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Original Article

Trust intermediary in a cryptomarket for illegal drugs

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Cooperation without third-party enforcement is particularly puzzling in illicit online markets given the anonymity of online exchanges in the 'dark web' and the asymmetry of information between buyers and sellers. Most of the literature investigates the effects of reputation systems on sales. Less is known about the role of (semi)institutionalized solutions to trust problems, such as the escrow service, which deposits payments for online purchases with the market platform and releases them only upon confirmation of the item delivery by a customer. We study the effect of such a trust intermediary on sales in a cryptomarket for illegal drugs. Using a large dataset of illegal online transactions, we estimate two sets of fixed effects models predicting the sellers' choice to offer the trust intermediary and examine the effects of such a choice on sales. Our results indicate that the trust intermediary *reduces* online drug sales. We explain this finding by showing suggestive evidence that escrow may crowd out traders' trust and reciprocity. Our findings have implications for theories of the role of institutions in online markets and offer policy recommendations for law enforcement agencies.

Introduction

Third-party enforcement is considered to be one of the most effective solution to the problem of social order (Nozick, 1974; Fehr and Fischbacher, 2004; Baldassarri and Grossman, 2011). One important modern manifestation of the problem of social order is the trust problem that occurs among exchanging partners in anonymous settings, such as online marketplaces.[1] To address this problem, online marketplaces have developed various institutional arrangements to facilitate and protect anonymous exchange, even in the absence of third-party enforcement. Most platforms offer a reputation system that disincentivizes dishonest behaviour by allowing customers to look into the history of transactions involving particular vendors (Diekmann *et al.*, 2014).

Other institutional forms of assurance in online exchange—embodied in the market platform—oversee the behaviour of the exchanging partners by acting as an intermediary in trust. One of the most common trust intermediaries in online exchange is the *escrow* service. Using this assurance device, the trading platform acts as a guarantor that holds payments for online purchases until the buyers have confirmed the receipt of a purchased product. In the absence of such confirmation, the platform adjudicates disputes. Such a trust intermediary is meant to solve trust problems that are inherent in online exchange—namely, the fact that the buyer has to pay in advance for products of uncertain quality and that s/he faces the risk that the products are not sent or delivered.

However, there is a crucial difference between the role of the market platform as trust intermediary and the classical guarantor described by Coleman (1990). A classical guarantor has a trust relationship with the final trustee and incurs financial risks associated with the behaviour of that trustee. By contrast, offering the escrow service, the market platform simply reverses the time asymmetry in the exchange between buyer and seller, thereby protecting the buyer from a possible misconduct of the seller, but does not incur financial risks. How does such a guarantor affect exchange?

It is widely believed that semi-formal trust intermediary institutions such as escrow solve the trust problems in peer-to-peer online exchanges (Hu *et al.*, 2004; Odabaş, Holt and Breiger, 2017). Yet, some scholars have questioned these beneficial effects of escrow (Holt, Smirnova and Hutchings, 2016). Theoretical

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predictions are likewise mixed. The classical studies of assurance devices find that trust intermediaries facilitate exchange. Others, however, argue that the costs of escrow tend to be higher than the expected benefits, undermining the efficiency of this trust intermediary (Antony, Lin and Hu, 2006).

In the present study, we investigate how the escrow service affects online trading in a very large cryptomarket (Alphabay). Cryptomarkets are online marketplaces located on the dark web, trading in illegal goods and services (more details about Alphabay in Supplementary Appendix A1). We focus on transactions involving illegal drugs.

Cryptomarkets for illegal drugs offer an interesting setting to study the effects of trust intermediaries. On the one hand, cryptomarkets are the kind of marketplace where escrow should arguably work best. First, the illegal nature of the trade implies that buyers and sellers are unable to rely on other institutional legitimate third-party enforcement services, namely, contract laws or legal oversight (Beckert and Dewey, 2017; Bakken, Moeller and Sandberg, 2018). Second, theoretically, the adoption of a trust intermediary is strategically rational only if the probability of encountering a dishonest exchange partner is not too small—a condition likely to hold in cryptomarkets (Hu *et al.*, 2004). Third, the anonymity of cryptomarket exchanges makes the development of stable dyadic trading outside the platform—based on reciprocal acquaintance—difficult (for an exception, see Childs *et al.*, 2020). All these factors should reinforce the demand for semi-institutional forms of assurance in cryptomarkets.

On the other hand, in cryptomarkets, the trust intermediary intended to protect the exchanging partners from fraud is offered by the market platform, which is by definition legally unaccountable and thus less credible—as a guarantor—than a legal platform (Moeller, Munksgaard and Demant, 2017). In addition, law enforcement authorities can disrupt the service and seize cryptocurrencies deposited in escrow at any time (Van Buskirk *et al.*, 2017; Ladegaard, 2020) . For all these reasons, traders may be sceptical about the benefits of using escrow in cryptomarkets. Therefore, whether the availability of an escrow service affects sales positively or negatively in a cryptomarket remains an empirical question. The present study addresses this question by investigating (i) determinants of the sellers' decision to offer escrow payment and (ii) the effects of the payment method chosen by the sellers (i.e. escrow vs advance payment) on the volume of sales.

