CLOUD COMPUTING

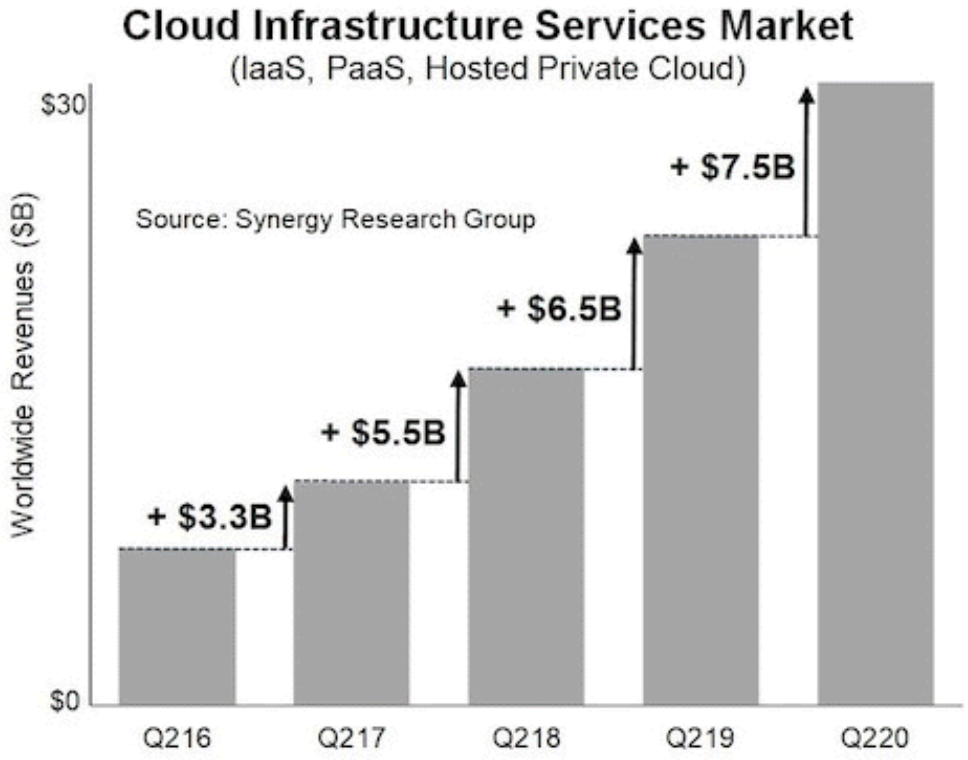
Economics

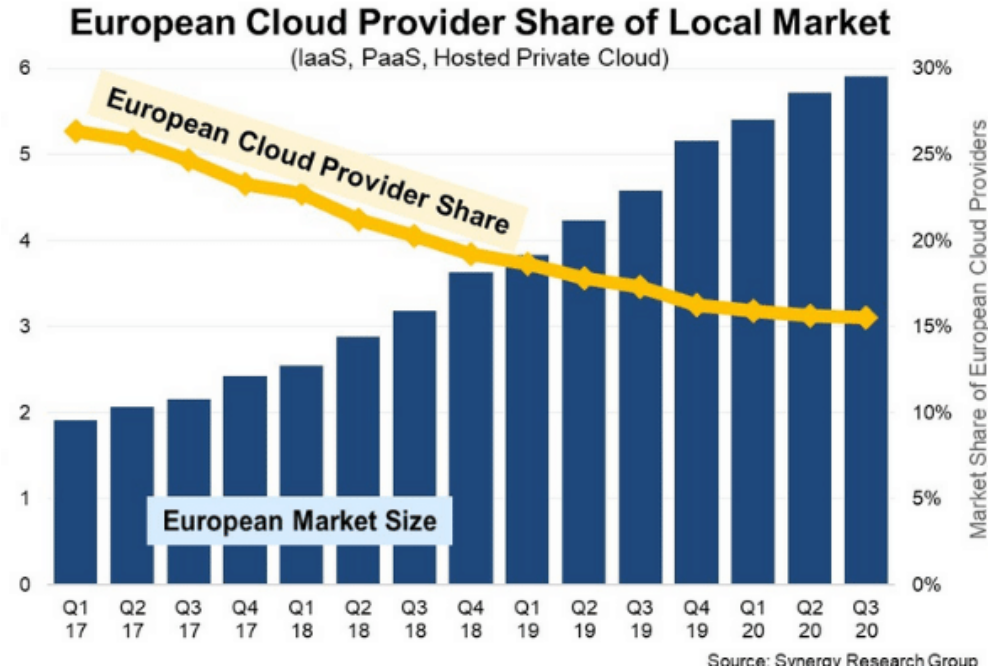
PAUL TOWNEND

ASSOCIATE PROFESSOR, UMEÅ

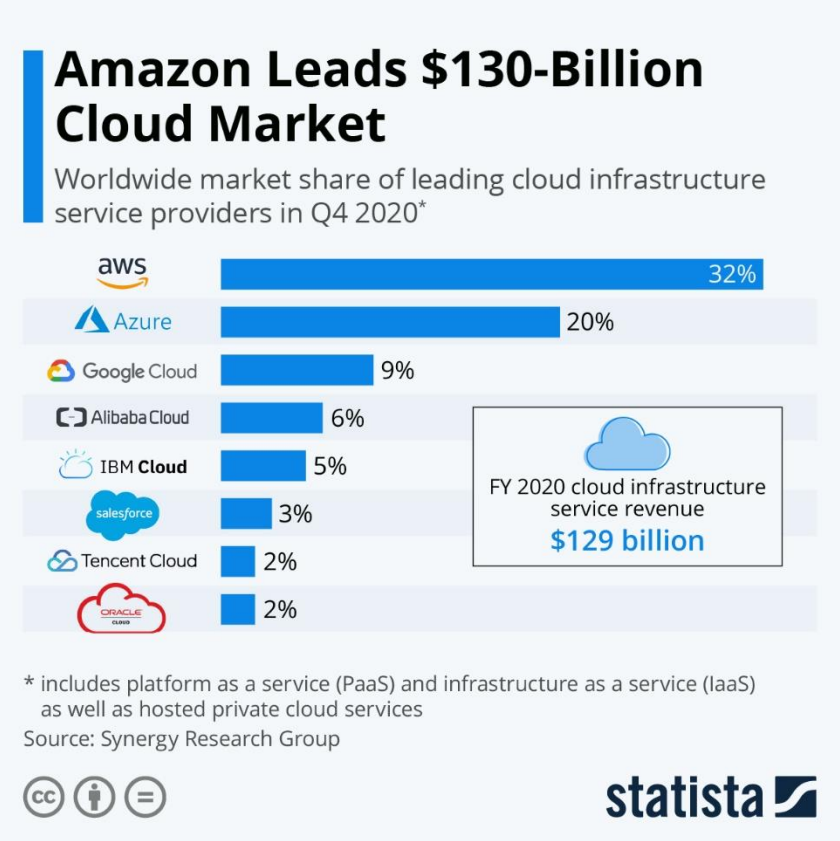
