

Randomness, Serendipity and Luck in Petroleum Exploration

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EARTH • ENERGY • ENVIRONMENT

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Talk outline

2

- What people say about luck in exploration.
- What data and randomness models suggest.
- Implications for you.

I've heard these from managers...

3

***“I do not need a good geologist;
I need a lucky one.”***

Anonymous CEO

“Lucky beats clever, every time.”

A New Ventures Manager

DeGolyer made me more curious

4

Everette Lee DeGolyer

AAPG Sidney Powers Memorial
Award in 1950

Called "petroleum industry's #1
geologist" after his death in 1956

Geophysical Research Corporation

DeGolyer and MacNaughton

Core Laboratories



*"It takes luck to discover oil.
Prospecting is like gin rummy.
Luck enough will win but not
skill alone.*

*Best of all are luck and skill in
proper proportion, but don't
ask what the proportion
should be. In case of doubt,
weight mine with luck."*

Survey on luck in petroleum exploration

5

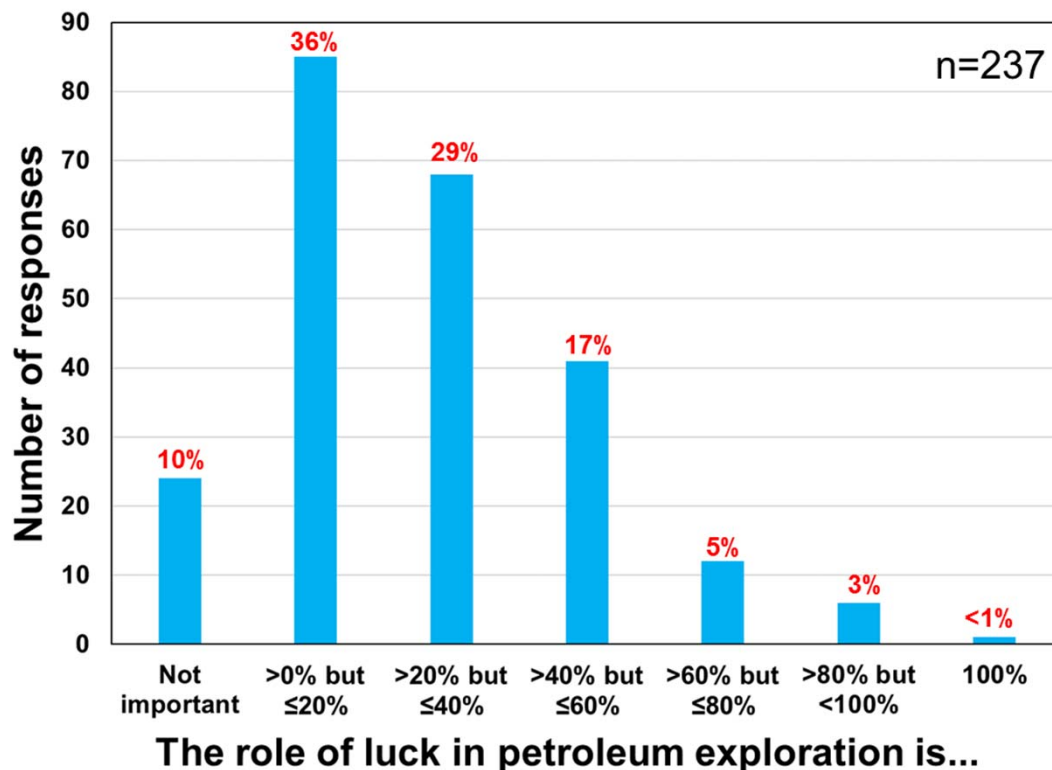
*“Some think that outcomes of petroleum exploration depend on luck and technical skill. In your opinion, **what is the role of luck in the outcome of petroleum exploration programs?**”*

- Background information collected:
 - ▣ Highest educational degree,
 - ▣ Type of company,
 - ▣ Years of experience,
 - ▣ Highest level position in exploration projects.



Perception of luck in exploration by industry practitioners

6

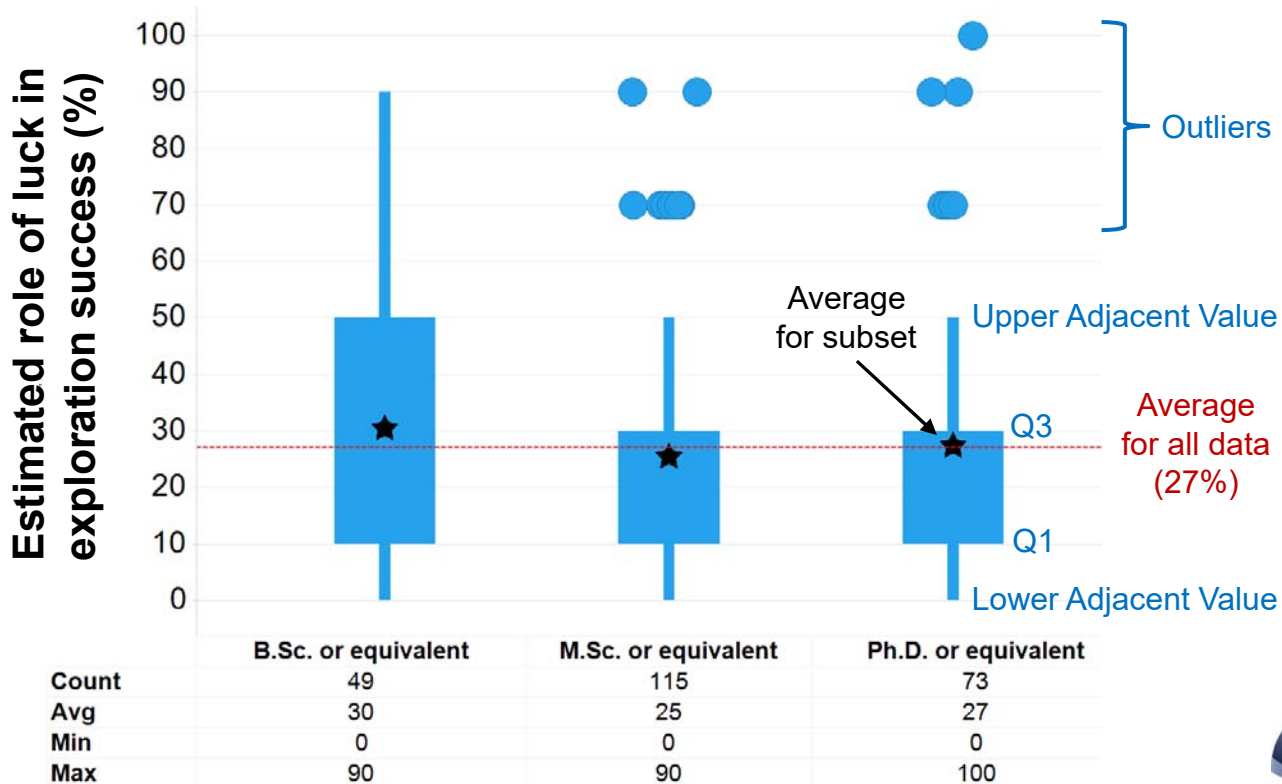


- 90% of respondents think that luck plays some role in the outcomes of petroleum exploration.
- Average role of luck is 27% (median 30%).

Milkov and Navidi (2019, AAPG Bull.)