Theory and hypotheses

The literature on the use of escrow and other semi-formal assurance mostly points to the likely positive effects of escrow on sales (Hu *et al.*, 2004). However, these predictions are typically derived from theoretical models that are rarely tested in empirical analyses (for exceptions, see Holt, Smirnova and Hutchings, 2016; Munksgaard, 2023). Evidence from lab experiments, by contrast, suggests more sobering conclusions (Bracht and Feltovic, 2008). Moreover, conclusions drawn from legal online marketplaces may not apply to illicit online trade, where all trading activities are anonymous and the platform administrators who set the rules are largely unaccountable.

A useful framework to analyse this ambivalent relationship between escrow and illicit online exchange comes from game-theoretical models of trust games with commitment devices (e.g. Raub, 2004).[2] The escrow system serves the same purpose as the commitment devices postulated in these theoretical models: it is meant to facilitate transactions in a risky environment. Raub's (2004) model makes three assumptions that are likely to hold in the cases of escrow. First, the model assumes that both honest and dishonest types of sellers exist, and the buyers do not know the seller's type before entering the interaction. Second, even if the seller is honest, the outcome of the transaction is uncertain, that is, there is a small probability that something goes wrong. The item can be lost, and the seller may appear to have behaved dishonestly even though she did not, for example, because the police discovered and impounded the illegal item. Third, the model also assumes that the seller has the option to post a hostage, offering some form of guarantee that protects the buyer against the transaction risks. Such an action is equivalent of providing security for customers by signalling one's honesty and thus increasing competitiveness.

Hu *et al.* (2004) present a more complex game-theoretical model—specifically designed to analyse the viability of the escrow services as trust intermediaries in online (legal) markets—that also assumes the existence of honest and dishonest types. In this model, the feasibility of the escrow service from the traders' point of view depends crucially on its cost and on the prevalence of dishonest types in the market. In cryptomarkets, the prevalence of dishonest types is certainly higher than in legal markets. Thus, the traders could be willing to pay a higher fee for the escrow service (Hu *et al.*, 2004). However, as stated above, in cryptomarkets more sources of uncertainty are present than in legal online markets, including possible mistrust towards the platform administrators and fear that law enforcement authorities overtake the platform and freeze all the assets, including cryptocurrencies deposited in the escrow.

In sum, in cryptomarkets, such as Alphabay, sellers decide whether to offer escrow or not. Buyers

cannot select the payment method, but they can choose between alternative offers of the same item—sometimes even from the same seller—that come with different payment methods. The choices of sellers and buyers are thus sequential and closely interrelated, mirroring the structure found in formal game-theoretical models (e.g. Hu *et al.*, 2004; Raub, 2004). Who thus uses semi-formal trust intermediaries, such as the escrow services, while trading illegal drugs online? And, how does the use of these trust intermediaries affect sales in cryptomarkets?

Determinants of escrow

From the seller's point of view, the escrow alters the decision sequence in a way that introduces an element of risk (Afilipoaie and Shortis, 2018; Ladegaard, 2020). Under advance payment, the seller only ships the goods upon receiving payment. Therefore, the seller faces no risk of incurring losses. By contrast, under escrow payment, the seller receives the payment only after the buyer has received the item and confirmed it to the platform. Therefore, selling under escrow implies that the payment to the seller is delayed and somewhat less certain: cryptocurrencies are highly volatile, and sums deposited in an escrow wallet—pending confirmation from the buyer—are subjects both to the risk of devaluation and to the risk of law enforcement seizure of the platform's assets (Ladegaard, 2020). Sellers may also fear platforms' exit scam, in which markets close and their administrator steal all cryptocurrencies deposited in escrow (Van Buskirk *et al.*, 2016). Moreover, to some extent, sellers are also uncertain about the true quality of their product (Reuter and Caulkins, 2004; Lakhdar *et al.*, 2013).[3] By offering escrow payment, vendors thus incur the additional risk that clients will be dissatisfied with the product and refuse to release the payment. These factors arguably make the escrow payment a less preferred option from the seller's perspective. At the same time, escrow is a default payment method in many cryptomarket, including Alphabay (see Supplementary Appendix A1). How thus do sellers get away with *not* offering the escrow service?

Transactions in a cryptomarket differ from the interaction assumed in the game-theoretical models of trust with commitments (Raub, 2004) in some important respects. These models generally assume that the interaction between seller and buyer is a one-shot game and the buyer has no information about the seller, besides what can be inferred from the seller's choice. For example, in signalling games, the choice to offer a commitment is a costly signal that reveals that the seller is an honest type (Spence, 1973; Przepiorka and Diekmann, 2013). By contrast, in terms of web service design, a cryptomarket is similar to any other online market platform. In exchange for a commission, customers can buy from a wide selection of sellers, they can buy repeatedly from the same seller, and there is a feedback mechanism allowing buyers to publicly rate every transaction and write a short review. Consequently, sellers can build a reputation.

In the literature on trust in embedded settings there is robust evidence that trust problems are easily solved when interactions are repeated (e.g. Camerer and Weigelt, 1988, see Barrera, 2008 for a review). Actors display higher trust in others with whom they had successfully exchanged in the past (Barrera, 2007). Once an exchange relationship is established, they tend to remain committed to their exchange partners even when presented with more attractive offers (Kollock, 1994). Commitment to a specific dealer is likely to be even stronger in a cryptomarket for illegal drugs, where customers are especially likely to return to the same vendors and buy more of the same product, provided that their trust was not abused (Décary-Hétu and Quessy-Doré, 2017; Duxbury and Haynie, 2018; Norbutas, Ruiter and Corten, 2020).