Cloud Providers: Global market trends

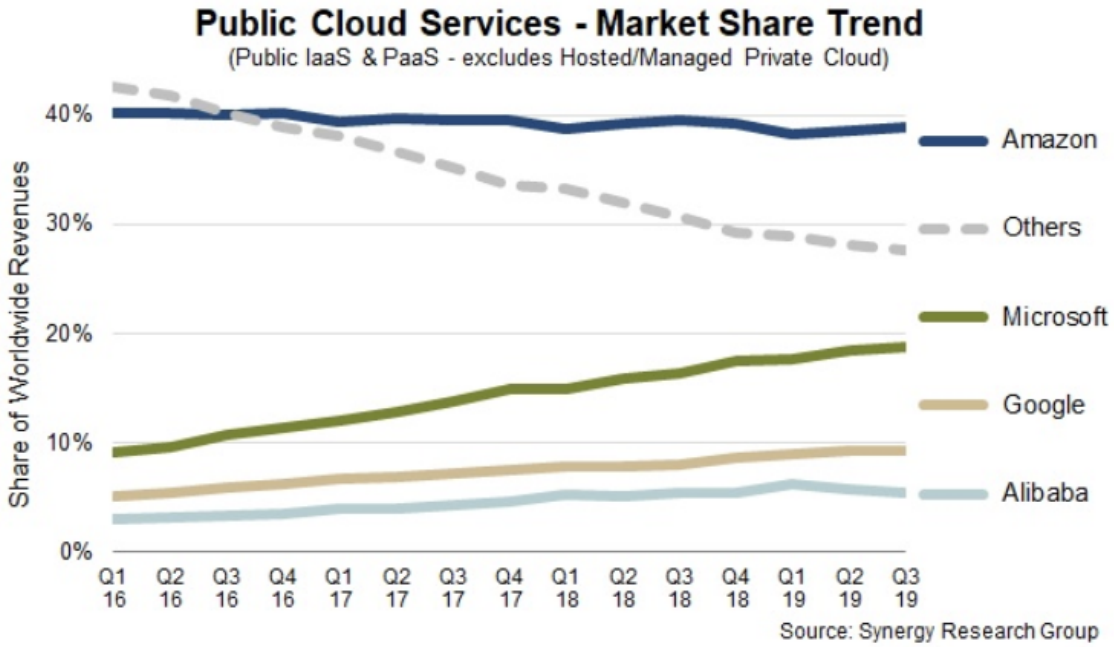
MARKET GROWTH



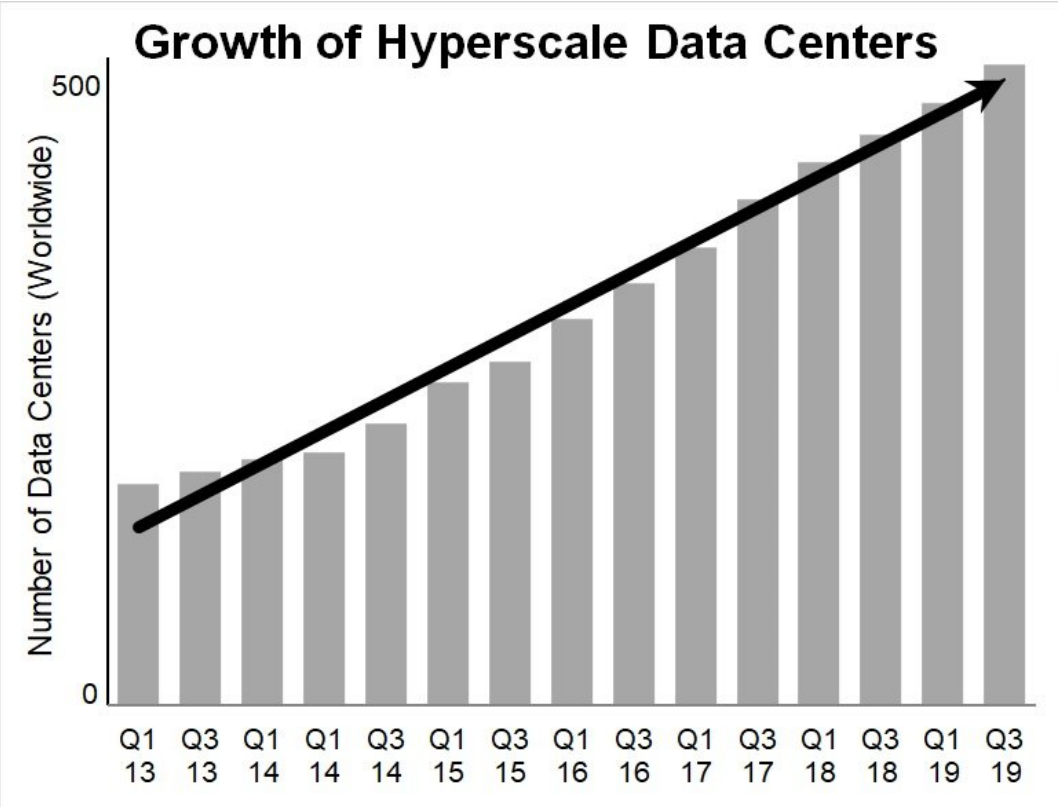


MARKET CONSOLIDATION





HYPERSCALE


Growth of Hyperscale Data Centers
