Measuring the Deterioration of Trust on the Dark Web: Evidence from Operation Bayonet

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Ten Years Since...

Image from Cointelegraph and Forbes.
Motivation

- How do we evaluate success of law enforcement (LE) operations on darknet markets?
  - Demand: ↓ in short run, ↑ in long run [1, 2]
  - Supply: displaced, not deterred [3, 4]
  - Prices: neither rise nor fall [5, 6]
  - Darknet market ecosystem continues to grow (COVID-19) [7, 8]

- What to conclude?
- How else have LE operations impacted the market?
Measuring Trust

- Darknet markets are anonymous, illegal, online
  - **Trust** crucial for market functioning \([9, 10]\)
  - Valid target for LE operations
- How to measure (change in) trust?
- I propose **vendors’ returns on reputation (RoR)**
  - \(\text{RoR} \rightarrow \text{trust} \rightarrow \text{LE success}\)
- Intuition: \(\partial \$, / \partial \text{reputation}\)
- RoR is...
  - Easily interpreted ("\(\beta\")
  - Data required is available
  - Well-studied in industrial org literature
Rating as Reputation

Dream market user interface. *Image from Dreammarket.link.*
Returns on Reputation

- Positive RoR shown:
  - On clearnet: eBay [11], Taobao [12]
  - And on darknet: Silk Road [13], Hansa [14]
  - Reputable $\rightarrow$ higher price markups!

- How does RoR change in response to LE operations?
Hypothesized Mechanism

- Intuition: buyers use vendor’s ★ rating (reputation) to trade off between price premium and risk
  - Risk-averse: high price ⇐ reputable vendor
  - Risk-loving: low price ⇐ “shady” vendor
- ★ rating captures all notions of reputation…
  - “Objective”: quality product, prompt delivery
  - “Subjective”: trustworthy, feeling safe
Hypothesized Mechanism

- If LE operation **does not** damage buyer’s trust in vendors:
  - No change in buyers’ tradeoffs, vendors’ RoR

- If LE operation **does** damage trust:
  - Vendor’s *a priori* reputation becomes important signal!
  - Higher ★ rating buffers vendors against fall in trust
  - Some buyers “switch” to more reputable vendors → RoR ↑

- Validate with **event study**
Operation Bayonet

- Led by FBI, Dutch police in 2017
- “Standard” takedown: did not damage trust in vendors
- Users moved to next-largest market, Hansa...
...but Hansa’s admin, as well as some vendors, were already controlled by Dutch police!

After 16 days, Hansa was taken down

“Impersonation campaign” sowed distrust across dark web
Predictions

- $t_1$ to $t_2$: no change in trust $\rightarrow$ no change in RoR
- $t_2$ to $t_3$: fall in trust $\rightarrow$ increase in RoR
Data

- Alphabay takedown: June 18
- Hansa takedown: July 20

All reviews on **Dream market** (3rd largest) from \( t_1 \) to \( t_3 \) [15]

- Aggregated to vendor-\( t \) level (\( n = 4,723 \))
Model

\[ y_{it} = \gamma_1 \text{Alpha}_t + \gamma_2 \text{Hansa}_t + \gamma_3 \star_{it} \]
\[ + \delta_1 \text{Alpha}_t \cdot \star_{it} + \delta_2 \text{Hansa}_t \cdot \star_{it} + \beta' \mathbf{X}_{it} + \alpha_i + \epsilon_i \]

indexed by vendor \( i \) and time \( t \), where:

- \( y_{it} \) is vendor’s mean revenue OR market share
- \( \text{Alpha}_t, \text{Hansa}_t \) are takedown dummies
- \( \star_{it} \) is vendor’s mean star rating
- \( \mathbf{X}_{it} \) are controls, \( \alpha_i \) is a fixed effect, \( \epsilon_i \) is an error term
Coefficients of Interest

\[ y_{it} = \gamma_1 \text{Alpha}_t + \gamma_2 \text{Hansa}_t + \gamma_3 \star_{it} \\
+ \delta_1 \text{Alpha}_t \cdot \star_{it} + \delta_2 \text{Hansa}_t \cdot \star_{it} + \beta' X_{it} + \alpha_i + \epsilon_i \]

- \( \delta_1 \) is effect of Alphabay takedown on RoR
  - expect \( \delta_1 = 0 \)
- \( \delta_2 \) is additional effect of Hansa takedown on RoR
  - expect \( \delta_2 > 0 \)
### Results

This is exactly what we find!

