The Limits of Reputation Signaling in Adversely Selected Markets: Applications to Dark Net Cocaine Markets

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Abstract

Dark net markets present a rare opportunity to examine markets with little contract enforcement and strong asymmetric information. The review systems on these sites prevent market collapse by allowing good vendors to accrue reputation, signaling high quality products. This paper examines cocaine listings on the Dream Market dark net site. Despite uniformly high ratings across all vendors, I find a price differential between escrow transactions—which function as strong contracts—and non-escrow transactions. This supports existing models of markets with reputation signaling that become heavily saturated with highly reputable vendors, yet these vendors still have a nonzero chance of scamming their customers in an exit-scheme. I argue that the price differential represents the discount high-reputation vendors must offer consumers to offset the inherent risk the transaction is a scam.

Keywords: Adverse Selection; Dark Net Markets; Moral Hazard; Online; Drugs.

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1. Introduction

Information asymmetry has a well-documented cost to the efficiency of markets. Under certain conditions, adverse selection can cause the collapse of a market and incur large welfare losses (Akerlof 1970). In environments where contracting or contract enforcement is impossible, signaling is often used to mitigate the effects of information asymmetry. For example, while it is often difficult to contract on the productivity of a worker (though not impossible), a potential hire can invest in an education to signal their productivity (Spence 1973). Thus, entire markets may be supported by the ability of buyers and sellers to signal.

This paper examines the upper-bounds of welfare gains from signaling alone. Cabral and Hortacsu (2004) demonstrate that markets may reach an equilibrium where all vendors are considered highly reputable but vendors have a nonzero chance of scamming their customers and exiting the market. Market efficiency then suffers as consumers must adopt the risk that they will be scammed regardless of vendor reputation. However, some markets may provide the option of holding funds in escrow which serves as a strong contract to prevent scams. If the escrow option is sufficiently trustworthy and if its usage is varied, there will exist a price differential between escrow and non-escrow options. This paper seeks to measure this price differential and relate it to the maximum efficiency signaling alone can provide in an adversely selected market.

Dark Net Markets (DNMs) provide an unusually clean environment to test theories on adverse selection and signaling. The Dark Net is portion of the internet not indexed by most search engines, making it inaccessible to the casual browser. Furthermore, most sites on the Dark Net are hidden behind an encryption software known as Tor. Tor anonymizes all behavior that flows through its network, lending anonymity and untraceability to those perusing the Dark Net. This has led to the creation of illicit markets on the Dark Net, allowing the purchase of everything from drugs to weapons to assassinations. These markets provide an environment where contracting is very limited, as participants have no adjudicating body to rely on. There is a large amount of information asymmetry as scams are commonplace,

product quality is unobservable, and most identifying data is purposely obscured by Tor.

This paper will focus on the Dream Market DNM. It's widely considered the largest operating DNM after law enforcement shut down the AlphaBay and Hansa markets and has been operating since 2013. I use a novel dataset of cocaine listings on Dream Market scraped from the site in July of 2017. I supplement this with a dataset of listings scraped for the site in April of 2016, allowing for the identification of long term vendors.

2. Existing Literature

Akerlof's (1970) *Market for Lemons* and Spence's (1973)*Job Market Signaling* are foundational for work in information asymmetry and signaling. While these theoretical papers establish the existence and cause of welfare loss due to adverse selection, experimental work helps indicate the magnitude of this loss in situations with human actors. In experimental work with undergraduates and assigned valuations and quality levels, Holt and Sherman (1990) are able to calculate the deadweight loss generated by adverse selection. They find that full-information market efficiency is 83.6 percent. Under asymmetric information where buyer's don't know seller's types, efficiency drops to 52.8 percent. They also find no gains in to efficiency from price advertising. While experiments with undergrads in universities are host to a litany of confounding factors, they are also likely to capture behavioral idiosyncrasies that will show up in empirical analyses of real life markets.