Highest academic degree

7

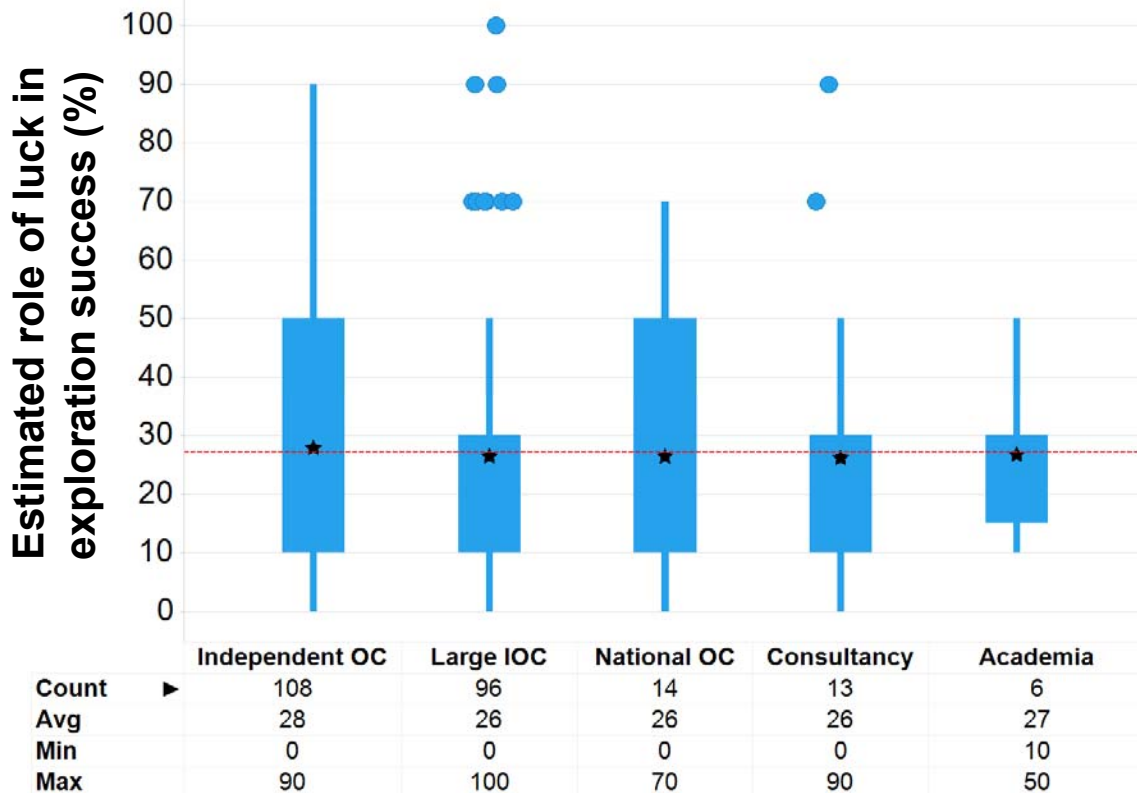


- Education has little influence on the perception of luck.

Milkov and Navidi (2019)

Company type

8

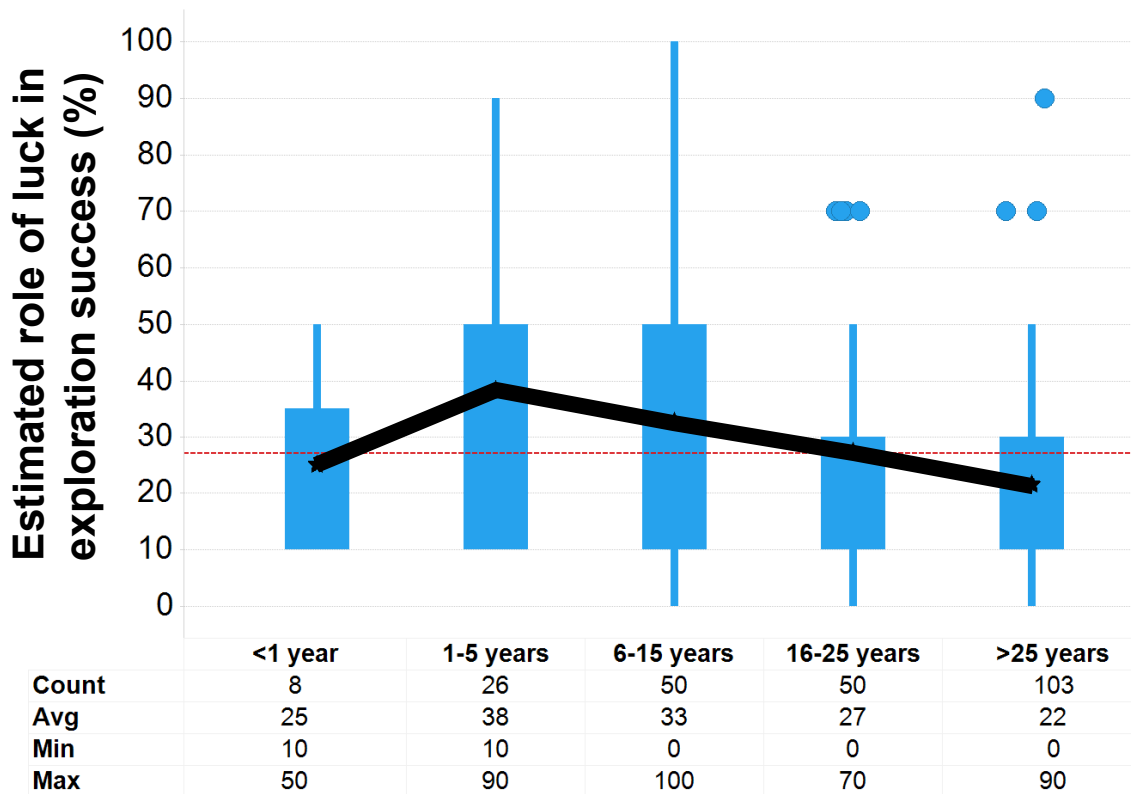


- The type of company has little influence on the perception of luck.

Milkov and Navidi (2019)

Years of experience

9

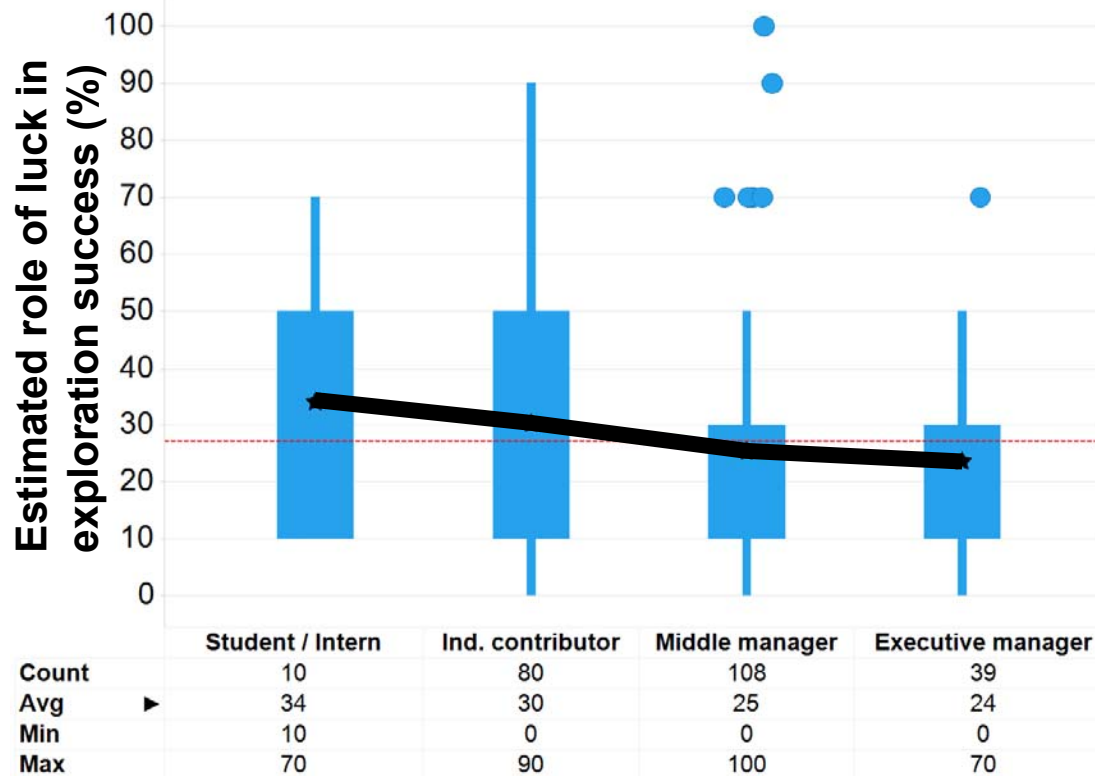


- Explorers with more years of experience assign lower significance to the role of luck in exploration.

Milkov and Navidi (2019)

Highest-level position in exploration projects

10



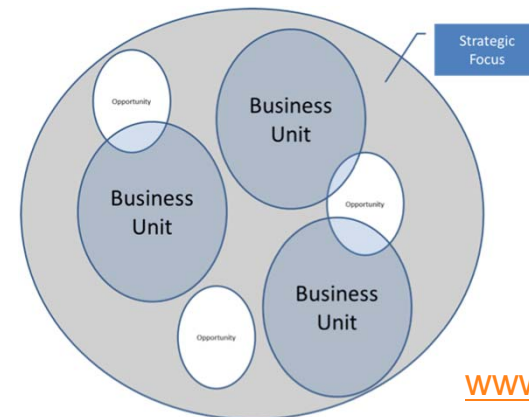
- Explorers with higher positions and larger responsibilities assign lower significance to the role of luck in exploration.

