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PRICE OF PRIVACY IN THE CLOUD,

OR THE ECONOMIC CONSEQUENCES OF MR SNOWDEN

PROFESSOR SIMON WILKIE

18 OCTOBER 2019


// A FILM BY ACADEMY AWARD® WINNER:
OLIVER STONE
THE ONLY SAFE PLACE IS ON THE RUN
SNOWDEN
JOSEPH GORDON-LEVITT // SHAILENE WOODLEY
// IN THEATERS SEPTEMBER 16
// DIRECTED BY:
OLIVER STONE
// SCREENPLAY BY:
KIERAN FITZGERALD & OLIVER STONE

NSA collecting phone records of millions of Verizon customers daily

Exclusive: Top secret court order requiring Verizon to hand over all call data shows scale of domestic surveillance under Obama

- Read the Verizon court order in full here
- Obama administration justifies surveillance

Under the terms of the order, the numbers of both parties on a call are handed over, as is location data and the time and duration of all calls. Photograph: Matt Rourke/AP

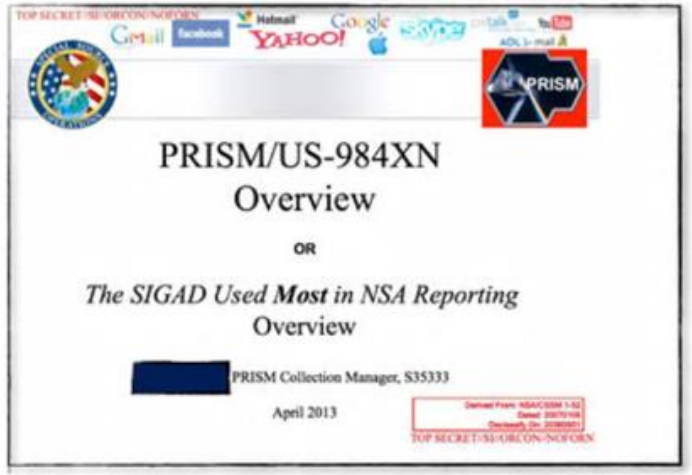
The National Security Agency is currently collecting the telephone records of millions of US customers of Verizon, one of America's largest telecoms providers, under a top secret court order issued in April.

The order, a copy of which has been obtained by the Guardian, requires Verizon

NSA Prism program taps in to user data of Apple, Google and others

- Top-secret Prism program claims direct access to servers of firms including Google, Apple and Facebook
- Companies deny any knowledge of program in operation since 2007

- Obama orders US to draw up overseas target list for cyber-attacks



A slide depicting the top-secret PRISM program.

The National Security Agency has obtained direct access to the systems of Google Facebook, Apple and other US internet giants, according to a top secret document obtained by the Guardian.

The NSA access is part of a previously undisclosed program called Prism, which allows officials to collect material including search history, the content of emails, file transfers and live chats, the document says.

NSA leaks: US and Britain team up on mass surveillance

Latest revelations from Edward Snowden show that the state risks crossing ever more ethical and legal boundaries

The so-called UKUSA agreement goes back over 60 years. Photograph: Alamy

Twelve years ago, in an almost forgotten report, the European parliament completed its investigations into a long-suspected western intelligence partnership dedicated to global signals interception on a vast scale.

Evidence had been taken from spies and politicians, telecommunications experts and journalists. In stark terms the report detailed a decades-old arrangement which had seen the US and the UK at first - later joined by Canada, New Zealand and Australia to make up the the so-called "Five Eyes" - collaborating to access satellites, transatlantic fibre-optic cables and radio signals on a vast scale.

SNOWDEN REVELATIONS

- Cloud adoption probably **most important economic transformation** that is ongoing
- 06/05/2013: Edward Snowden Revelations – Shock to Privacy

(1) US telecommunications firms **handed over metadata** to every international phone call to the NSA

- The Foreign Intelligence Surveillance Act (FISA), 2001 USA Patriot Act

(2) **"PRISM" program**: a surveillance program under NSA

- A codename of a mass electronic surveillance data mining program
- Partnerships with nine major tech companies (AOL, Apple, Facebook, Google, Microsoft, PalTalk, Skype, Yahoo!, Youtube

(3) NSA with British Government Communications Headquarters (GCHQ) had tapped into 200 undersea optic fiber cables.

IMPACT OF SNOWDEN REVELATIONS

The Snowden revelations **affect public trust in integrity and security** of data held with US firms

- In particular, foreign firms rely on US infrastructure and services

International legal blowbacks

- European Court of Appeals struck down the privacy “Safe harbor” agreement between the US and the EU
- Several countries passed **new data sovereignty laws**
  - Brazil: the Marco Civil was passed in law and the law includes the ability to require that data about Brazil be stored in Brazil
  - Russia: new data localization law, Federal Law No. 242-FZ
  - Germany: data sovereignty + local ownership of the data center

THE WALL STREET JOURNAL.

TECH

Microsoft Offers EU Customers Option to Store Data in Germany

Move addresses security concerns about U.S. data centers following surveillance reports

By FRIEDRICH GEIGER

Updated Nov. 11, 2015 12:49 p.m. ET

- Microsoft Corp. said Wednesday it would offer European customers the option of storing their cloud data in Germany, addressing concerns about the security of data centers in the U.S. following reports of surveillance by U.S. intelligence agents.
- Microsoft had announced plans to offer cloud services from U.K.-based data centers a day earlier.
- The announcement came weeks after the European Court of Justice struck down and agreement between the U.S. and European Union that had allowed the transfer of Europeans' personal data to the U.S.
- Microsoft believes that with the planned data centers in Germany, U.S. authorities' access to the data can be prevented.

Europeans by exposing them to allegedly indiscriminate surveillance by the U.S. government, according to the court. German data protection authorities, after the ruling, said they wouldn't allow any new data transfers to the U.S.

The ruling by the EU's highest court has upended technology plans for many trans-Atlantic companies. "It undermines all businesses," said U.S. Commerce Secretary Penny Pritzker during a recent visit to Germany.

next year. It would allow data to be replicated within the U.K. for backup and recovery with reduced network distance and lower latency.