Thus, once vendors have established relationship with customers who are likely to return to buy products from them, *irrespective* of the payment method, they have incentives to gradually opt out of escrow in favour of advance payment. This allows them to avoid the costs and risks associated to the escrow without losing clients.

Hypothesis 1. The higher the number of recurrent customers a seller has, the less s/he is likely to prefer escrow to advance payment.

As argued by Yamagishi (2011), problems of trust are more salient when the social uncertainty inherent in an interaction is higher. Accordingly, every piece of information that reduces the uncertainty has the effect of moderating the problem of trust. As we stated earlier, the escrow system serves the purpose of reducing risk (social uncertainty in Yamagishi's terms) for the buyer. However, the reputation scores that are available in online markets, including cryptomarkets, serve the same purpose. The positive effects of reputation scores both on the number of sales per offer and on the price are consistent with various rational choice models describing embedded settings (Buskens and Raub, 2013). While it is still debated whether reputation increases prices (see Holt, Chua and Smirnova, 2013 vs Hardy and Norgaard, 2016; Munksgaard and Tzanetakis, 2022), there is some evidence linking reputation to higher sales in another cryptomarket (Przepiorka, Norbutas and Corten, 2017). Therefore, sellers with a good reputation should be more likely to opt out of escrow.[4]

Hypothesis 2: The higher the reputation score of a seller, the less s/he is likely to prefer escrow over advance payment.

Effects of escrow

Turning to the effects of escrow on the buyers' decision, theoretical models of trust games incorporating commitment devices generally predict that the use of commitments, such as the escrow, facilitates cooperation through various mechanisms. First, a commitment device, such as the escrow, can bind the seller to a cooperative behaviour, thereby significantly reducing the risk that trust is abused. Second, escrow can compensate the buyer for the loss that occurs when trust is abused or when the item is lost due to exogenous contingencies. Third, a commitment device can signal the seller's type, thereby allowing the buyer to avoid exchanges with dishonest types (Raub, 2004; Przepiorka and Diekmann, 2013). All these mechanisms predict a higher rate of successful transactions when commitment devices are available and used.

Hypothesis 3: Offers with escrow generate a higher number of successful transactions than comparable offers requiring advance payment.

In contrast to this line of reasoning, some scholars studying cryptomarkets highlighted possible counterproductive effects of escrow. Sellers are likely to raise the price for offers with escrow payment, in order to compensate for the risk that they are taking (Holt, Chua and Smirnova, 2013; Munksgaard and Tzanetakis, 2022). Higher prices, in turn, can reduce the appeal of escrow as an assurance device, and discourage buyers from purchasing products through escrow.

Moreover, the escrow would not have the same properties of a commitment device—as postulated in theoretical models—if the platform was *not* perceived to be as reliable as the contract law in a legal market. We can hardly rule out such a possibility. Note that, although the cryptomarket administrators have the power to ban users at their discretion, buyers do not have the possibility to hold the administrators accountable for their behaviour (Horton-Eddison and Di Cristofaro, 2017; Van Buskirk *et al.*, 2017). If buyers are indeed suspicious of escrow's reliability, the system is likely to backfire.

Last, there may be better options for ensuring trust in cryptomarkets than escrow. Scholars have shown that online drug traders' communities exhibit high levels of trust, operating according to strong reciprocity norms supported by reputation systems (Przepiorka, Norbutas and Corten, 2017; Masson and Bancroft, 2018; Munksgaard *et al.*, 2022; see also, Moeller and Sandberg, 2019). The introduction of the escrow payment may be incompatible with these forms of informal social control, thus crowding out trust between traders. In general, crowding out can occur when the introduction of institutions designed to promote cooperation undermines the intrinsic motivation to act cooperatively on the basis of trust (see Frey and Jegen, 2001; Bohnet and Baytelman, 2007; Mulder *et al.*, 2006). As a result, in our case buyers may be inclined to pass on the escrow offers and select into transactions that rely on informal social control. Based on these insights, we propose an alternative hypothesis regarding the effects of escrow on sales.

Hypothesis 4: Offers with escrow generate a lower number of successful transactions than comparable offers requiring advance payment.

How can we reconcile these contradictory predictions under Hypotheses 3 and 4? Paying a higher price for a safer offer may be more appealing for buyers with no or little information on the trustworthiness of vendors in the cryptomarket. Once a buyer has identified a seller with a history of positively rated transactions, however, things could change. A seller with a good reputation faces large potential damage from defrauding customers. Thus, once trust in a specific dealer has been established due to their reputation, a buyer will be inclined to pass on the escrow offer and opt for advance payment, especially if the latter comes at a lower price. Accordingly, we expect sellers to complete less sales with escrow, when they have a good reputation.

Hypothesis 5: The higher the reputation of a seller, the more the number of successful transactions per offer using escrow will decrease.

Until now we have discussed the risk associated with completing a transaction in a cryptomarket focussing on the buyer's perceived probability that things can go wrong and the buyer loses her money. However, even if that probability was perceived to be very small, the trust problem can be severe if the amount at stake is very high. In terms of the overall value, transactions on cryptomarkets are very heterogeneous, not only because the price per gram varies considerably depending on the substance sold, the country in which it is sold, and the country of origin, but also because the quantity exchanged in a single offer range between a few grams and several kilograms. High-stake transactions incentivize untrustworthy behaviour of the sellers. For very high-value transactions, the long-term costs of a single defection (negative feedback, possible closure of account, or loss of platform deposit of 300 USD) are much lower than potential short-term gains from dishonest behaviour (see Décary-Hétu and Leppänen, 2013; Holt, Smirnova and Hutchings, 2016). Ceteris

paribus, we thus expect that actors are more cautious when the stakes are higher. An escrow offer should thus be attractive especially to buyers intending to purchase large quantities.