Milkov and Navidi (2019)

Why more experience and higher position reduce appreciation of luck factor?

11

- Self-serving attribution and overconfidence biases?
 - ▣ Believe that their contribution to success is more valuable than it actually is.



www.emba.mit.edu

- Appreciation of portfolio approach?
 - ▣ Executive managers of Large IOCs and NOCs average 16% (n=10) while overall executive group averages 24% (n=39).

The concept of luck

12

“Luck is success or failure apparently brought by chance rather than through one's own actions.”

“Small probability events in essentially random processes” (Rescher, 1995).

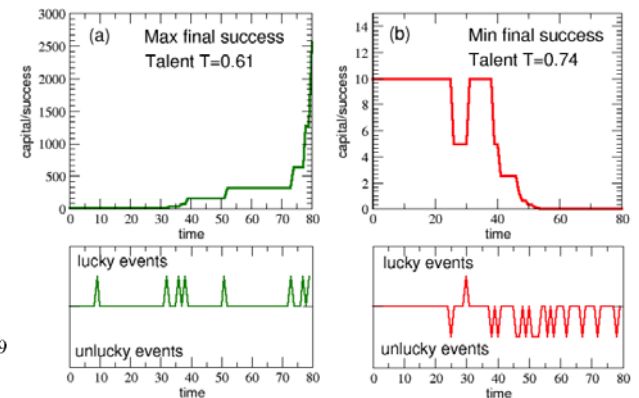
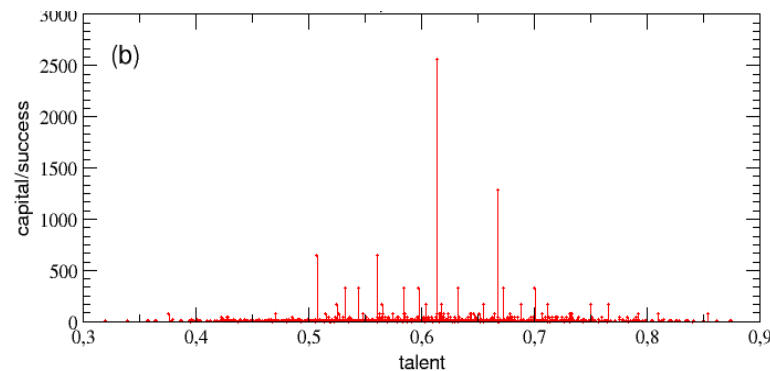
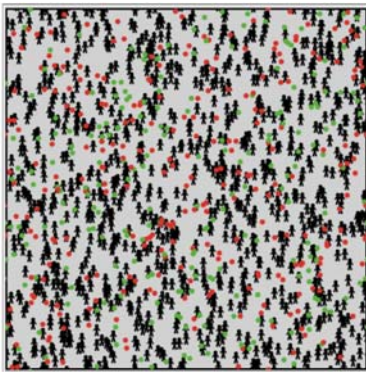
Good luck



Bad luck

Role of luck in life – mathematical model

13



- 1000 people, each starts with the same capital.
- Normal distribution of talent.
- Random walks. Lucky events (green circles) double the capital, unlucky (red circles) events halve the capital.

- The most successful individuals are not the most talented ones.

- Strong correlation between success and luck.

Pluchino et al. (2018)

Real life example

14



https://www.reddit.com/r/funny/comments/7gp3ye/this_vanity_tag/

Was Jeff Bezos lucky?

15

1999

<http://www.whiskeyriff.com/2018/01/02/amazon-founder-jeff-bezos-in-his-office-in-1999-is-all-the-motivation-you-need-for-2018/>



2018

<https://twitter.com/jeffbezos>



~130 billion \$

*"The price of admission to space is very high. I'm in the process of converting **my Amazon lottery winnings** into a much lower price of admission so we can go explore the solar system."*

Based on Koetsier (2018)

Mark Zuckerberg knows he was lucky

16

“You don't get to be successful like this just by being hard working or having a good idea... You have to get lucky in today's society in order for that to happen.”



Photo by Bloomberg. Facebook could encompass one-third of the world's population by this time next year, according to New York magazine.

Mark Zuckerberg is 33 years old, worth almost \$70 billion, according to Forbes, and is running one of the largest, most influential tech companies in the world.

Why and how is he so successful? Luck has a lot to do with it, he says.

<https://finance.yahoo.com/news/mark-zuckerberg-success-mine-only-190652552.html>

Definitions

17

- **Randomness** is the lack of predictability in events.
- Chance is a possibility of something happening in an essentially random process.
- **Luck** describes good or bad chance events with low probabilities that actually happened.
- **Serendipity** is finding valuable things that were not sought.

Examples of serendipitous petroleum discoveries

18

Countries and Basins

- Germany - first oil discovered in 1858 by the well drilled to locate coal in the Lower Saxony Basin
- Canada, Australia, Argentina, Volga-Urals (Russia)...
- Many discoveries in the first half of 20th century.

Plays

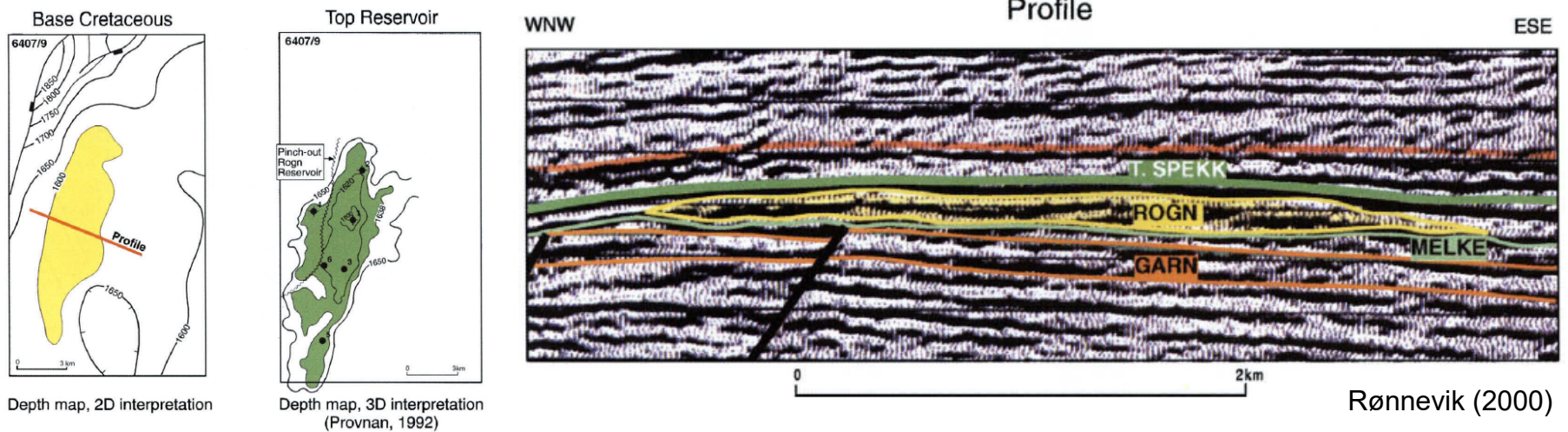
- Basement play, West of Shetlands, UK.
- Fat Sand play (Triassic Solling Formation), Northern Dutch offshore.
- Bakken oil play, USA.
-

Fields

- Groningen gas field (Netherland) - 100 tcf.
- Dayung gas field (Indonesia) - 15 tcf.
- Alba oil field (UK North Sea) - produced >425 mmbo.
- Draugen field (offshore Norway).
- ...

Example of serendipity in conventional petroleum exploration

19

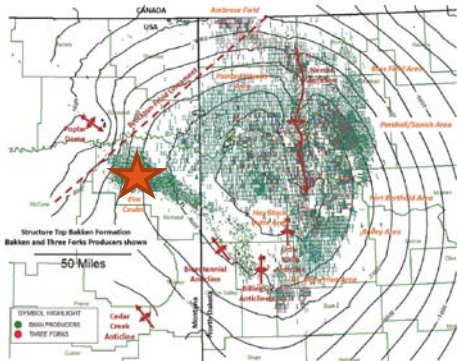


- The first well on Draugen (offshore Norway) targeted a low-relief Middle Jurassic structure with reservoir in the Garn Formation.
- Major surprise - the discovery was made in the Rogn Formation (Upper Jurassic), by then yet unknown reservoir.

