journal, 2022). In relation to this operation, the U.S. Department of Justice has obtained an indictment against Dmitry Olegovich Pavlov for his alleged role in operating the company that administered Hydra's servers (United States v. Pavlov, 2022). The terms of the indictment are conspiracy to distribute narcotics and conspiracy to commit money laundering.

[2] The marketplace that this paper discusses should not be confused with another marketplace that had the same name and was shut down in 2014 (U.S. Department of Justice, 2014).

[3] While wholesale could be considered any sale to retailers for the purpose of resale, for all quantitative analysis we will be following Demant et al. (2018) and defining it as any transaction which a value above $1000.

[4] Pre-hidden drug stashes that made the transactions possible without any physical interaction between sellers and buyers.

[5] The quality of these consultations, as well as the qualifications of the people who were providing them, remains unclear.

[6] To the best of our knowledge, this paper is the first comprehensive quantitative assessment of this marketplace in academic literature. Zvonka (2017) is an early analysis of data scraped from Hydra and RAMP, the marketplace that Hydra initially competed against until RAMP was closed in 2017. Proekt (2019) is a journalist-led investigation conducted in 2019 which was one of the first discussions of Hydra in the media.

[7] Some sellers on Hydra also used mail for selling drugs, though dead-drops were by far the most widespread delivery method.

[8] Exit scams refer to situations where the operators of a darknet platform shut down the site and abscond with the funds of users held by the platform either in escrow or account balances.

[9] In Section 4, we discuss marketplaces that became popular after the shutdown of Hydra. While all of them existed before 2022, they did not have significant popularity prior to Hydra's shutdown (see the analysis of darknet market shares in Chainalysis, 2021 and 2022).

[10] Currently, the website of Hydra is not accessible. We have saved HTML files for these pages.

[11] All materials are available upon request from the authors.

[12] The only information that a potential user was required to provide was login, display nickname, and password.

[13] Additionally, Hydra had a feature called "roulette," which allowed consumers to participate in a lottery. Participation cost less money than the product price, but consumer would win the desired product with a probability less than 1.

[14] The saved HTML files are available upon request from the authors.

[15] The "snow dig" method was introduced after the time when our data set was collected.

[16] We find that the ratio of mailed listings to instantaneous dead-drop listings is ≈10% for LSD and ≈5% for mushrooms, which is several times larger than the same ratio for other drugs. Unlike instantaneous listing, one mailed

listing does not correspond to a particular district and instead can serve the whole country. Thus, this ratio is likely to underestimate the proportion of mailed orders for these drugs. This is in line with the anecdotal evidence from our informants that mail was mainly used for psychedelics on Hydra.

[17] The user could add additional comments to the review during the first 36 hours.

[18] For sellers without the status, proceeds from disputed sales were held by the system until a decision was made by a moderator.

[19] Here and below, we use the exchange rate for May 2020, roughly equal to 74 rubles per U.S. dollar.

[20] When we observe several reviews that have the same text and are left by the same user, we only keep one of them in the data. We have 414,700 reviews prior to removal.

[21] We will similarly be removing duplicates any time we aggregate listings across days.

[22] Bhaskar et al. (2019) collected data for over a year and observed lower numbers of sellers on the other major marketplaces: 902 on The Silk Road, 796 on Silk Road 2.0, 1754 on Evolution, and 1836 on Nucleus.

[23] Some stores appear to use "holding" prices when they exhaust their inventory. Rather than removing a listing, they would instead set a price so high that no consumer would attempt to purchase the listing.

[24] Which often is done through a so-called *master dead-drop*.

[25] The results are robust to removing fixed effects from the specification.

[26] While ratings are given out of 10, when displayed next to reviews they were converted to a rating out of 5.

[27] We find that this word most often was used to express that a dispute was closed in favor of the shop.

[28] As is discussed in Section 2.2, selling outside of the marketplace was forbidden by the rules of Hydra. Thus, before the shutdown the largest shops on Hydra could not operate elsewhere under the same brand.

[29] This analysis relies on known links between Bitcoin wallets and the relevant markets, so there is some uncertainty in the exact number of transactions these darknet markets receive. Chainalysis, using similar techniques, estimates that total darknet revenues are still slightly below their levels before the shutdown of Hydra (Chainalysis, 2023a). Regardless, it seems clear that the reduction in transactions on the Russian darknet has been short-lived.

[30] These costs typically are higher for a darknet platform than for a "clearnet" platform. For example, software engineers must be compensated more for working on an illegal project, and hosting a darknet website is more expensive.