Write to Friedrich Geiger at friedrich.geiger@wsj.com

CLOUD AND DATACENTER BASICS

This

Not this

[with apologies to MS Marketing]

WHAT IS THE ECONOMIC IMPACT

An **ongoing controversy** about the impact of the Snowden Revelation on the US cloud computing industry

1. Castro (2013) by ITIF: government surveillance has led to a reduction in the US GDP of $22 - $35bln over three years

2. Ferrara et al. (2015) by Forrester Research: PRISM has driven more use of encryption but no impact of migration.

Who is right?
Castro assumes an unfound 10% loss of market share by US companies

WE APPLY THREE MODELS OF CLOUD ADOPTION TO ANSWER THE ISSUE

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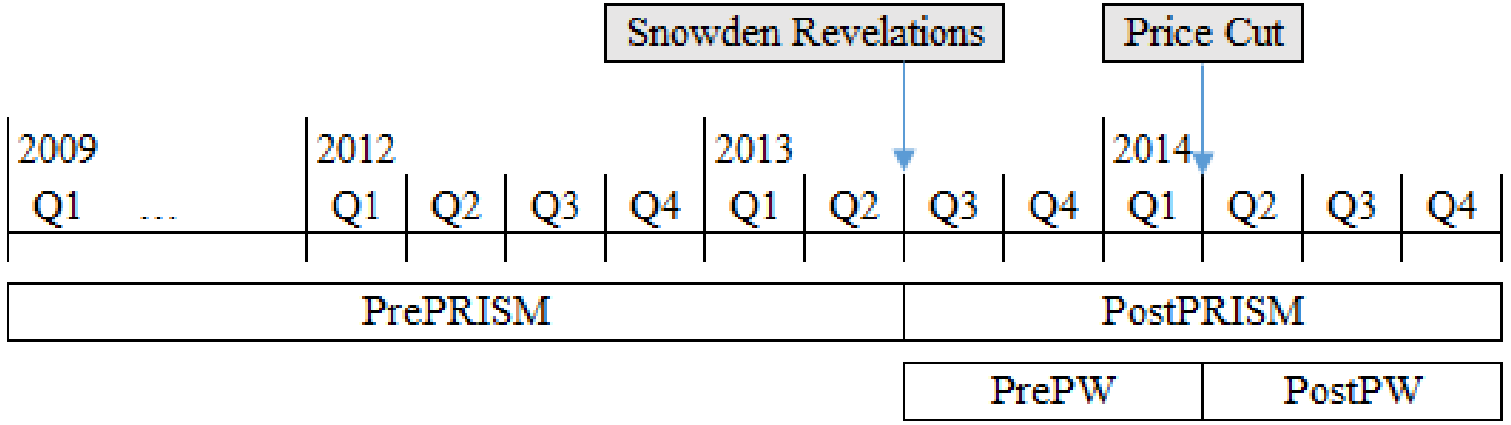
TIME LINE

Two Big Events

- PRISM: June 2013
- Price War: April 2014 (65%, price cut)



MODEL OF CLOUD ADOPTION

- Simple dynamic model of consumer preferences
- Bernanke (1983) examines the **role of uncertainty** in the investment decision
- Adoption of **new technology**
- Assume three options US Cloud, EU Cloud, none “outside option”
- **Optimal decision rules**

  Invest in an irreversible project in period t if and only if:
  Cost of delays ≥ Probability that a current commitment will be revealed to be a mistake in t+1 times expected cost of the mistake, given that a mistake is revealed in t+1.

- Both terms in RHS are increases if firms are concerned about NSA spying and it leads to an **increase in the decision to delay adoption** or a slowdown in growth and substitution from US to non-US providers

MODEL

PRIVACY AND DISCRETE CHOICE MODEL OF CLOUD ADOPTION

- A consumer receives the utility, u_{it} if he/she purchases one of available option, *i* at *t=0,1*

$$u_{it} = f_{it} - p_{it} - q_{it}$$

Where f_{it}*:* consumer's valuations toward product *i*

p_{it}*:* disutility from price for available option

q_{it}*:* disutility from privacy concerns

- Outside option, *i=0* and the corresponding utility is normalized to zero $(u_{0t} = 0)$
- *Adjustment cost, A* of changing platform

A(t)= A if you switch in time *t*

0 if you do not switch

MODEL

PRIVACY AND DISCRETE CHOICE MODEL OF CLOUD ADOPTION

- Expected utility from investing in cloud platform i

$$U_i = \sum_{t=1}^{\infty} \beta^t \left[u_{it} - A(t)\right]$$

Where $\beta = \frac{1}{1+r}$

- *A fully revealing signal arrives at time 1 and prices are constant.*
- *net utility is constant for each option*

$$U_x = \sum_{t=1}^{\infty} \beta^t u_x - A = \frac{u_x}{r} - A$$

$$U_y = \sum_{t=1}^{\infty} \beta^t u_y - A = \frac{u_y}{r} - A$$

MODEL

PRIVACY AND DISCRETE CHOICE MODEL OF CLOUD ADOPTION

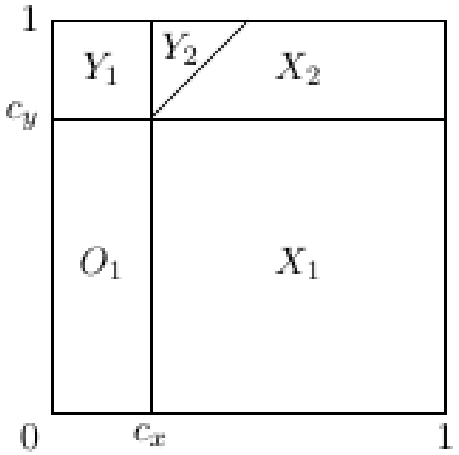
The optimal platform choice rule at time 1