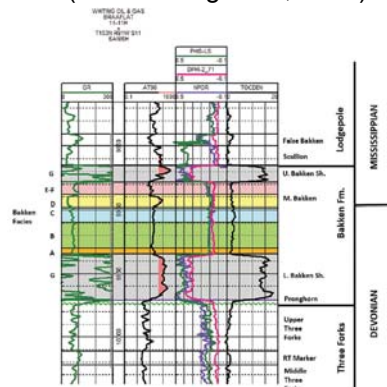
Example of serendipity in unconventional petroleum exploration

20

Structure map on top Bakken, CI=500 ft (Sonnenberg et al., 2017)

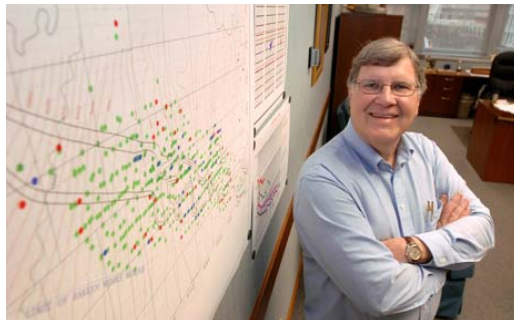


Well log display of Bakken (Sonnenberg et al., 2017)



- Elm Coulee Field, Montana – initial discovery (1996) of modern Bakken oil play in the Williston basin.
- Story told by Richard “Dick” Findley credited with discovery:
 - Drilled vertical well for bypassed oil on a small structural closure. **Were not targeting Bakken.**
 - On the way down to the target, **noticed 400-unit gas increase in Middle Bakken.** Thought “this is interesting”.
 - The original target (deeper) was non-commercial. **Decided to complete the Middle Bakken as a “bailout”.**
 - After a frac, had 157 BOPD initial potential. No steep decline, which was a surprise. Very different from Upper Bakken.
 - Called “Sleeping Giant Prospect”. Drilled first horizontal well in 2000, fracked, got over 400 BOPD. This became Elm Coulee.

<https://www.geoexpr.com/articles/2010/02/sourcing-an-oil-boom>



Sternbach et al. (2017)

We do not know how common serendipitous discoveries are, but...

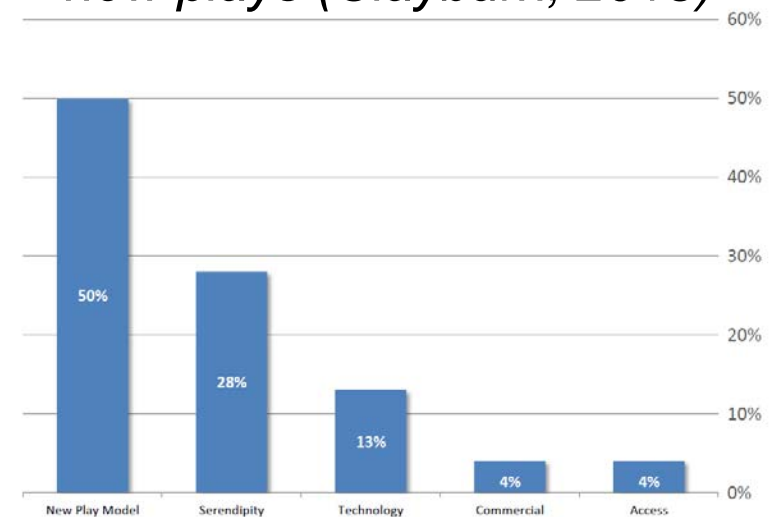
21

Perhaps >50% of conventional discoveries in the Permian basin are serendipitous (Elam, 1984)

74% of ~200 successful wells drilled in 2004-2006 were ... due to mere chance since relevant pre-drill predictions and evaluations ... were greatly different or wrong compared with the final results of drilled wells. But, all the above was sold and rewarded as geological “excellence”!

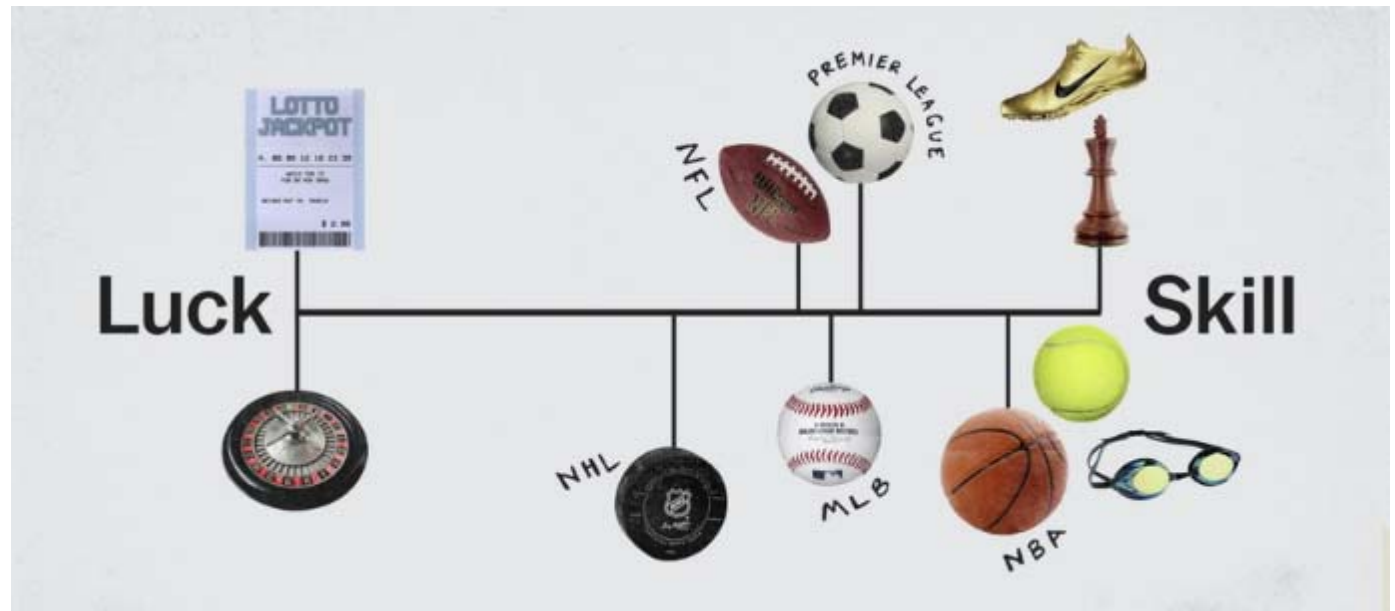
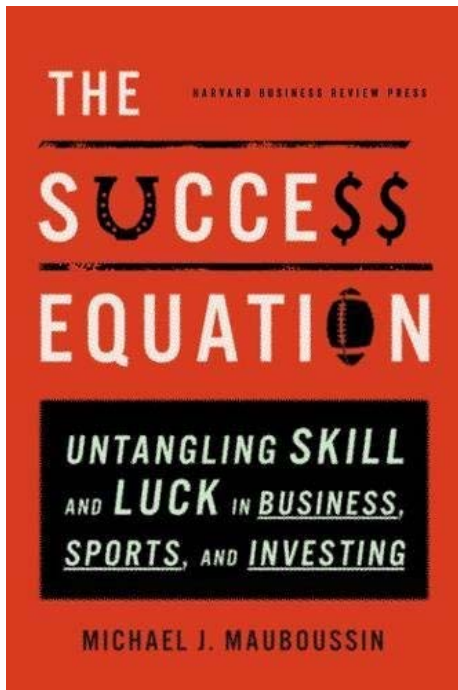
(Albino Quadrelli, AGIP)

Critical success factors for new plays (Clayburn, 2018)



