

Lecture 10:

# Beyond Silk Road: Developments in anonymous online marketplaces

Nicolas Christin

Carnegie Mellon University

[nicolasc@cmu.edu](mailto:nicolasc@cmu.edu)

Joint work with Kyle Soska

# Relevant bibliography

N. Christin. Traveling the Silk Road: A measurement analysis of a large anonymous online marketplace. *WWW'13*

K. Soska and N. Christin. Measuring the Longitudinal Evolution of the Online Anonymous Marketplace Ecosystem. *USENIX Security'15*

# Conventional commerce



# Internet commerce

1-24 of 509,703 results for Home & Kitchen : Home Décor : Clocks : Wall Clocks : "wall clock"

Show results for

< Any Category  
< Home & Kitchen  
< Home Décor  
< Clocks  
Wall Clocks

Refine by

Amazon Prime

☐ Prime

Avg. Customer Review

★★★★★ & Up (4,921)

★★★★☆ & Up (6,334)

★★★☆☆ & Up (6,984)

★★☆☆☆ & Up (7,693)

Brand

☐ Howard Miller  
☐ Infinity Instruments  
☐ Seiko  
☐ La Crosse Technology  
☐ Geneva  
☐ iCasso  
☐ Westclox  
☐ Advance Clock  
☐ Decho  
☐ Tiim  
☐ LexMod  
☐ hito  
☐ Lorell  
☐ Chaney Instruments  
☐ Decodyne

+ See more

Price

Under \$25 (312,090)

\$25 to \$50 (154,383)

\$50 to \$100 (23,065)

\$100 to \$200 (14,692)

\$200 & Above (6,008)

\$  to \$

Home Décor Theme

Showing results in Home & Kitchen. Show instead results in All Departments.

Related Searches: large wall clock.

Home Décor Theme: Vehicles & Transportation | Churches, Buildings & Houses | Romance & Love | Animals | Sports | See more



See Size Options

Universal Indoor/Outdoor Clock, 13 1/2-Inch, Black (11381)  
by Universal

**\$16.05** ~~\$22.99~~ Prime  
Get it by **Thursday, Aug 6**

More Buying Choices

**\$12.38** new (33 offers)

**\$11.97** used (1 offer)

**#1 Best Seller** in Wall Clocks

★★★★★ 418



See Package Quantity Options

ADVANCE CLOCK CO. 10" Wall Clock [Black]  
by Advance Clock

**\$9.19** Prime  
Get it by **Thursday, Aug 6**

More Buying Choices

**\$6.29** new (28 offers)

★★★★★ 387



See more choices

Ikea Wall Clock, White, Clear  
by Ikea

**\$6.93** ~~\$14.99~~ Prime  
Only 12 left in stock - order soon.

More Buying Choices

**\$1.75** new (28 offers)

Show only Ikea items

★★★★★ 129



La Crosse Technology WT-8002U Digital Wall Clock  
by La Crosse Technology

**\$18.75** ~~\$49.95~~ Prime  
Get it by **Thursday, Aug 6**

More Buying Choices

**\$18.75** new (7 offers)

**\$14.95** used (6 offers)

★★★★★ 716



See Color Options

12" Vintage France Paris Colourful French Country Tuscan Style  
Paris Wood Wall Clock  
by Decho

**\$7.80**

More Buying Choices

**\$7.80** new (37 offers)

FREE Shipping

★★★★★ 202



See Size Options

Geneva 14-Inch Plastic Decor.  
by Geneva

**\$26.06**

More Buying Choices

**\$17.29** new (9 offers)

FREE Shipping





























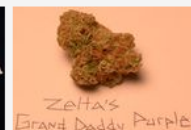
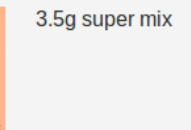
★★★★★ 261



# Conventional illicit commerce



# Illicit Internet commerce

 cheeba chews quad dose 0.49443757 BTC	 Purple Romulan (114 g) 2.29556772 BTC	 1oz. 0.77697333 BTC	 AB-CHMINACA 1KG 6.71022426 BTC	 DISCOUNT PRICE 7g 0.41674024 BTC
 3.5g HIGHGRADE 0.23733003 BTC	 7G OF GOLD POLM 0.29118841 BTC	 3g soft squigy Afghan 0.13773618 BTC	 100G OF PP100 HASH 3.25269291 BTC	 CannaJuice Variety 0.51209606 BTC
 3g Blue Dream AAA+ 0.40610983 BTC	 25 Canna-Caps - 0.38848666 BTC	 112 grams mazar 2.18965212 BTC	 HempVap Hemp Oil vape 0.12360939 BTC	 1G OF MOROCCAN 0.05512978 BTC
 AFGHAN GOLD SEAL 0.12360939 BTC	 QP 4oz / 112g / quarter 2.66643122 BTC	 Norge: 5 gram Oslo 0.42380363 BTC	 Afghan Seeds x 3 0.04944375 BTC	 Super Strength African 0.10909411 BTC
 3.5g OG Kush! TRUE 0.10595090 BTC	 2.2g HIGHGRADE 0.12926010 BTC	 3.5g BUD + MID GRADE 0.15892636 BTC	 Swazi Kush 100g 1.41267879 BTC	 20 Mixed Marijuana 0.17654953 BTC
 28G OF KETAMA GOLD 1.10259579 BTC	 Cannatonic high-CBD Oil 0.30019424 BTC	 Blue Dream Bubble Hash 0.10591559 BTC	 1/4th Grand Daddy 0.31432103 BTC	 3.5g super mix 0.17658484 BTC

# (Centralized) Anonymous marketplaces

- Amazon.com of illegal goods
  - Drugs, CC's & Fake IDs, Weapons, etc.
  - No Child Porn
- Safety
- Convenience
- Variety
- Accountability
- Competition

# How do anonymous marketplaces work?

- For buyers: Registration free, open to anyone
  - For sellers: Relatively modest account fee
- Tor “hidden service”
  - Website uses Tor to connect to the Internet
  - **Only** accessible through Tor
    - .onion address as opposed to .com, .org, .net
  - Server is very hard to locate for an attacker
- Bitcoin for payments
  - Peer-to-peer, decentralized currency
  - Pseudonymous (no identity bound to wallets)
    - However the entire chain of transactions is public
- Marketplace provides escrow mechanism to guarantee transaction completion



# Tor primer

[Dingledine et al., 2004]

- Client first gets IP address of possible Tor entry nodes from directory server

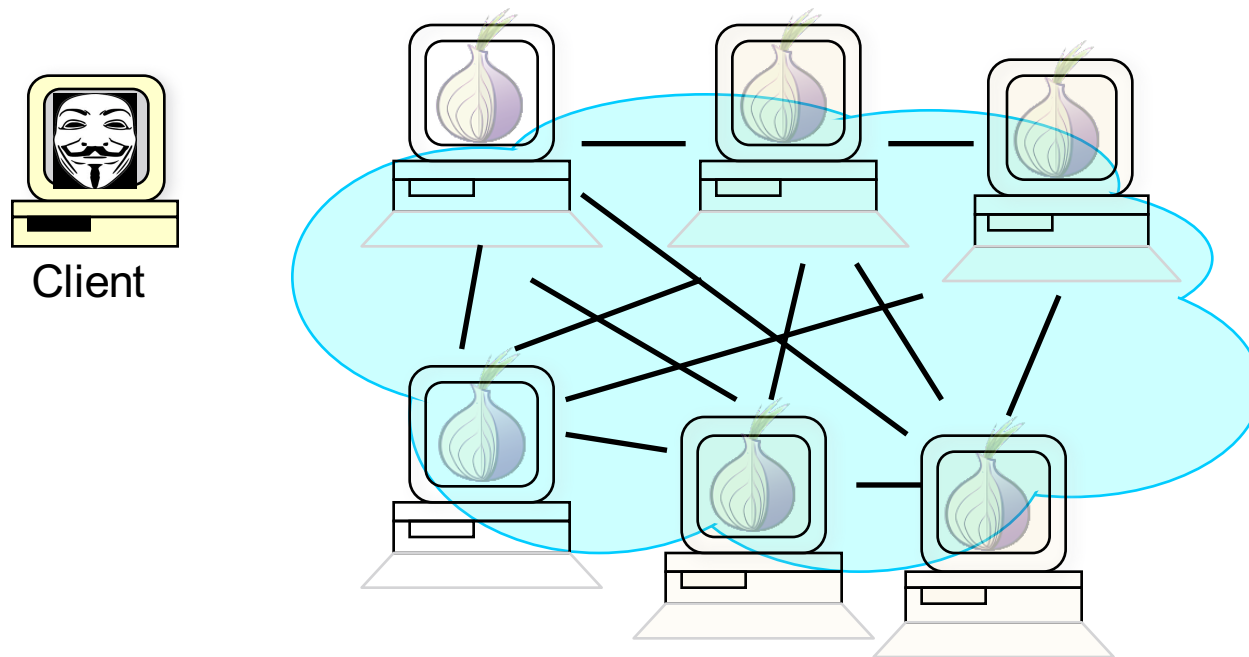


Client

# Tor primer

[Dingledine et al., 2004]

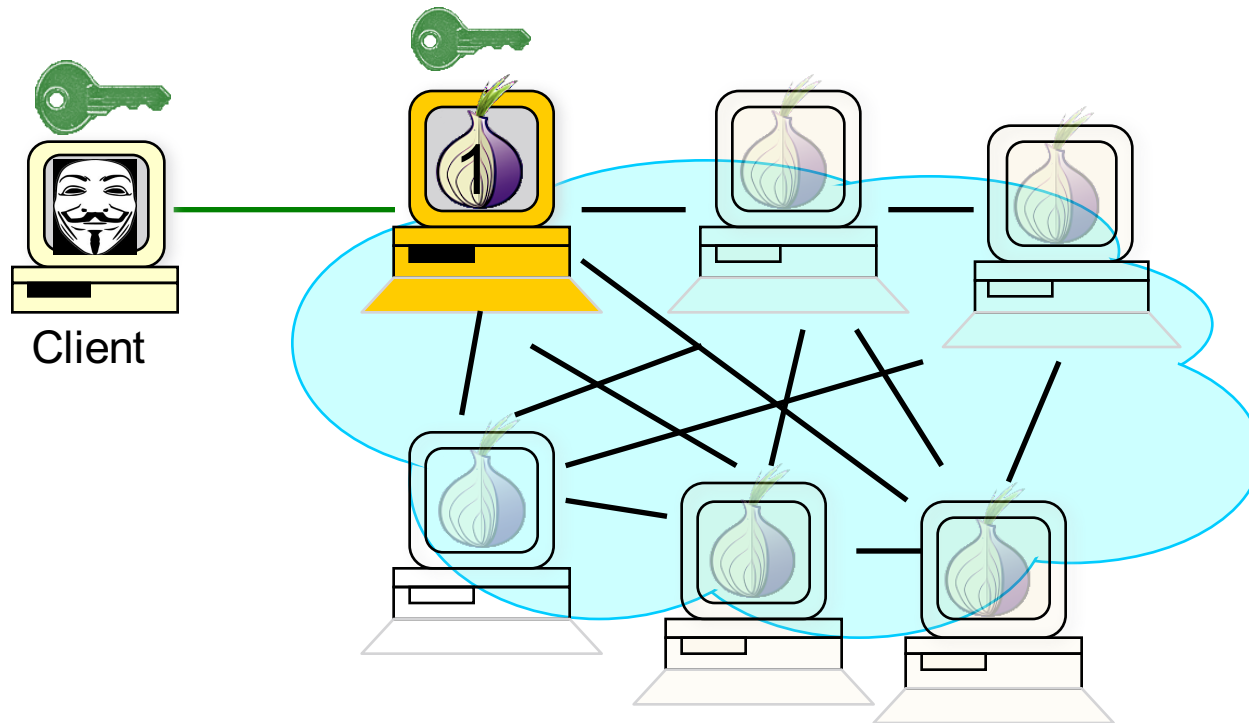
- Client first gets IP address of possible Tor entry nodes from directory server



# Tor primer

[Dingledine et al., 2004]

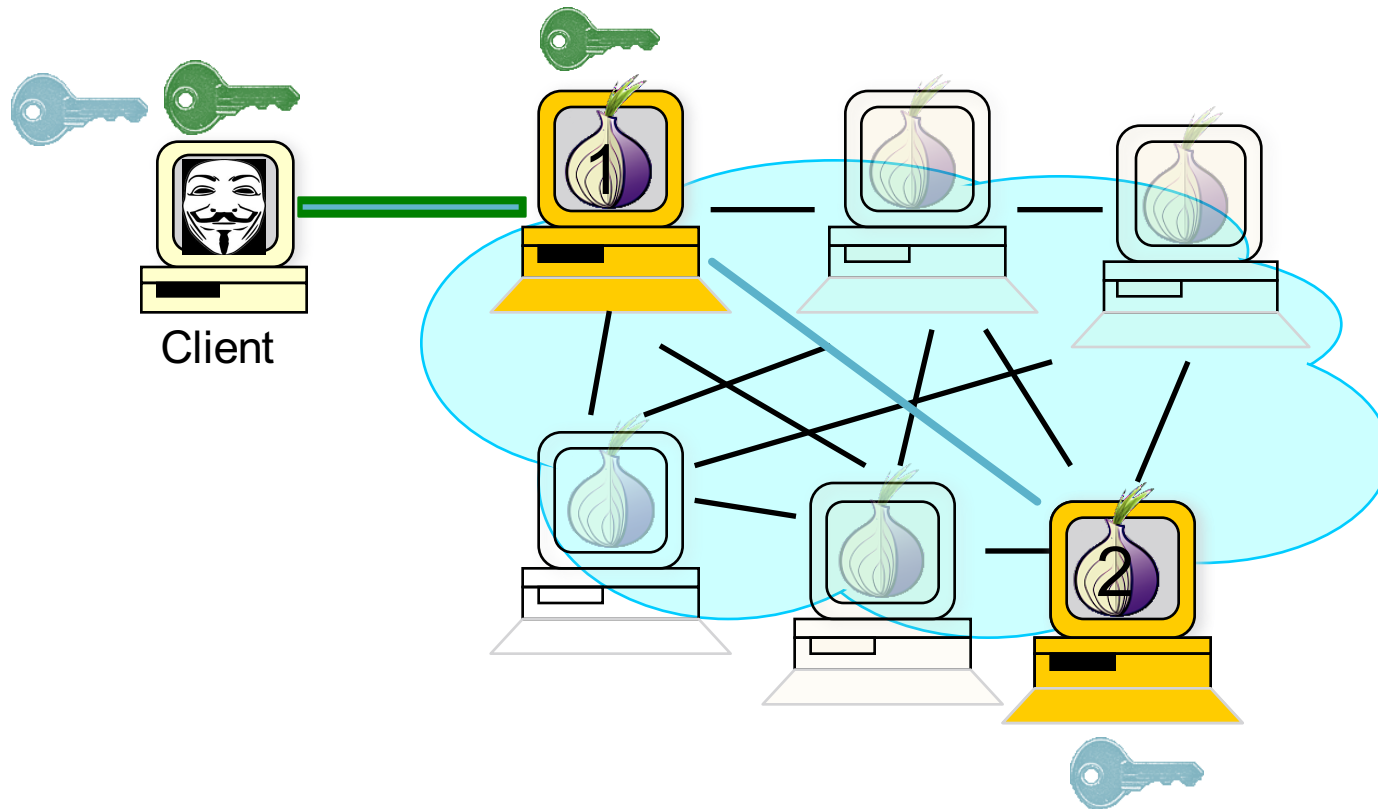
- Client proxy establishes session key+circuit w/ Onion Router 1



# Tor primer

[Dingledine et al., 2004]

- Client proxy establishes session key+circuit w/ Onion Router 1
- Proxy tunnels through that circuit to extend to Onion Router 2

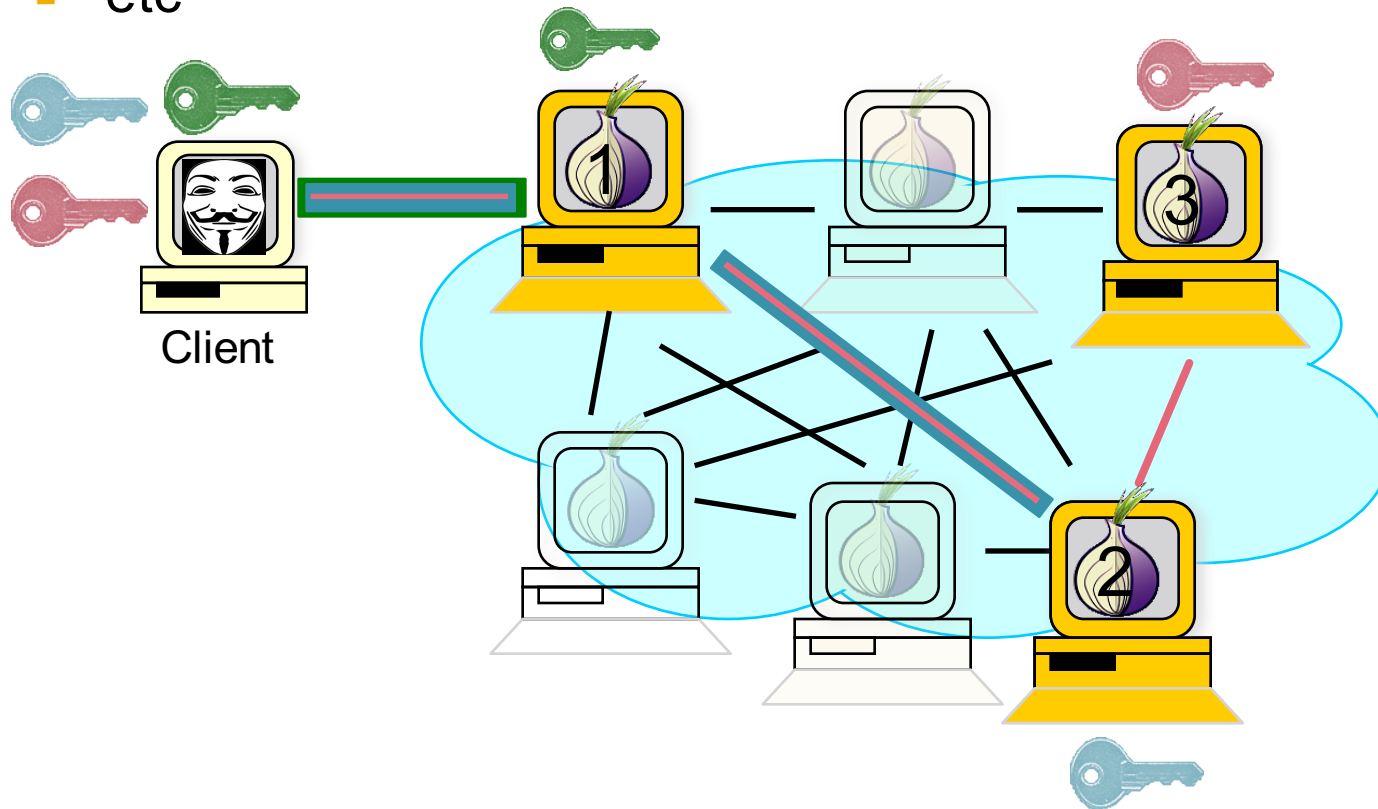




# Tor primer

[Dingledine et al., 2004]