Hypothesis 6: The higher the transaction value, the more the number of successful transactions per offer using escrow will increase.

Design

Data

We use a dataset of auction-listings and transactions from the Alphabay cryptomarket between March 2015 and January 2017 (collected by McKenna and Goode, 2017). Our data includes the following information on listings: product description, number of sales per listing, origin and destinations of the listed goods, method of payment, and transaction feedback (see Figure A1 in Supplementary Appendix). We also have information on sellers' nicknames and their lifespan on the platform. Following Przepiorka, Norbuta, and Corten (2017), we restrict our data to transactions concerning a subset of illegal drugs, that is, buds and flowers, cocaine, hashish, heroin, ketamine, MDA, MDMA, and methamphetamine. We do so to avoid bias due to *unobserved* item heterogeneity (Diekmann *et al.*, 2014). Additionally, by focussing on illegal drugs we are able to use some common metrics to control for *observable* heterogeneity (e.g. quantity and price per gram). (Note that similar metrics do not exists for forged documents or illegal weapon, for instance.) The final dataset includes 466,714 transactions linked to 30,459 listings posted by 2,566 sellers.

Measurement

We measure escrow payment with a dummy variable (*Escrow*) taking value 1 if the offer uses escrow and 0 if it requires advance payment (also known as 'finalized early' or 'FE' in the cryptomarket jargon).

Our first explanatory variable in the models testing Hypotheses 1 and 2 is the number of recurrent customers the seller has had by the time their item is first listed online (*Recurrent clients*). We identify recurrent customers analysing the text of feedback comments. We focus on keywords pointing to the evidence of repeated transactions between specific buyers and the seller (details in Supplementary Appendix A3). Our second set of explanatory variables in the models testing Hypotheses 1 and 2 is the number of positive and negative feedback the seller has received by the time their item is first listed online (*Positive reviews* and *Negative reviews*, respectively). We follow Przepiorka, Norbutas and Corten (2017) and interpret the latter two variables as measures of reputation. Since most of Alphabay feedback is positive (see Table 1), we also use the length of seller's history of trading on the platform (in days) as a complementary measure of positive reputation (*Days selling*). By doing so, we follow Reichelt, Sievert and Jacob (2014) who show that seniority is a signal of trustworthiness in online environments. We use natural logs + 1 of the above explanatory variables.

Importantly, we construct *longitudinal* measures of recurrent clientele and reputation by aggregating transactions that have occurred prior to the time the item is listed. We do so thanks to information about the date of each transaction. For example, vendor X sold 10 g of heroine to buyer Y on 31 January 2016. To approximate vendor X's reputation at the time of listing the product Y later bought, we look at X's previous transactions between 31 January and the moment when s/he started selling on Alphabay—distinguishing between transactions that led to positive and negative reviews.[5] We use analogous procedure to calculate the number of recurrent customers at each point in time by aggregating transactions marked as 'recurrent' by a given date.

Table 1 Descriptive statistics

	Mean	SD
Vendor-level variables		
Recurrent clients	7.861	81.185
Positive reviews	45.534	442.060
Negative reviews	0.492	4.476
Days selling	26.750	67.121
Listing-level variables		
Sales	14.853	72.708
Escrow	0.797	0.403
Grams	98.335	798.241
Price per gram	35.091	53.416
Transaction value	938.428	3794.826
International sale	0.612	0.487
Buds and Flowers	0.415	0.493
Cocaine	0.178	0.382
Hash	0.106	0.308
Heroin	0.051	0.220
Ketamine	0.036	0.185
MDA	0.004	0.067
MDMA	0.156	0.363
Meth	0.055	0.227
N (vendor-level)	2,566	
N (listing-level)	30,459	

Notes: The table shows the mean and the standard deviation of the indicated variables.

Following Przepiorka, Norbutas and Corten (2017), our main dependent variable in tests of Hypotheses 3–6 is the log of the number of sales per listing + 1 (*Sales*). To test Hypotheses 5 and 6, we interact the escrow dummy with the vendor's reputation (measured as the number of positive and negative reviews) and the value of a given transaction (total price in USD for an offered quantity of drugs). The descriptive statistics of all the variables are presented in Table 1. Note that the unit of most forthcoming analyses is listing. Yet, for some analyses, it is transaction. Therefore, the number of observations in different models varies, as explained in table notes.

Main results

Determinants of escrow

Is the escrow payment more frequently chosen by vendors who do not have many recurrent customers (Hypothesis 1), and who have not (yet) established a good reputation on the platform (Hypothesis 2)? To test these hypotheses, we regress the escrow payment on our measures of recurrent clientele and reputation.

We estimate two types of models. First, we estimate a multi-level model with random intercepts. Our units of analysis are listings nested within sellers. The intraclass correlation coefficient is 0.73, thus roughly 73 per cent of the variance is attributable to the vendor-level variables. The model includes the likely correlates of using escrow at the listing level, namely the quantity of grams per sale and destination market (dummy variable for international sales). We also use a series of fixed effects for (i) the type of substance (eight categories of drugs mentioned above), (ii) substance's country of origin (56 countries), and (iii) month-year of the posting (to capture periodic macro fluctuations observed in cryptomarkets). Second, we estimate an analogous listing-level longitudinal linear probability model with seller fixed effects and standard errors clustered at the seller level.