Luck-skill continuum in competitive activities

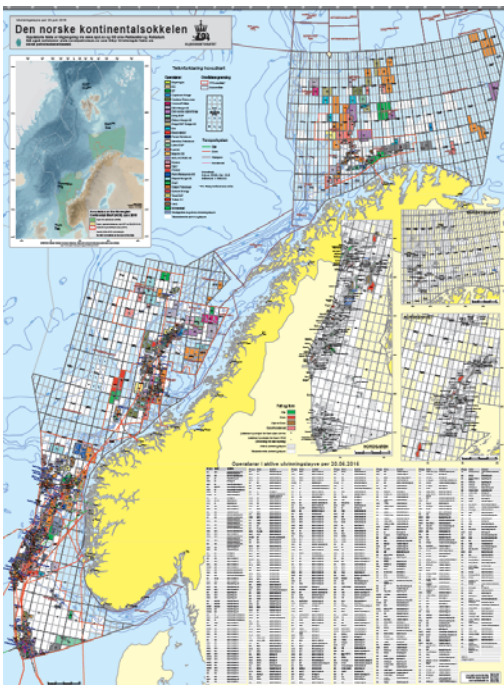
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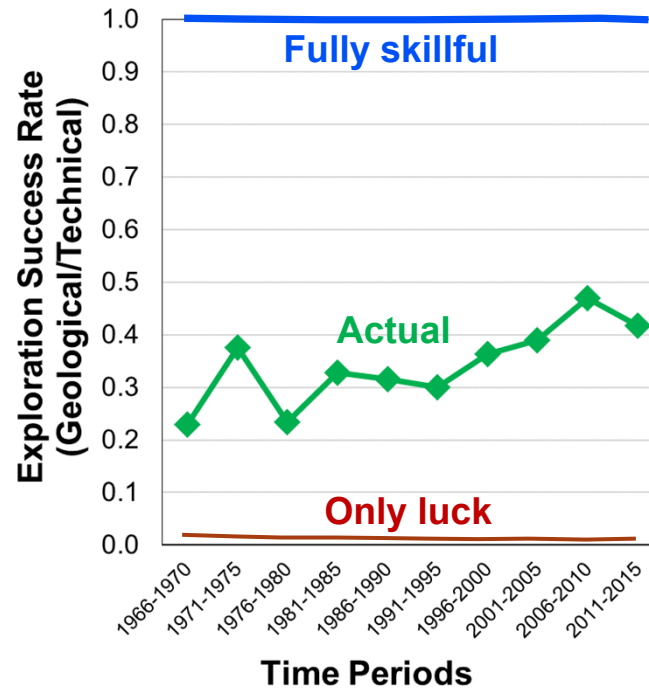
<https://www.vox.com/videos/2017/6/5/15740632/luck-skill-sports>

Exploration success rates on the Norwegian Continental Shelf (NCS)

23



<http://www.npd.no/en/Maps/Map-of-the-NCS/>

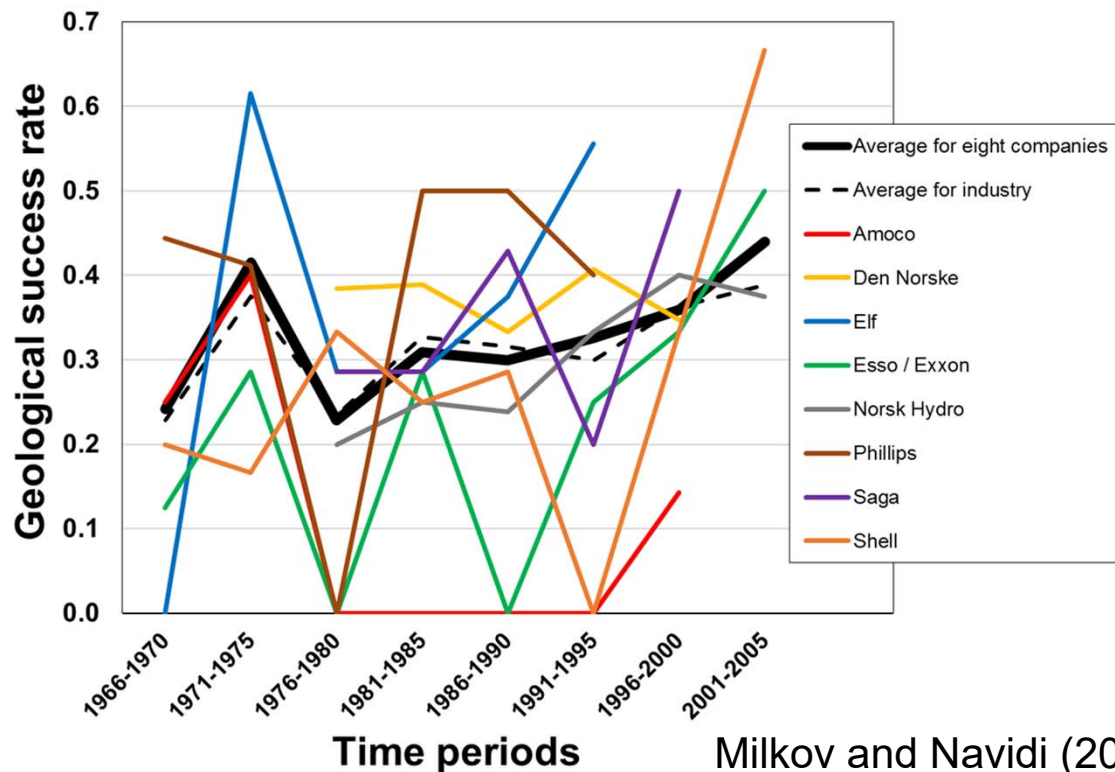


Milkov and Navidi (2019)

- Random drilling success rate 1.3% (mid-2017).
- 100% success if fully skillful.
- Industry average success rate increased from ~20% to ~40-50% over 50 years.

Evidence of luck in exploration on the NCS

24



- 8 largest companies drilled 497 exploration wells (of 636 total by the industry) in 1966-2005.
- Regression to the mean is a signal of luck.
- Consistency is a signal of skill.

Measure of variance in success rate

25

Number of wells drilled
by each company Success rate
for each company Overall
success rate

$$z_i = \frac{\sqrt{n_i}(p_i - \bar{p})}{\sqrt{\bar{p}(1 - \bar{p})}}$$

Difference between i th company
success and overall success, in
units of standard deviation

- Used z_i^2 to measure the difference between the success rate of company i and the overall success rate of the group (\bar{p}).

Actual vs simulated random results of exploration drilling

26

	66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	Total
Shell	0.05	1.53	0.19	0.13	0.01	1.94	0.02	0.63	4.48
Amoco	0.00	0.01	1.18	1.34	1.29	1.94	1.43	-	7.18
Den norske	-	-	1.81	1.07	0.11	0.81	0.01	-	3.81
Elf	0.95	2.15	0.13	0.02	0.21	2.16	-	-	5.62
Esso/Exxon	0.59	0.48	0.30	0.02	1.71	0.11	0.01	0.09	3.30
Norsk Hydro	-	-	0.07	0.33	0.38	0.01	0.11	0.27	1.17
Phillips	2.03	0.00	2.07	0.34	0.38	0.12	-	-	4.94
Saga	-	-	0.13	0.04	1.10	1.09	0.86	-	3.21
Total	3.62	4.17	5.88	3.29	5.20	8.16	2.43	0.99	

- Values of z^2 for each company for each 5-year period.

Results for one simulation

- Generated 10,000 data sets in which variation was entirely due to chance (randomness).
- Computed values of z^2 for each data set.

	66-70	71-75	76-80	81-85	86-90	91-95	96-00	01-05	Total
Shell	0.69	0.17	3.28	1.36	0.01	0.11	0.52	0.14	7.28
Amoco	1.27	0.30	1.18	0.01	0.02	0.55	1.37	-	4.70
Den norske	-	-	1.81	0.17	0.66	0.01	0.3	-	2.95
Elf	0.14	0.05	0.13	0.02	1.17	0.00	-	-	1.51
Esso/Exxon	0.00	0.01	0.30	3.13	0.05	0.11	0.01	1.25	5.53
Norsk Hydro	-	-	0.76	0.77	1.65	0.63	0.56	0.27	4.64
Phillips	0.02	0.00	0.29	0.34	0.86	0.12	-	-	1.63
Saga	-	-	0.29	0.04	1.65	0.37	0.07	-	2.42
Total	2.12	0.53	8.04	5.84	6.07	1.90	2.83	1.66	

Tested hypotheses

27

1. Difference in success rate from the overall rate for a particular company over the time is entirely due to chance.

	<i>P</i>
Shell	0.8523
Amoco	0.3407
Den norske	0.3707
Elf	0.3955
Esso/Exxon	0.9342
Norsk Hydro	0.9511
Phillips	0.4503
Saga	0.5931

2. Variation in success rates between companies within a given 5-year period is entirely due to chance.

Period	<i>P</i>
1966–1970	0.5302
1971–1975	0.3940
1976–1980	0.5936
1981–1985	0.8840
1986–1990	0.6670
1991–1995	0.3227
1996–2000	0.8209
2001–2005	0.4902
2006–2010	0.5259