<table>
<thead>
<tr>
<th></th>
<th>Log meanrevenue (1)</th>
<th>Log meanrevenue (2)</th>
<th>Log mktshare (3)</th>
<th>Log mktshare (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>rating</strong></td>
<td>-0.00581</td>
<td>-0.0143</td>
<td>0.0457</td>
<td>0.0197</td>
</tr>
<tr>
<td></td>
<td>(-0.06)</td>
<td>(-0.17)</td>
<td>(0.30)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Alphabay × <strong>rating</strong></td>
<td>-0.112</td>
<td>-0.0885</td>
<td>-0.207</td>
<td>-0.142</td>
</tr>
<tr>
<td></td>
<td>(-1.01)</td>
<td>(-0.88)</td>
<td>(-1.14)</td>
<td>(-0.95)</td>
</tr>
<tr>
<td>Hansa × <strong>rating</strong></td>
<td>0.377***</td>
<td>0.325**</td>
<td>0.687***</td>
<td>0.565**</td>
</tr>
<tr>
<td></td>
<td>(3.32)</td>
<td>(2.80)</td>
<td>(3.92)</td>
<td>(3.28)</td>
</tr>
<tr>
<td>Alphabay</td>
<td>0.675</td>
<td>0.552</td>
<td>0.302</td>
<td>-0.000903</td>
</tr>
<tr>
<td></td>
<td>(1.24)</td>
<td>(1.13)</td>
<td>(0.34)</td>
<td>(-0.01)</td>
</tr>
<tr>
<td>Hansa</td>
<td>-1.877***</td>
<td>-1.592**</td>
<td>-3.003***</td>
<td>-2.299**</td>
</tr>
<tr>
<td></td>
<td>(-3.40)</td>
<td>(-2.82)</td>
<td>(-3.52)</td>
<td>(-2.74)</td>
</tr>
<tr>
<td>Controls</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.161</td>
<td>0.211</td>
<td>0.244</td>
<td>0.341</td>
</tr>
<tr>
<td>Observations</td>
<td>4723</td>
<td>4723</td>
<td>4723</td>
<td>4723</td>
</tr>
</tbody>
</table>

* t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
## Dream: Market Share

<table>
<thead>
<tr>
<th></th>
<th>$t_1$</th>
<th>$t_2$</th>
<th>$t_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputable market share</td>
<td>31.12</td>
<td>10.68</td>
<td>15.08</td>
</tr>
<tr>
<td>New vendors</td>
<td>32</td>
<td>277</td>
<td>77</td>
</tr>
</tbody>
</table>

“Reputable”: vendors with above-median ★ rating

- **$t_1$ to $t_2$:** reputable vendors’ market share ↓
  - Alphabay users migrating to Dream

- **$t_2$ to $t_3$:** reputable vendors’ market share ↑
  - Damaged trust: buyers switch to higher-★ vendors!
  - Consistent with hypothesized mechanism
Robustness

- Regression results are robust to
  - z-scoring ★ rating
  - other specifications for reputation
  - different assumptions on review data latency

- Placebo test: In a market where user identities are verifiable, impersonation campaign had **no effect on RoR!** Valhalla
Implications

- Damaging buyer trust raises vendor barriers to entry!
  - Fewer, more conspicuous vendors [16]
- RoR seems a good proxy for (change in) trust
  - Wider toolbox to evaluate LE impersonations/“psy-ops”
- Thank you!
Hansa takedown notice

**THIS HIDDEN SITE HAS BEEN SEIZED**

**and controlled since June 20**

by the Dutch National Police in conjunction with the Bundeskriminalamt, Lietuvos Policija, Federal Bureau of Investigation and Europol, under the authority of the Dutch National Prosecutor’s Office and the Attorney General’s office of the Federal State of Hessen (Germany).

The Dutch National Police have located Hansa Market and taken over control of this marketplace since June 20, 2017. We have modified the source code, which allowed us to capture passwords, PGP-encrypted order information, IP-addresses, Bitcoins and other relevant information that may help law enforcement agencies worldwide to identify users of this marketplace. For more information about this operation, please consult our hidden service at politieoph1zextorion.

This seizure was part of Operation Bayonet, which includes the takeover of Hansa Market by the National Police of the Netherlands and the takedown of AlphaBay Market by the Federal Bureau of Investigation of the United States of America on July 4, 2017.