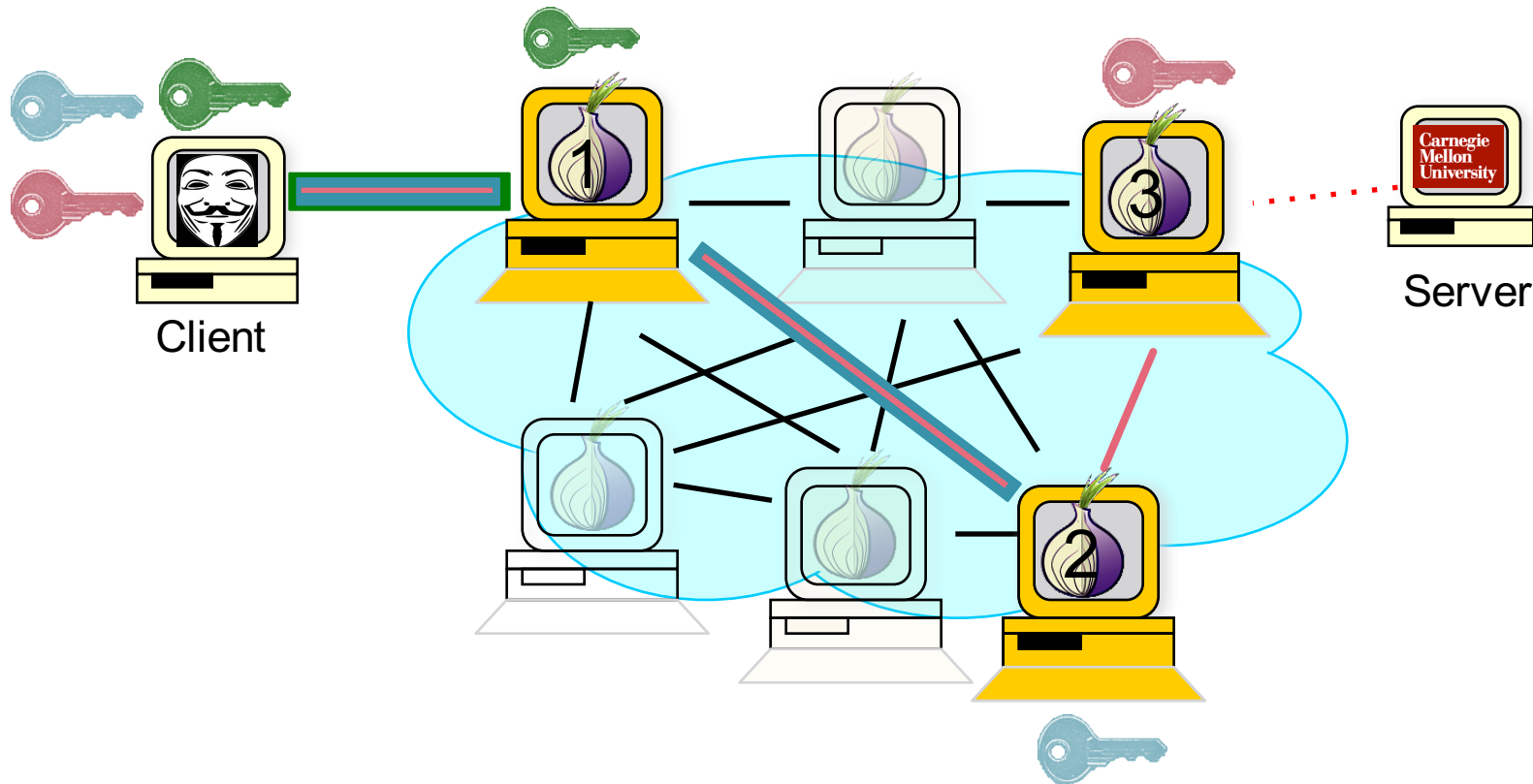
- Client proxy establishes session key+circuit w/ Onion Router 1
- Proxy tunnels through that circuit to extend to Onion Router 2
- etc



# Tor primer

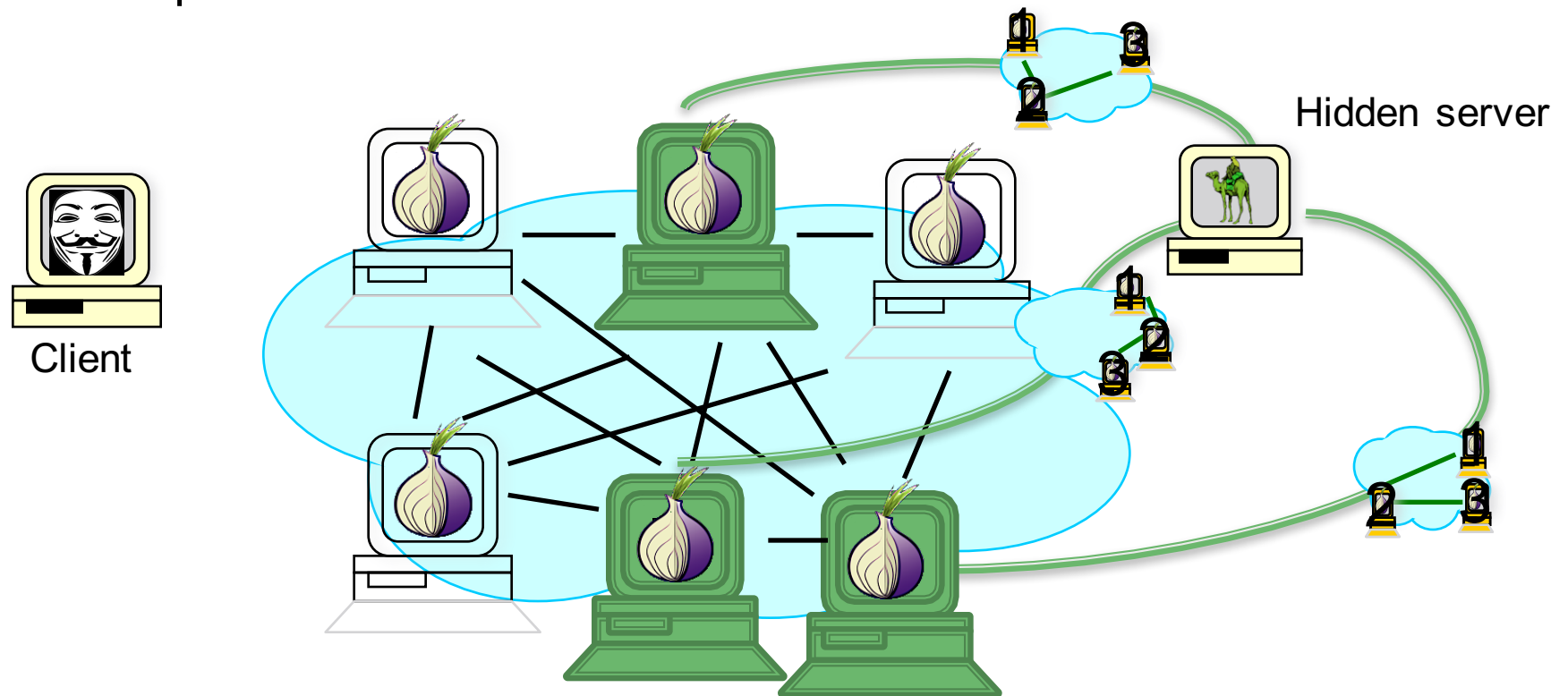
[Dingledine et al., 2004]

- Once circuit is established, applications connect and communicate over Tor circuit



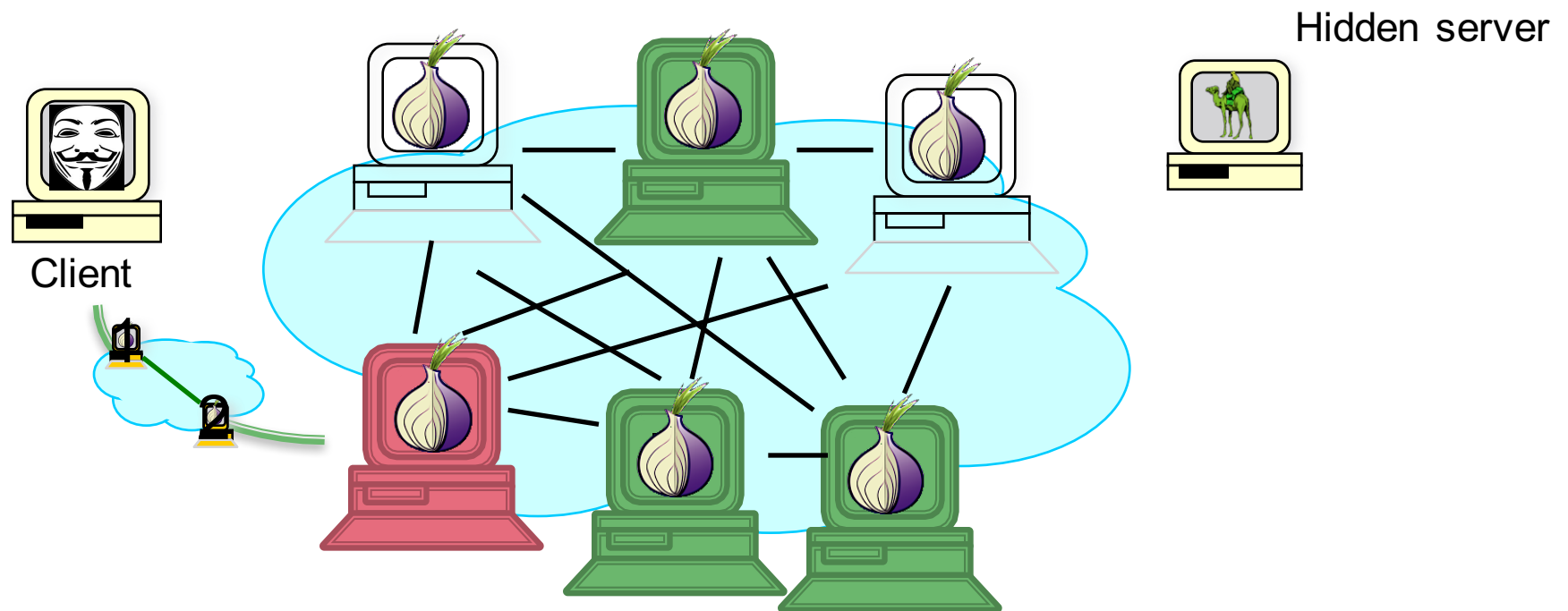
# Hidden services primer

- Hidden server uses Tor to contact 3 “introduction points” (Tor relays)
- Server upload Introduction Points info to DB server



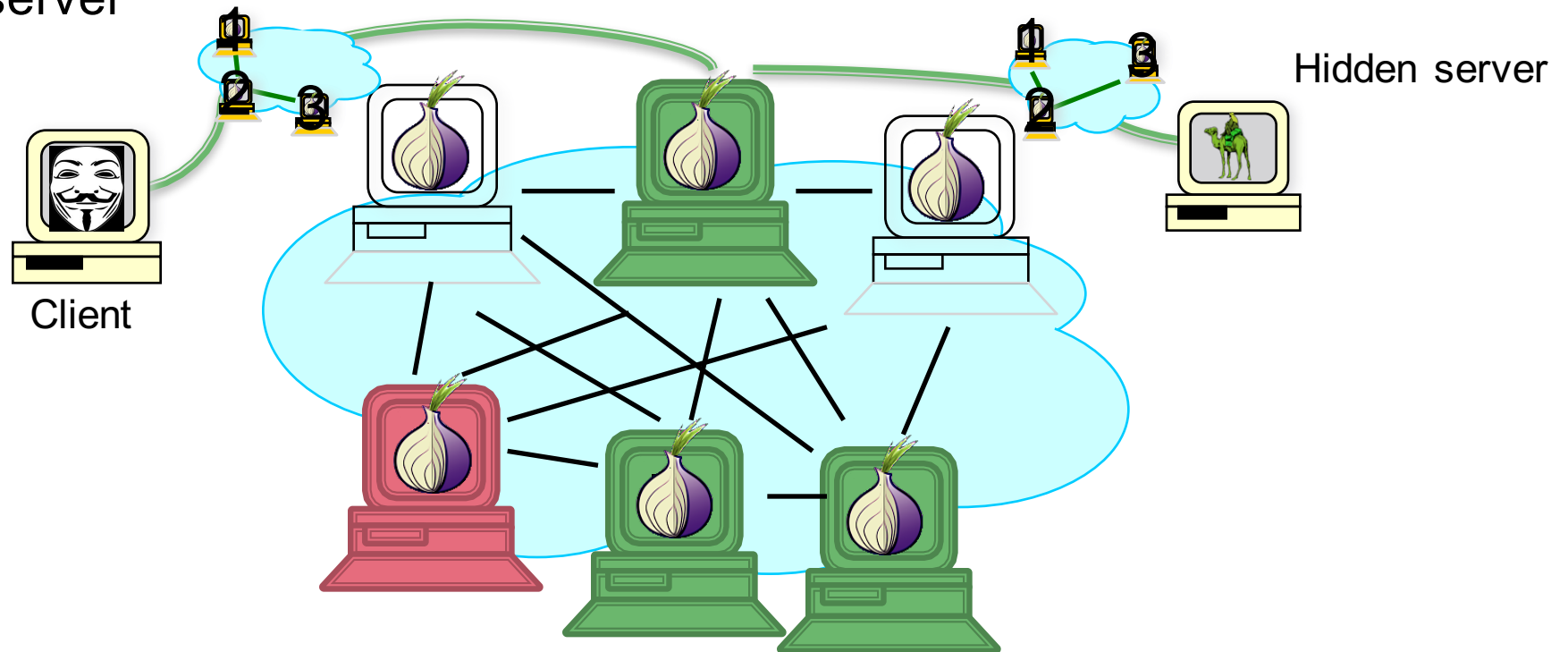
# Hidden services primer

- Client hears about hidden server, gets introduction points from DB
- Client sets up rendez-vous point (3<sup>rd</sup> node of a circuit built by client)



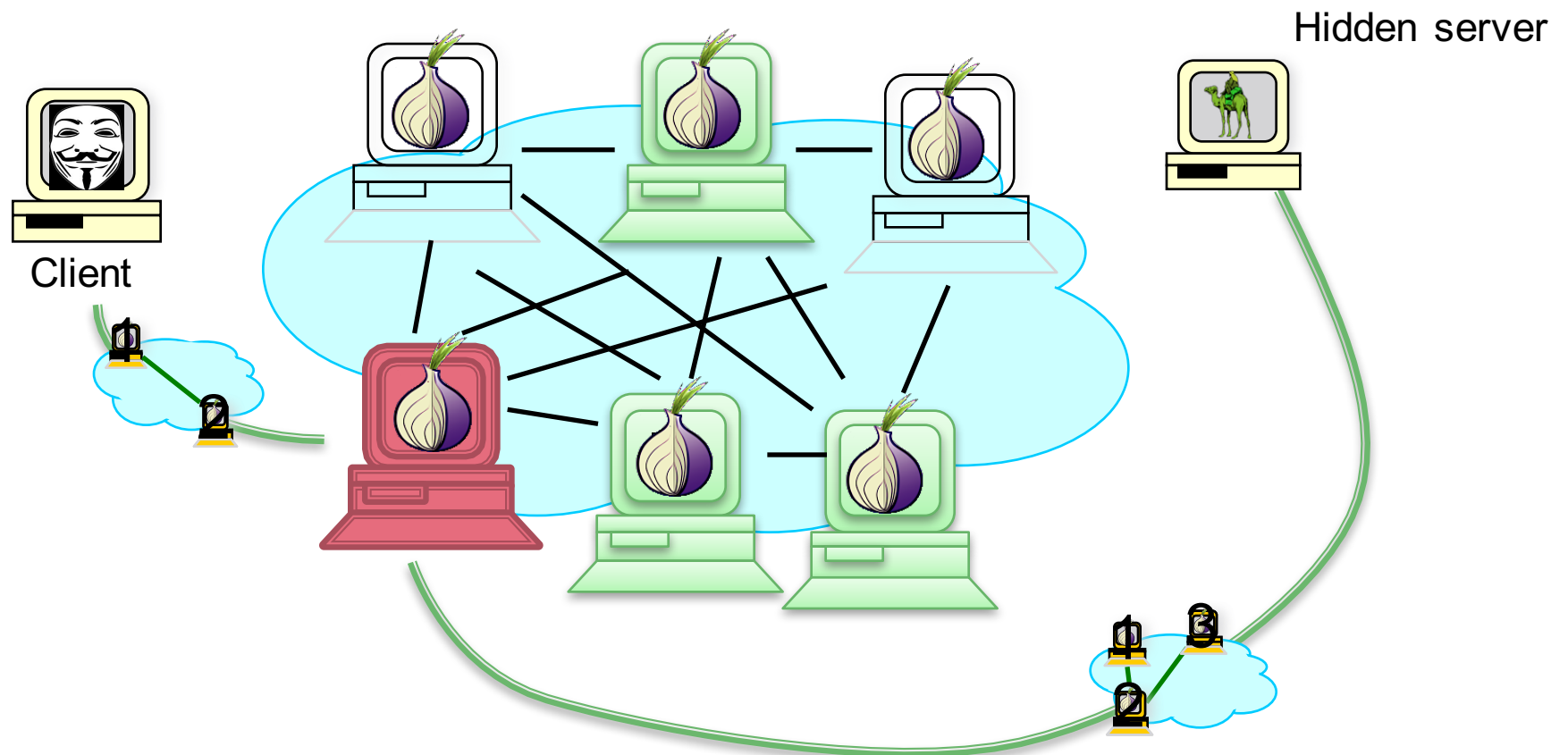
# Hidden services primer

- Client tells hidden server about Rendez-Vous Point by contacting one of the Introduction Points and asking them to relay message to server



# Hidden services primer

- Client communicate with hidden server through rendez-vous point from then on
- 6 hops (3 picked by client, including RP, 3 picked by server)



# Bitcoin primer



**Not today.**



Shop by Category

Drugs 11,247

Cannabis 2,664

Dissociatives 269

Ecstasy 1,262

Opioids 667

Other 551

Precursors 102

Prescription 2,447

Psychedelics 1,213

Stimulants 1,551

Apparel 341

Art 3

Biotic materials 2

Books 912

Collectibles 14

Computer equipment 74

Custom Orders 89

Digital goods 630

Drug paraphernalia 330

Electronics 103

Erotica 626

Fireworks 15

Food 9

Forgeries 158

Hardware 27

Herbs & Supplements 11

Home & Garden 11

Jewelry 90

Lab Supplies 53

Lotteries & games 53



Royal Customers 10G

₪1.66



Decanoate250, (1 x 10ml = 2.500mg)