Theoretical models have been developed to analyze online vendor behavior, many of which deal with reputation. Cabral and Hortacsu (2004) studied vendors on eBay, the online auction site, to understand the effect of negative reviews. They consider a market with good sellers—who always produce high quality transactions—and bad sellers who produce high quality transactions with probability α at effort cost e or with probability β at no effort cost. Sellers live for infinite periods with discount factor δ. Thus, consumer's expected probability of a positive transaction is

$$\upsilon(\mu, \rho) = \mu + (1 - \mu)(\rho\alpha + (1 - \rho)\beta$$

Where μ represents consumers belief that the seller is good given their reputation and ρ is the belief that a bad seller will still exert the effort to produce a good transaction (Cabral and Hortacsu 2004).

Assuming an intermediate discount factor, their analysis finds that bad sellers are incentivized to exert high effort until they receive their first bad review. That review then lowers their expected profit, as consumers update μ which causes the seller's ρ to decline. They conclude that after the first bad review, seller effort declines and more bad reviews occur at an accelerating rate. This leads sellers to choose low effort and once this model is extended to exit and entry, exit the market.

Cabral and Hortacsu's empirical findings on a panel dataset of vendor listings note several stylized facts that match their model. First, reputation very weakly impacts listed price on eBay. Second, vendor age, regardless of reputation, increases prices. Third, lower reputations lead to an increased likelihood of exit. Fourth, sellers exhibited profit-taking behavior at their exits.

> "Some of the examples were quite striking: one of the sellers in our sample, who had 22755 positives, racked up 11 negatives in her last 25 transactions; whereas she had a total of 54 negatives in her previous transactions (the percentage of negatives and neutrals over her overall history was 0.6%, versus 44% in the last 25 transactions). On average, the percentage of negatives in the last 25 comments of exiting sellers (excluding those who remained as buyers and those sellers whose IDs became invalid, and thus we could not get data) was 4.38%, as opposed to an average 1.61% over their entire histories. This difference is statistically significant at the 1% level." (Cabral and Hortacsu 2004)

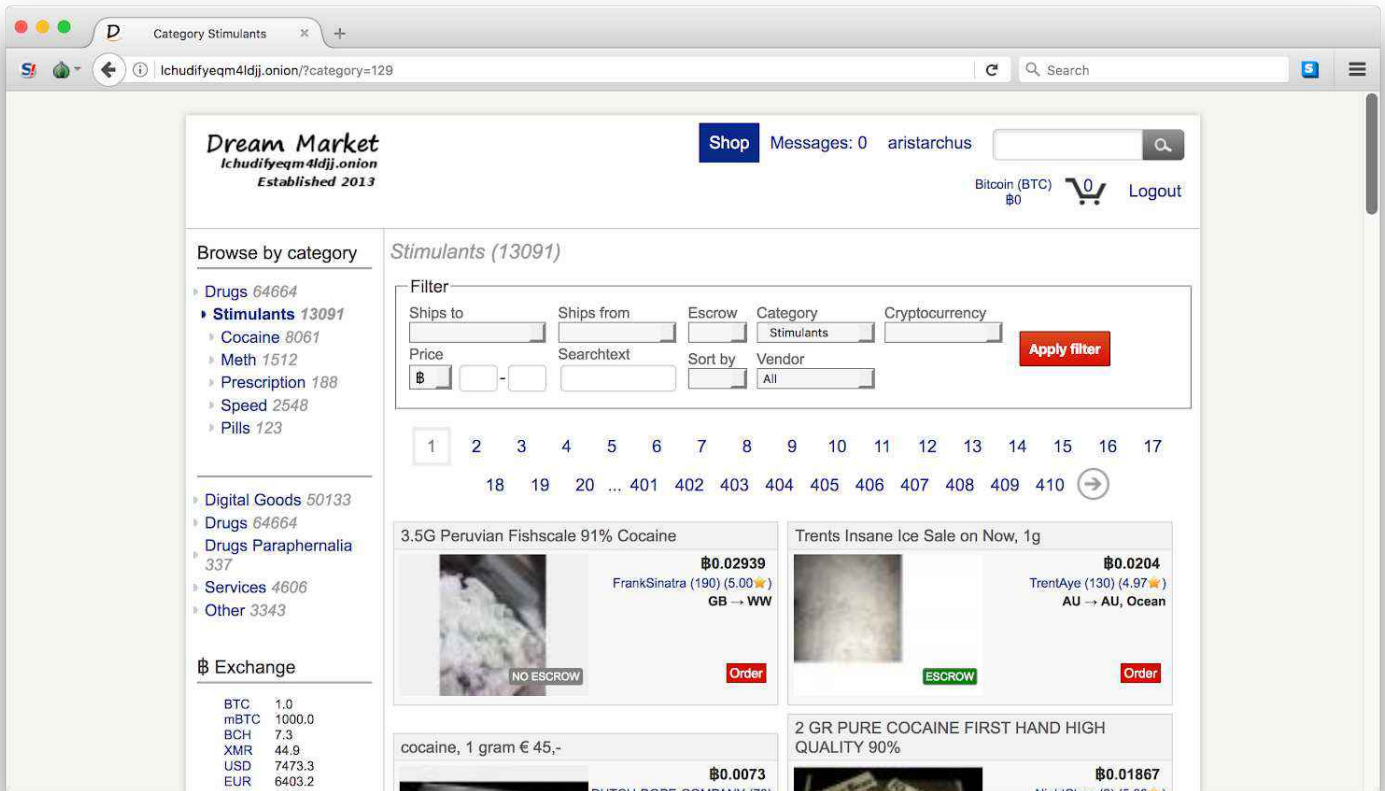I find very similar behavior in the following analysis.