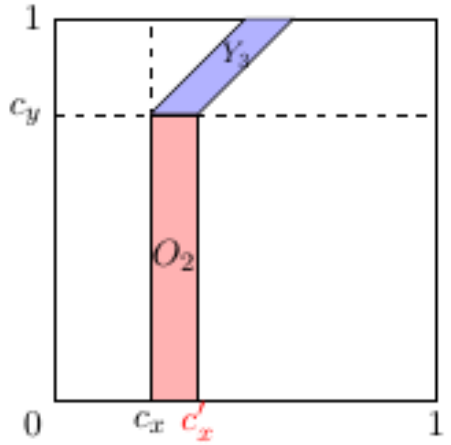
x, if and only if $\boldsymbol{u_x \geq u_y \; and \; u_x \geq rA}$

y, if and only if $\boldsymbol{u_y \geq u_x \; and \; u_y \geq rA}$

outside option, otherwise

(Case 1) $\boldsymbol{c_x < c_y \; and \; c'_x < c_y}$

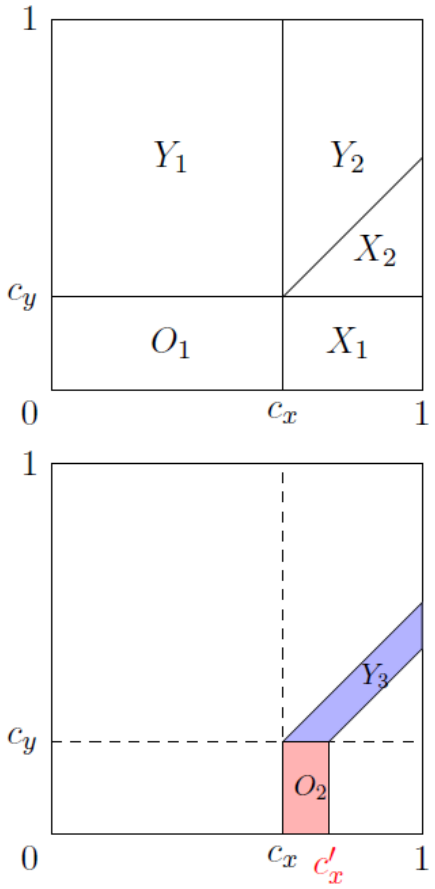




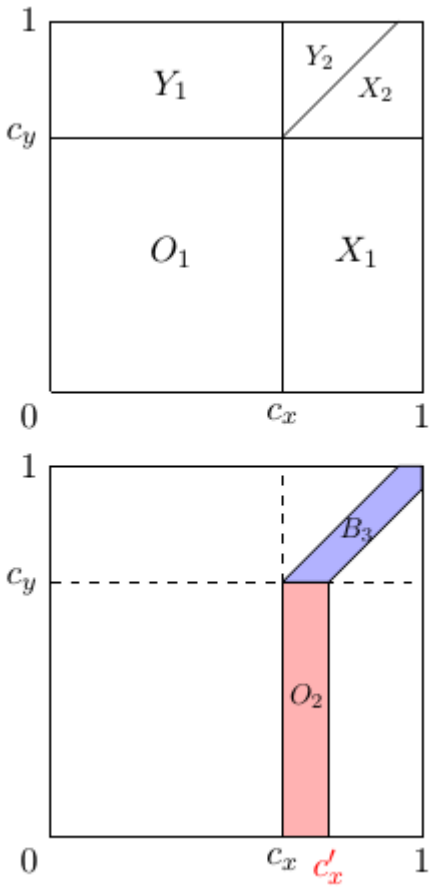
MODEL

PRIVACY AND DISCRETE CHOICE MODEL OF CLOUD ADOPTION

(Case 2) $c_x > c_y$



(Case 3) $c_x < c_y$ $\&c'_x > c_y$



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MODEL

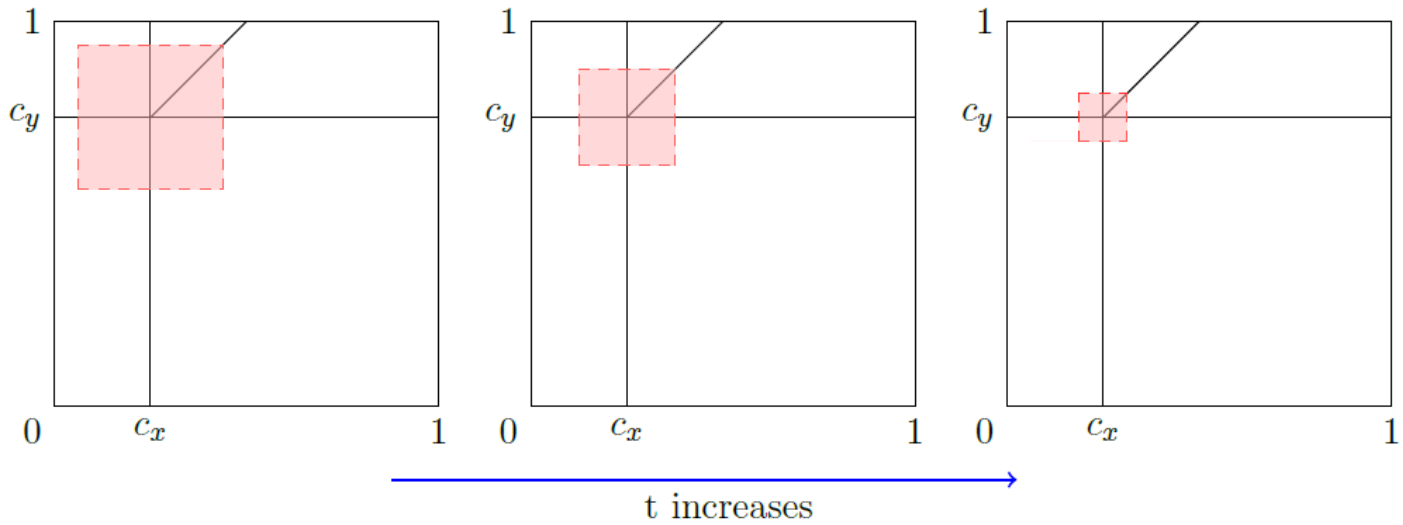
CLOUD ADOPTION MODEL WITH SIGNAL

$(c_x\ c_y)$ is not known till the last perion, T

Consumers receive a signal, $(x_t\ y_t)$ *about the relative value of each platform in period t*

$$x_t = c_x + \frac{\varepsilon_x}{t^n}, \qquad y_t = c_y + \frac{\varepsilon_y}{t^n} \ \textbf{where}\ (\varepsilon_x, \varepsilon_y) \sim (\underline{m}, \overline{m})$$