₪0.39



XTC Pills MDMA 175mg x500

₪19.28



100g Dimethoxbenzaldehyde

₪1.45



LECKERMAN WEEKLY SKUNK IS BACK STRONG

₪0.52



Good Quality Soap Bar | 126g(4.5oz) | UK Vendor

₪2.78



Modafinil 200mg - 300 Pills

₪2.65



0.2g DMT Freebase

₪0.48



1g cocaine high premium quality FLEX - high grade

₪1.32



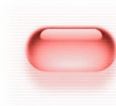
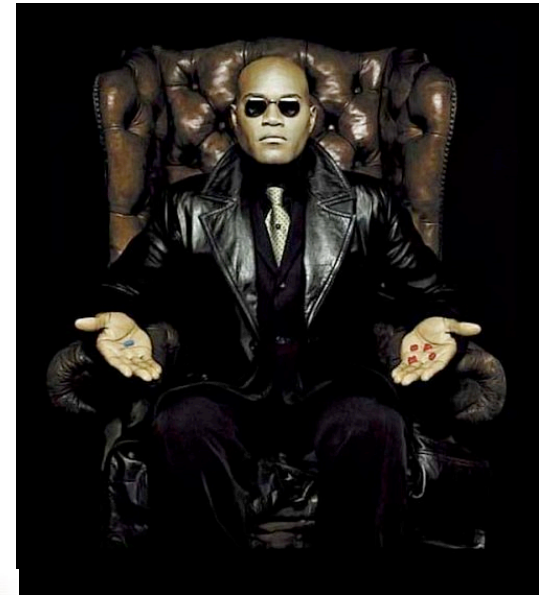
# Silk Road's real business

- Silk Road was actually **not** in the business of selling drugs
  - That was their sellers' businesses
- Silk Road sold:
  - Escrow
    - ~7% commission
  - Hedging
    - Possibility of holding your price constant in USD and have SR shoulder potential losses due to BTC volatility
- **This was essentially an insurance/financial services company selling risk management**
  - On completely illicit goods for which there was a great need for such a service...
  - Using a highly volatile currency

# Escrow



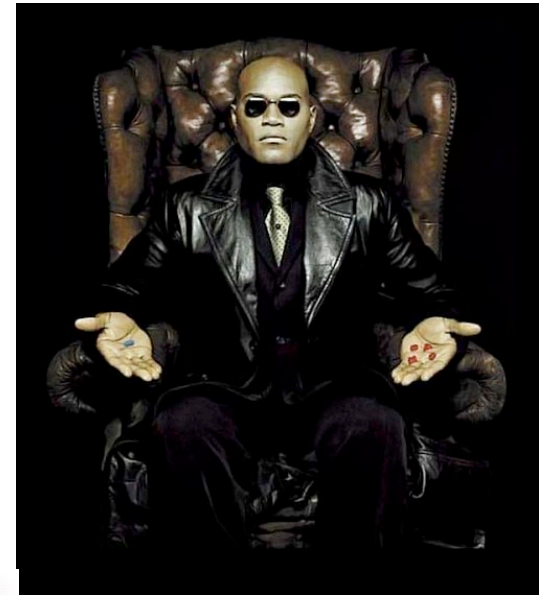
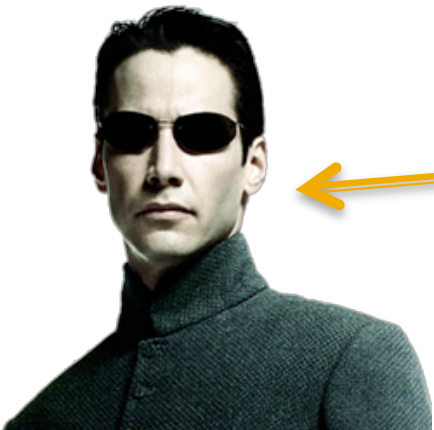
"I'll take the red pill"



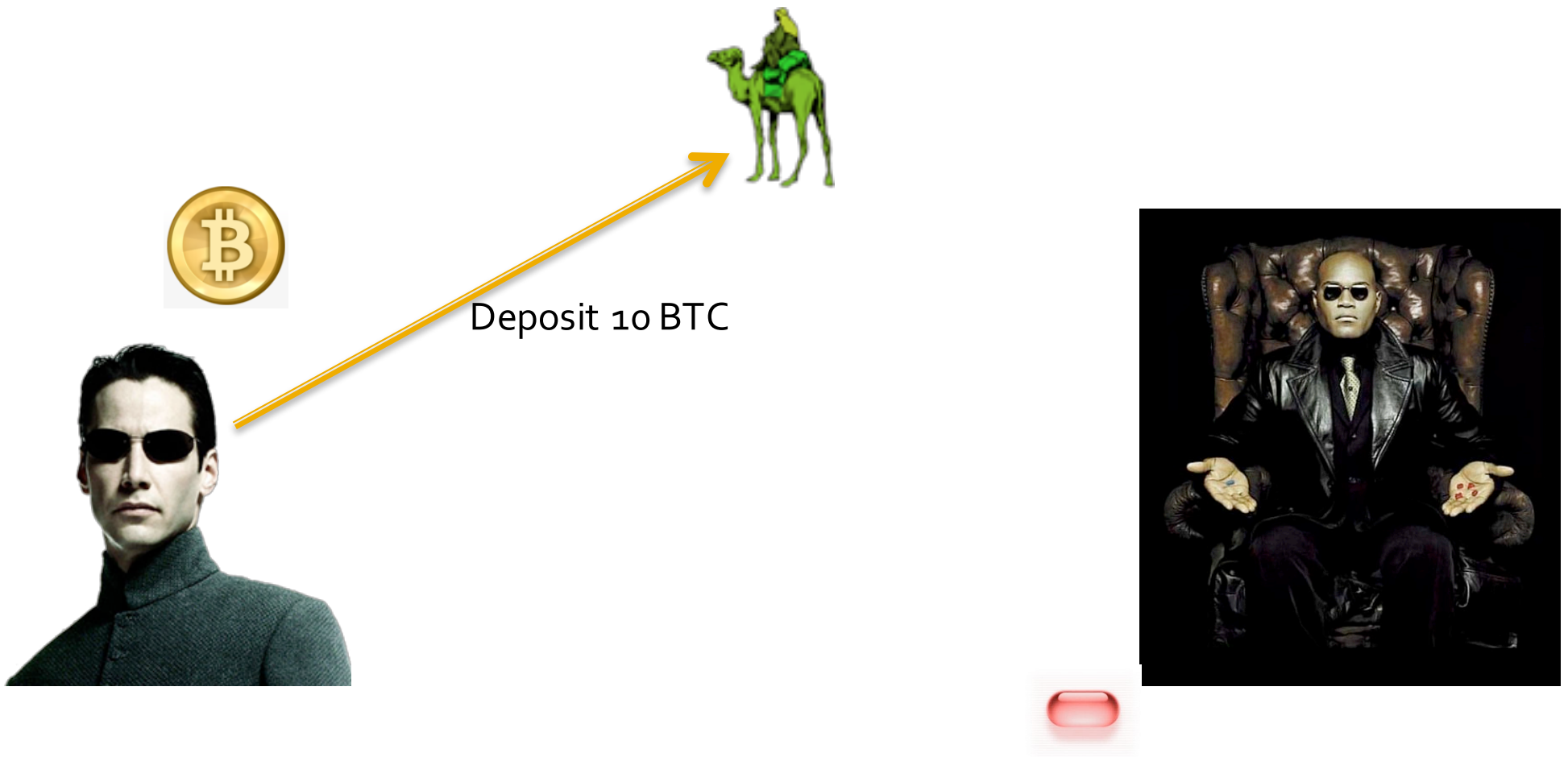
# Escrow



"The red pill is 10 BTC"



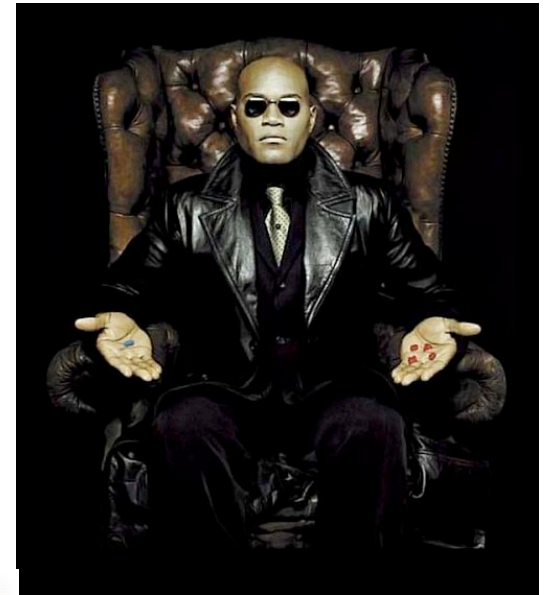
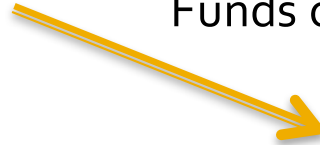
# Escrow



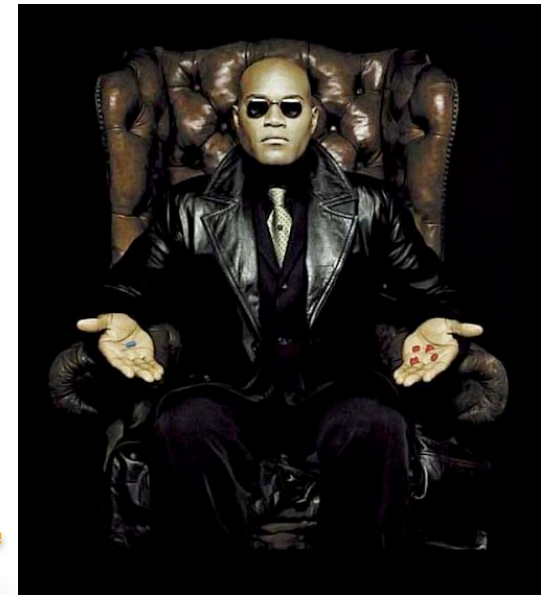
# Escrow



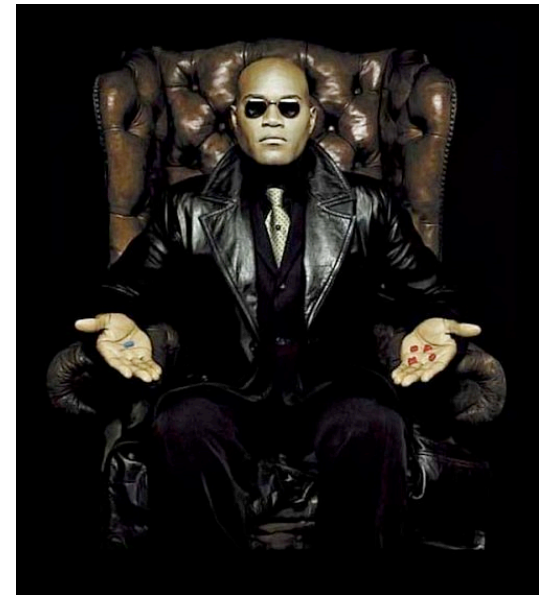
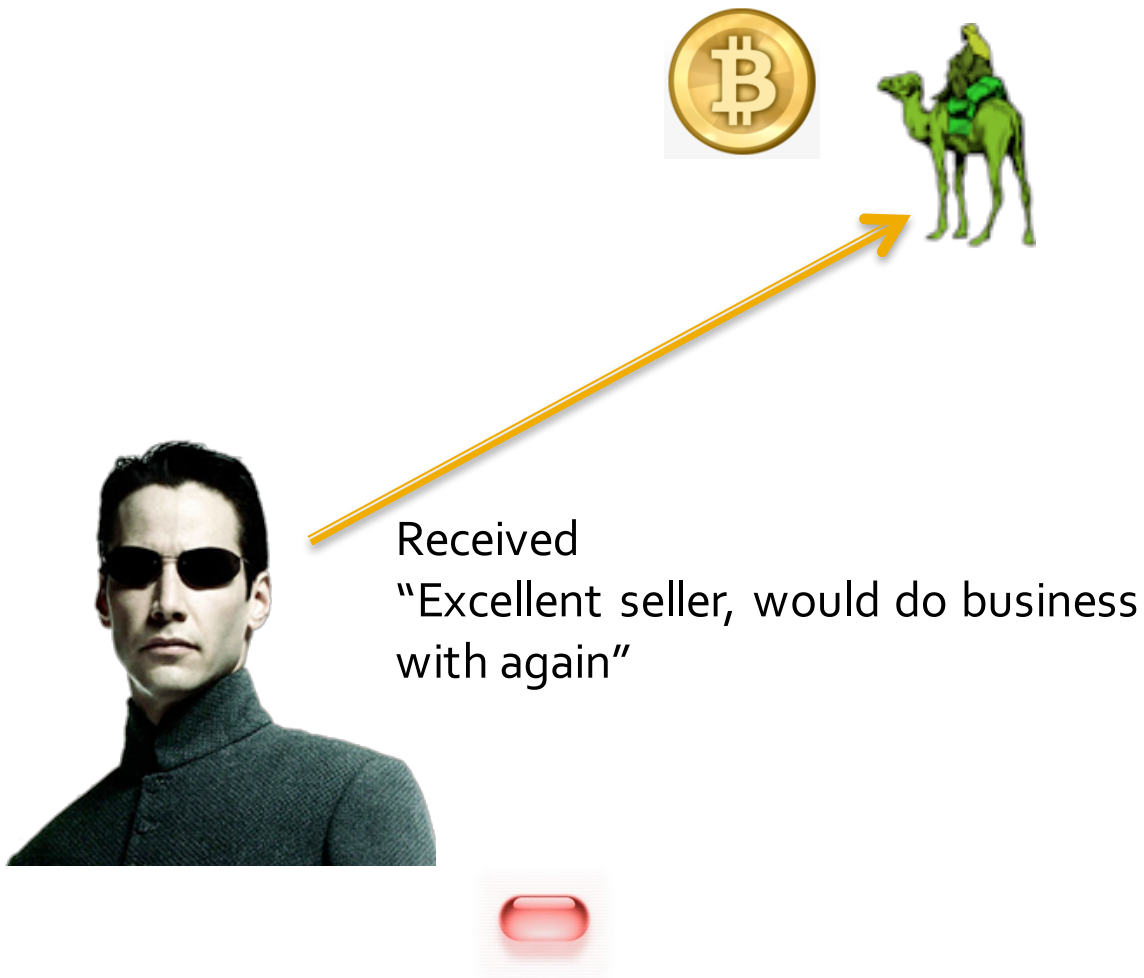
Funds ok



# Escrow

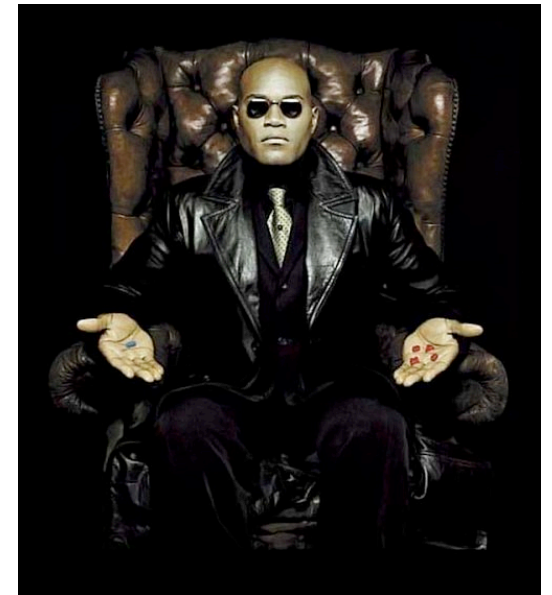
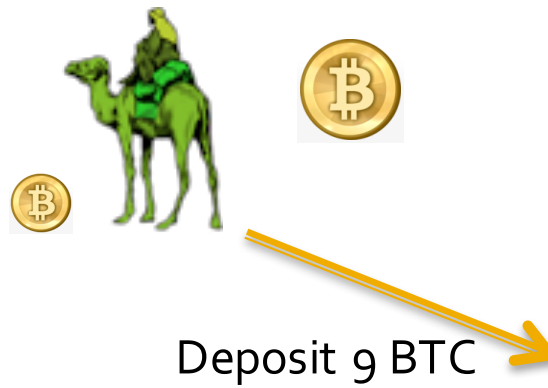


# Escrow





# Escrow





# Original research questions

[WWW 2013]

- **How can we measure activity on such sites?**
- **What is being sold?**
  - Exhaustively list items present on the website
- **Who is selling?**
  - Figure out seller information
- **How much are they selling?**
  - Get an idea of transaction volumes
- **What can we do about it?**
  - Explore various intervention policies

# Key idea:

## Draw inferences from public info

### Hacking for beginners

**Seller:**

**hackingtech (98)**

**Price:**

**฿0.12**

**Ships from:** undeclared

**Ships to:** Worldwide

#### Description:

Hacking For Beginners is a reference book for beginners to learn ethical hacking for free and from basic level to clear all the fundamental concepts of ethical hacking. the book has been prepared by Hacking Tech ( [www.hackingtech.co.tv](http://www.hackingtech.co.tv) ) website for the users benefit. so enjoy the book and site...