3. Data

Fig. 1. Screenshot of Dream Market home page

I use a dataset collected by data scientist Skip Everling[1]. He used a python based web-scraper to extract listings from the Dream Market cocaine section. This dataset includes product title, the country the product ships from, the countries a vendor is willing to ship to, the percent pureness of the cocaine, price in bitcoin, whether an escrow service is offered, unique vendor names, number of successful transactions by vendor, and vendor rating out of 5. Bitcoin price was then converted into dollars using the average bitcoin price over the time period that this data was scraped (July 14th to July 21st of 2017). This data was supplemented by a similar dataset from the darknet search engine Grams, collected in April

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[1]He goes through his process on his blog post here: https://medium.com/thought-skipper/dark-market-regression-calculating-the-price-distribution-of-cocaine-from-market-listings-10aeff1e89e0

Fig. 2. Screenshot of listing by vendor FrankSinatra, note the lack of escrow, perfect 5 star rating, and advertising of fishscale cocaine.

of 2016. Though this dataset is less rich, it does allow me to identify which vendors have been in the market for at least a year.

	Mean/Std.
Price per pure gram	84.7
	(62.2)
Successful transactions	339.8
	(527.9)
Escrow	.754
	(.430)
Rating	4.88
	(.121)
N	1504

Table 1: Summary Statistics. Rating is uniformly high across the market and roughly a quarter of the market eschews escrow.

	Non-Escrow. Mean/Std.	Escrow Mean/Std.
Log price per pure gram	4.183	4.242
	(0.319)	(0.660)
Successful transactions	226.4	
	(206.3)	(646.9)
Escrow	0	1
	(0)	(0)
Rating	4.857	4.869
	(0.118)	(0.134)
N	176	763

Table 2: Difference Statistics (excluding Australia, France, and for non-flake cocaine). A semi-naive difference shows about a 5% price differential.

As shown in Table 3, Australia demonstrates unusually high prices and low usage of escrow. Literature on Australian drug enforcement, particularly on the high rate of mail parcel interception, helps explain why this is the case. Indeed, the Global Drug survey ranks Australian street cocaine as the second most expensive in the world at $311 a gram compared to a global average of $127. The prices on Dream Market are markedly lower, which may be explained by the competitiveness of the market where prices are easily compared as opposed to street cocaine, where there's virtually no ability to compare prices.