*Image from Quartz.com.*
## Summary Statistics

<table>
<thead>
<tr>
<th>Description</th>
<th>$t_1$</th>
<th></th>
<th>Description</th>
<th>$t_2$</th>
<th></th>
<th>Description</th>
<th>$t_3$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>meanrevenue (mean, median, SD)</td>
<td>Mean</td>
<td>Median</td>
<td>SD</td>
<td>Mean</td>
<td>Median</td>
<td>SD</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>mean revenue / transaction, USD</td>
<td>678.10</td>
<td>245.05</td>
<td>1,491.39</td>
<td>874.45</td>
<td>292.42</td>
<td>2042.97</td>
<td>711.69</td>
<td>258.30</td>
</tr>
<tr>
<td>mktshare (mean, median, SD)</td>
<td>0.082</td>
<td>0.000</td>
<td>0.506</td>
<td>0.056</td>
<td>0.000</td>
<td>0.398</td>
<td>0.057</td>
<td>0.000</td>
</tr>
<tr>
<td>vendor’s share of period sales, %</td>
<td>0.082</td>
<td>0.000</td>
<td>0.506</td>
<td>0.056</td>
<td>0.000</td>
<td>0.398</td>
<td>0.057</td>
<td>0.000</td>
</tr>
<tr>
<td>meanrating (mean, median, SD)</td>
<td>4.87</td>
<td>5.00</td>
<td>0.38</td>
<td>4.86</td>
<td>5.00</td>
<td>0.35</td>
<td>4.85</td>
<td>4.985</td>
</tr>
<tr>
<td>period mean star rating</td>
<td>4.87</td>
<td>5.00</td>
<td>0.38</td>
<td>4.86</td>
<td>5.00</td>
<td>0.35</td>
<td>4.85</td>
<td>4.985</td>
</tr>
<tr>
<td>fivestars (mean, median, SD)</td>
<td>30.86</td>
<td>13.00</td>
<td>49.29</td>
<td>44.05</td>
<td>18.00</td>
<td>79.11</td>
<td>49.95</td>
<td>22.00</td>
</tr>
<tr>
<td>number of 5-star reviews</td>
<td>30.86</td>
<td>13.00</td>
<td>49.29</td>
<td>44.05</td>
<td>18.00</td>
<td>79.11</td>
<td>49.95</td>
<td>22.00</td>
</tr>
<tr>
<td>meanuntil (mean, median, SD)</td>
<td>4.76</td>
<td>4.92</td>
<td>0.74</td>
<td>4.57</td>
<td>4.92</td>
<td>1.18</td>
<td>4.79</td>
<td>4.92</td>
</tr>
<tr>
<td>lifetime mean star rating</td>
<td>4.76</td>
<td>4.92</td>
<td>0.74</td>
<td>4.57</td>
<td>4.92</td>
<td>1.18</td>
<td>4.79</td>
<td>4.92</td>
</tr>
<tr>
<td>txns (mean, median, SD)</td>
<td>39.96</td>
<td>17.00</td>
<td>65.96</td>
<td>59.01</td>
<td>25.00</td>
<td>97.71</td>
<td>48.55</td>
<td>20.00</td>
</tr>
<tr>
<td>number of period transactions</td>
<td>39.96</td>
<td>17.00</td>
<td>65.96</td>
<td>59.01</td>
<td>25.00</td>
<td>97.71</td>
<td>48.55</td>
<td>20.00</td>
</tr>
<tr>
<td>txnsuntil (mean, median, SD)</td>
<td>159.82</td>
<td>65.00</td>
<td>247.91</td>
<td>140.35</td>
<td>40.00</td>
<td>269.93</td>
<td>186.81</td>
<td>64.50</td>
</tr>
<tr>
<td>number of past transactions</td>
<td>159.82</td>
<td>65.00</td>
<td>247.91</td>
<td>140.35</td>
<td>40.00</td>
<td>269.93</td>
<td>186.81</td>
<td>64.50</td>
</tr>
<tr>
<td>diversity (mean, median, SD)</td>
<td>0.312</td>
<td>0.355</td>
<td>0.288</td>
<td>0.308</td>
<td>0.346</td>
<td>0.290</td>
<td>0.285</td>
<td>0.260</td>
</tr>
<tr>
<td>HHI index, 1 is most diverse</td>
<td>0.312</td>
<td>0.355</td>
<td>0.288</td>
<td>0.308</td>
<td>0.346</td>
<td>0.290</td>
<td>0.285</td>
<td>0.260</td>
</tr>
<tr>
<td>new vendors (mean, median, SD)</td>
<td>32</td>
<td>277</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>vendors with no sales before $t$</td>
<td>32</td>
<td>277</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>total vendors (mean, median, SD)</td>
<td>1,219</td>
<td>1,772</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
</tr>
<tr>
<td>vendors who made a sale in $t$</td>
<td>1,219</td>
<td>1,772</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
<td>1,736</td>
</tr>
</tbody>
</table>

Summary statistics (mean, median, standard deviation) of Dream vendor-level variables, by time period.
Valhalla is a closed-door darknet market

Registering on Valhalla (as buyer or vendor) requires a “referral link” from an existing user [17]

Theoretically, the true identity of each Valhalla user would be known by at least one other user → more resistant to impersonation campaigns

Expect Operation Bayonet to have **no effect at all** on vendor RoR
## Valhalla Results

<table>
<thead>
<tr>
<th></th>
<th>Log revenue per transaction</th>
<th>Log market share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>thumbsup</td>
<td>-0.0168</td>
<td>-0.0181</td>
</tr>
<tr>
<td></td>
<td>(-0.89)</td>
<td>(-0.98)</td>
</tr>
<tr>
<td>Alphabay × thumbsup</td>
<td>0.0117</td>
<td>0.0210</td>
</tr>
<tr>
<td></td>
<td>(0.45)</td>
<td>(0.76)</td>
</tr>
<tr>
<td>Hansa × thumbsup</td>
<td>0.00745</td>
<td>-0.000582</td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(-0.03)</td>
</tr>
<tr>
<td>Alphabay</td>
<td>-0.212</td>
<td>-0.239</td>
</tr>
<tr>
<td></td>
<td>(-1.31)</td>
<td>(-1.34)</td>
</tr>
<tr>
<td>Hansa</td>
<td>-0.00135</td>
<td>0.0346</td>
</tr>
<tr>
<td></td>
<td>(-0.01)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.111</td>
<td>0.132</td>
</tr>
<tr>
<td>Additional dummies</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>314</td>
<td>314</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Selected References I