**add to cart**

#### Recent feedback

rating	feedback	freshness
5 of 5	Fast delivery	3 days
5 of 5	Thanks!	4 days
5 of 5	Leave feedback here	9 days
5 of 5	Leave feedback here	9 days



**Feedback is mandatory!**

➔ Acceptable proxy for sales volume

# Collection methodology

- Test run in November 2011 of Silk Road
  - Entire crawl of the site: Did not get noticed
- Daily data collection for Silk Road
  - 6 months (February 3, 2012 – July 24, 2012)
  - Crawl the entire web site using HTTrack (website mirroring tool)
    - Use an assortment of techniques to conceal our activity
      - Random start-up delays, frequent change of Tor circuits...
    - Each crawl took between 3 and 30 hours (average = 14 hours)
    - Between 250MB and 1GB of data
- Parse each page and build database

# Collected data (original Silk Road study)

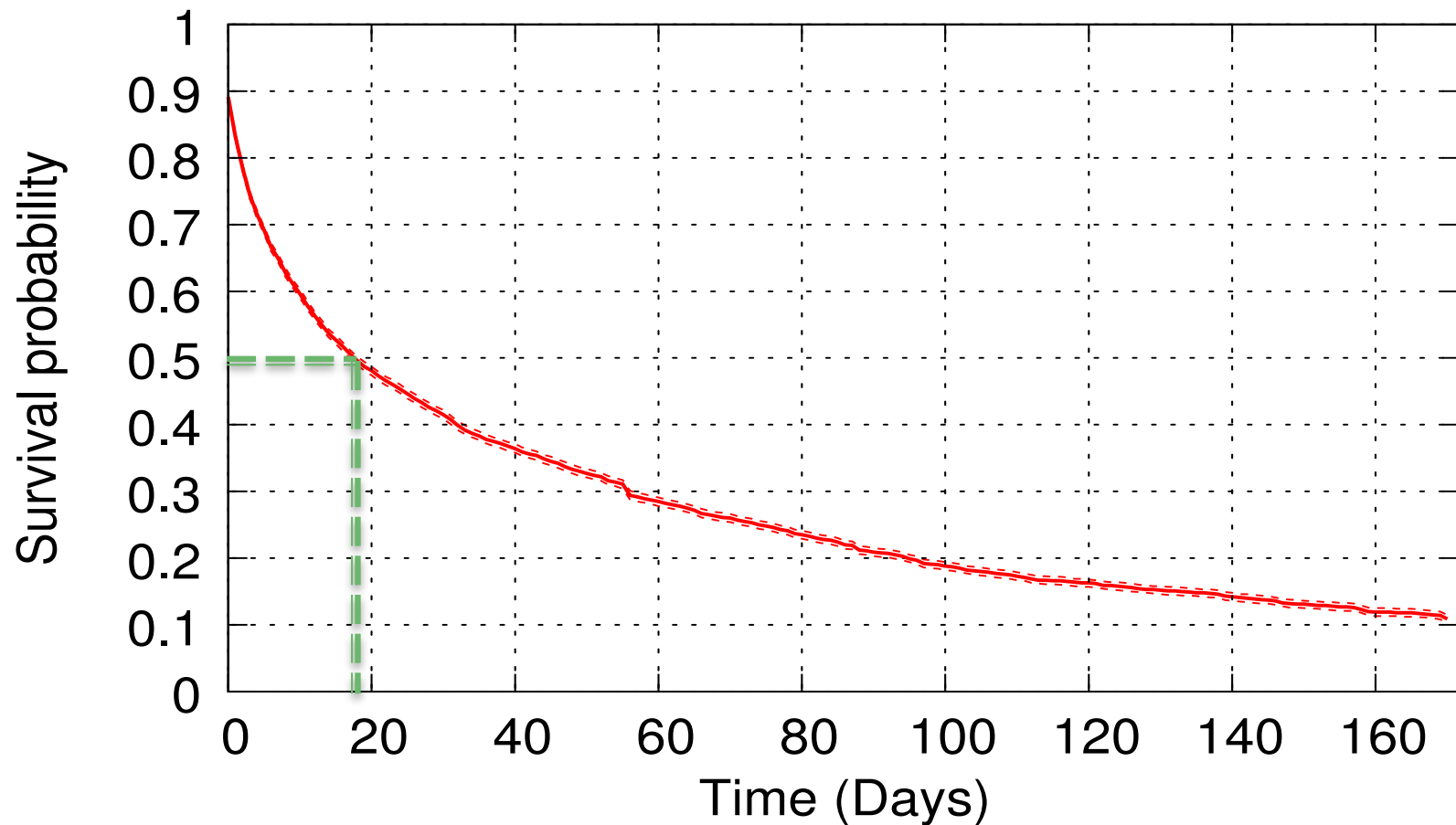
- 6 months (February 3, 2012 – July 24, 2012)
- 24, 422 unique items observed
- 1,397 unique seller accounts observed
  - Although far less are active at a given point in time
- 187,825 pieces of feedback ( $\approx$  transactions) collected

# What was being sold?

Category (listed by seller)	Number of items	Percentage of all items
Weed	3,338	13.7%
Drugs	2,194	9.0%
Prescriptions	1,784	7.3%
Benzos	1,193	4.9%
Books	955	3.9%
Cannabis	877	3.6%
Hash	820	3.4%
Cocaine	630	2.6%
Pills	473	1.9%
Blotter (LSD)	440	1.8%

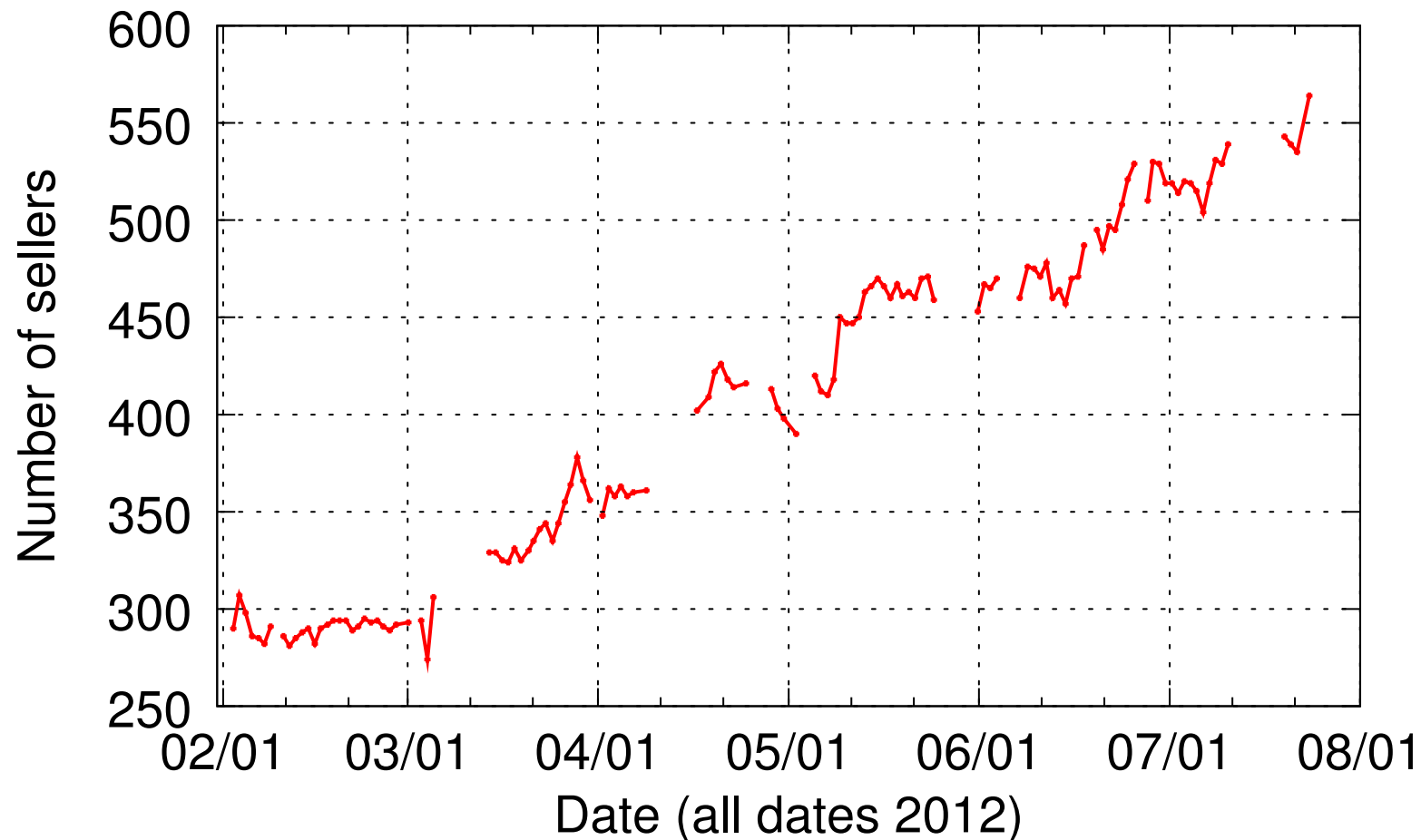
Surprise (not): Silk Road is mostly about drugs, as advertised

# Item availability



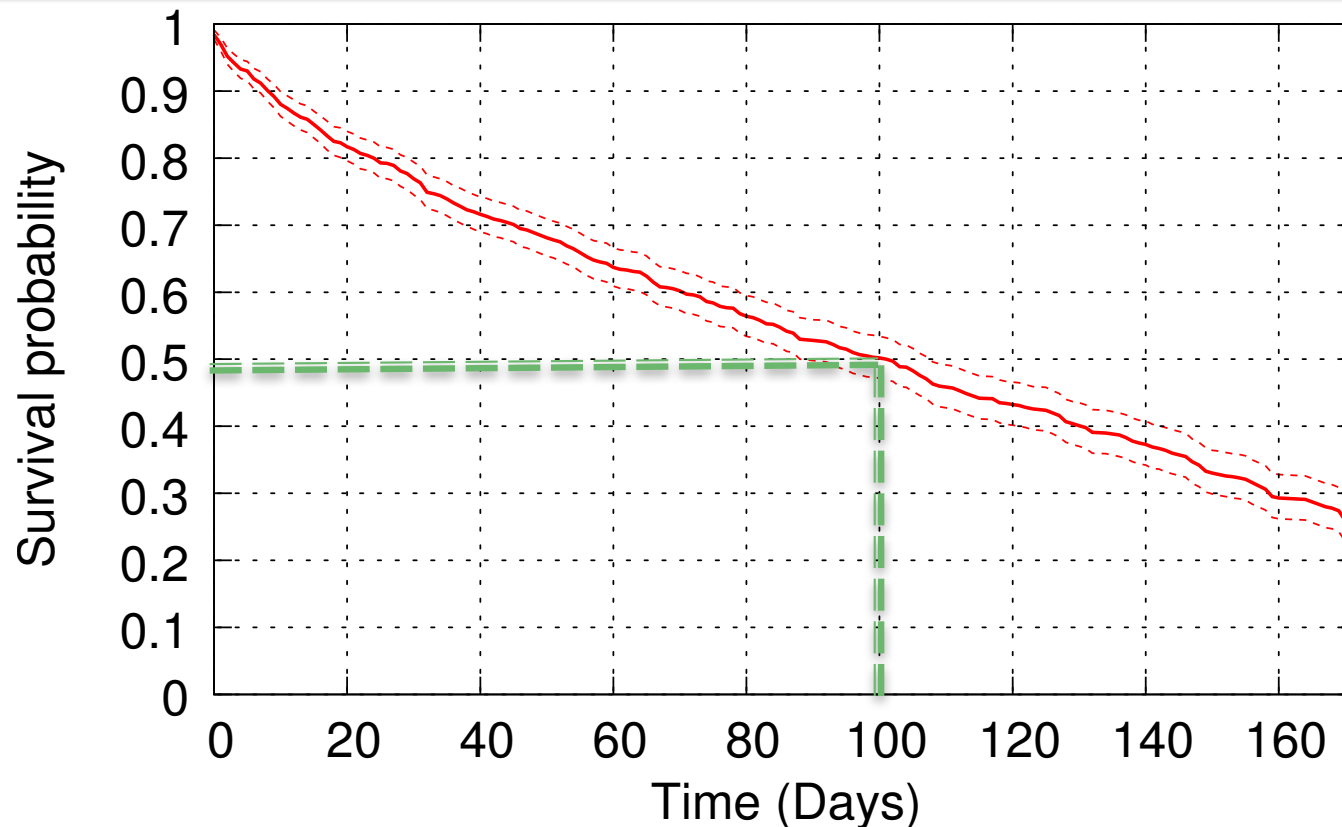
- Fairly rapid turnover
- A lot of items only listed for a couple of days

# Who was selling?



- Number of active sellers steadily increasing over time

# Seller turnover



- 1,293 different seller accounts total
  - But only between 250 and 600 active at a given time
- Relative stability
  - Average “lifespan” is a little bit over three months
  - About 60 “long timers” present over the whole interval



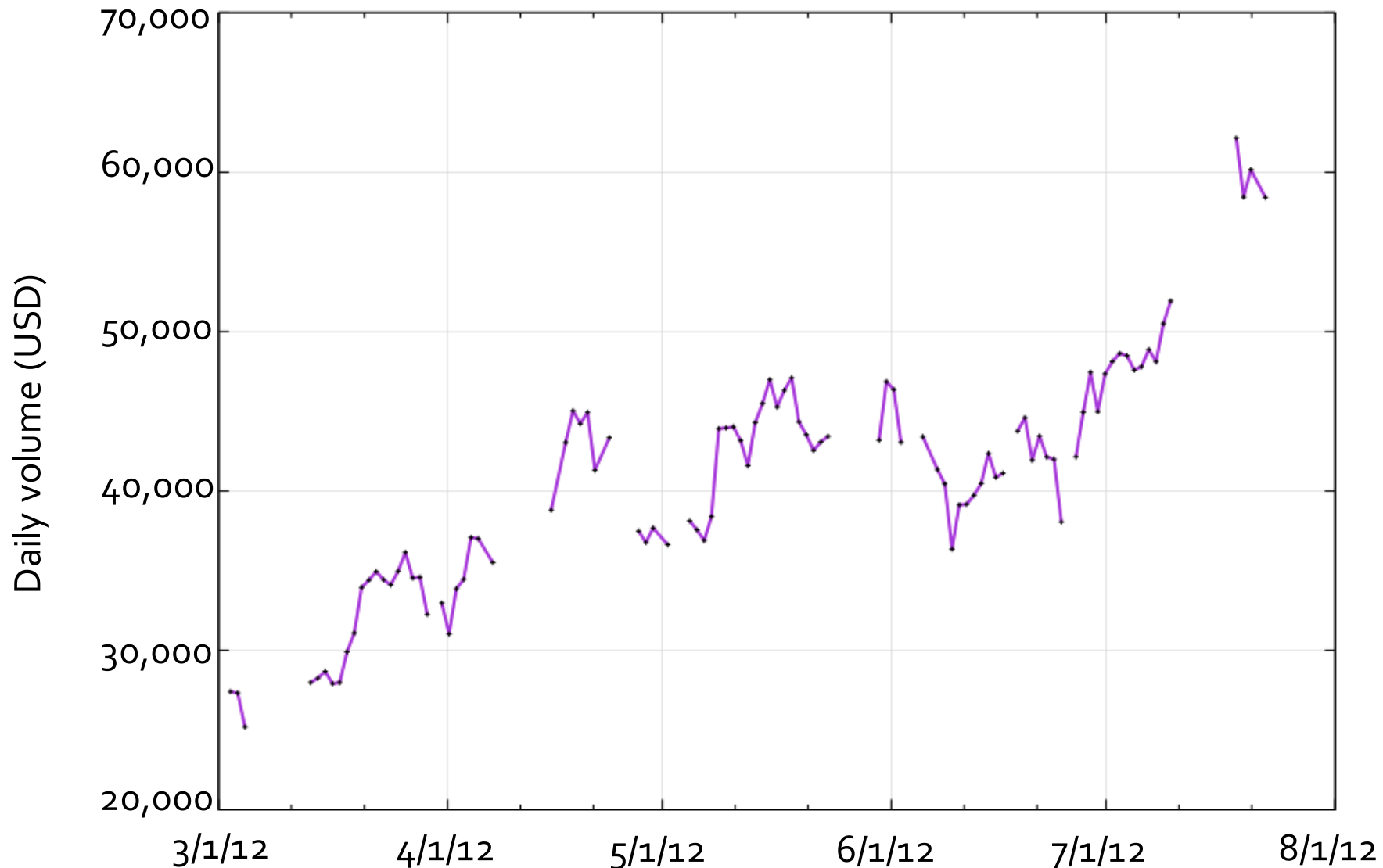
# Origins and destinations

Country	Percentage	Country/Region	Percentage
<b>USA</b>	<b>43.83%</b>	<b>Worldwide</b>	<b>49.67%</b>
Undeclared	16.29%	USA	35.15%
UK	10.15%	European Union	6.19%
Netherlands	6.52%	Canada	6.05%
Canada	5.89%	UK	3.66%
Germany	4.51%	Australia	2.87%
Australia	3.19%	Worldwide, no USA	1.39%
India	1.23%	Germany	1.03%
Italy	1.03%	Norway	0.70%
China	0.98%	Switzerland	0.62%
Spain	0.94%	New Zealand	0.56%
France	0.82%	Undeclared	0.26%

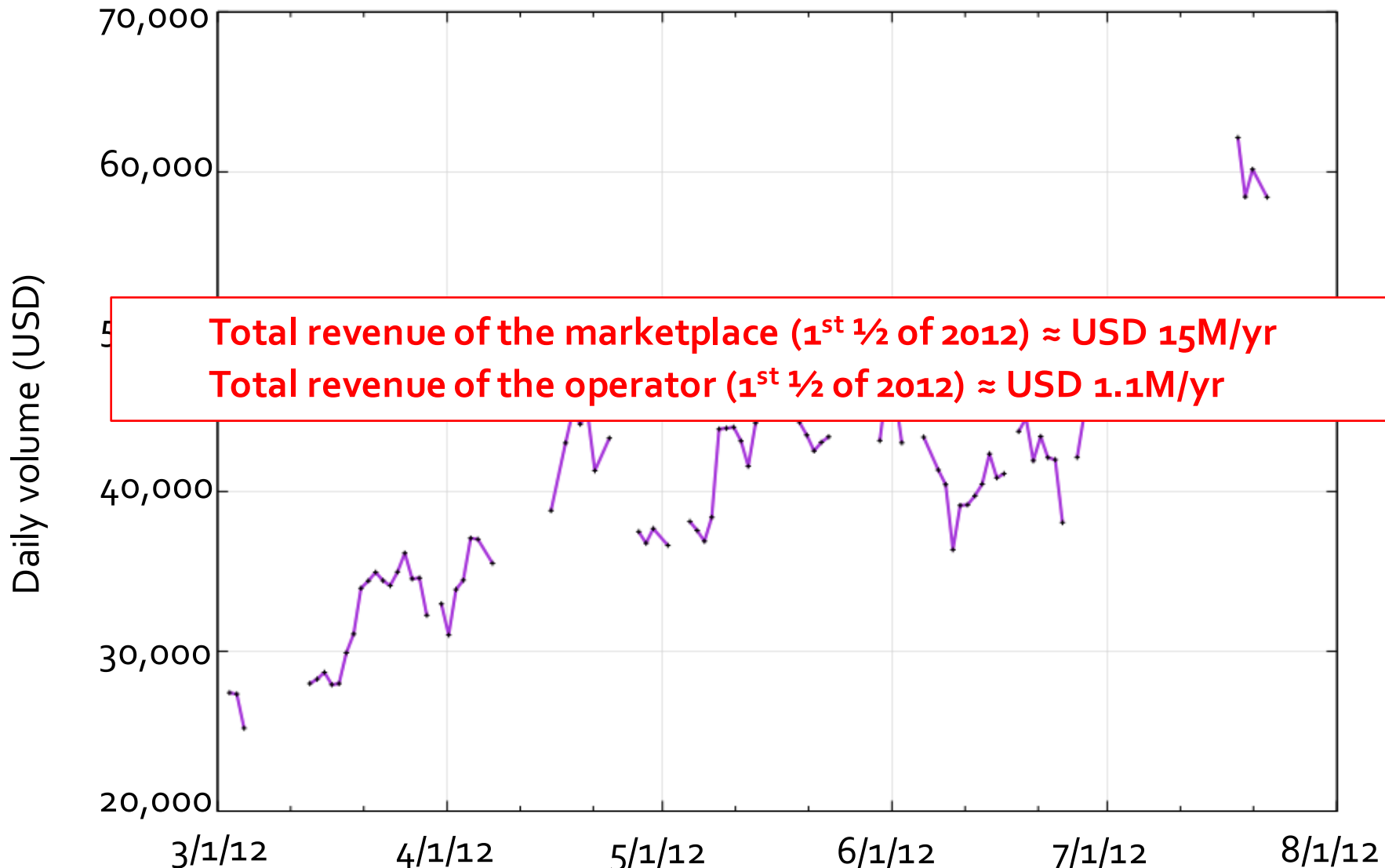
# How much were they selling?

- Sales volume can be estimated from feedback data
- **Assumption 1: 1 piece of feedback = 1 sale**
  - Dishonest sellers may be inserting fake feedback
    - Noticeable behavior, reported in forums → marginal
  - 1 piece of feedback may be equal to  $x$  quantities
- **Assumption 2: feedback timestamp accurate**
  - True in the first 24 hours ( $ts = n$  hours)
  - Somewhat true in the first 29 days ( $ts = n$  days)
  - Completely approximate afterwards ( $ts = n$  months)
- **Assumption 3: Feedback isn't counted twice**
  - Very often, buyer leaves feedback at order time, then updates it after reception of parcel; **no way of telling!**
  - Use moving averages over last 29 days

# How much were they selling?



# How much were they selling?



# And then on September 27, 2013...

Approved:  13 MAG 2328  
Serrin Turner  
Assistant United States Attorney

Before: HONORABLE FRANK MAAS  
United States Magistrate Judge  
Southern District of New York

UNITED STATES OF AMERICA

- v. -

ROSS WILLIAM ULBRICHT,  
a/k/a "Dread Pirate Roberts,"  
a/k/a "DPR,"  
a/k/a "Silk Road,"

Defendant.