	Non-Australia	Australia
	Mean/Std.	AU Mean/Std.
Price per pure gram	78.4	268.2
	(39.3)	(129.4)
Successful transactions	340.1	331.2
	(527.06)	(567.06)
Escrow	.771	.125
	(.419)	(.334)
Rating	4.88	4.94
	(.1223537)	(.0349495)
N	1464	40

Table 3: Summary Statistics excluding AU. Australia has noted irregularities in enforcement leading to extraordinarily high cocaine prices and risk of confiscation in the mail, hence the low use of escrow. This difference is the reasoning behind my use of shipping variables in my estimation equation

4. Econometric Design

Characteristics of the listing can be considered product qualities. Thus, my regression to determine the impact of escrow and reputation is a simple logistic hedonic. My primary estimation equation is as follows:

$$ln(USPricePerGramPure_i) = \beta_0 + \beta_1 Escrow_i + \beta_2 ln(SuccessfulTrans_j)$$
$$+ \beta_3 InMarket2016_j + \beta_i X_i + \epsilon_{ij}$$

Where the dependent variable is the natural log of the price per pure gram of co-

caine of listing i, $Escrow$ is a dummy variable for the existence of an escrow contract, $ln(SuccessfulTrans)$ is the natural log of vendor j's total number of successful transactions, $InMarket2016$ is a dummy variable for if the vendor appeared in the 2016 Grams dataset (and therefore at least a year old), and X is a vector of product characteristics such as shipping dummies and whether the listing advertises so called flake or fishscale cocaine, which is a particularly high quality form of cocaine.

Since unobserved vendor characteristics will lead to correlation of the residuals for listings within a certain vendor, I cluster my errors on individual vendors to correct for autocorrelation.

In my regressions I include only shipping variables for Australia and France as they are the only countries that seem to have an significant effect, but the model will demonstrate robustness to a whole host of shipping variables.

5. Empirical Results

VARIABLES	(1) Basic	(2) Prod. Char.	(3) Shipping
Escrow	-0.106	-0.0688	0.112***
	(0.0720)	(0.0805)	(0.0393)
Rating	0.153	0.124	-0.0412
	(0.188)	(0.190)	(0.171)
Log Successful Transactions	0.0365*	0.0354*	0.0454**
	(0.0212)	(0.0209)	(0.0186)
Flake		0.114**	0.164***
		(0.0532)	(0.0426)
Active in 2016		0.107	0.165***
		(0.0680)	(0.0417)
Ships from AU			1.494***
			(0.0954)
Ships from FR			0.311***
			(0.0487)
Constant	3.480***	3.545***	4.084***
	(0.883)	(0.889)	(0.790)
Observations	1,504	1,504	1,504
R-squared	0.019	0.031	0.202
cluster on vendor?	yes	yes	yes
shipping dummies?	no	no	yes

Robust, clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Main regressions. Note the impact of including shipping variables on escrow price

I find that escrow options increase listing price by around 11%, significant at the 1% level. I take the log of successful transactions to account for the high value of the first few successful transactions and the diminishing returns after a vendor has accumulated many successful transactions. This coefficient increases price by around 4%, significant at the 5% level. Older vendors as well as those who advertise flake cocaine see price increases of around 16%. The coefficients on shipping from Australia and France have profound impacts on price due to the drug enforcement regimes in those countries. As was shown before, Australia's high prices and low use of escrow skew the regressions in columns 1 and 2 and we see both

the sign of the *escrow* coefficient flip and the result becomes significant.

Most notable is that the rating variable has no significant impact on price. This flies in the face of standard assumptions about an adversely selected market, however it fits the behavior of the models presented by Cabral and Hortacsu. This result suggests that the power of the reputation system on Dream Market is such that low rated vendors are driven out of the market nearly instantaneously, and that the market equilibrium is highly saturated with high ranked vendors. Indeed, a graph of the distribution of reputation confirms this.
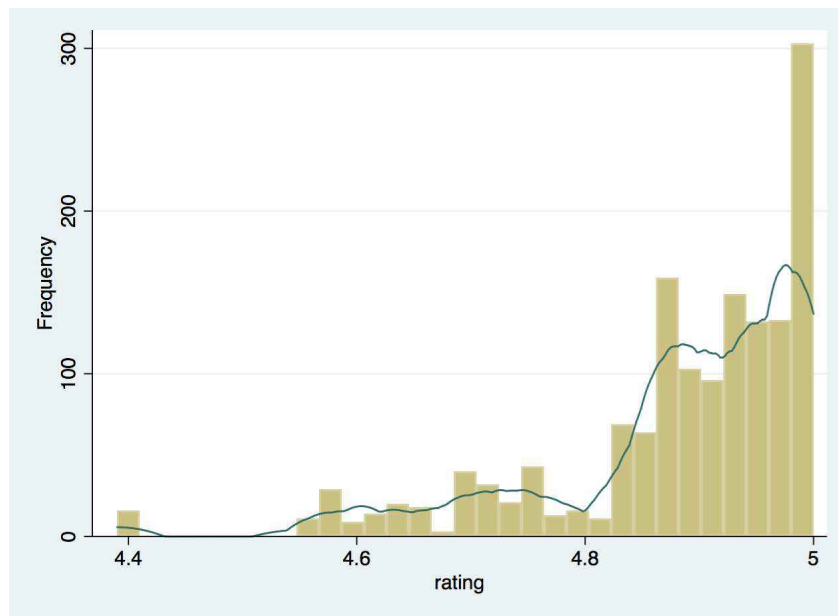