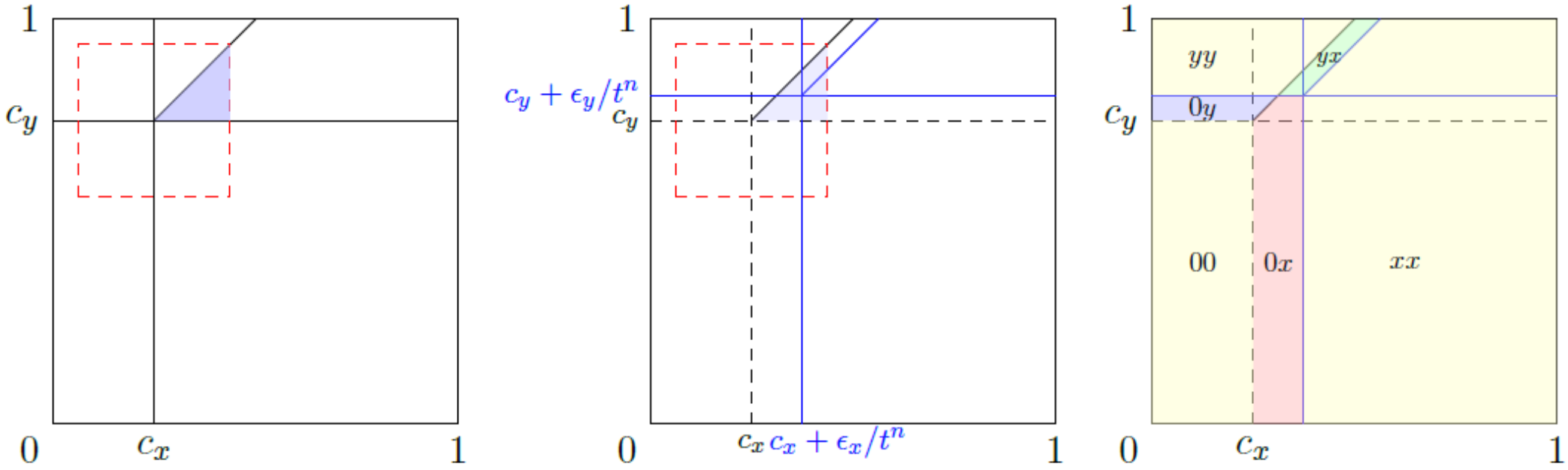
$x_t \to c_x$ and $y_t \to c_y$ as $t \to T$ (as long as $n > 0$)