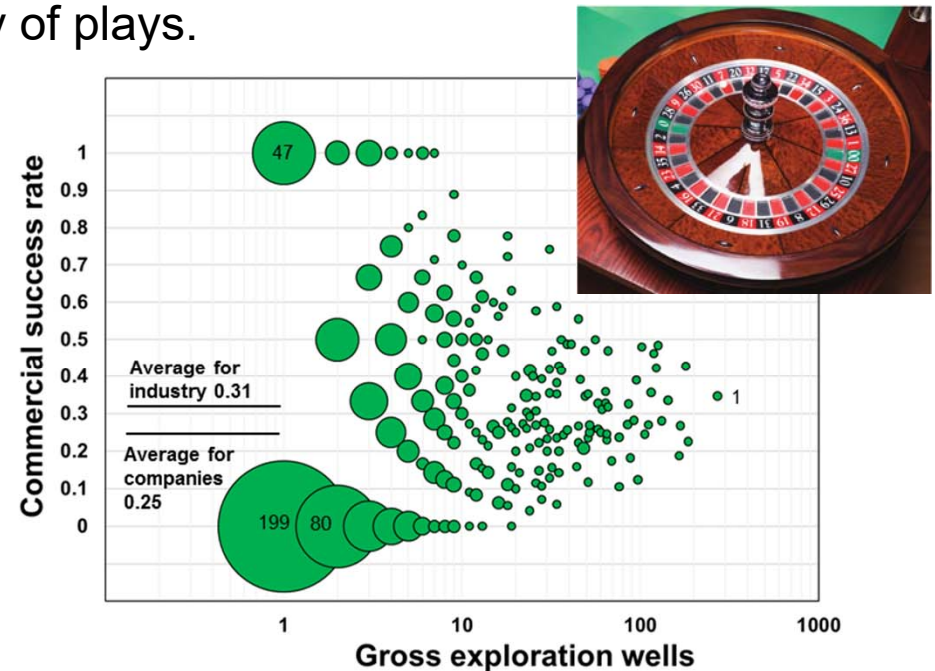
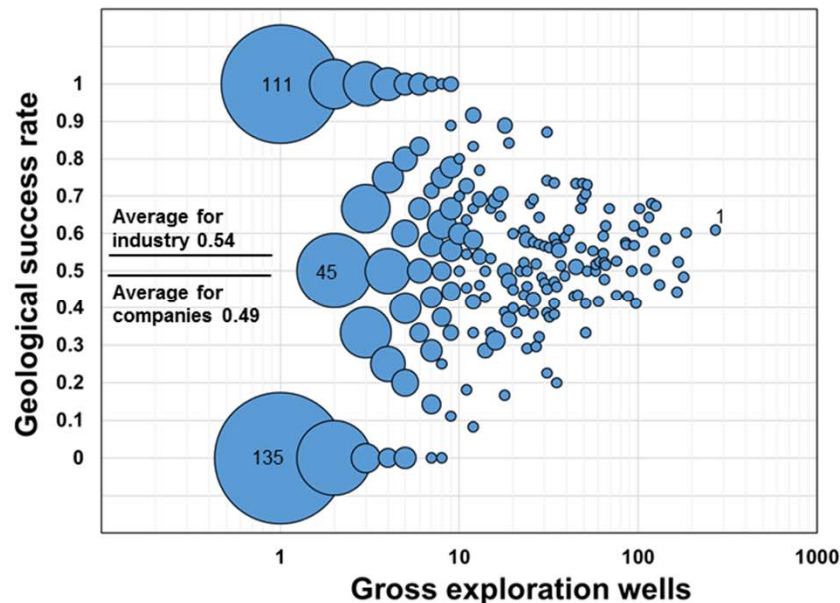
- *P*-values are proportions of simulated data sets for which the sum of z^2 values was greater than that in the real data.
- Reject hypothesis if its *P*-value is <0.05 .

Both hypotheses are consistent with the data

Evidence of luck in global exploration

28

- 733 companies participated in 8,096 gross (3,258 actual) exploration wells completed in 2008-2017 across a variety of plays.



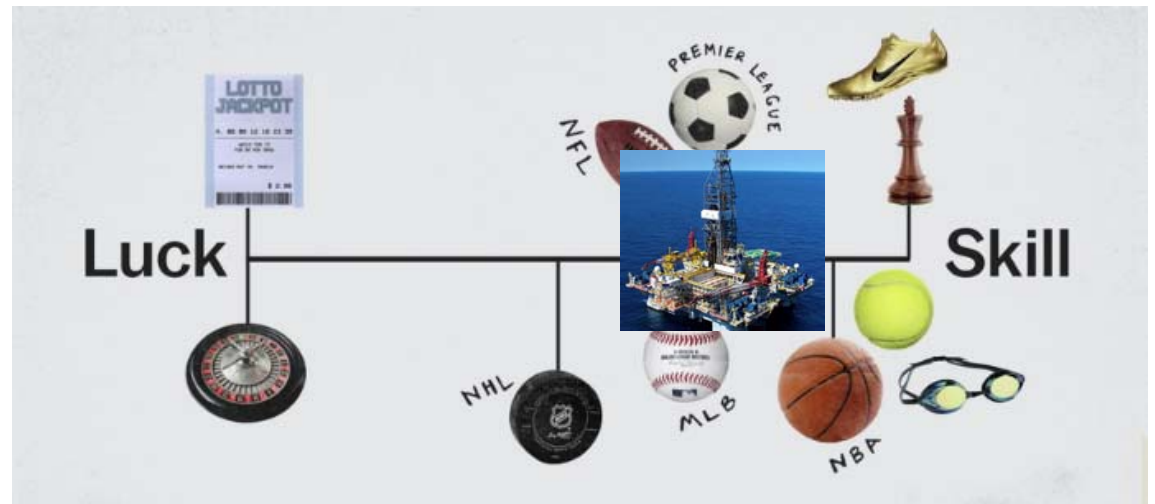
Data from Wildcat database (Westwood Energy)

Milkov and Navidi (2019)

Where is exploration on the luck-skill continuum?

29

- Compute variance expected from luck alone as a proportion of the observed variance.
 - ▣ The sum of z^2 scores is the observed variance for technical (191) and commercial (291) success rates.
 - ▣ The expected sum of z^2 scores for equally skilled companies is ~ 74 (companies with the same number of wells).

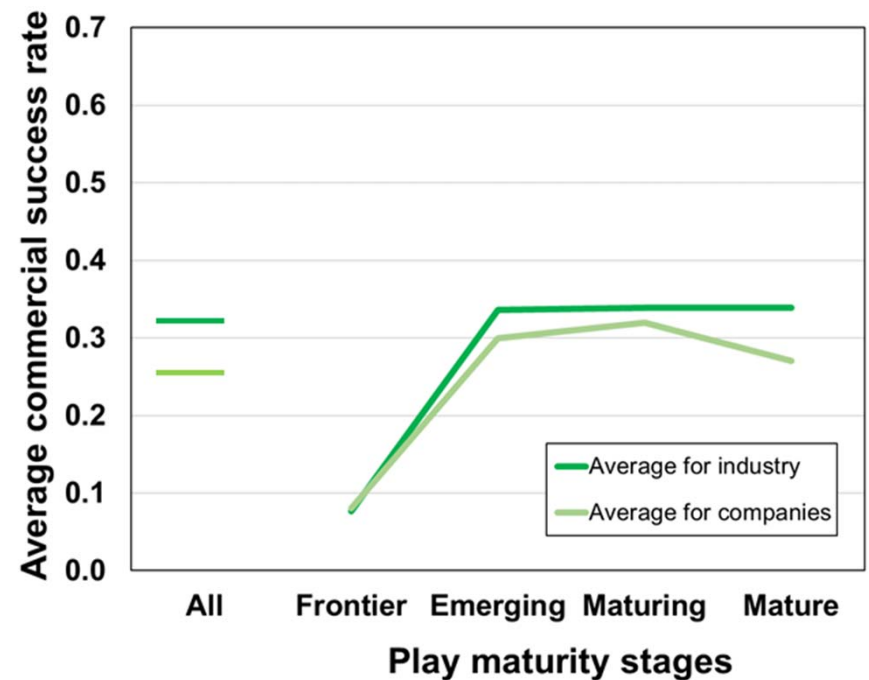
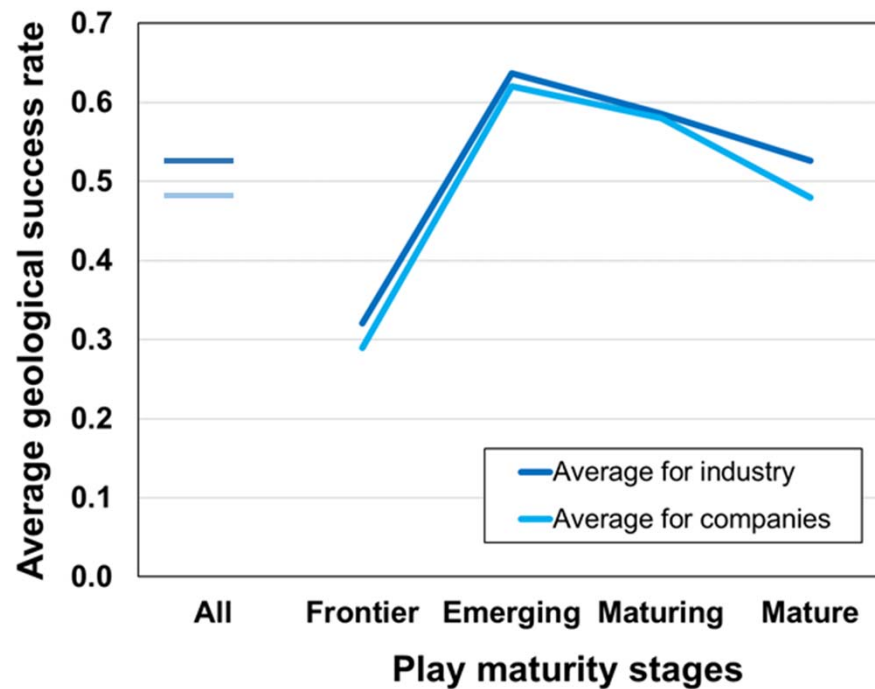