Number of Data Centers (Worldwide)
500
0
Q1 13
Q3 13
Q1 14
Q1 14
Q3 14
Q1 15
Q3 15
Q1 16
Q3 16
Q1 17
Q3 17
Q1 18
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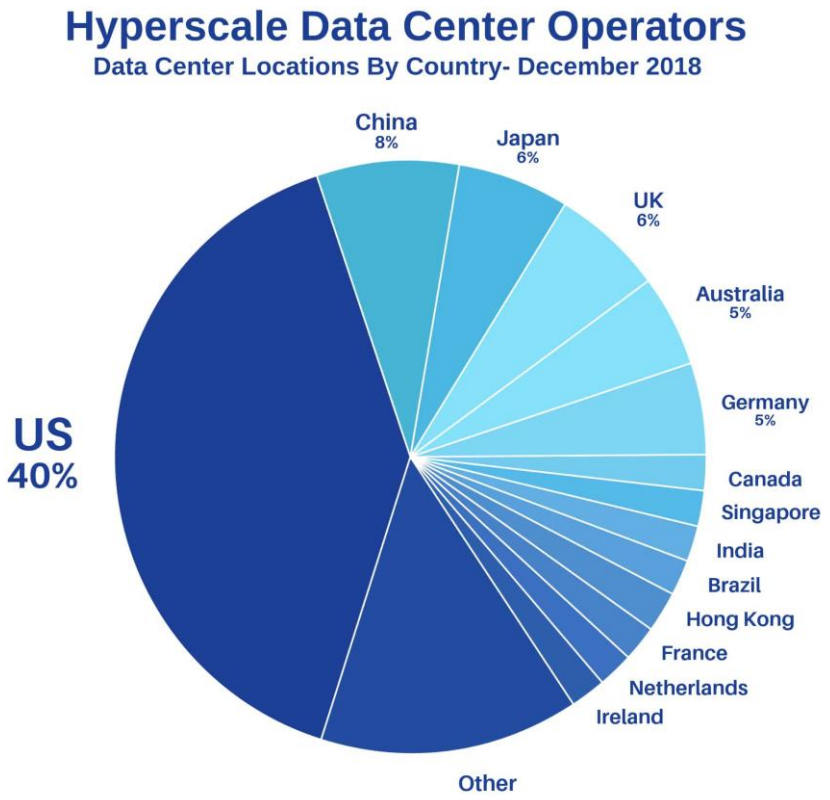