Fig. 3. Graph of distribution of rating. Green line is the kernel density estimation.

The impact of escrow contracting on price as well as an unusual saturation of high rated vendors point to the existence of an adversely selected market with a large amount of "bad vendors" with near perfect reputations.

5.1. *Escrow*

If, as suggested by my results, escrows allow for a strong contract between buyers and vendors, the question remains why any vendors don't select the escrow option. The escrow option comes with no monetary cost to consumer nor vendor. However, I argue that use of

escrow is risky for both consumers and vendors who could face losses if it doesn't go their way. Thus, use of escrow is determined by risk tolerance which varies by individual.

First, escrow dispute arbitration is performed by Dream Market staff and seems to be mainly based on whether a vendor violated the terms listed on their offer page. Namely, if the vendor indicates that they are willing to refund potentially intercepted packages, then they are bound to do so. However, there's no standardization in these terms and thus are left to interpretation by the Dream Market staff. As such, a vendor risks being forced to refund a buyer despite not having violated any of their listed terms. Browsing these terms and conditions, one finds that countries with high risks of parcel interception, namely Australia, are often listed on the list of countries for which vendors will not refund. It follows that vendors are worried about package interception and that the escrow process poses risks to the vendor due to variability.

On the buyer side, high amounts of trust seem to be the reason that any buyer is willing to buy from a non-escrow listing. Depending on buyer preference for risk, the lower prices for non-escrow options also provide an incentive for less risk-averse customers. It's worth noting that risk preferences among those perusing an online cocaine marketplace probably trend towards relatively less risk-averse than the average population.

For both populations, there exists a threat of a market scam. In this case, a long operating market will stop releasing the bitcoins deposited in escrow and then shut down the site, taking the escrow funds with them. One particular example is the East India Company marketplace, which scammed its users after a period of great success. In many ways, this mimics the behavior of high reputation vendors exiting and scamming their customers.

Given that escrow is both a risky proposition to vendors but also allows them to charge 11% more as it provides strong contracting, it makes sense that we see some vendors opting to use escrow and some opting not to.

5.2. Vendor Behavior

The price increase associated with escrow is evidence that there exists risks that buyers are willing to pay to avoid. Thus, escrow forms a contract that mitigates the scamming of consumers by high reputation vendors. Consider a vendor with discount factor δ and a near perfect reputation. Based on the equilibrium identified by Cabral and Hortacsu, these vendors are incentivized to exert effort at cost to increase ρ, the probability of a "bad vendor" producing a positive transaction in order to maximize their net present profit.

Whether a vendor engages in high effort, non-scamming behavior or low effort, scamming behavior is dependent on δ—below a certain value, a vendor will engage in the latter and vice versa[2]. δ is subject to variation on the basis of several factors. First, vendors may have a desire to exit the drug business and are subject to changing concerns about being arrested by law enforcement. Second, vendors may expect a market to either exit scam or get shut down by authorities. There seems to be a steady market turnover characterized by the top markets being taken down by authorities. As such, vendor's expectations of the length of the repeated game they play may vary, which would change the net present profit of their strategy of exerting effort. This may cause vendors to flip to low effort and effectively spend their accrued reputation to gain profit at the expense of scammed customers.