Table 2 shows the results of our analysis. First, we find that sellers with higher numbers of recurrent clients—that is, clients who repeatedly buy from the same individuals—use the escrow service less often. The model estimates a 1 percentage-point reduction in the probability of using escrow linked to having 305 more transactions from recurrent clients. Such transactions, however, constitute between 15 and 34 per cent of the trade at Alphabay, according to our estimates. The result is in line with Hypothesis 1.

Second, we do *not* find consistent evidence that sellers who have established reputation on the market use escrow less often (Hypothesis 2). The coefficients for the number of positive and negative reviews have expected signs (negative and positive, respectively; see column 1) but they are not statistically significant. When we use the vendor's lifespan on the platform as an alternative measure or reputation (the log of *Days selling*), the correlation becomes statistically significant (columns 1 and 2 of Table A1 in Supplementary Appendix). The latter model suggests that 100 additional days of selling on Alphabay reduces the probability of using escrow by a 1 percentage point.[6]

We probe robustness of this finding in two ways. First, we address a possible source of bias in our measurement of recurrent clientele, coming from the fact that recurrent customers may stop leaving comments after multiple successful transactions with a given seller. If this were the case, our measure would underestimate the amount of recurrent clientele. We explore how this underestimation might affect our results by adopting the lower and upper bound approach. We consider the original measure of recurrent clients as a lower bound estimate. To produce an upper bound estimate, we code every transaction without a feedback as recurrent. Table A2 in Supplementary Appendix shows the results of our models using the upper bound estimates. The results are substantively the same.

Second, we exclude offers that did not generate a single purchase (Table A3 in Supplementary Appendix). In these cases, drug dealers may have used the Alphabay platform to advertise their products online, but sold them offline to local clientele. Encouragingly, the results remain unchanged.

Effect of escrow on sales

The above evidence confirms that the choice of using escrow is not random. It depends on the vendors' history of trade on the platform. The resultant endogeneity makes it difficult to estimate the effect of escrow on sales by simply comparing listings requesting the escrow payment or not. Such comparisons could be biased. Most straightforwardly, low reputation or less recurrent clients simultaneously affect the vendors' probability of using escrow and the vendors' number of sales per listing.

We address this problem by comparing the escrow listings to the non-escrow ones while keeping all relevant vendor characteristics constant—both time-variant and time-invariant ones. Specifically, we regress the log of sales per listing on the type of payment (escrow vs advance payment) and a series of fixed effects:

$$Y_{ijg} = \alpha_{ijg} + \beta_1 \text{Escrow}_i + \text{Vendor FE}_j + \text{Date FE}_g + \varphi_i + \gamma_{jg} + \varepsilon_{ijg}$$

Whereby Y is the outcome of interest for auction-listing i, by vendor j, on date g (month-year). Escrow_i is an indicator variable equal to 1 if the item offered for sale could be purchased through the escrow payment (vis-à-vis advance payment). Vendor fixed effects (Vendor FE_j) and date fixed effects (Date FE_g) allow

Table 2 Determinants and effects of escrow

	(1)	(2)	(3)	(4)	(5)
	Escrow (multi-level)	Escrow (clustered SE)	Sales per item (log)	Sales per item (log)	Sales per item (log)
Grams (log)	−0.006***	−0.008*	0.034	−0.262***	−0.255***
	(0.002)	(0.004)	(0.033)	(0.041)	(0.033)
International sale	−0.011**	−0.022	0.095*	0.088	0.078
	(0.005)	(0.018)	(0.055)	(0.056)	(0.056)
Transaction value (log)	−0.002	−0.000	−0.292***	−0.016	−0.192***
	(0.002)	(0.005)	(0.047)	(0.036)	(0.035)
Recurrent clients	−0.010**	−0.012*	−0.191***	−0.190***	−0.209***
	(0.004)	(0.007)	(0.024)	(0.025)	(0.025)
Positive reviews	0.001	0.003	0.012	0.012	0.076**
	(0.002)	(0.003)	(0.016)	(0.017)	(0.030)
Negative reviews	−0.005	0.012	−0.108***	−0.107***	−0.161***
	(0.009)	(0.010)	(0.037)	(0.036)	(0.049)
Escrow			−0.255**	−0.256**	−1.238***
			(0.103)	(0.102)	(0.200)
Price per gram (log)				−0.411***	−0.402***
				(0.050)	(0.046)
Escrow × Transaction value (log)					0.212***
					(0.032)
Escrow × Positive reviews					−0.072**
					(0.027)
Escrow × Negative reviews					0.093
					(0.060)
Month-year FE	—	Yes	Yes	Yes	Yes
Vendor FE	—	Yes	Yes	Yes	Yes
Drugs type FE	Yes	Yes	Yes	Yes	Yes
Drugs origin FE	No	Yes	Yes	Yes	Yes
Unit of analysis	Listing	Listing	Listing	Listing	Listing
N	29,791	29,478	29,472	29,441	29,441

Notes: The table shows point estimates and standard errors of regression of the indicated outcomes on the indicated variables. Robust standard errors clustered at the date (month-year) and vendor levels. Note that the above analyses rely on a counterfactual logic. Yet, there are some listings for which we were unable to find a meaningful counterfactual. As a result, these observations could not be analysed in our difference-in-differences framework and thus were dropped from the regressions. This explains slight variations in the number of observations in different models (also compared to the complete dataset of listed items). ***$P < 0.01$, **$P < 0.05$, *$P < 0.10$.

us to exploit variation in the payment method within auctions by the same vendors posted roughly at the same time.