Hyperscale Data Center Operators
Data Center Locations By Country- December 2018
US
40%
China
8%
Japan
6%
UK
6%
Australia
5%
Germany
5%
Canada
Singapore
India
Brazil
Hong Kong
France
Netherlands
Ireland
Other

TRENDS

Strong growth in the Cloud market

Consolidation: small number of companies have a rising market share

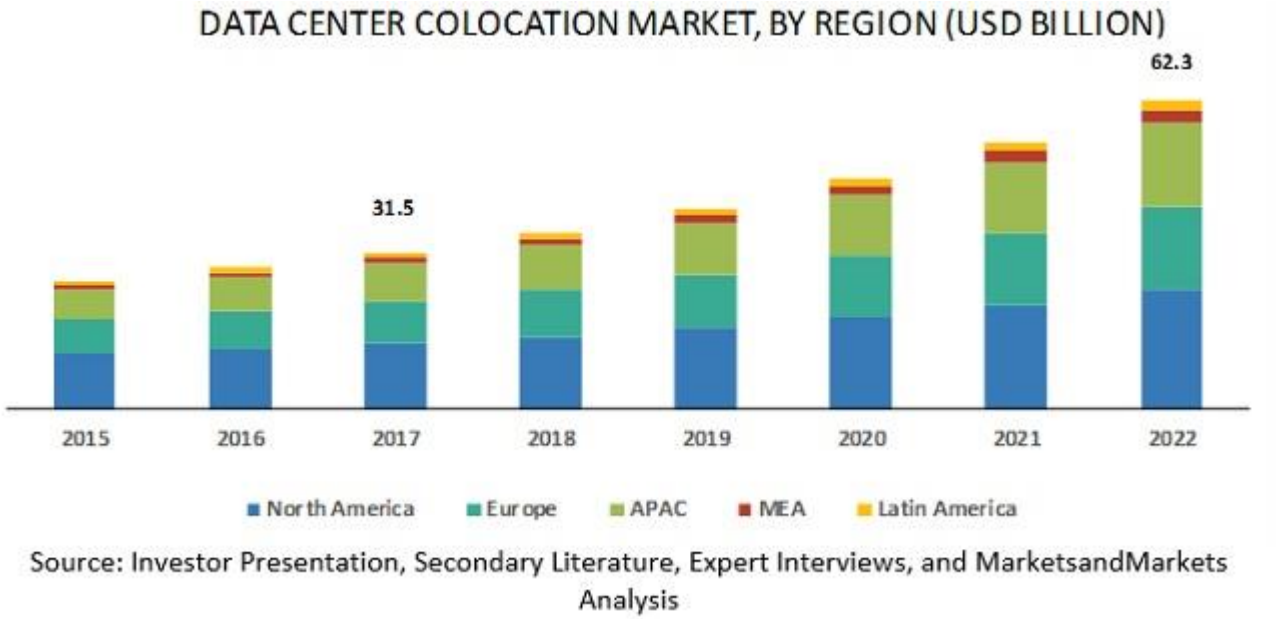
Decline in European Cloud provider market