The positive coefficient on successful transactions may indicate that consumers have expectations about the variability of vendor δs. In short, a vendor with a long history may signal that the vendor's constantly changing δ has a low variation, decreasing the risk that δ dips below the threshold that they vendor will flip.

I contend that the 11% coefficient on *Escrow* represents the price consumers are willing to pay to avoid the behavior described above. It follows that this coefficient then relates consumer beliefs about the evolution and variation of vendor δs and ultimately, to the risk that a reputable vendor will scam their customers.

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[2]For a derivation of this inequality condition, see Cabral and Hortacsu 2004

5.3. Robustness

I intentionally did not use vendor fixed effects in my model as it led to loss of key
variables due to collinearity. However, here I demonstrate the model's robustness to vendor
fixed effects, extensive shipping variables, and interaction terms on young vendors and rating.

VARIABLES	(1) Fixed Effects	(2) Full Shipping Dummies	(3) Interactions
Escrow	0.140***	0.110***	0.0906*
	(0.0431)	(0.0327)	(0.0543)
Log Successful Transactions		0.0243	0.0570**
		(0.0187)	(0.0272)
Flake	0.0966	0.142***	0.171***
	(0.0647)	(0.0368)	(0.0450)
Active in 2016		0.154***	
		(0.0368)	
Escrow * Young vendor			-0.0749
			(0.0867)
Rating * Young vendor			0.490
			(0.315)
Young vendor			-2.295
			(1.564)
Rating			-0.479*
			(0.259)
Constant	4.190***	3.909***	6.189***
	(0.0396)	(0.123)	(1.277)
Observations	180	1,504	1,504
R-squared	0.659	0.254	0.195
vendor fixed effects?	yes	no	no
shipping dummies?	no	yes	yes
clustered?	yes	yes	yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: (1) Variables are ommitted due to collinearity with vendor fixed effects. (2) A full
range of shipping variables is included. (3) Interaction terms with young vendor dummy

We see that coefficient on the escrow variable remains significant through vendor fixed
effects and robust shipping variables. Regression 1 is the same as my main regression, but
with vendor fixed effects. Regression 2 includes fixed effects for where the vendor ships from

and where the vendor ships to, effectively capturing country effects as well as vendor shipping capabilities. In regression 3, I attempt to account for the findings of Janetos and Tilly (2017) who find that reputation has a significant impact on price only for young vendors. I define a young vendor as a vendor with less than the median number of transactions, around 150. I then interact rating with this $youngVendor$ dummy. The $Escrow$ coefficient does lose a level of significance when this interaction is included, but the coefficient on $ratingYoung$ is not significant. This does point to perhaps more complex interaction between reputation and vendor characteristics than my model captures, but generally does not refute my result.

6. Conclusion

I have demonstrated empirically that escrow contract options lead to a statistically and economically significant impact on cocaine prices. I also find this empirical result consistent with predatory exit-scamming behavior by high reputation vendors consistent with models proposed in the literature on online vendor behavior.

Research on dark net markets is unique in that it provides rich datasets on illicit and unregulated activity. Most research into adversely selected markets and incomplete contracts is muddled by the ability of market participants to rely on judicial systems or informal contracts, thus reducing the size and effect of adverse selection. However, an illicit online market provides an unusually clean setup for adverse selection. Vendors and buyers have no recourse outside of the escrow contract and reputation system, meaning adverse selection reigns.

It's notable that under these relatively strict and clean conditions, we see a plausible argument for vendor behavior mimicking theory. Vendors play a pure strategy of high reputation accrual but may switch to–depending on the evolution of their discount factor– predatory scamming and quickly exit the market.

Ideally, a full structural model could be used and estimated to attempt to more finely

relate discount factor, escrow price differential, and the risk consumers face when purchasing from non-escrow listings. Additionally, a full panel dataset would allow us to examine vendor exits in much greater detail which would definitively answer the question of predatory exits by high reputation vendors.

In short, this paper supplements existing literature and models of online vendor behavior, providing some new empirical insights based on a dataset that reflects many of the qualities desirable in empirical research on adverse selection.

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