Listing-level characteristics captured by φ_i include: (i) the type of drugs (eight categories), (ii) drugs' country of origin (56 countries; see Červený and Ours, 2019), (iii) price per gram, (iv) the quantity of grams per sale (see Caulkins, 1994), and (v) destination market (country dummies). Lastly, vendor's *time-variant* characteristics captured by γ_{ig} include: (i) the number of recurrent customers and (ii) the number of positive and negative reviews. We estimate models with and without price per gram control.

Columns 3 and 4 of Table 2 show the results. In line with Hypothesis 4, we find that escrow payment is associated with a decrease in the number of sales per listing. The effect is sizeable: 5.4 fewer items sold per listing using the escrow payment, compared to

the advance payment (column 3).[7] Interestingly, the negative effect of escrow is virtually unchanged in regressions in which we control for the price of drugs, compared to specifications in which we do not use this control (compare columns 3 and 4). We return to the role of prices in the *Increased prices* section.

Heterogeneous effects

The fact that transactions in escrow result in the lower number of sales is in contrast with theoretical models that predict positive effects of assurance devices. To better understand this finding, we explore hypothesized heterogeneities in the reported effects—related to vendor's reputation (Hypothesis 5), and transaction value (Hypothesis 6). We re-estimate our model including interactions between the escrow variable and the aforementioned moderators:

$$\begin{aligned} Y_{ijg} = {} & \alpha_{ijg} + \beta_1 \text{Escrow}_i + \beta_2 \text{Stakes}_i \\ & + \beta_3 \text{Reputation}_i + \beta_4 \text{Escrow} \times \text{Stakes}_i \\ & + \beta_5 \text{Escrow} \times \text{Reputation}_i + \text{Vendor FE}_j \\ & + \text{Date FE}_g + \varphi_i + \gamma_{jg} + \varepsilon_{ijg} \end{aligned}$$

All the interaction terms are statistically significant (column 5 of Table 2). First, we find evidence of the moderating effect of reputation. The volume of sales for an auction-listing with the escrow payment is lower, the more positive reviews the seller has received before posting the offer. The reverse is true for the number of negative comments: it reinforces the negative effect of escrow. These results are consistent with Hypothesis 5 and suggest that once trust in a specific seller has been established due to their reputation, additional assurance devices become redundant.

Second, we find evidence of the moderating effect of transaction value. We find that transaction value attenuates the negative effect of escrow. The effect of escrow has a significant effect on sales for transactions whose overall value is above 1,098 USD, as illustrated in Figure 1 (please note that the figure presents logarithmic transformation of the transaction value variable). The positive interaction between escrow and transaction value suggests that escrow increases sales, but only for very expensive purchases. This finding is consistent with Hypothesis 6.

We probe the robustness of these findings in two ways. First, we replicate our results including the share of *item-specific* positive reviews as another control. This variable may have an independent effect on sales, capturing the unobserved variation in product quality. The inclusion of item-specific ratings in the model does not alter our previous results (see Table A4 in Supplementary Appendix).

Second, we examine heterogeneity in the moderating effect of transaction value breaking the analyses by the drug's country of origin and the type of substance. We focus on six countries with more than 20,000 transactions in the data. Figures A2 and A3 in Supplementary Appendix show the effects of escrow conditional on the transaction value by countries and substances, respectively. The results are largely in line with our main findings.[8]

Mechanisms

We have documented a relationship between the use of escrow and reduction in online sales of illegal drugs. What explains this finding? Below, we evaluate two hypothesized mechanisms: (i) increased prices, and (ii) crowding out of trust between traders. Supplementary Appendix A5 addresses alternative explanations: mistrust in the platform and its failure to adjudicate disputes to the buyers' satisfaction.

Increased prices

A possible explanation of the buyers' preference for advance payment over escrow could be related to the fact that escrow is associated with increased prices. We do not find clear evidence for this pattern. Drugs sold in escrow seem to be on average 1.08 USD more expensive per gram (holding time and vendor-level characteristics constant; see column 1 of Table 3). However, the estimate is considerably reduced (0.34 USD) while we control for listing-level characteristics (column 2) and the result is no longer statistically significant.

Could thus higher prices explain the negative effect of escrow on sales? Intuitively, the buyers may not want to pay for the escrow service while engaging in transactions that could be regulated by reputation systems. This logic is consistent with the fact that escrow correlates with greater reduction in sales when offered by sellers who have built a good reputation on the platform (the negative interaction between escrow and reputation; column 5 of Table 2). Put differently, reputation may provide sufficient assurance against untrustworthy behaviours.

The explanation is also consistent with the positive interaction between escrow and transaction value (column 5 of Table 2). From the sellers' perspective, in high-value transactions, a one-shot defection could possibly outweigh the costs of reputation damage related to untrustworthy behaviour. As a result, if the stakes are high, reputation feedback alone may not suffice to incentivize the sellers' honest behaviour, making the escrow service a desirable safeguard.