MODEL

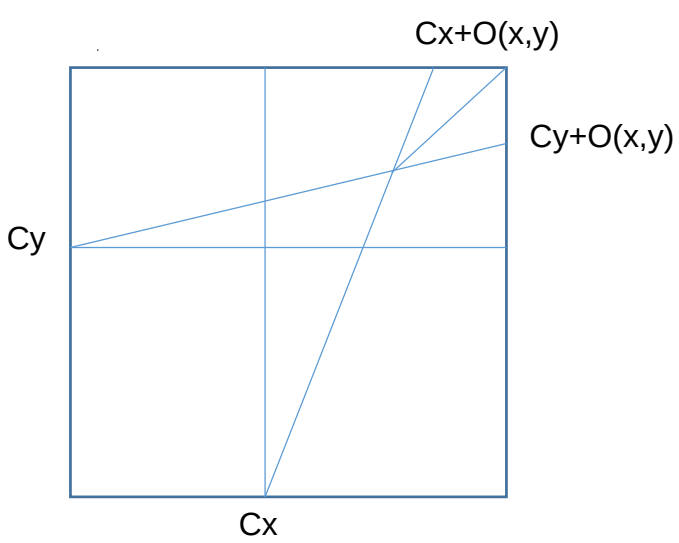
CLOUD ADOPTION MODEL WITH SIGNAL

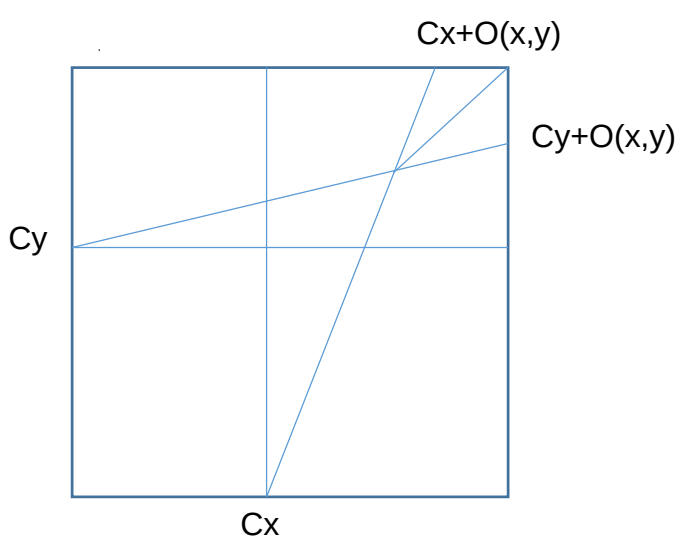
Snowden revelations

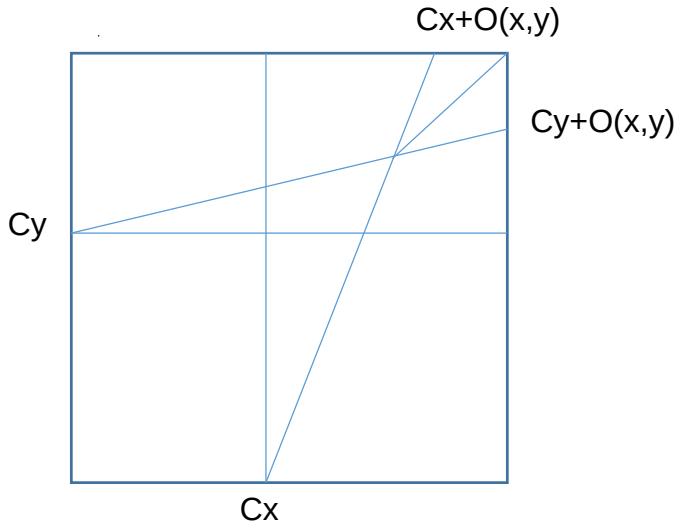


MODEL

CLOUD ADOPTION MODEL WITH SIGNAL







Increase in delay
= slowdown in growth

BASS MODEL

- Bass (1969): new technology adoption model
- “Early adopters” behave the same but the Snowden revelations impact the adoption rate of “imitators” entering the market

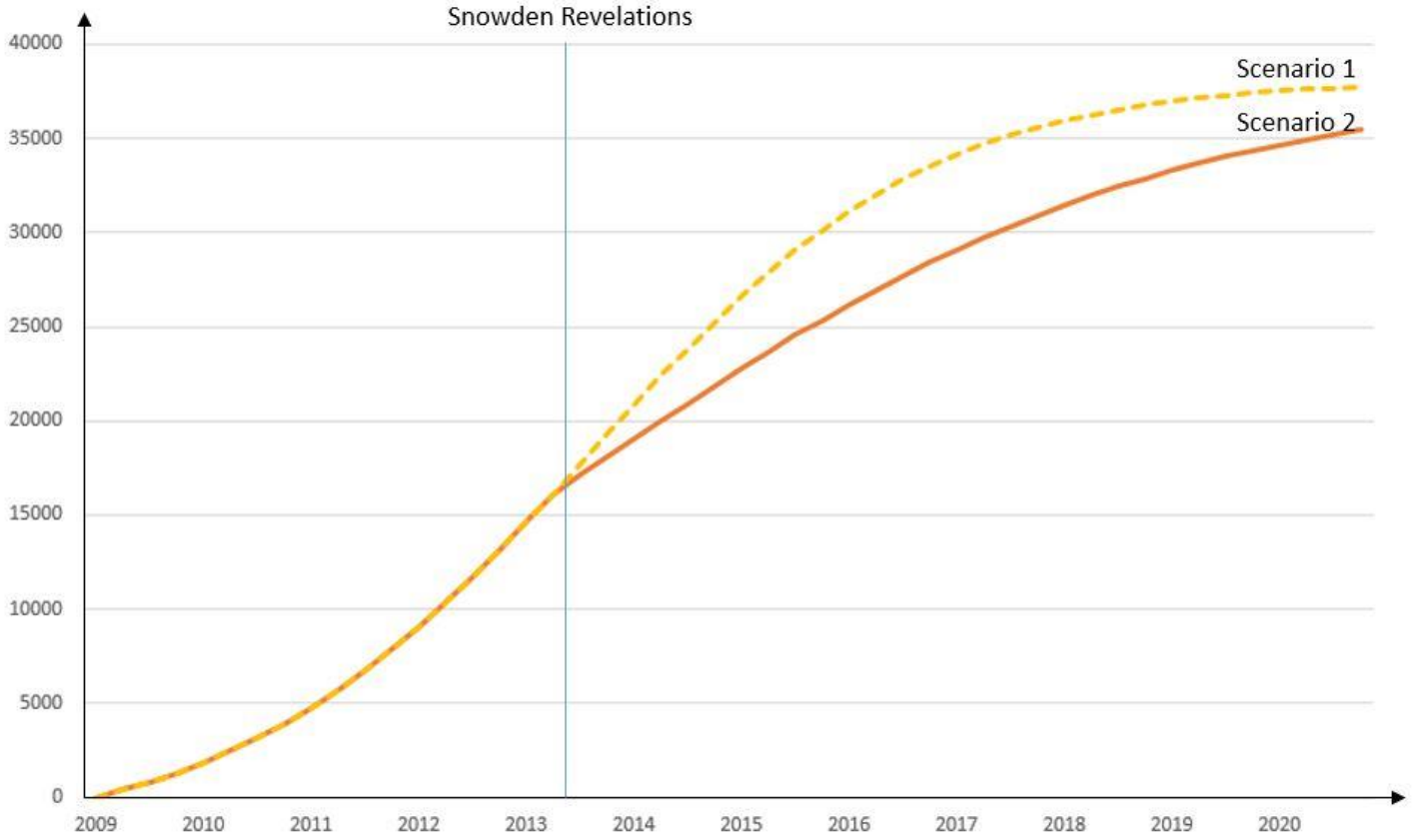
$$\frac{f(T)}{a - F(T)} = p + qF(T)$$

Where $f(T)$: likelihood of purchase at T

p: coefficient of innovation

q: coefficient of imitation

CALIBRATED BASS MODEL OF ADOPTION



Scenario 1

the Bass model and data prior to the Snowden revelations with
p=0.0101
q=0.1435
N: the normalized accumulated adopters

Scenario 2

q drops to 0.08 and
p and N: unchanged

DATA

- Source: Synergy Research*
- Total Revenue of cloud computing companies
- Panel data: company-quarter
  - N=111 (US: 51, Non-US: 60)
  - T=24 (2009 Q1-2014 Q4)
- Segments
  - Cloud Infrastructure (IaaS, PaaS, Private/Hybrid)
  - Rental colocation
  - Managing hosting
  - CDN/AND