Market is dominated by the US

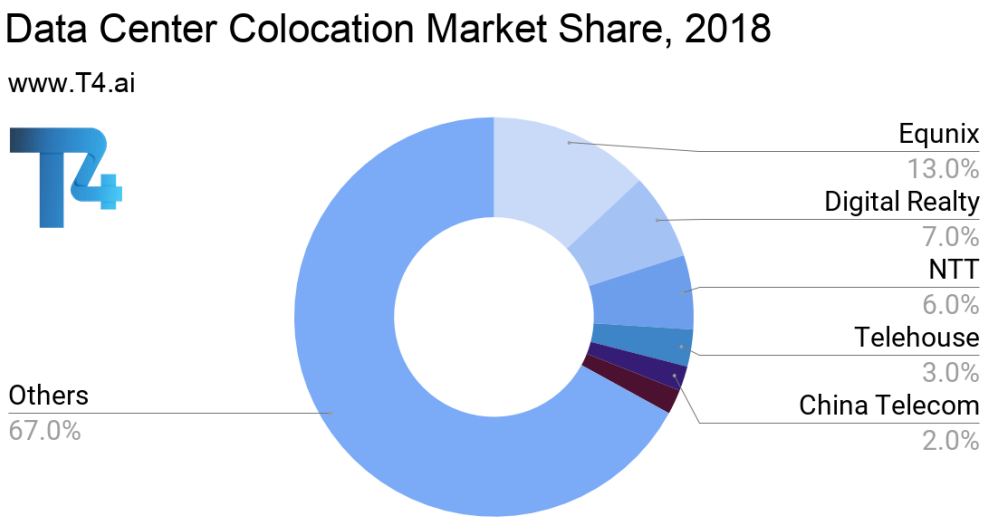
Rise of the hyperscale data center

Why do you think these trends are occurring?

DON'T FORGET THE CO-LO MARKET



Source: Investor Presentation, Secondary Literature, Expert Interviews, and MarketsandMarkets Analysis



Surveys

VENDOR LOCK-IN

Survey of 114 participants from UK industry (small to large enterprises)

J. Opara-Martins, R. Sahandi, F. Tian, "Critical analysis of vendor lock-in and its impact on cloud computing migration: a business perspective", Journal of Cloud Computing: Advances, Systems and Applications (2016)

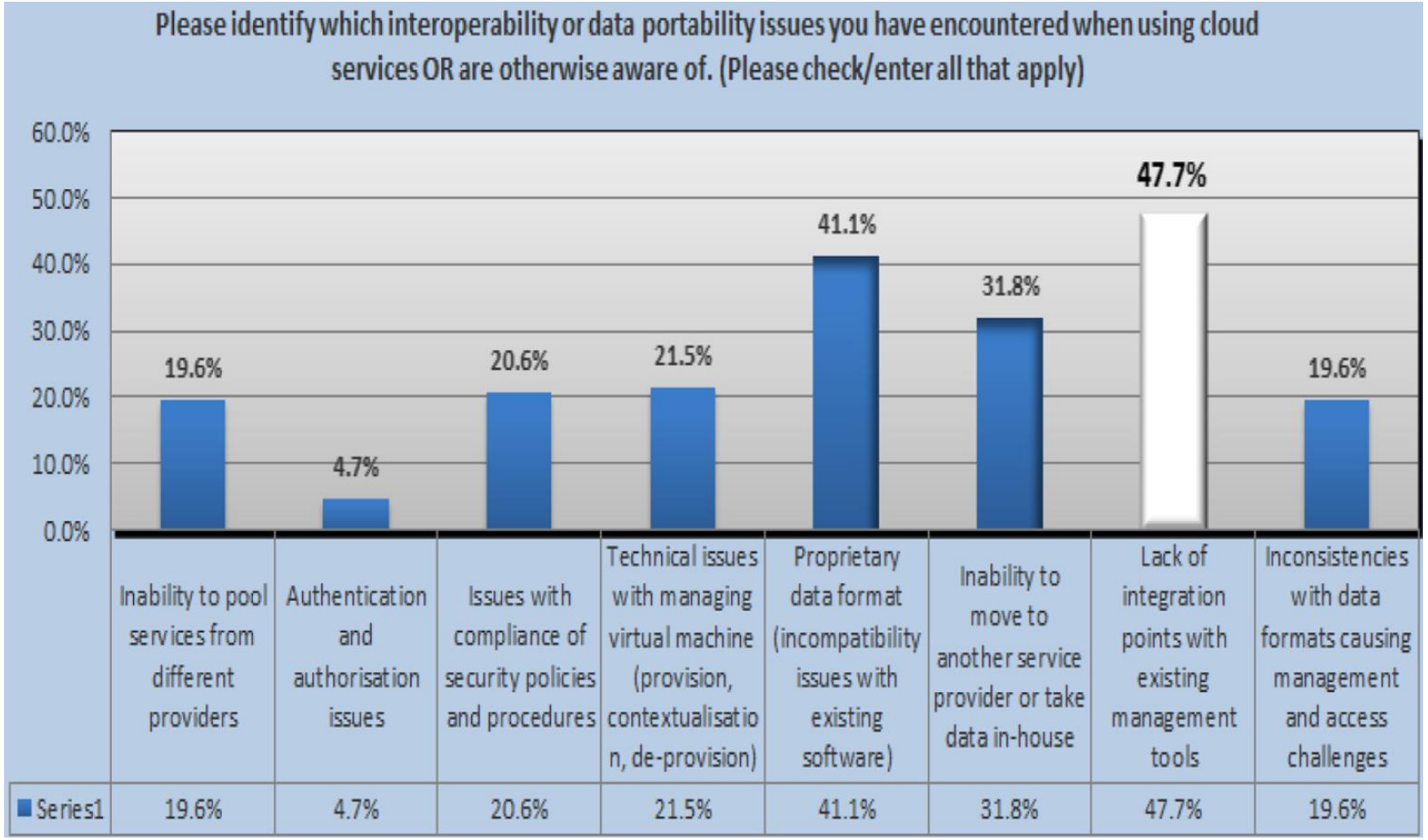
Lock-in is a deterrent to Cloud migration