Crowding out of trust between traders

In the theory section, we proposed that escrow may backfire by crowding out trust between traders. We find two pieces of evidence that are consistent with this mechanism. First, we do a sentiment analysis of reviews, comparing comments posted after transactions

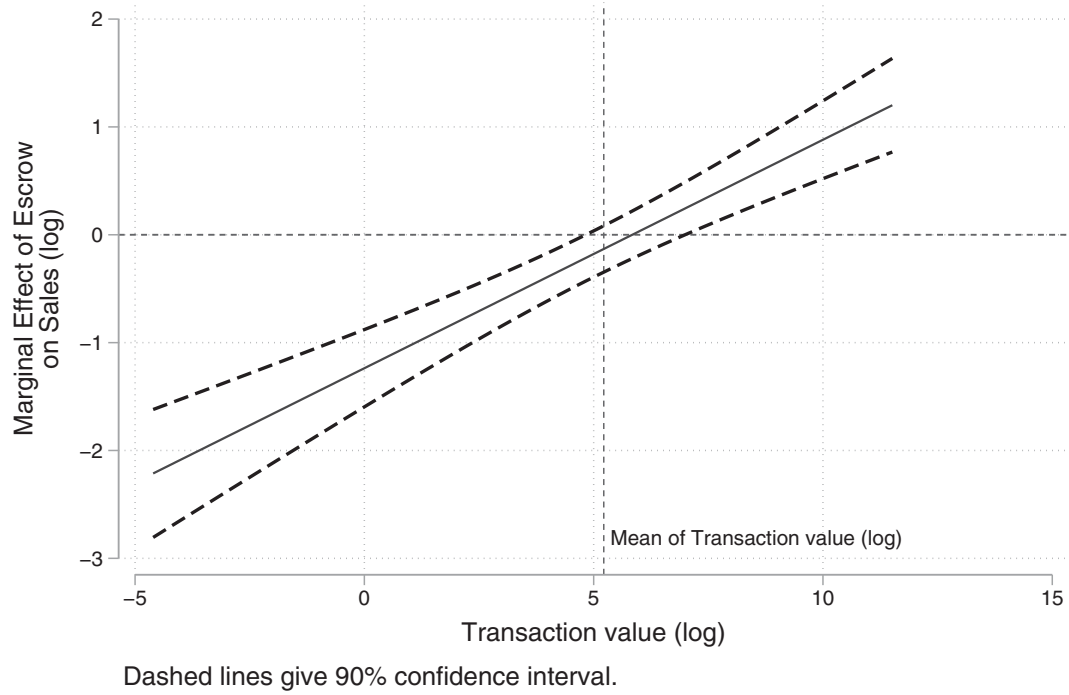

Figure 1 Moderating effect of transaction value. Notes: The figure plots the marginal effect of the escrow dummy and its 90 per cent confidence interval from the linear regression of the indicated outcomes. The effect of escrow is broken by the log value of transactions in USD.

in escrow and advance payment, using AFINN lexicon (more details on the procedures and supporting qualitative evidence in Supplementary Appendix A6). Column 4 of Table 3 shows that feedback posted after advance payment transactions is more positive compared to feedback posted after escrow transactions. The differences are statistically significant. The model uses an analogous specification to model 5 in Table 2, yet the feedback is measured at the transaction (not listing) level, which changes our unit of analysis.

The second piece of suggestive evidence in support of the crowding out mechanism comes from a keyword-based analysis of feedback. We classify all the comments based on whether they include any trust-related keywords. We conservatively rely on the word 'trust' and its synonyms taken from the Oxford Dictionary of English (see Supplementary Appendix A7). Column 5 of Table 3 shows that trust-related keywords appear more frequently in feedback posted after transactions that rely on advance payment (vis-à-vis escrow). Again, the differences are statistically significant, although substantively small (plausibly due to the very conservative selection of keywords).

Discussion and conclusion

We analysed the effects of escrow on online sales in a very large cryptomarket for illegal drugs. We find that escrow is associated with *reduced* sales of drugs, as measured by the number of purchases per auction-listing. We provide suggestive evidence that escrow may be incompatible with informal social control of typical drugs users' communities, crowding out trusting and reciprocal behaviours between traders (see Bohnet and Baytelman, 2007; Holmås *et al.*, 2010). This finding resonates with criminological research that describes illicit economies as 'pre-modern' and strongly reliant on informal social control (see, e.g. Reuter, 1983; Beckert and Wehinger, 2013).

Before concluding, we briefly outline some limitations. The data on which we conducted our analyses concern illegal transactions in the 'dark web'. We thus do not know whether and to what extent our results generalize to other settings. Many legal markets rely on analogous assurance devices, including PayPal and Authorize.net services (see González, 2004). If the crowding out mechanism is a dominant channel behind the escrow backlash, the reported effects may not apply to online marketplaces which are *not* characterized by strong community ties (such as Amazon or eBay). Still, our conclusions may generalize to some online trading communities, such as traders in CD and vinyl records at Discogs platform or similar collectors' communities whose users are linked through strong reciprocity norms. That said, future research should explore the applicability of our mechanisms in different contexts.