*https://www.srgresearch.com/

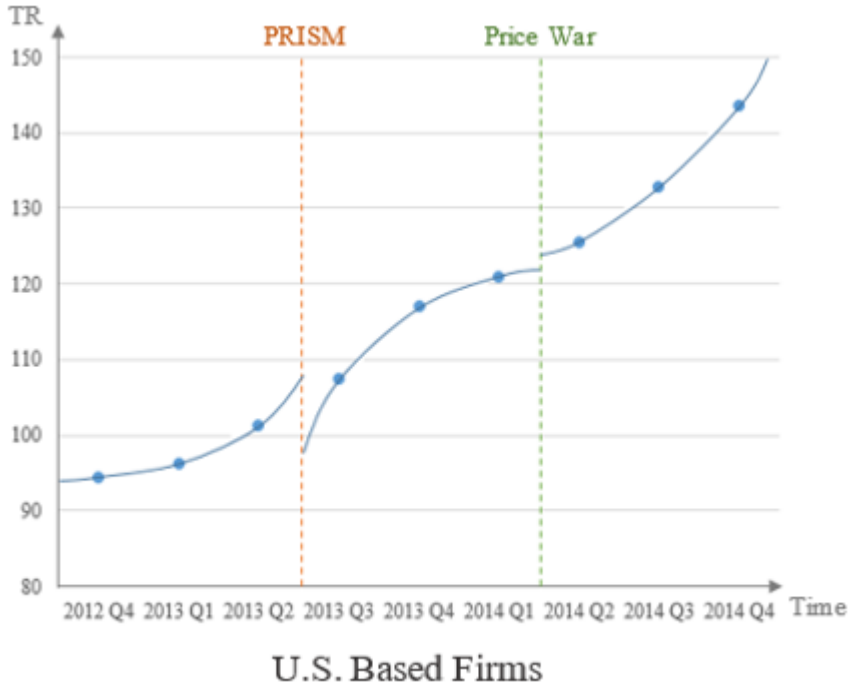
SUMMARY STATISTICS

	All Countries			US			Non-US		
	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs
Entire Group	73.83	120.75	2664	80.86	143.07	1224	67.86	97.51	1440
Cloud Infrastructure	12.99	62.19	2664	21.45	89.94	1224	5.79	12.99	1440
IaaS	6.66	45.34	2664	11.08	66.36	1224	2.9	5.48	1440
PaaS	3.39	18.47	2664	6.74	26.68	1224	0.54	2.96	1440
Private & Hybrid	2.94	9	2664	3.66	11.23	1224	2.34	6.48	1440
Rental Colocation	22.69	48.68	2664	22.46	62.4	1224	22.9	32.8	1440
Managed Hosting	30.98	60.22	2664	26.95	61.27	1224	34.41	59.11	1440
CDN	7.17	34.14	2664	9.99	49.03	1224	4.76	10.09	1440

* NOTE: in millions

PRISM AND PRICE WAR

Figure 1: Conditional Mean of Total Revenue



U.S. Based Firms

Non-U.S. Based Firms

*NOTE: (1) Graph: histogram-style conditional mean drawn by cmogram by STATA with qfit option

(2) Using linear spline regresssion, the kinked point is tested. The kinked point at the PRISM is significant at 5% and the kinked point at the Price War is significant at 10%. Appendix 1 for further details.

DIFFERENCE IN DIFFERENCES

	Pre PRISM	Post PRISM	Difference
US Firms (Treat)	$\beta_0 + \beta_1$	$\beta_0 + \beta_1 + \beta_2 + \beta_3$	$\Delta y_t = \beta_2 + \beta_3$
Non-US firms (Control)	β_0	$\beta_0 + \beta_2$	$\Delta y_c = \beta_2$
Difference			$\Delta\Delta Y = \beta_3$

$$\Delta\, log(TR_{ijt}) = \beta_0 + \beta_1 US + \beta_2 Post\ PRISM + \beta_3 US \times Post\ PRISM + \gamma_j + \theta_k + \delta_t + \varepsilon_{ijt}$$

Post PRISM=1 if $t \geq 19$ $(Q3\ 2013)$

=0 otherwise

US=1 if firm i based on the U.S.

=0 otherwise

RESULTS 1 DID (Entire Periods)

	(1)	(2)	(3)	(4)	(5)
US	0.041***	-0.041***	0.041***	0.047***	-0.011
	(2.91)	(2.90)	(2.90)	(8.08)	(-1.07)
Post PRISM	-0.063***	0.024	0.024	0.024	0.027
	(-2.84)	(0.66)	(0.66)	(0.65)	(0.67)
US X Post PRISM	-0.108***	-0.108***	-0.108**	-0.108***	-0.116***
	(-4.93)	(-4.91)	(-4.91)	(-4.91)	(-5.14)
Country Fixed Effects	No	Yes	No	Yes	Yes
Quarter Fixed Effects	No	No	Yes	Yes	Yes
Sector Fixed	No	No	No	No	Yes
Observations	2553	2553	2553	2553	2553

- NOTE: (1) OLS Estimates with robust standard errors clustered at regional level.
  (2) Dependent variable: Δlog(TR). (3) t statistics in parentheses (4) * p<0.10, ** p<0.05, *** p<0.01

RESULTS 2 DID (Pre Price War Only)

	(6)	(7)	(8)	(9)	(10)
US	0.041***	0.019***	0.041***	0.019***	-0.036***
	(2.90)	(13.03)	(2.88)	(12.97)	(-3.57)
Post PRISM	-0.025***	-0.025***	-0.102**	-0.102*	-0.098*
	(-2.62)	(-2.61)	(-2.15)	(-2.14)	(-2.27)
US X Post PRISM	-0.210***	-0.210***	-0.210***	-0.210***	-0.218***
	(-21.64)	(-21.55)	(-21.55)	(-21.47)	(-21.40)
Country Fixed Effects	No	Yes	No	Yes	Yes
Quarter Fixed Effects	No	No	Yes	Yes	Yes
Sector Fixed	No	No	No	No	Yes
Observations	2220	2220	2220	2220	2220