SEALED COMPLAINT

Violations of  
21 U.S.C. § 846;  
18 U.S.C. §§ 1030 & 1956

COUNTY OF OFFENSE:  
NEW YORK

SOUTHERN DISTRICT OF NEW YORK, ss.:

Christopher Tarbell, being duly sworn, deposes and says  
that he is a Special Agent with the Federal Bureau of  
Investigation ("FBI") and charges as follows:

COUNT ONE  
(Narcotics Trafficking Conspiracy)



**Kate Vinton** Forbes Staff

*I write about data breaches, cyber security, and crime.*

[FOLLOW](#)

**TECH** 5/29/2015 @ 4:16PM | 15,937 views



Share

# Silk Road Creator Ross Ulbricht Sentenced To Life In Prison

[+ Comment Now](#) [+ Follow Comments](#)



*Fin*





# Competition rising



Sheep  
Marketplace

Forum

Help and example

What are you?

illegal a

**BlackMarket  
Reloaded**

<http://5onwnspjvuk7cwwk.onion>

**Welcome to the BlackMarket Reloaded**

Make sure your browser displays the following address in your

If you're unsure, you may use our redirect URL: <http://www.1>

In order to enter this site you need either to login or register

Atlantis

Users

## Welcome to Atlantis

The new and improved virtual black market. *Cheaper rates, advanced features, ease-of-use, **Litecoin** and **Bitcoin** su*

Atlantis has been designed from the ground up to improve on all aspects of competitor markets. We use **Litecoins** at

Register

Sign in

*Why we're better than the competition:*

### Cheaper Rates

We undercut all competitor markets to present you with the cheapest rates available online. All

### Better Security

We use advanced encryption services to ensure your purchases and sales are safe and

### Fan M

Our fan mana with your favc

# ... and falling



Sheep  
Marketplace

Help and Support

Black Market Reloaded

<http://5onwnspjvuk>

Welcome to Black Market Reloaded

Make sure your browser displays the following address in your address bar:

If you're unsure, you may use our redirect URL: <http://www.1>

In order to enter this site you need either to login or register

Register

Sign in

Why we're better than our competition:

## Cheaper Rates

We undercut all competitor markets to present you with the cheapest rates available online. All

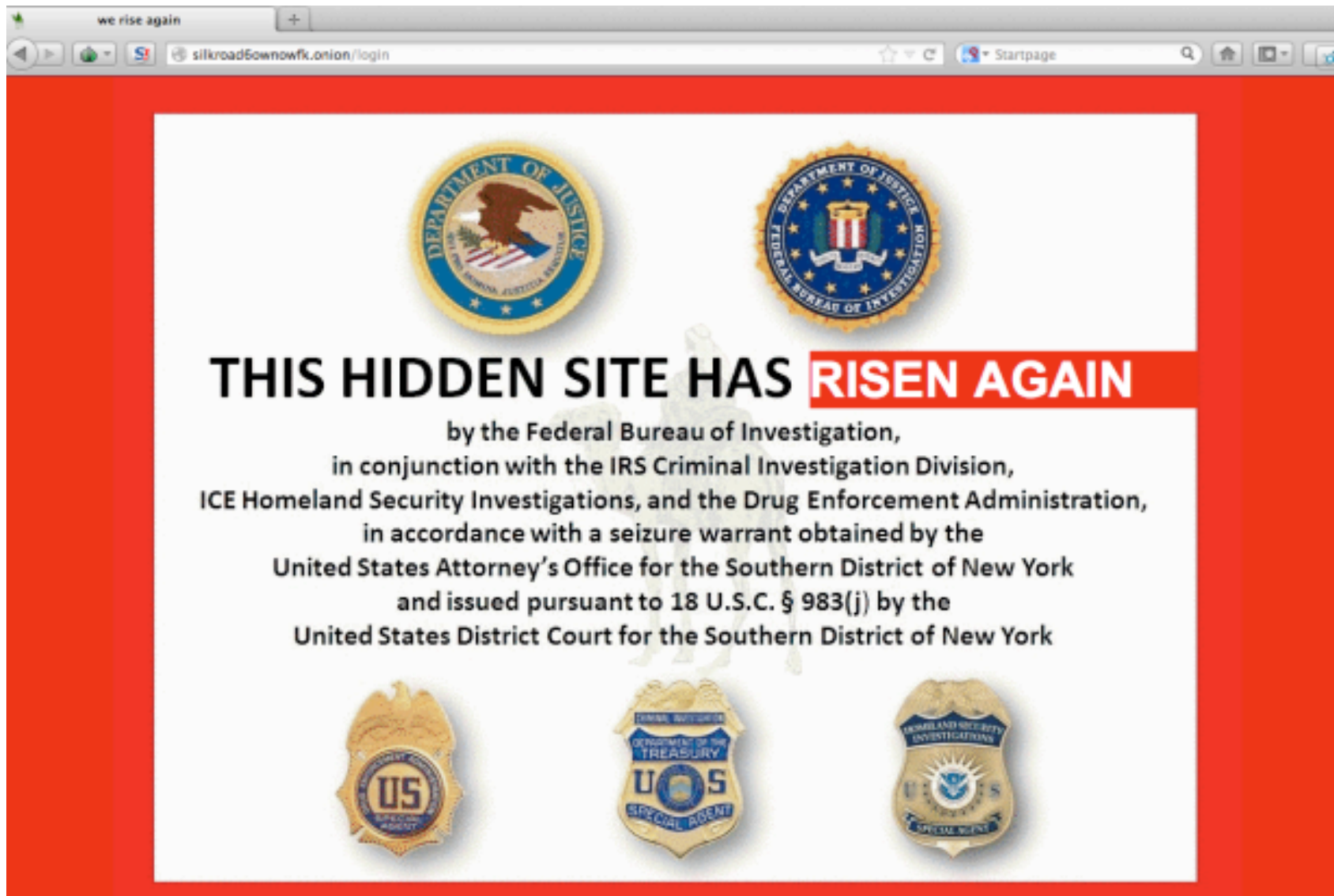
## Better Security

We use advanced encryption services to ensure your purchases and sales are safe and

## Fan M

Our fan mana with your favc

# November 2013: Silk Road 2.0



# And then on November 6, 2014...

Approved: T.H.Q.  
TIMOTHY T. HOWARD  
Assistant United States Attorney

Before: HONORABLE GABRIEL W. GORENSTEIN  
United States Magistrate Judge  
Southern District of New York **14 MAG 2427**

---

UNITED STATES OF AMERICA

- v. -

BLAKE BENTHALL,  
a/k/a "Defcon,"

SEALED COMPLAINT

Violations of  
21 U.S.C. § 846;  
18 U.S.C. §§ 1028, 1030 &  
1956

That he is a Special Agent with the Federal Bureau of Investigation ("FBI") and charges as follows:

COUNT ONE  
(Narcotics Trafficking Conspiracy)

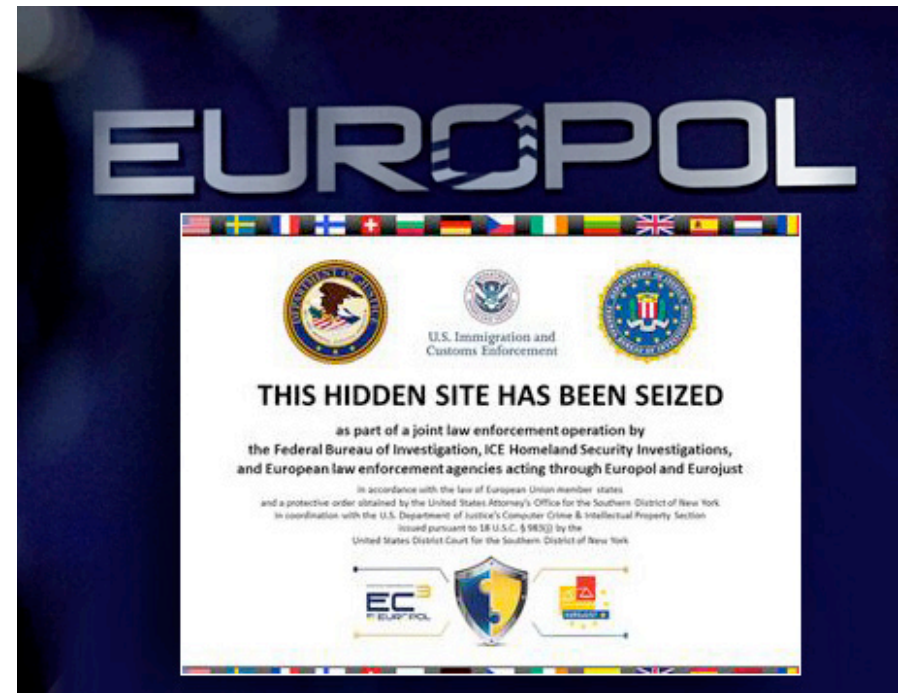
1. From in or about November 2013, up to and including in or about October 2014, in the Southern District of New York and elsewhere, BLAKE BENTHALL, a/k/a "Defcon," the defendant, and others known and unknown, intentionally and knowingly did combine, conspire, confederate, and agree together and with each other to violate the narcotics laws of the United States.

New complaint alleges 8M USD per month...  
but that's only ONE market!



# Operation Onymous

- 27 “onion” web sites seized on November 5-6, 2014
- Apparently independent operation of SR 2.0 takedown, but coordinated to maximize impact
- We do **not** know **for sure** how they located the websites
  - Poor operational security
  - Summer 2014 Tor vulnerability?
  - Centralization in VPS used?



- Largest marketplaces (e.g., Agora, Evolution) unaffected

# Today's landscape

- Highly dynamic ecosystem
- Marketplaces come up, go down frequently
  - Law enforcement seizures (Operation Onymous, Silk Road 1 and 2, ...)
  - More frequently: “Rip-and-run” (Sheep, Evolution, ...)
- Despite adversarial landscape, the overall ecosystem seems to have significantly grown overall...

# Marketplaces analyzed

[Soska & Christin, USENIX Security 2015]

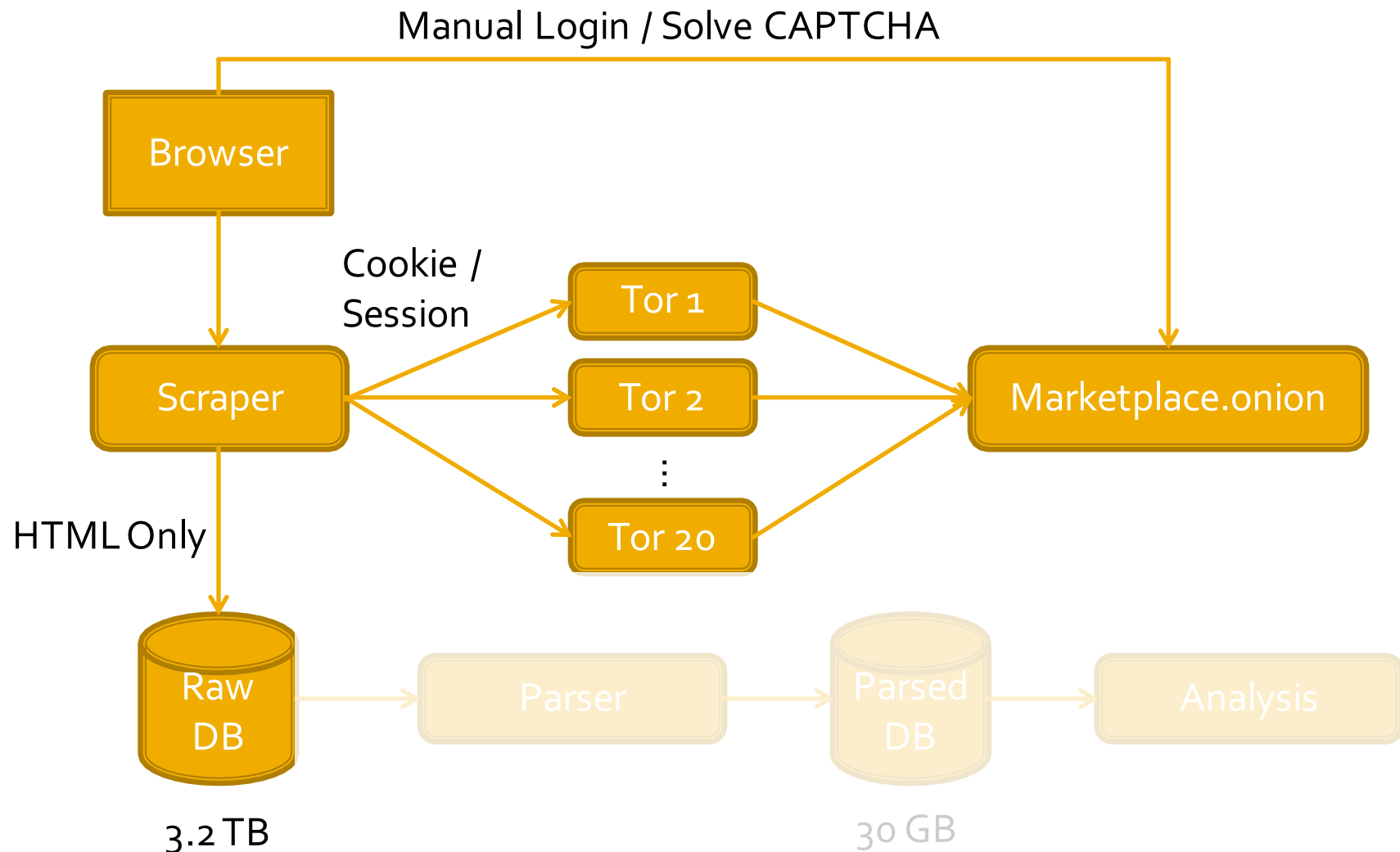
- From mid-2013, scraped all marketplaces we could find as soon as we were aware of them
- Parsed the most prominent ones (as of 2015)
  - **Scraped & Parsed:** Agora, Atlantis, Black Flag, Black Market Reloaded, Tor Bazaar, Cloud 9, Deep Bay, Evolution, Flo Market, Hydra, The Marketplace, Pandora, Sheep, Silk Road (July 2013), Silk Road 2.0, Utopia
  - **Scraped only:** Andromeda, Behind Blood Shot Eyes, Black Bank, Blue Sky, Budster, Deep Shop, Deep Zone, Dutchy, Area 51, Freebay, Middle Earth, Nucleus, Outlaw, Python Market, White Rabbit, The Pirate Shop, The Majestic Garden, Tom Cat, Tor Market
- 35 marketplaces
- 2,000+ scrapes
  - ranging from 27 to 331,691 pages each
- Overall 3.5+ TB of raw data
- **More recent scraping (no parsing yet):** Acropolis, AlphaBay, Apple Market, Dark Rabbit, Darknet Heroes, Dream Market, Hansa Market, Oasis, The Real Deal, Silk Kittie, Silk Road 3.0, Tochka Market, Zocalo

# Monitoring large marketplaces

- Data collection of that magnitude is much harder than what we originally had for Silk Road
- Need several properties, at odds with each other
  - **Stealth:** Should not alert the operators of the marketplaces so that they do not adjust their behavior
    - In particular, need to avoid blocking on the operator side
  - **Completeness:** Scrapes need to represent an entire marketplace
    - Very hard to do when typical uptime is ~70%
  - **Instantaneousness:** Scrapes must complete in as little time as possible to give a proper snapshot
    - Very hard to do when there are 300,000+ pages to parse over Tor
    - e.g., AlphaBay currently hosts more than 500,000 pages
- Custom-built Python scraper and parser, built on top of Tor circuits



# Measurement platform overview



# Anti-scraping measures

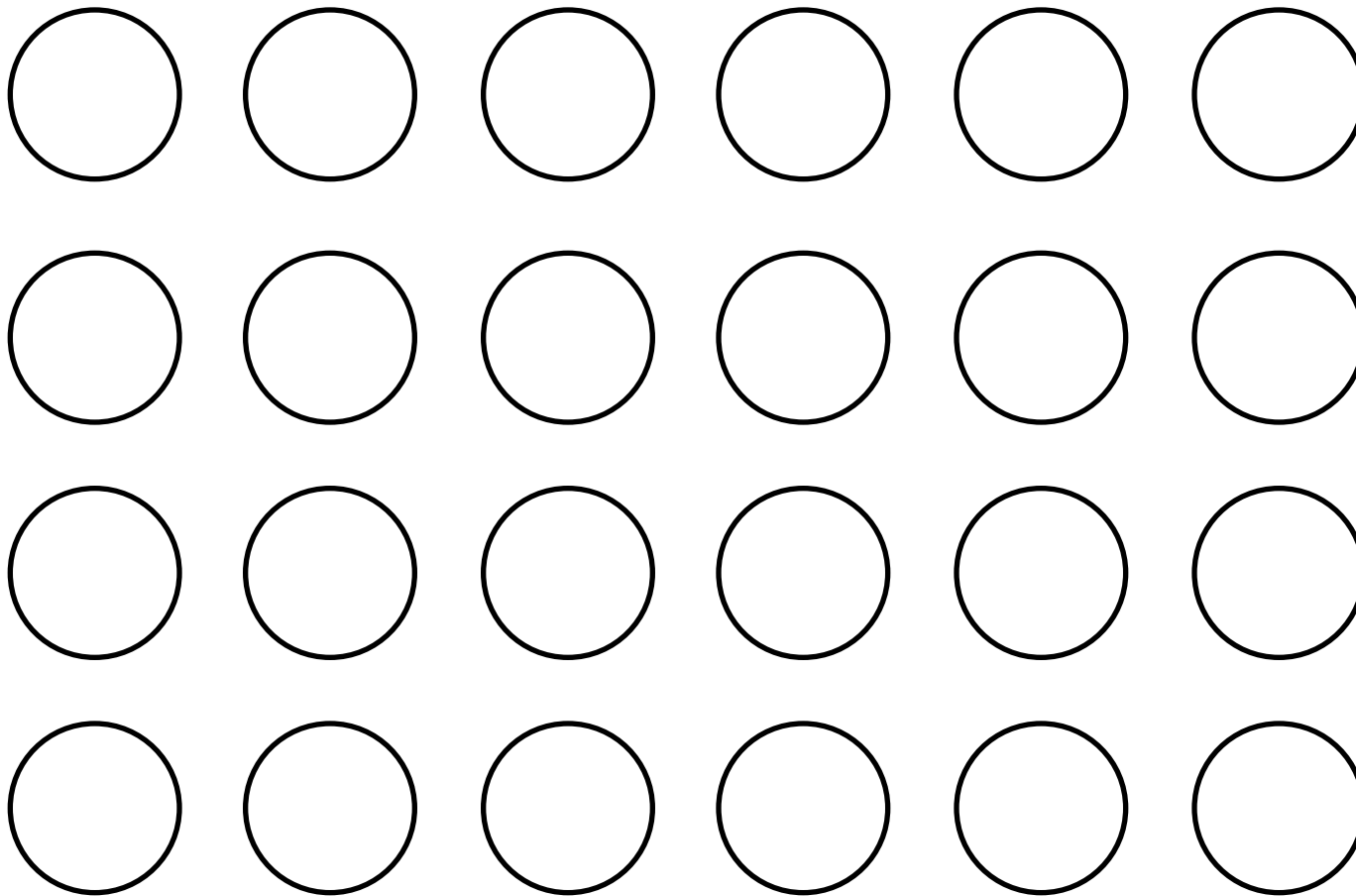
- **Anti-scraping encountered**
  - Rate limits
  - Cookie timeout
  - User account suspension