The proportion of variance due to luck:

- Geological success: $74/191 = 0.39$
- Commercial success: $74/291 = 0.25$

Success rates across play maturity stages

30

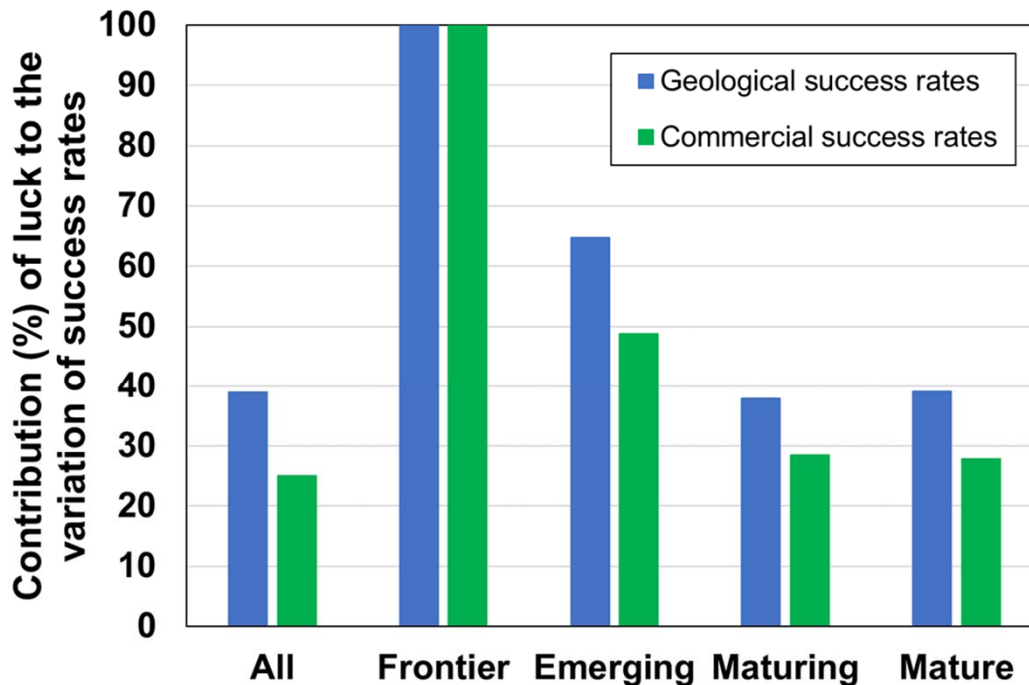


Data from Wildcat database
(Westwood Energy)

Milkov and Navidi (2019)

Role of luck across play maturity stages

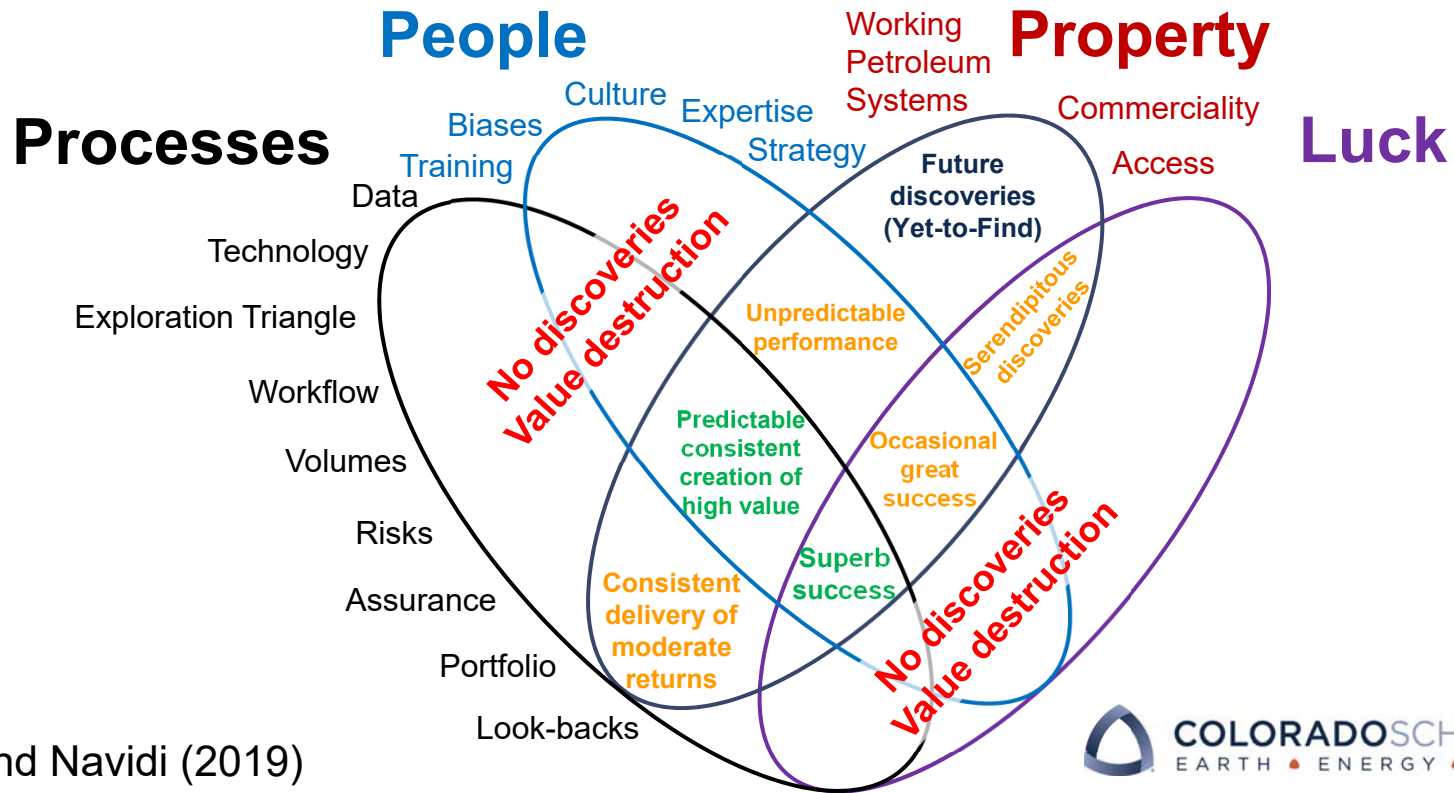
31



- In frontier plays, exploration success is essentially random:
 - Many unknowns,
 - Companies have similar skills.
- As plays mature, the skill becomes more important.