- NOTE: (1) OLS Estimates with robust standard errors clustered at regional level.
  (2) Dependent variable: Δlog(TR). (3) t statistics in parentheses (4) * p<0.10, ** p<0.05, *** p<0.01

RESULTS
INTERPRETATION

- Post PRISM: growth rate **↓11.6%**
- Post PRISM & Pre Price War: growth rate **↓21.8%**

- 11.6% : total **loss of $18.072 billion** to the US cloud computing industry (6 quarters)
- 21.9% (Pre PW): a **reduction of $11.094 billion** (only 3 quarters)

ROBUSTNESS

FIXED EFFECTS ANALYSIS

$$\Delta \log(TR_{ijt}) = \beta_0 + \beta_1 PostPRISM \times PrePW + \beta_2 POSTPW + \alpha_i + \varepsilon_{ijt}$$

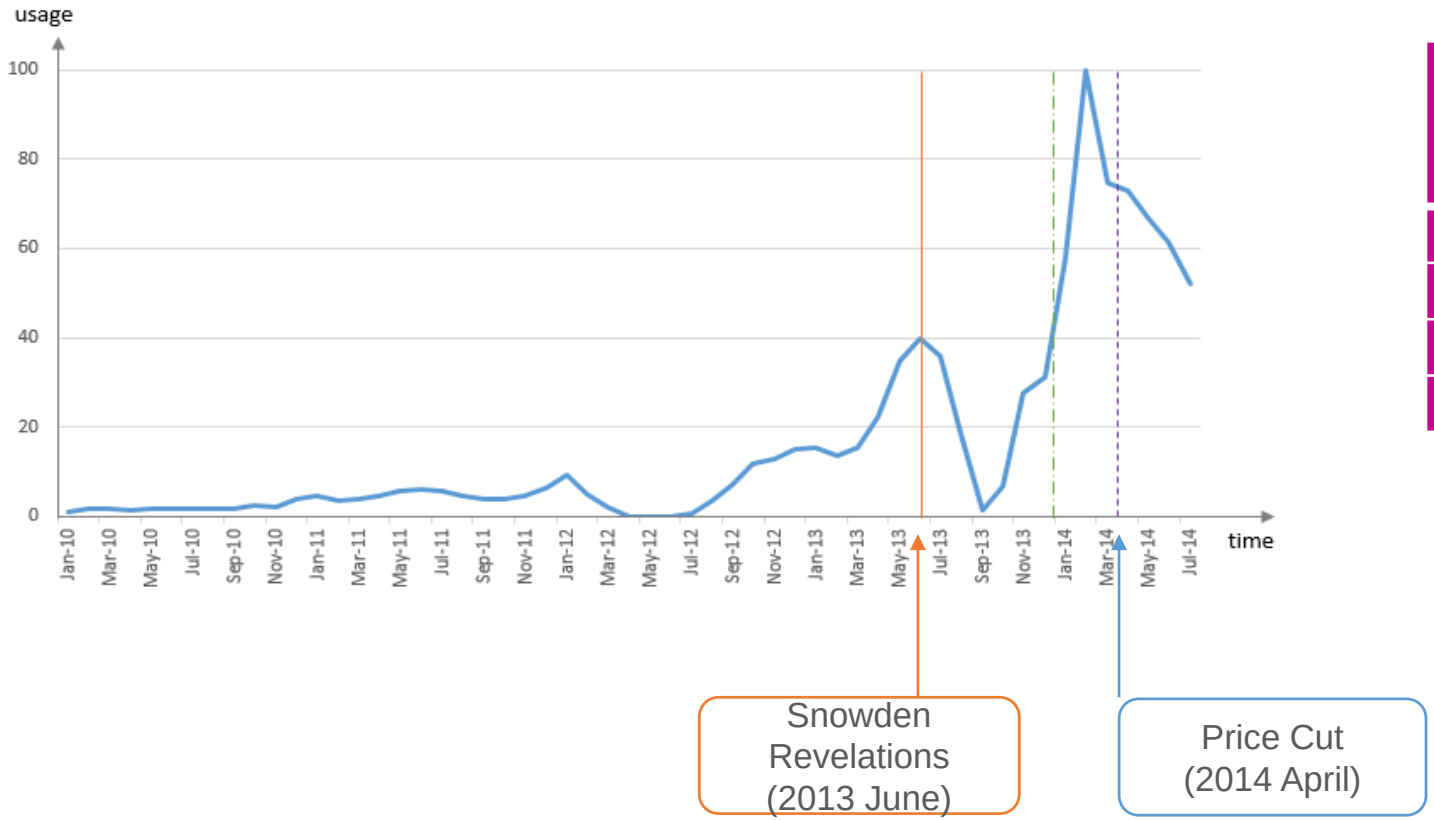
	All Sectors			Cloud Infrastructure Sector Only		
	All Countries	US	Non-US	All Countries	US	Non-US
	(1)	(2)	(3)	(4)	(5)	(6)
PostPRISM X PrePW	-0.122***	-0.237***	-0.024	-0.287***	-0.405***	-0.188***
	(-3.70)	(-3.57)	(-1.07)	(-4.61)	(-3.98)	(-2.45)
PostPW	-0.103***	-0.107	-0.099***	-0.203***	-0.215***	-0.192***
	(-3.12)	(-1.62)	(-4.42)	(-3.25)	(-2.12)	(-2.51)
Observations	2553	1173	1380	2553	1173	1380

* NOTE: (1) FE estimates. (2) Dependent variable: ∆log(TR). (3) * p<0.10, ** p<0.05, *** p<0.01
(4) PostPRISM X PrePW is equal to 1 if t=18,19,20 and equal to 0 otherwise.
(5) PostPW is equal to 1 if t=21,22,23 and equal to 0 otherwise.