# Data completeness

- **How complete is the data?**
  - Unreliable dynamic marketplaces that take days to scrape
  - Empirical observations – lower bound
- **Idea:** Estimate population via mark and recapture
  - Schnabel estimator allows multiple recapture

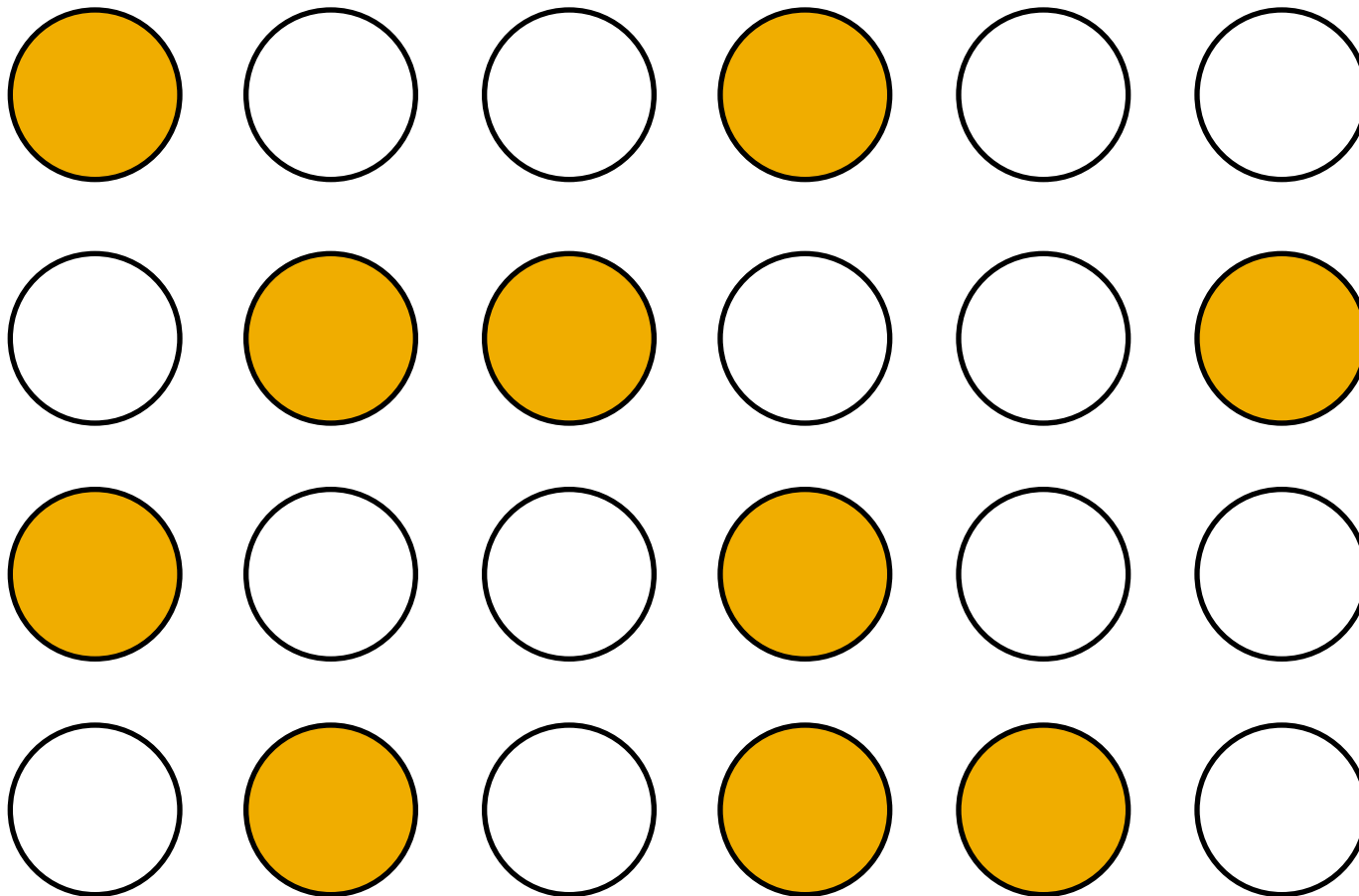
# Mark and recapture

Population Size = 24



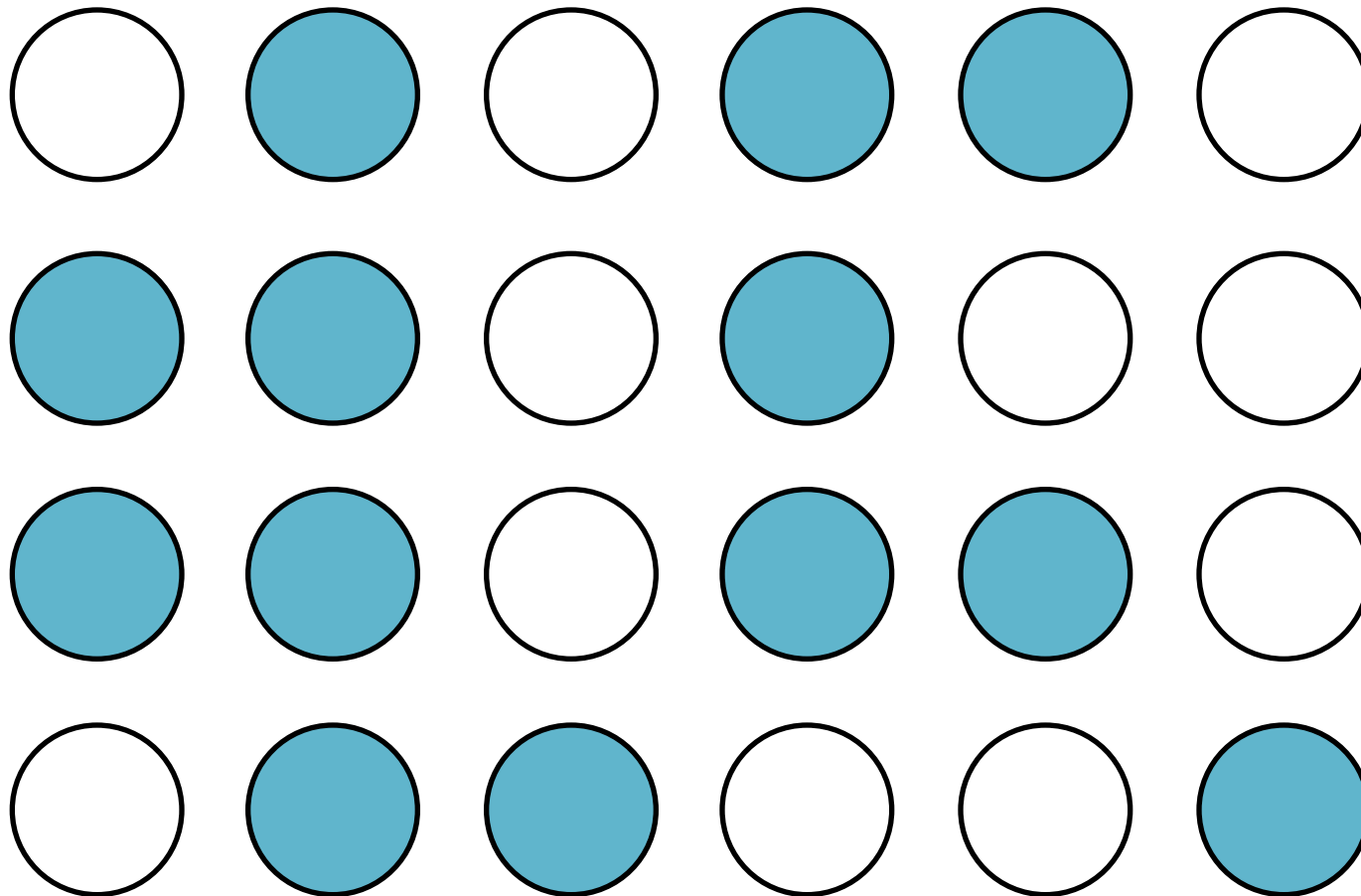
# Mark and recapture

Sample Size = 10



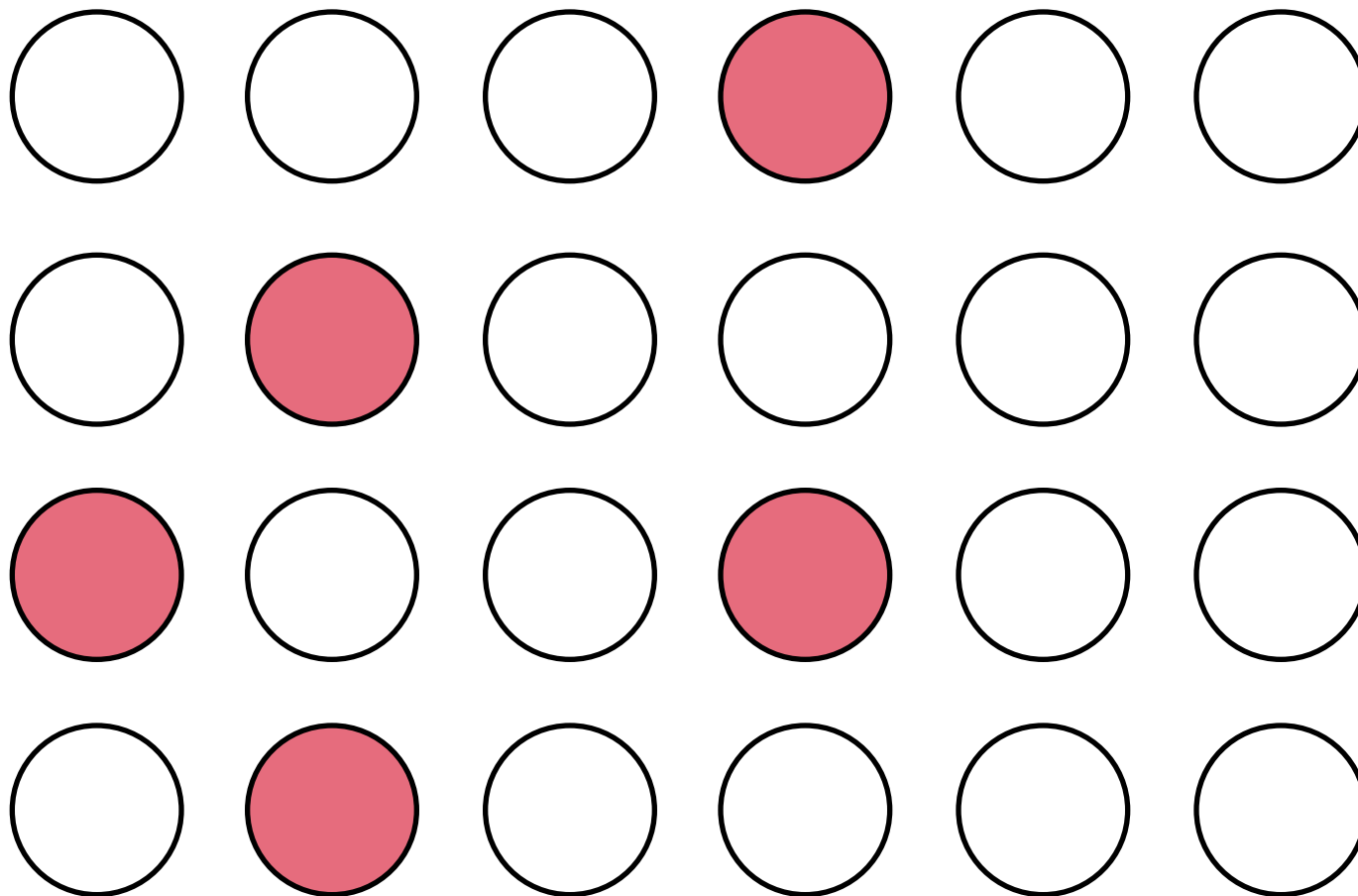
# Mark and recapture

Sample Size = 13

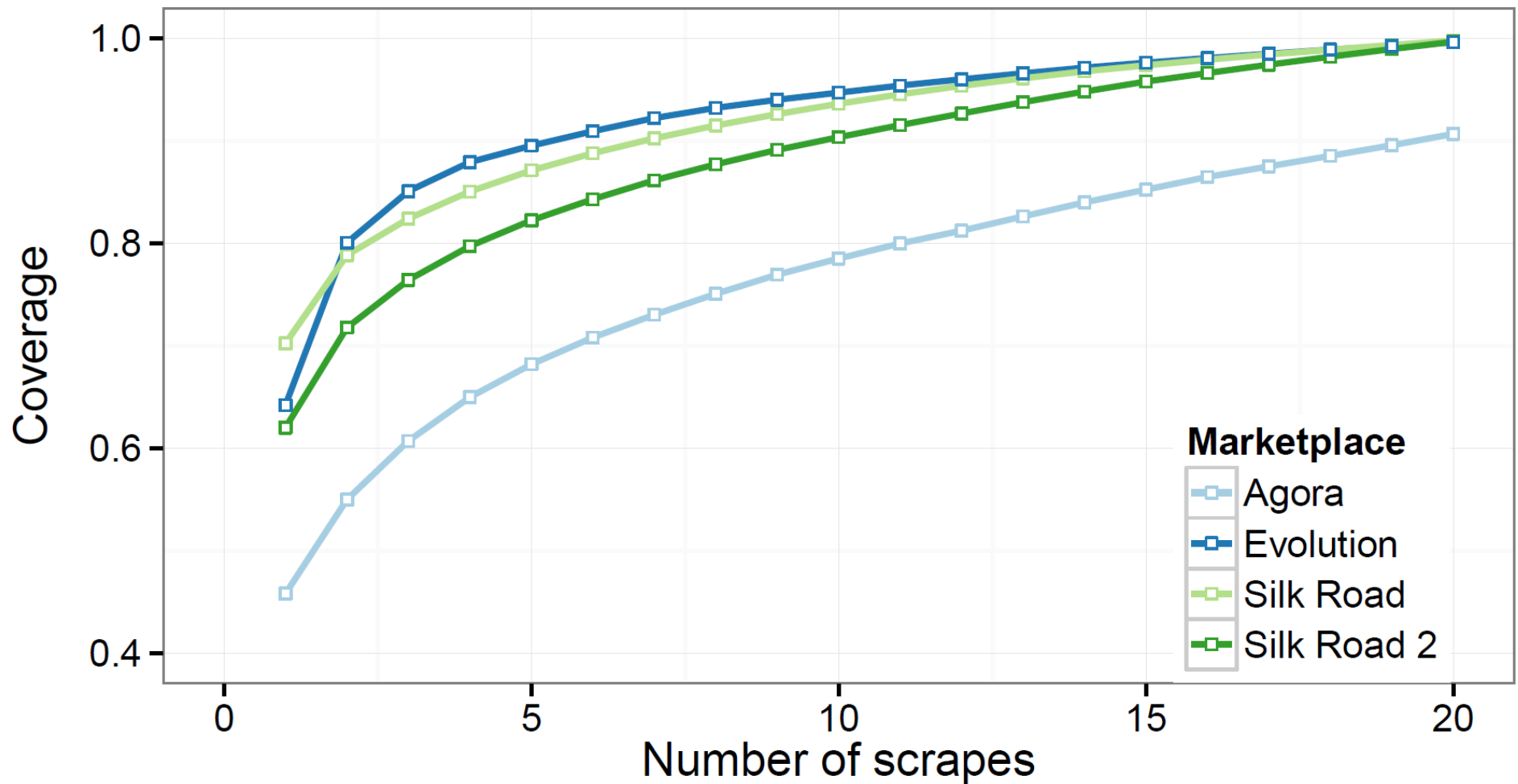


# Mark and recapture

Overlap = 5, Population Estimate = 26

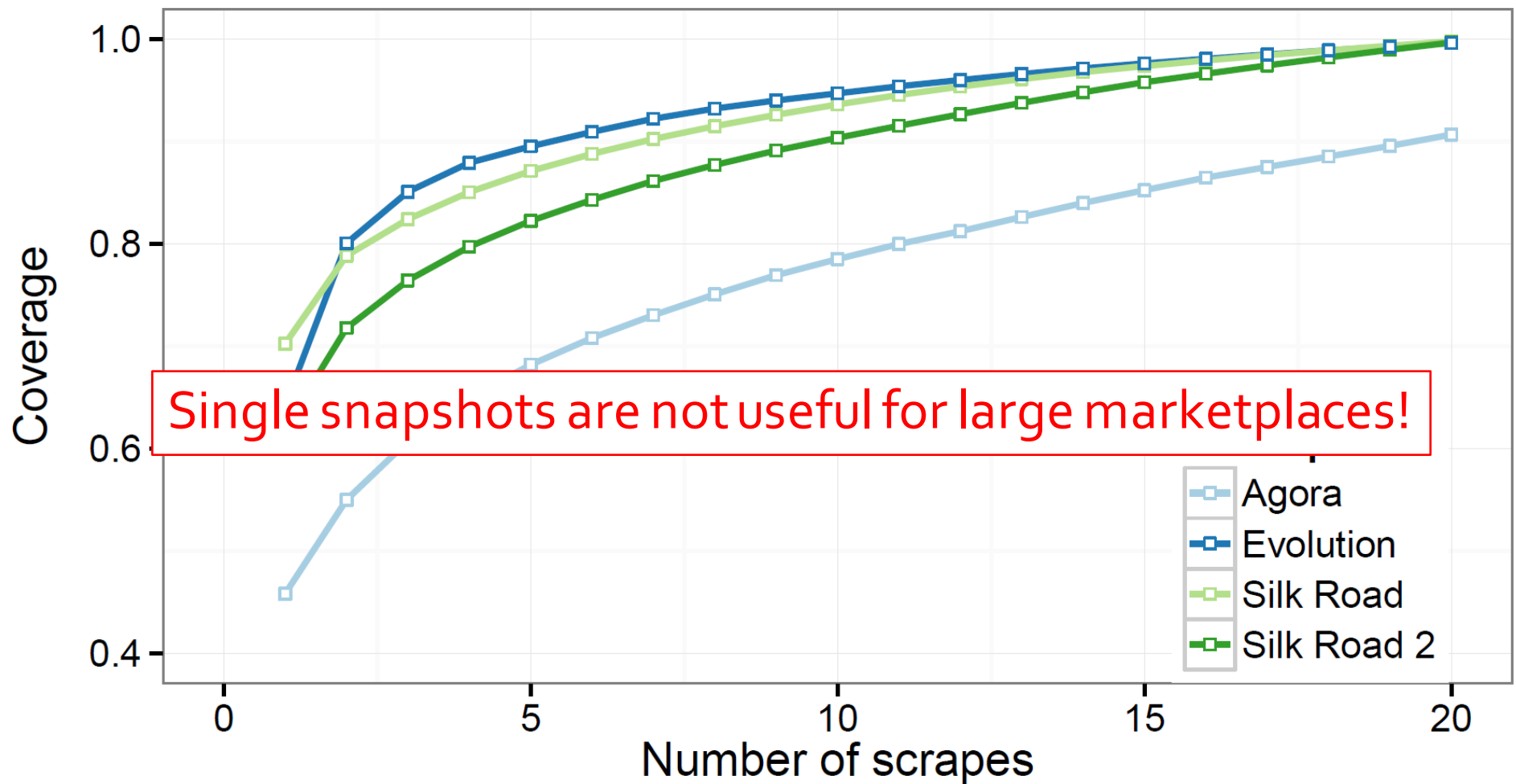


# Data completeness





# Data completeness



# Alternative transaction proxies

- **Counting # Item Listings**
  - Very efficient and convenient
  - Assumes that there exists some stable ratio between transaction volume and # listings
  - Daily  $\frac{\text{volume}}{\# \text{ Listings}}$  for The Evolution Marketplace in July 2014 and September 2014 **differ by factor of 4**
    - Vendor listing the same thing on multiple marketplaces
    - No stable conversion rate (e.g., expensive items sell less frequently than cheap ones)
  - **Terrible proxy for transaction volume**
    - “Studies” based on it have no validity and can be thrown out