Definitely yes	Possibly yes	Not sure	No
9%	71%	11%	9%

VENDOR LOCK-IN (2)

Discussion

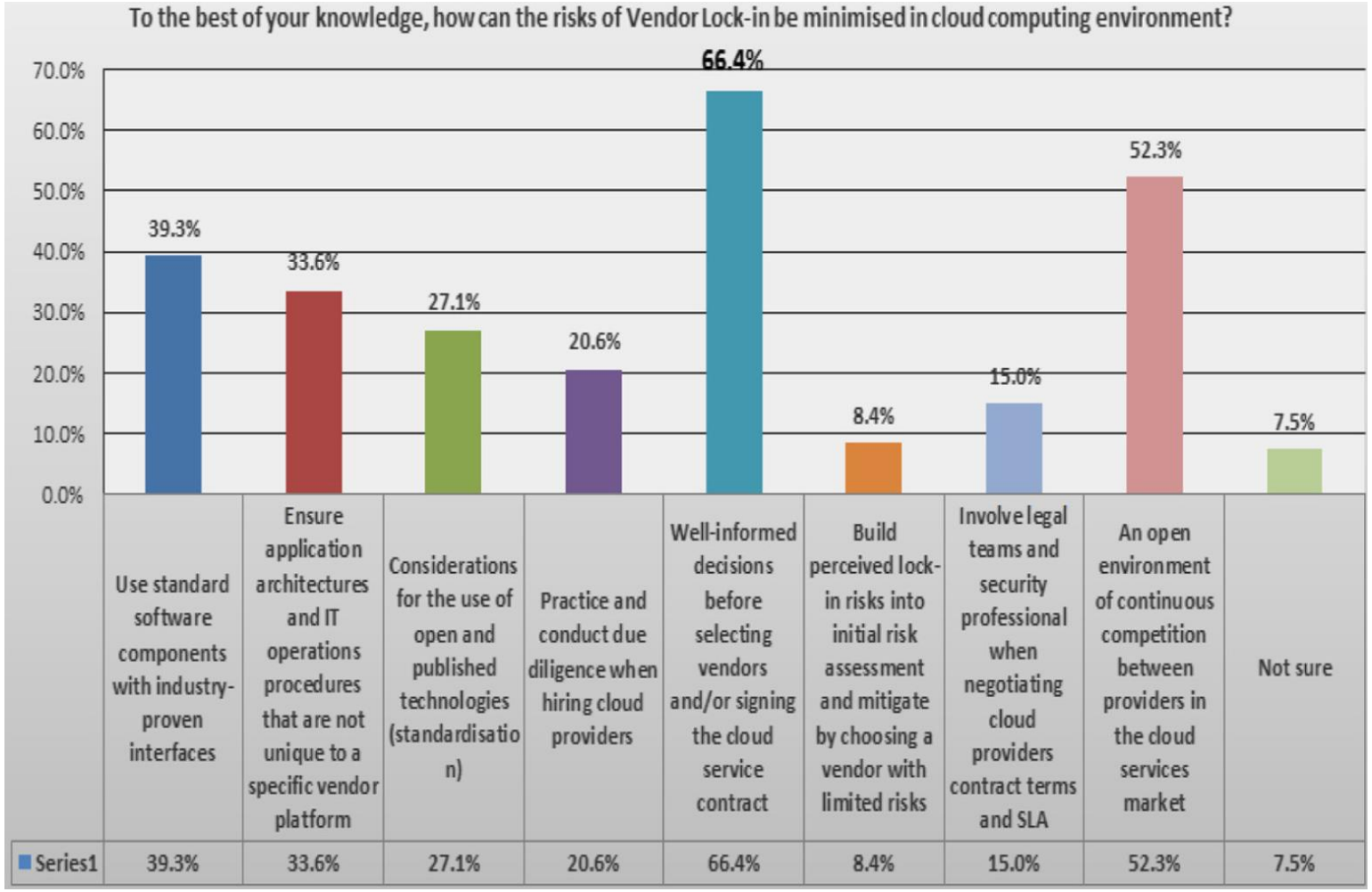
What sort of interoperability / data portability challenges might companies face?