Table 3 Escrow and mechanism

	(1)	(2)	(3)	(4)	(5)
	Price per gram (log)	Price per gram (log)	Trust words in feedback	Feedback sentiment	Feedback sentiment
Escrow	0.065**	0.032	−0.003**	−0.087**	
	(0.031)	(0.027)	(0.001)	(0.038)	
Escrow vs FE mention					−0.506*
					(0.278)
Recurrent clients	0.028	0.018	0.001	0.026	0.354
	(0.030)	(0.015)	(0.001)	(0.023)	(0.223)
Transaction value (log)	−0.042***	−0.088***	0.002***	0.036**	−0.008
	(0.005)	(0.004)	(0.000)	(0.014)	(0.070)
Positive reviews	−0.018	−0.008	−0.000	−0.020	−0.232
	(0.021)	(0.009)	(0.000)	(0.015)	(0.168)
Negative reviews	−0.016	0.005	−0.001	−0.007	−0.067
	(0.024)	(0.013)	(0.001)	(0.015)	(0.093)
Month-year FE	Yes	Yes	Yes	Yes	Yes
Vendor FE	Yes	Yes	Yes	Yes	Yes
Drugs type FE	No	Yes	Yes	Yes	Yes
Drugs origin FE	No	Yes	Yes	Yes	Yes
Controls	No	Yes	Yes	Yes	Yes
Unit of analysis	Listing	Listing	Review	Review	Review
N	29,449	29,443	430,457	430,457	6,062

Notes: The table shows point estimates and standard errors of linear regressions of the log of sales outcome on the indicated variables. Standard errors are clustered at the date (month-year) and vendor levels. ***$P < 0.01$, **$P < 0.05$, *$P < 0.10$.

Further limitations come from the operationalization of some of our key variables and a few data-related concerns. First, we identified recurrent customers using qualitative information provided in the feedback messages (see Supplementary Appendix A3). Relying on selected keywords to identify recurrent customers certainly yields a rough measurement. However, as repeated transactions are known to be prevalent in cryptomarkets (Dècary-Héetu and Quessy-Doré, 2017), false negatives are more probable than false positives. Thus, although we may have underestimated recurrent customers, this is likely to result in a conservative bias.

Second, our sentiment analysis of transaction feedback could be imprecise due to the fact that some comments are written in languages other than English and the AFINN lexicon might not recognize the cryptomarket jargon. We address both concerns in Supplementary Appendix A6. For example, in one supplementary exercise, we only select comments that *explicitly* mention escrow and advance payment ('finalized early'). We find that comments mentioning the escrow payment have a significantly less positive sentiment scores than comments mentioning advance payment (column 5 in Table 3). This finding builds confidence in our sentiment analysis.

Our article has some important implications. We find that the negative effect of escrow on sales turns positive for high-value transaction (i.e. above 1,100 USD). One possible implication is that criminal organizations who generally trade large quantities are more likely to operate on markets with a higher degree of institutionalization. As noted by Aldrige and Decary-Hetu (2014), most of the drug deals on cryptomarkets involve small quantities. However, a minor percentage of higher-value transactions generates a huge share of the market revenues (on Alphabay 108 million USD, accounting for 44 per cent of the total revenues; see Table A5 in Supplementary Appendix), indicating that some business-to-business trading operates in cryptomarkets, at least at the lower level of the distribution network. Therefore, inasmuch as cryptomarkets are capable to develop reliable institutions, these may principally attract drug traffickers.

Notes

1. One could describe online exchange as 'pseudo-anonymous', given that traders often use pseudonyms, which makes them recognizable to each other to a certain extent (see Supplementary Appendix A2).

2. A commitment device is an arrangement through which a person makes it impossible (or non-profitable) for herself to deviate from a promised course of action. An assurance device is an arrangement through which a person protects herself from untrustworthy behaviours of others by making it impossible (or non-profitable) for them to deviate from a promised course of action. Escrow can be seen as a commitment device from the perspective of a seller, and an assurance device from the perspective of a buyer.
3. Note that sometimes sellers may be unable to verify the quality of the products. Purity is not perfectly correlated with the positive effects of substances, and drug quality control is a complex process that requires technical knowledge (Broséus, Gentile and Esseiva, 2016).
4. One could wonder whether sellers are able to opt out of escrow only once they have established a history of honest behaviour on the platform. In our data (details in the Data section), we find that no seller traded outside escrow on the first day of their activity on the platform. The earliest sale without escrow involved a seller who, by that time, had been trading for 9 days. Yet, during these nine days the seller had completed no other transaction. Thus, Alphabay does not seem to limit the availability of escrow payment to sellers with a history of honest behaviour.
5. Our data also include 'trust level' and 'vendor level' scores, which are reputation indicators assigned by the platform on a rating scale. We did not use these variables, since they correlate with both number of days selling and percentage of positive reviews. Moreover, these two variables are constant within seller, given that the data was collected through a single 'crawl'. It is thus not possible to construct longitudinal measures for these variables, as we did for the number of positive and negative reviews.
6. One could argue that established sellers learn that providing extra service to their clientele pays off, and escrow is such a service. Therefore, established sellers may be in a better position to opt out from escrow, but may decide to not do it for the sake of giving clients an additional choice.
7. Our tests of Hypotheses 3 and 4 assume that the seller does not modify the chosen payment method after the item has been listed. Encouragingly, we have not detected any modifications of the payment method or any other characteristics of the *ongoing* listings.
8. Interestingly, the effect of escrow does *not* turn positive for purchases above 1,100 USD for drugs originating from Australia and the United Kingdom, and for heroine. Future research could investigate these puzzling heterogeneities.

Supplementary Data

Supplementary data are available at *ESR* online.

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Author contributions

Filippo Andrei: Conceptualization-Equal, Data curation-Equal; Davide Barrera: Conceptualization-Equal, Writing – original draft-Supporting, Writing – review & editing-Supporting; Krzysztof Krakowski: Conceptualization-Equal, Formal analysis-Lead, Methodology-Lead, Validation-Lead, Visualization-Lead, Writing – original draft-Lead, Writing – review & editing-Lead; Emilio Sulis: Data curation-Equal

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