# Uniqueness

## ■ Problem:

- 100s of observations of same feedback
- Double counting leads to over-estimations
- Feedback may be updated, deleted

## ■ Solution:

- Automatically detect updated feedback messages
  - Only keep most recent version
- Hash {timestamp, title, vendor, message, rating}

# Holding prices

- Feedbacks are useful to vendors but are destroyed when the listing is removed
- Vendors raise listing prices prohibitively high



\$0.02 -> \$1,000.00



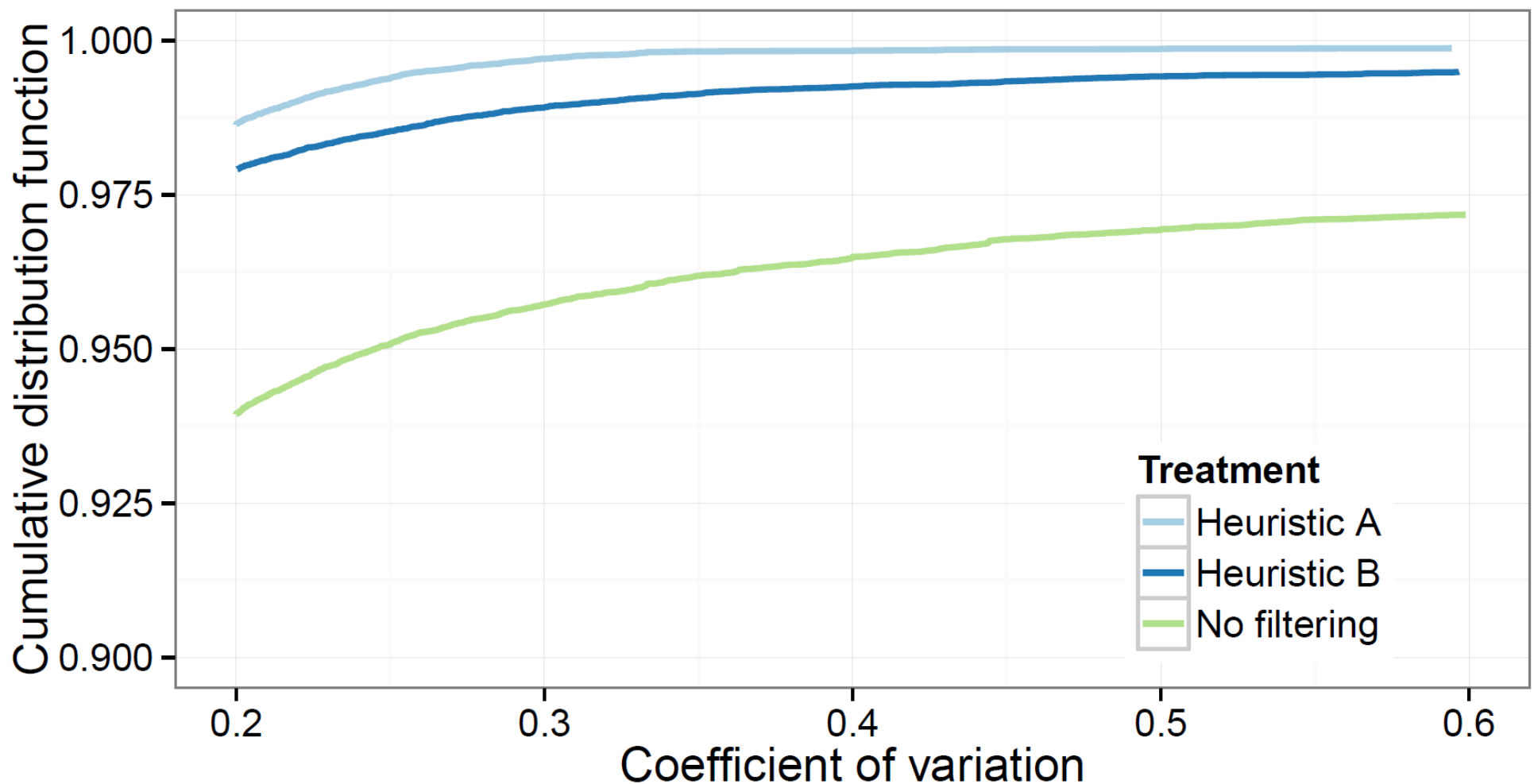
\$1,100.00 -> \$1,000,000.00

- Need to look at historical price for item

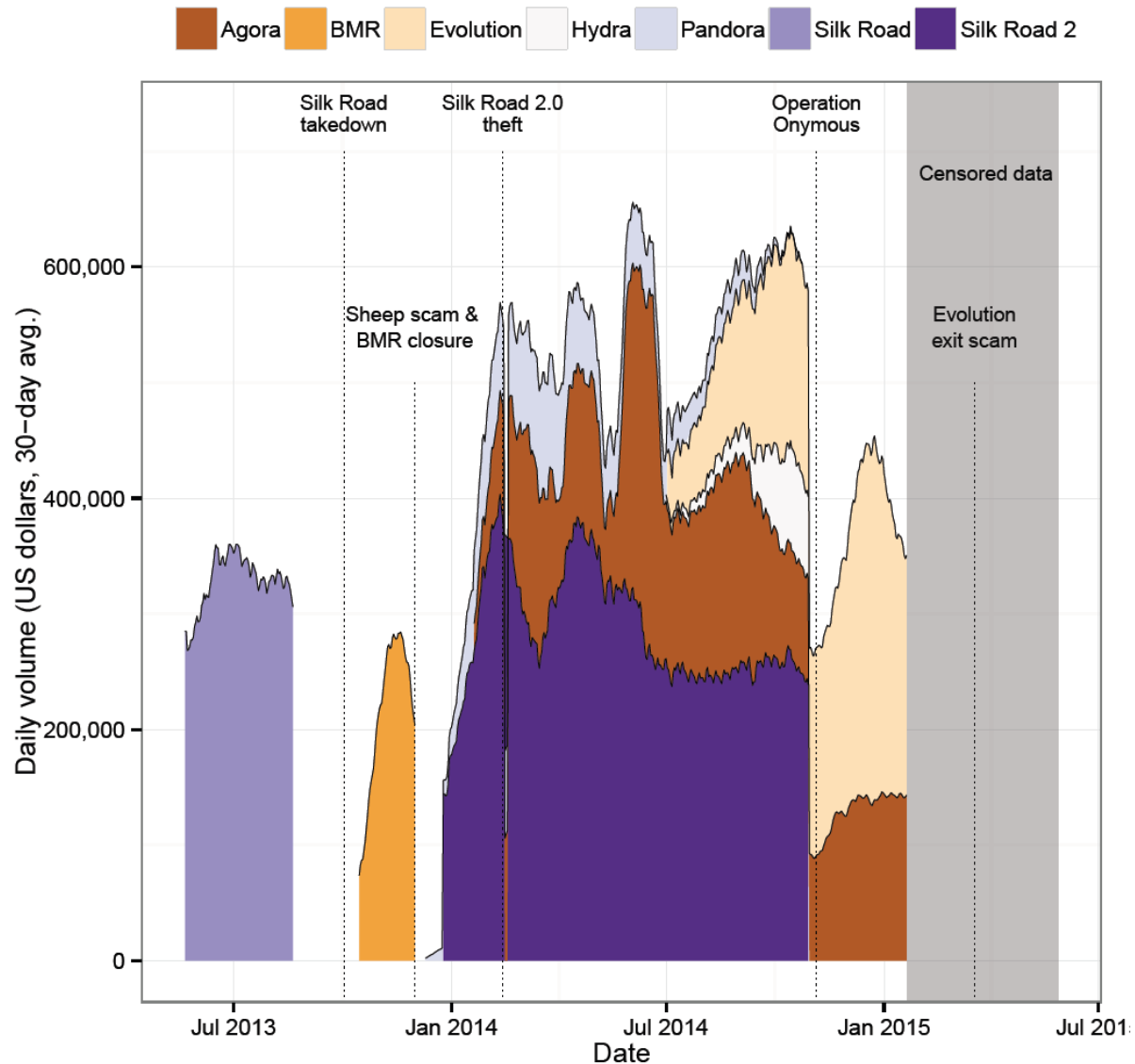
# Holding prices

- Heuristic A:
  - Remove all free items
  - Remove all items > \$100,000
  - Calculate median of remaining prices
  - Remove everything greater than 5x median
  - Remove items less than 25% of median
- Heuristic B:
  - Remove all items > \$100,000
  - Remove upper quartile
  - Remove everything greater than 100x cheapest non-zero price
- Evaluation
  - Coefficient of Variation  $c_v = \frac{\sigma}{\mu}$

# Holding prices CDF



# Sales volume



# Classifying products

- How has the sale of products evolved since the days of Silk Road?
- Are recreational drugs still dominating the market?
- **Major challenge:** classification is hard because categories are self-reported, inconsistent and at times purposefully wrong



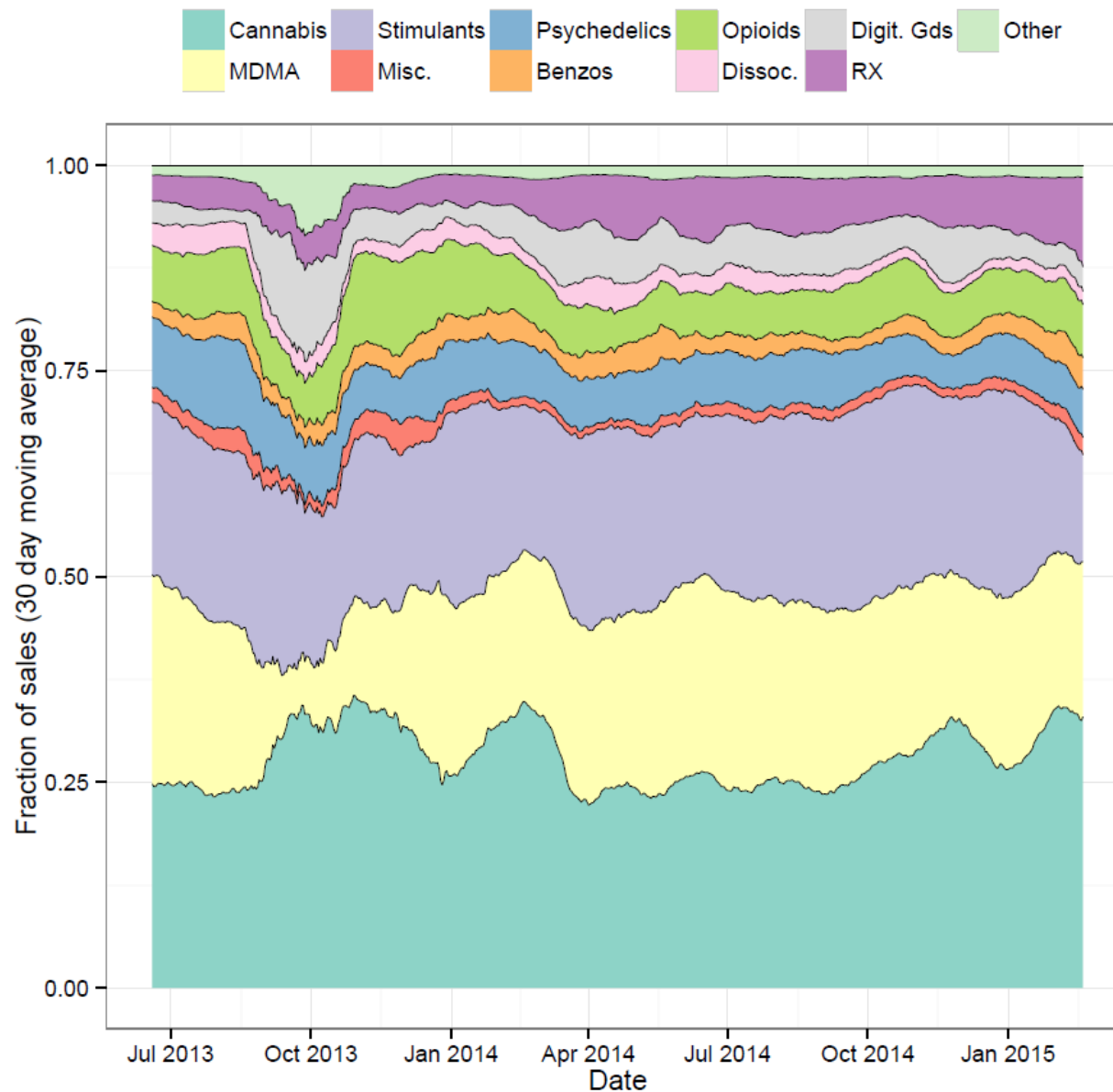
- **Solution:** build our own classifier which assigns categories based on text content
  - Very good performance (almost always >95% accurate) when comparing with ground truth (obtained through human assessment)



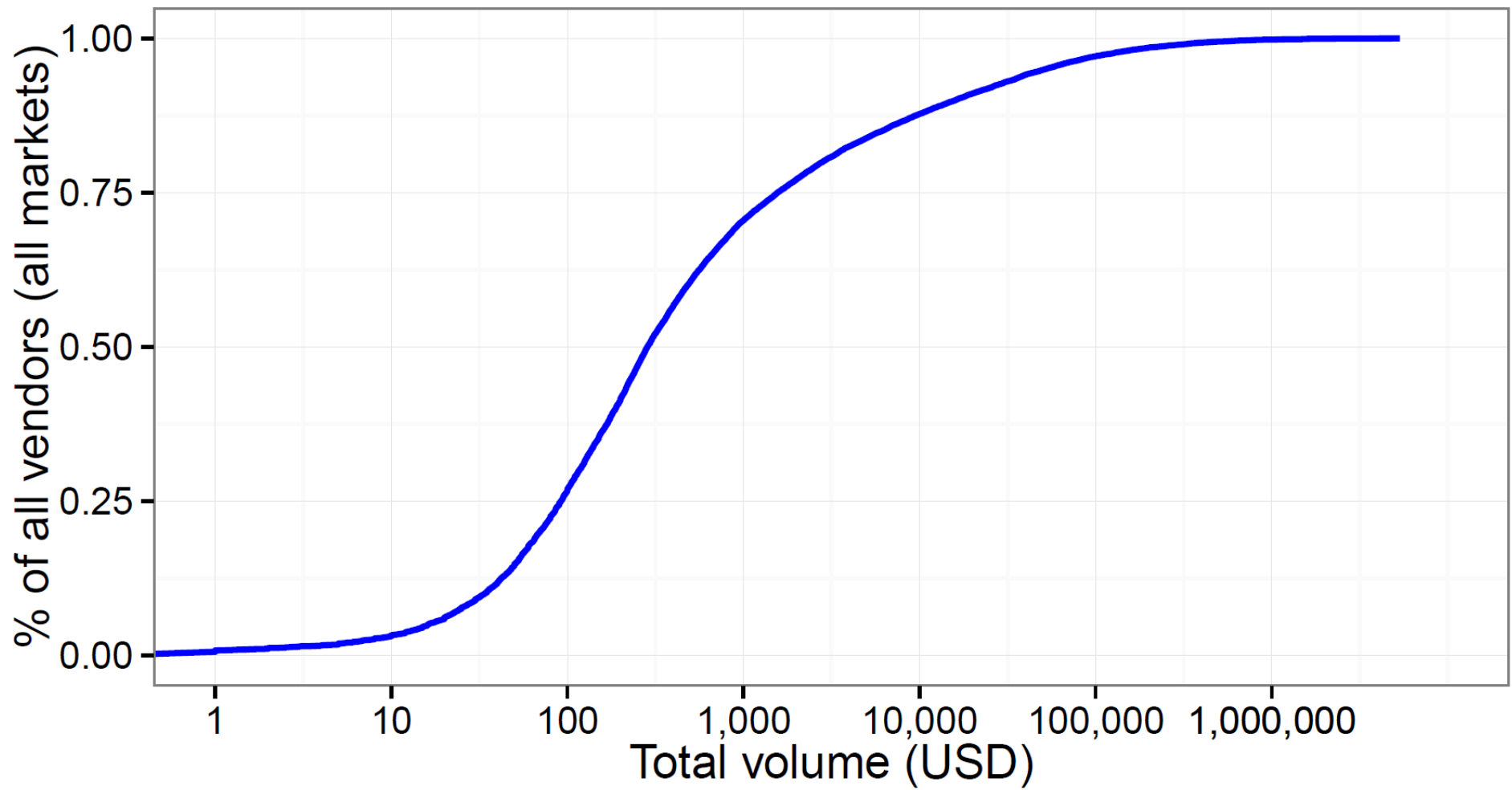
# Confusion matrix

BNZ	0.98	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
DG	0	0.96	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0
DIS	0	0	0.99	0	0	0	0	0	0	0	0	0	0	0	0	0
ELEC	0	0.03	0	0.92	0.02	0	0.02	0	0	0	0	0	0	0	0.01	0
MISC	0	0.2	0	0	0.8	0	0.01	0	0	0	0	0	0	0	0	0
OP	0	0	0	0	0	0.98	0	0	0.01	0	0	0	0	0	0	0
PAR	0	0	0	0	0	0	0.99	0	0	0	0	0	0	0	0	0
PSY	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
RX	0.03	0	0	0	0	0.02	0	0	0.93	0	0.02	0	0	0	0	0
SL	0	0	0	0	0	0	0	0	0.02	0.98	0	0	0	0	0	0
STI	0	0	0	0	0	0	0	0	0	0	0.99	0	0	0	0	0
STR	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
THC	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TOB	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
WPN	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.98	0
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.99
	BNZ	DG	DIS	ELEC	MISC	OP	PAR	PSY	RX	SL	STI	STR	THC	TOB	WPN	X