VENDOR LOCK-IN (3)

Discussion

How can companies minimise the risk of vendor lock-in in a Cloud environment?



VENDOR LOCK-IN (4)

Provider perspective	User perspective
Produces a steady income	Less flexible
Easier to predict how much hardware needed	Can be cheap (discounts)
Cheaper	The longer used, the harder to leave

EGRESS FEES

EGRESS FEES

	AWS per GB	Azure per GB	Google
1 GB	0.09 $	0.087 $	0.12 $
1 TB	0.09$	0.085 $	0.12 $
10 TB	0.085 $	0.083 $	0.11 $
150-500 TB	0.05 $	0.05 $	0.08 $
500+ TB	Custom deal	Custom deal	0.08 $

COST OF EGRESS EXAMPLE

	AWS	Azure	Google
1 GB	0.09 $	0.087 $	0.12 $
1 TB	90 $	85 $	120 $
10 TB	850 $	830 $	1100 $
500 TB	25000 $	25000 $	40000 $

As an example, NASA is migrating 247 PB to AWS
Egress of this data will cost approximately $12 M

CO-LOCATION

Up to seven times cheaper in some scenarios

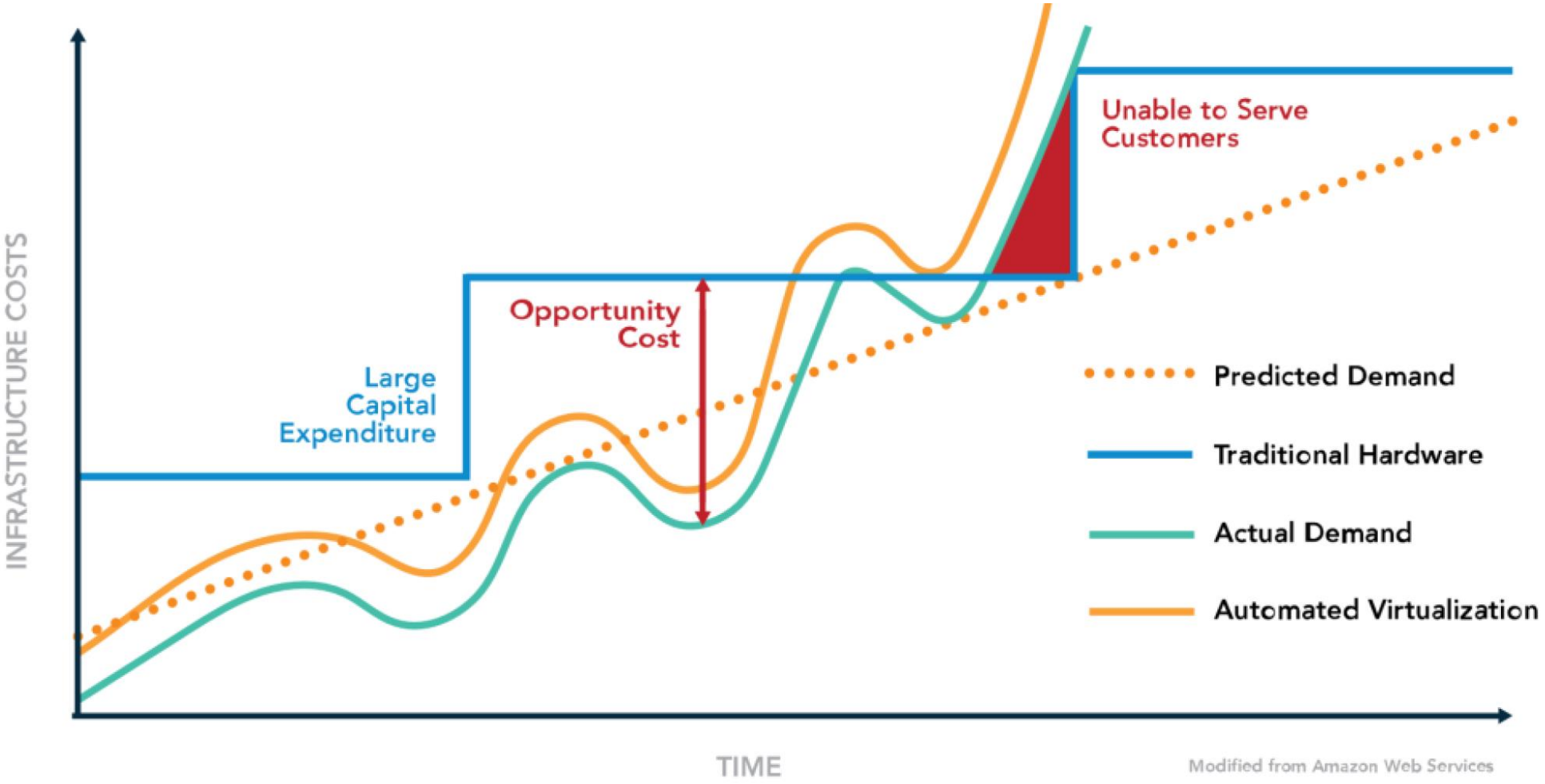
Can take a few years to pay off

You choose the hardware, systems, and tools

Bigger risk for smaller companies

Difficult to scale

CAPITAL VS OPERATIONAL COST



Cost comparison of providers

COMPARING PROVIDERS

Comparing providers is not trivial

Providers purposefully do not want to allow simple price comparisons

Each provider wants to emphasise their advantages

Many factors impact the final cost

Each provider has their own discount model (often high)

Two very similar configurations can have different pricing

Discounts and prices change periodically

COMPARING PROVIDERS

Tools exist to compare prices

https://azure.microsoft.com/en-us/pricing/calculator/

https://calculator.aws/

https://cloud.google.com/products/calculator/

All are quite complex interfaces, with many tuneable parameters

COMPARING PROVIDERS (2)

Reserved instances are one reason why providers are difficult to compare

Typically 1-3 year contract, paid monthly	Pay for estimated usage	Costs the same no matter what utilisation
Can often be cancelled or upgraded for a fee	Can reduce costs by a lot – 72% for AWS and Azure, etc.	Highest discount is achieved when paid upfront

PROVIDER COMPARISON: FAAS (SERVERLESS)

512MB RAM
1 second execution
Bandwidth usage not included in Azure or AWS
Both Azure and AWS include 1M requests and 400,000 GB-s for free

What is a GB-s?

Observed resource consumption is calculated by multiplying average memory size in gigabytes by the time in milliseconds it takes to execute the function

# Requests	Azure	AWS	Google CF
10^6	$1.61	$1.63	$6.8 (10KB)
10^9	$8193	$8494	$21089

PROVIDER COMPARISON: STORAGE

No reserved instances, basic license

500 million inserts, 500 million fetches

Services are not entirely equivalent