NON PRICE EFFECTS

FREE TRIAL USAGE

A CROSS-CHECK WITH PRICE FIXED AT ZERO



	Recovery period (months)	Size (monthly usage before Snowden)
All	6.33	100%
US	6.58	47%
Asia	5.61	16.5%
Europe	6.015	31%

* Note: usage is measured by the used GB times shadow cost + VMs times shadow cost

PRIVACY POLICY

Company	Before PRISM	After PRISM	Changes
Amazon	2	2	0
Apple	1	6	5
AT&T	1	2	1
Comcast	2	3	1
Dropbox	5	6	1
Facebook	3	6	3
Foursquare	4	3	-1
Google	5	6	1
Linkedin	5	5	0
Microsoft	4	6	2
Myspace	3	3	0
Sonic.net	6	6	0
SpiderOak	5	5	0
Twitter	6	6	0
Tumblr	3	5	2
Verizon	0	4	4
Wordpress	4	5	1
Yahoo!	1	6	5
Mean	3.33	4.72	1.39

- **Pre PRISM**: EFF's 2013 annual reports, released on April 30, 2013 (Cardozo et al, 2013)
- **Post PRISM**: EFF's 2014 reports (Cardozo et al, 2014)

- The Electronic Frontier Foundation (EFF)'s criteria to access company practices and policies

(1) Requires a warrant for content

(2) Tells users about government data requests

(3) Publishes transparency reports

(4) Publishes law enforcement guidelines

(5) Fights for users' privacy rights in courts

(6) Fights for users' privacy rights in Congress

PRIVACY POLICY

	1		2		3		4		5		6	
Company	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Amazon	0	1	0	0	0	0	0	0	1	1	1	0
Apple	0	1	0	1	0	1	0	1	0	1	1	1
AT&T	0	0	0	0	0	1	0	1	0	0	1	0
Comcast	0	0	0	0	0	1	1	1	1	1	0	0
Dropbox	1	1	1	1	1	1	1	1	0	1	1	1
Facebook	1	1	0	1	0	1	1	1	0	1	1	1
Foursquare	1	1	1	1	0	0	1	1	0	0	1	0
Google	1	1	0	1	1	1	1	1	1	1	1	1
Linkedin	1	1	1	1	1	1	1	1	0	0	1	1
Microsoft	1	1	0	1	1	1	1	1	0	1	1	1
Myspace	1	1	0	0	0	0	1	1	1	1	0	0
Sonic.net	1	1	1	1	1	1	1	1	1	1	1	1
SpiderOak	1	1	1	1	1	1	1	1	0	0	1	1
Twitter	1	1	1	1	1	1	1	1	1	1	1	1
Tumblr	1	1	0	1	0	1	1	1	0	0	1	1
Verizon	0	1	0	0	0	1	0	1	0	0	0	1
Wordpress	1	1	1	1	0	1	1	1	0	0	1	1
Yahoo!	0	1	0	1	0	1	0	1	1	1	0	1
Mean	0.7	0.9	0.4	0.7	0.4	0.8	0.7	0.9	0.4	0.6	0.8	0.7

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ENCRYPTION

	1	2	3	4	5	Score
	Encrypt data center links	Supports HTTPS	HTTPS Strict (HSTS)	Forward Secrecy	STARTLS	
Amazon	0	0	0	0	0	0
Apple	0	1	0	0	0	1
AT&T	0	0	0	0	0	0
Comcast	0	0	0	0	0	0
Dropbox	1	1	1	1	1	5
Facebook	1	1	1	1	1	5
Foursquare	0	1	1	0	0	2
Google	1	1	1	1	1	5
Linkedin	0	1	1	1	1	4
Microsoft	1	1	1	1	1	5
Myspace	0	1	0	0	0	1
Sonic.net	1	1	1	1	1	5
SpiderOak	1	1	1	1	1	5
twitter	1	1	1	1	1	5
tumblr	0	1	1	1	0	3
Verizon	0	0	0	0	0	0
Wordpress	0	1	0	0	0	1
Yahoo!	1	1	1	1	1	5
Mean	0.44	0.78	0.61	0.56	0.50	2.89

1. Encrypts data center links
2. Supports HTTPS,
3. HTTPS Strict (HSTS)
4. Forward Secrecy
5. STARTTLS

*Source: EFF's Encrypt the web report, 2014

CONCLUSION

- The Snowden revelations decreased the growth of revenues of US providers by 11%.
  - 11% estimate: **$17 billion loss**
  - 22% (Pre PW) and 11% (Post PW): **$32 billion loss**
- A price war (up to 65% cut in prices) occurs after the negative demand shock
- Snowden effect is also evident in MSFT data
  - Free trial usage plummets - direct measures lack of trust
  - IaaS take off stalls

IN THE LONG RUN, FIRMS'STRATEGIC REACTION

LOWERED EQUILIBRIUM PRICES WITH A HIGHER QUALITY **OF DATA PROTECTION**

	Entire	1. Cloud	1.1 IaaS	1.2 PaaS	1.3 Private /Hybrid	2. Retail Colocation	3. Managed Hosting	4. CDN /AND
1	Amazon	Amazon	Amazon	Amazon	IBM	Equinix	Rackspace	Akamai
2	Equinix	Microsoft	Microsoft	Microsoft	Amazon	NTT	Verizon	Amazon
3	NTT	IBM	IBM	salesforce	Rackspace	Verizon	AT&T	ChinaNetCenter
4	IBM	Google	Rackspace	Google	HP	CenturyLink (Savvis)	IBM	ChinaCache
5	Akamai	salesforce	Google	IBM	Deutsche Telekom	China Telecom	NTT	KDDI
6	Verizon	Rackspace	Alibaba	Fujitsu	AT&T	TelecityGroup	China Telecom	Verizon
7	Microsoft	Fujitsu	NTT	Oracle	Fujitsu	Interxion	Deutsche Telekom	Highwinds
8	AT&T	NTT	Fujitsu	Engine Yard	NTT	KDDI	British Telecom	Limelight
9	Rackspace	Deutsche Telekom	Deutsche Telekom	VMware	Verizon	AT&T	CenturyLink	Level 3
10	Deutsche Telekom	AT&T	Softbank	NTT	Dell	SunGard	Fujitsu	Deutsche Telekom

THANK YOU

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