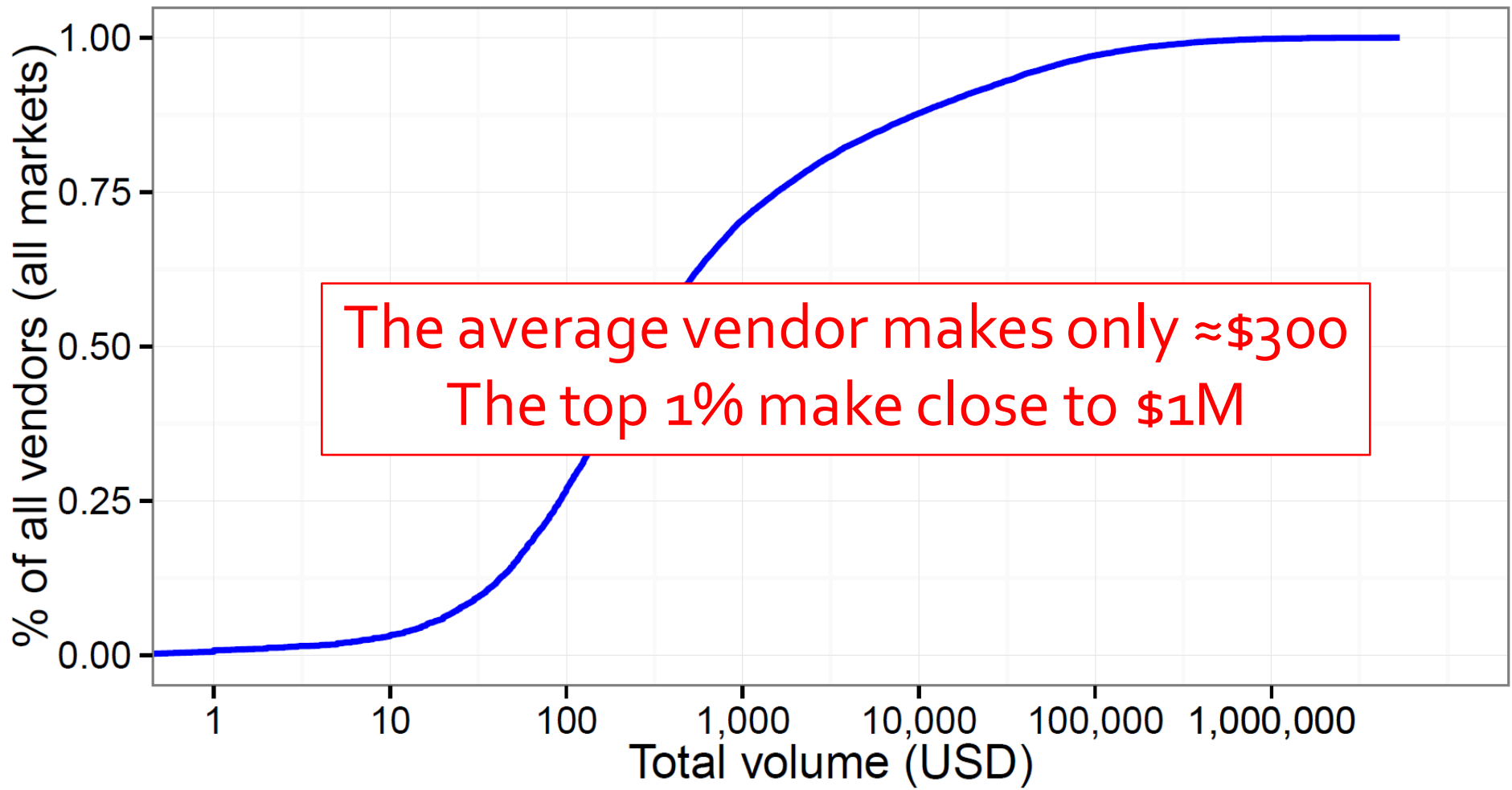
# Item sales per category



# Big or small vendors?



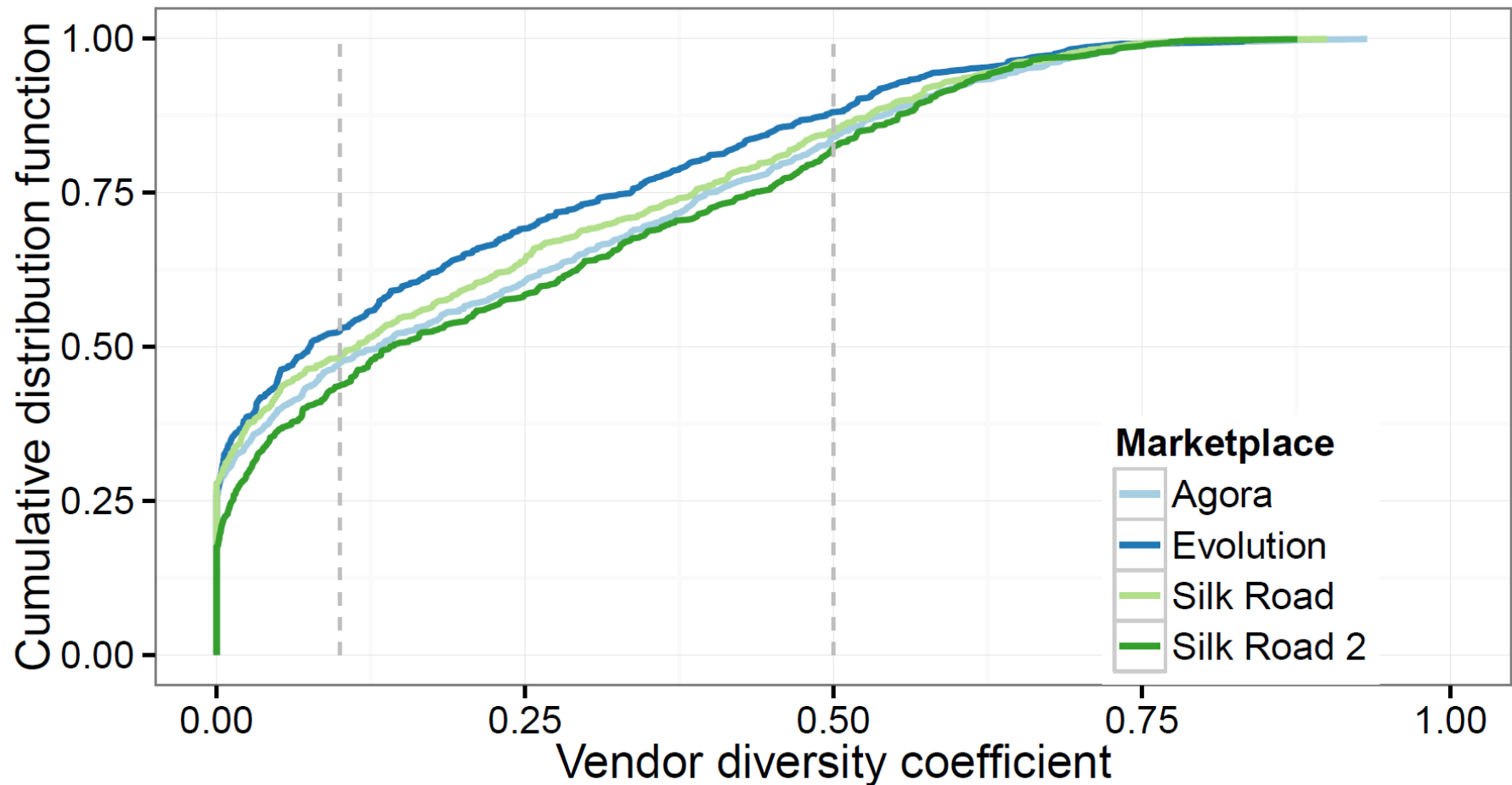
# Big or small vendors?



# Vendor diversity

- **Do vendors specialize in what they are selling?**
  - Do vendors sell what they make?
  - Does a single online presence sell goods for several diversified suppliers?
- **Coefficient of diversity  $\in [0, 1]$** 
  - 0 – all sales from same category
  - 1 – equal sales from each category
  - Only vendors > \$10,000 total sales considered

# Vendor diversity CDF



# Validation

- Validation is hard: these marketplaces do not publish their earnings!
- **Internal validation:** From the parsed databases, two of us internally derived numbers completely independently **using separate code bases**
  - Match within a couple of percentage points attributable to slightly different outlier filtering techniques
- **External validation:** Can only spot-check from
  - Court cases when criminal complaints are filed (e.g., Silk Road, Silk Road vendors)
  - Leaked vendor data
- **Observed that:**
  - Estimates are very close to Silk Road's "ground truth"
  - Estimates match actuals closely for vendors for whom other sources of data is available

# Validation

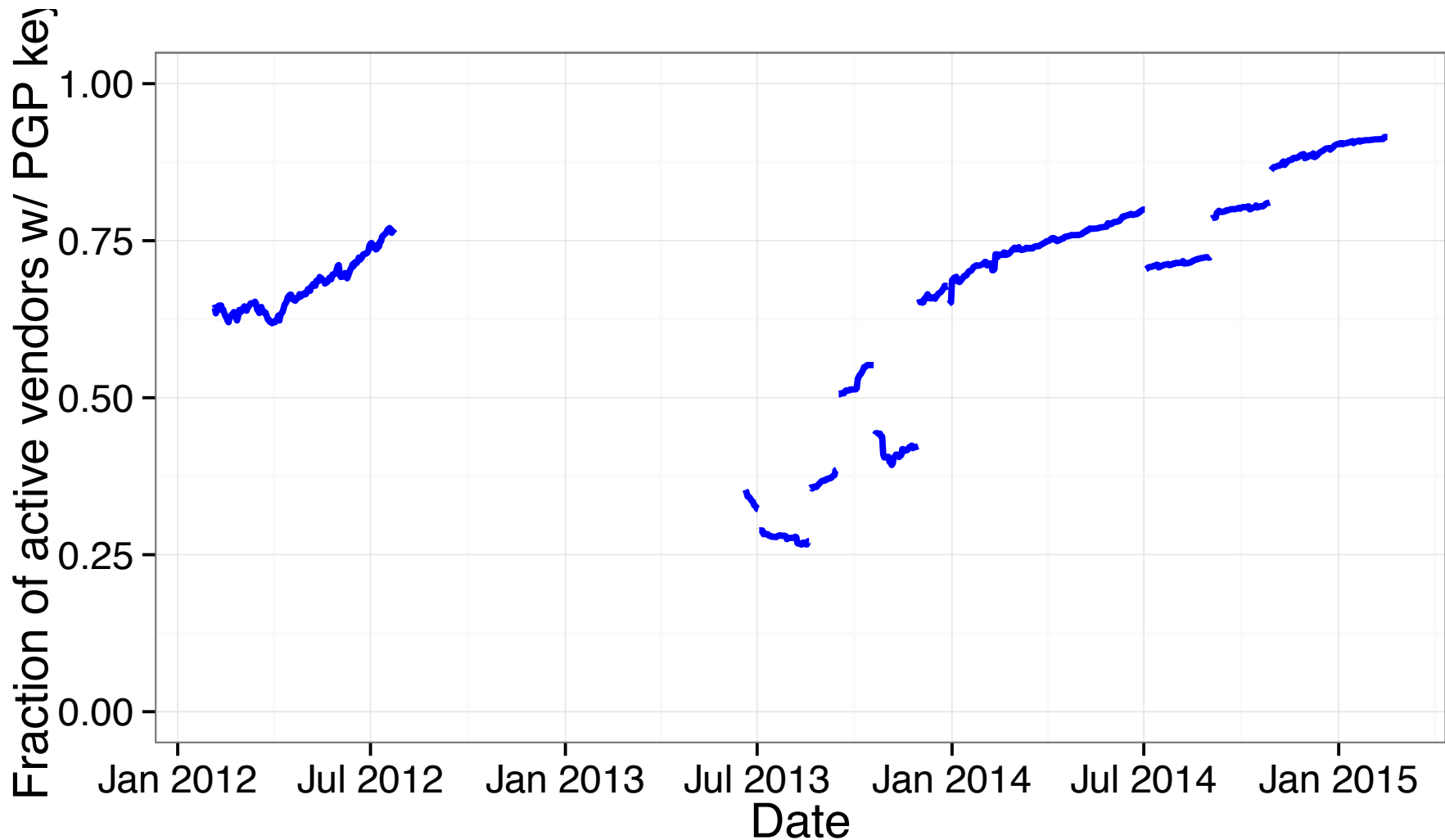
- Trial evidence GX226A, GX227C places Silk Road 1 weekly volumes at \$475,000/week in late March 2012, consistent with our estimates
- Administrator reports Silk Road 2 daily volumes of around \$250,000 in September 2014, similar to our estimated \$270,000
- Leaked Agora vendor page shows sales total on June 5, 2014 to be \$3,460, our observations yielded \$3,408



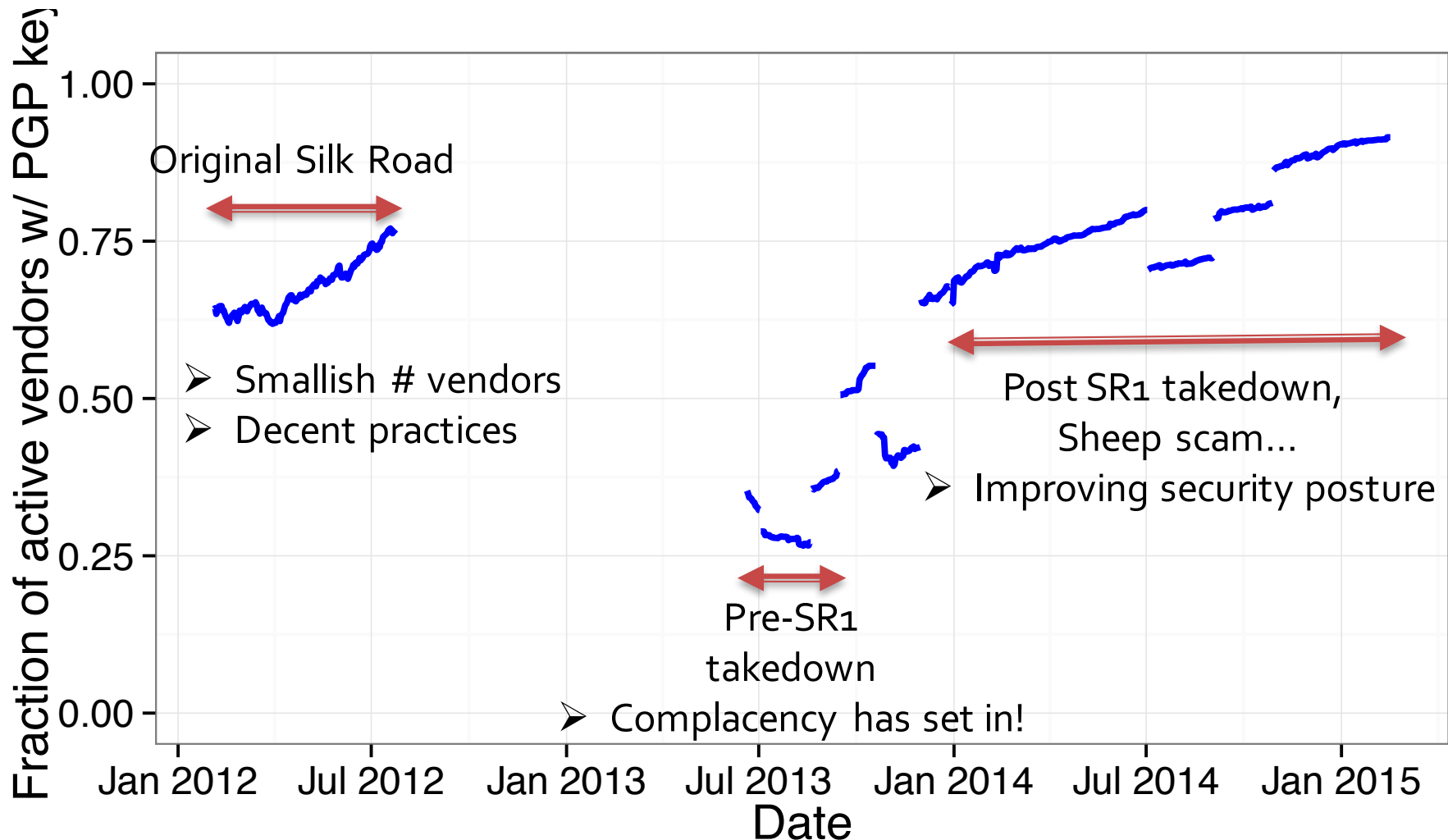
# Security posture

- At the time of Silk Road, feeling of invincibility
  - See DPR's interview in Forbes
- Shattered by Ross Ulbricht's arrest, Operation Onymous
- Countermeasures
  - Deployment of Bitcoin "multi-sig"
    - 2-of-3 allows to unlock transactions, even if marketplace operator incapacitated
    - Supposedly pioneered by Evolution Marketplace
      - ... but the interface **actually didn't work!**
    - Questionable usability
    - Questionable anonymity
      - multisig still rare enough that "transactions glow in the dark"
  - Reported increased use of PGP
  - Decentralized anonymous marketplaces

# PGP/GPG support (by vendor)



# PGP/GPG support (by vendor)



# Decentralized anonymous marketplaces

- “Peer-to-peer” marketplaces
  - Evolution analogous to Napster → Gnutella
  - E.g., OpenBazaar
- Main issue
  - How to maintain reliable reputation signal while offering decent anonymity properties?
  - Requires to mitigate Sybil attacks
- **Decentralized anonymous marketplaces have applications far beyond illicit goods**
  - Imagine Uber/Lyft without obscene user tracking
- **Active area of research**
  - Stay tuned for exciting results...

# General takeaways

- Anonymous marketplaces are very easy to setup and use and have wide customer appeal
- Anonymous marketplace ecosystem transacts in excess of \$500,000 / day
- Anonymous marketplaces are primarily used (~75%) for recreational drugs
- Anonymous marketplace ecosystem has historically recovered from takedown efforts and scams
- Overall security posture has apparently improved
- Anonymous marketplaces are controlled by small set of highly influential vendors

# Policy takeaway

- **Online anonymous markets form a highly resilient ecosystem**
  - Take downs have only had transient effect
  - More surprisingly (to us), scams have not dented customer confidence
  - Both essentially caused the market to shift to different marketplaces
  - Seems to be a recurring pattern
    - Currently processing data from the Evolution scam fallout

# Policy takeaway

## ■ Strengthen existing police procedures

- Online anonymous markets = novel retail channel
- Replace “weed guy”
  - Only a few sellers sell in bulk
  - Most quantities small
- Supply side presumably still relies on “traditional” channels
- Physical side seemingly more vulnerable
  - Drugs have to be shipped, received
  - Money has to enter/leave the BTC network



## ■ Strengthen inspection at customs, post-office

- Not necessarily easy (high volume, stealthy packages)
- But has been done successfully: primary way of arresting vendors

# Broader questions

- Ecosystem resilience probably fueled by simple economics
  - High demand for drugs means supply will exist
  - These marketplaces are probably not going anywhere
- **Even considering drugs are harmful**, could there be social value in these marketplaces?
  - Displacing the trade of drugs from the streets to online could reduce potential for physical harm
  - “Quality control” through feedback from many customers, forum discussions, harm reduction practices
  - ... **but** does online availability increase demand?
  - Needs to be measured through surveys and human subject studies – not easy to do properly (population biases, etc)

Email: [nicolasc@cmu.edu](mailto:nicolasc@cmu.edu)

Web: <https://www.andrew.cmu.edu/user/nicolasc>

Twitter: @nc2y