Storage	Azure	AWS	Google CF
1 TB	$1771	$3000	$2720
10 TB	$2324	$3239	$2905

PROVIDER COMPARISON: DATABASE

PostgreSQL, storage with backup

Bound to instances, not exactly the same for all providers

Cheapest instance used

Storage	Azure	AWS	Google CF
500 GB	$111	$90	$100
1 TB	$162	$163	$186

PROVIDER COMPARISON: SUMMARY

Service	Azure	AWS	Google
FaaS	1.61	1.63	6.8
FaaS	8193	8494	21089
DB	111	90	100
DB	162	163	186
Storage	1771	3000	2720
Storage	2324	3239	2905

A BRIEF SUMMARY

Cloud is still experiencing huge market growth

Hyperscale DCs are eating smaller rivals.. But don’t forget the co-lo market

Is vendor lock-in a problem or just perceived to be?

Are egress fees still a problem?

It’s hard to compare costs between providers

What is the future of Cloud?

Before our main keynote...

COURSE SUMMARY

Give you a flavour of Cloud and its technologies	Show you that the ERDC exists and you can use it for your PhD	Basic Cloud terminology	Data centers and how they work
HDFS distributed storage	Hadoop MapReduce	Spark distributed in-memory processing	Storm stream processing
Edge, fog	Serverless	Containers and Kubernetes	Economics

COURSE SUMMARY

I will upload all slides to Canvas later today

Your ER DC accounts will not stay active for long – but as WASP PhDs, you can ask for a new account and then use ER DC to set up your own clusters and run experiments for your PhD

More details about the assignment will be uploaded to Canvas. HOWEVER, I can now reveal….

COURSE ASSIGNMENT!

WASP courses shouldn't give you work just for the sake of it – your real job is your PhD

Let's do something that won't take too long, but can benefit us all

Write a 2.5 - 3 page essay:

1st paragraph: introduce your research/area (200 words)

Remainder of essay: how Cloud technology can be useful to your research. Talk about at least four of the concepts mentioned on the previous slide.

Deadline is 26th May 2021.

Write three pages (that are original and show you've thought about this) and you pass, otherwise you fail.

After 26th May, I will condense all the essays into a 250 page document and put on Canvas so we can all read and get ideas from each other.

FINAL WORDS BEFORE KEYNOTE

I hope you got something out of this course!
We have covered a lot of ground, and the practical was complicated.
If you can apply one thing that you've learnt to your PhD then it's a success.

You can always email me: paul.townend@umu.se if you want my opinion on anything Cloud in future.

You can connect on LinkedIn if you like (but I am slow to use that!)

Please turn cameras on for intro and final questions to Steve Webster

Starts at 16:30