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APPENDIX A: WITHIN-CITY DISPERSION

In Section 3.3.1, we discuss that the spatial distribution of dead-drops within a city responds to variation in the demand and thus reflects the socio-economic differences between city districts. In particular, in Figure 4 we illustrate this for Moscow. In Figure A.1, we present maps with the
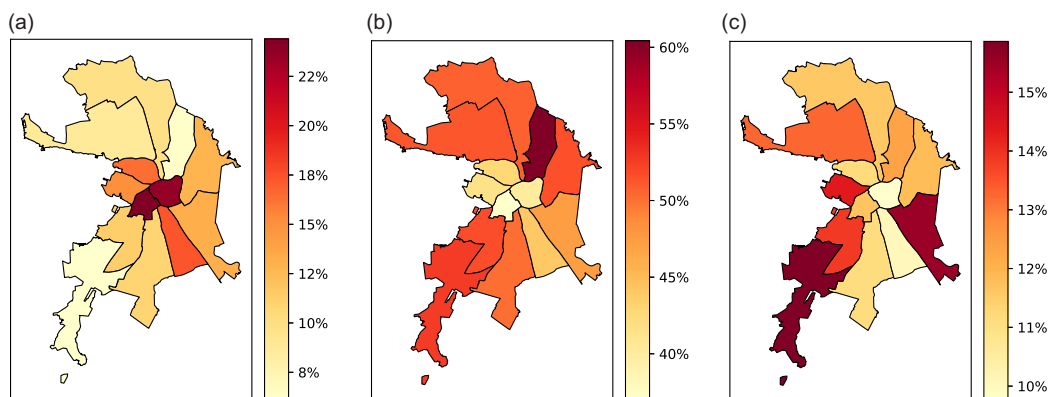
FIGURE A.1 Spatial distribution of dead-drops in Saint Petersburg. [Color figure can be viewed at wileyonlinelibrary.com]

Note: Map of Saint Petersburg showing the proportion of listings of the given drug type as a proportion of the total number of drug listings in that district. Synthetics include methamphetamine, amphetamine, MDMA, alpha-PVP, MDPV, and mephedrone. Only districts with the largest number of dead-drops are included: Admiralteysky, Vasileostrovsky, Vyborgsky, Kalininsky, Kirovsky, Krasnogvardeysky, Krasnoselsky, Moskovsky, Nevsky, Petrogradsky, Primorsky, Frunzensky, Tsentralny.

spatial distribution of listings for Saint Petersburg, the second largest market on Hydra. Similarly to Moscow, cocaine is concentrated in the center of the city, while cheaper drugs like mephedrone and marijuana are more present in peripheral districts.

APPENDIX B: OTHER SCREENSHOTS

FIGURE B.1 The page of a Kraken vendor describing job for couriers. [Color figure can be viewed at wileyonlinelibrary.com]

APPENDIX C: EXAMPLES OF REVIEWS

TABLE C.1 Examples of reviews with highest rating and negative sentiment.

Date	Drug	Translation	Original	Rating
June 4, 2020	Amphetamine	Fast collection, with respect to the courier. But the quality is below average, I expected a lot more. Did not get any pleasure or feelings from it.	В касание, минеру респект. Но качество ниже среднего, я ожидал на много большего, а не получил от этого ни удовольствия ни ощущений	10
June 9, 2020	Heroin	Fast collection, the product is damp. Brothers, do not even think to buy heroin from here, the dead-drops are from the winter, and the product does not work well.	Забрал в касание, товар отсырел, братчанин, не вздумай тут покупать хмурый, зимние адреса,товар прёт ну точно не 777	10
June 9, 2019	Mephedrone	Did not find the dead-drop, but I can only blame myself. Also, do not want to start a dispute because of just 0.5 grams. I guess I will not buy dug dead-drops for a while.	Сокровище не нашёл, но тут скорее могу винить только себя, да и из-за 0.5 диспут открывать не хочется.. Пожалуй, не буду больше пока брать прикопы)	10
August 1, 2020	Amphetamine	Fast collection, also an interesting experience. But the quality is quite bad… No offense guys. Rating 10/10/10, will not lower it.	В касание! Интересный опыт по касашке… Но качество чёт подводит…. Без обид, пацаны. Оценка 10.10.10 понижать не буду	10
May 26, 2020	Mephedrone	We found everything but with lots of complications. The product was around the specified location.	Все нашли но с большими трудностями товар был рядом с указанным местом	10
February 15, 2019	MDMA	In general it was good, but some of the pills were broken. The courier confuses left and right. Liked the quality.	В целом всё в порядке, но таблы оказались поломанные. И кладмен путает лево и право. Качество понравилось	10

(Continues)

TABLE C.1   (Continued)

Date	Drug	Translation	Original	Rating
April 3, 2020	Marijuana buds	Good buds but not dried enough. Thus, the quantity actually is smaller than specified	Хорошие шишки, только недосушены, соответсвенно количество меньше чем заявлено	10
May 20, 2020	Hashish	Did not find the dead-drop, it was hidden badly and the location was marked badly. When you pay 2800 rubles per 1 gram you expect a good dead-drop. The support responses are slower than once per day. In the end, they gave me a coupon. Overall, not satisfied with the shop.	Был ненаход, откровенно говоря плохо спрятали и плохо метку поставили, когда 2800 за 1г. отдаешь рассчитываешь на нормальную закладку, поддержка у магазина отвечат даже не раз в сутки, в итоге разошлись купоном, всем магазином в целом не доволен.	10

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