Milkov and Navidi (2019) **Play maturity stages**

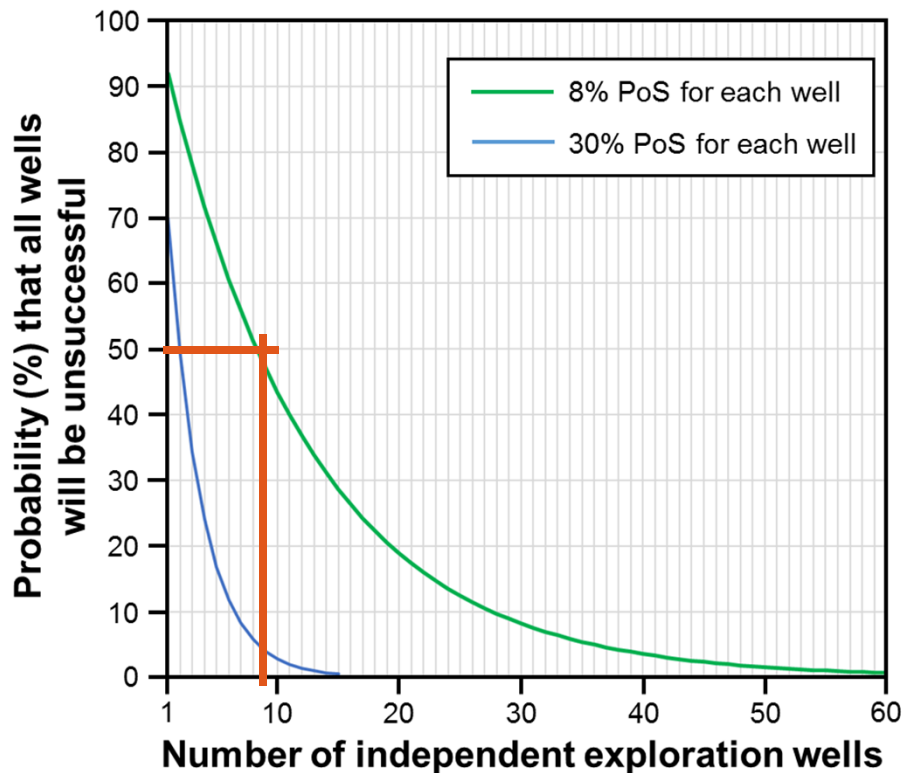
Exploration success equation



Milkov and Navidi (2019)

Implications for investors: Have realistic (probabilistic) expectations

33



Results from 2008-2017

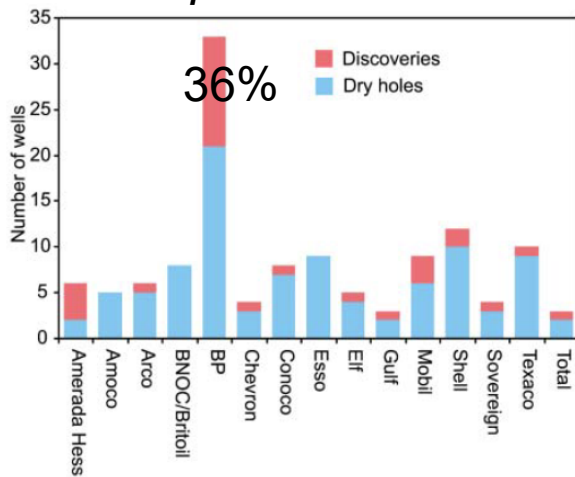
Company	Gross Frontier Wells	Commercial Discoveries
BP	14	0
Petronas	19	0
Repsol	25	1
Total	26	1
Avner	1	1
Pearl	1	1

Implications for strategies: Change plays carefully

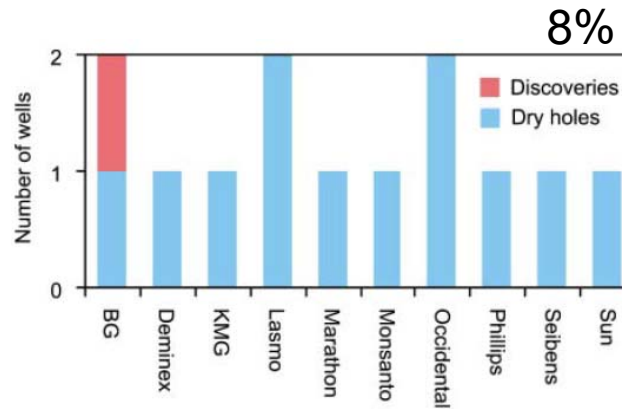
34

Exploration success rates, West of Shetland

Operators with 3 or more exploration wells



Operators with 1 or 2 exploration wells



Loizou (2005)

- Skill is relatively more important than luck in maturing and mature plays.
- Play-specific skill may not be easy or fast to obtain or transfer.

Implications for performance management: Appreciate the role of luck

35

		Outcome	
		Dry Hole	Discovery
Process	Shallow	Failure: Criticize and Fix	Just Good Luck: Stop Praising
	Deep	Smart Test but Bad Luck: Praise, Learn, Repeat	Success: Reward and Repeat

Inspired by Adam Grant (2017)

- Good outcome from good process may not happen in every exploration well, but it will happen over sufficiently large number of wells.

Implications for companies: Participate in more wells

36

Total Announces New Major Discovery in the North Sea

Laxman Pai • January 30, 2019



Image: Total



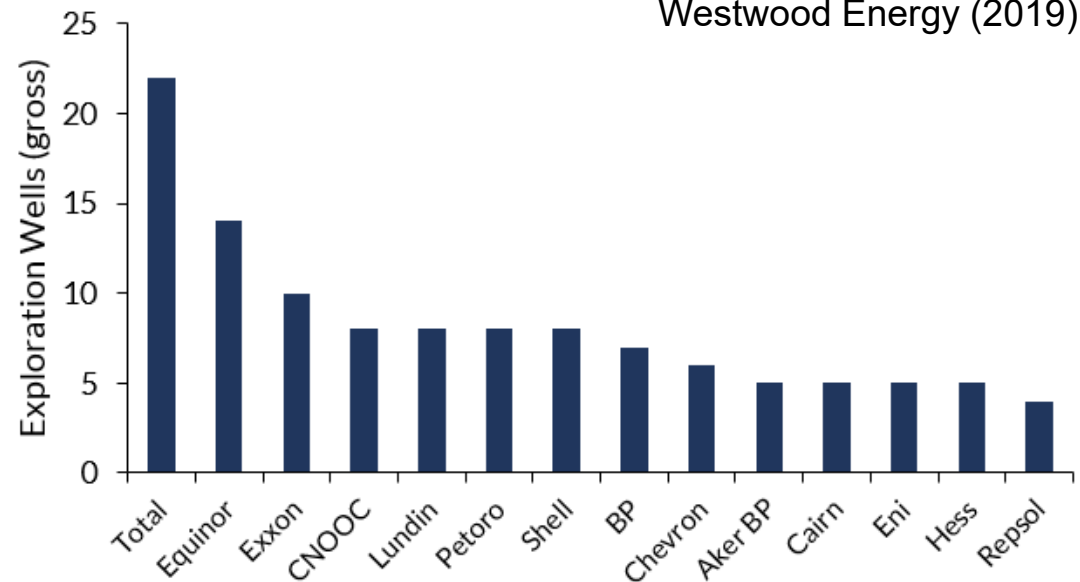
French energy giant Total has made "a new significant discovery" on the Glengorm prospect located off in the Central Graben in the North Sea, whose recoverable resources are estimated close to 250 million barrels of oil equivalent.

In a press release, Total said the well was drilled to a final depth of 5,056 meters and encountered 37 meters net gas and condensate pay in a high quality Upper Jurassic reservoir with excellent properties.

<https://www.oedigital.com/news/462287-total-announces-new-major-discovery-in-the-north-sea>

2019 Planned & Drilling High Impact Exploration Wells

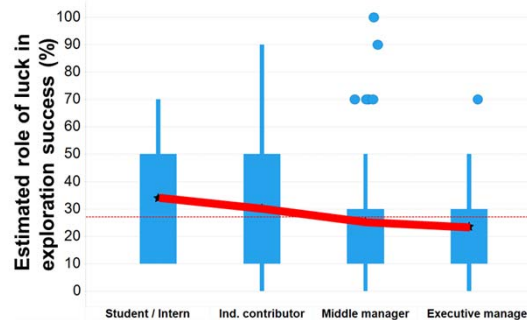
Westwood Energy (2019)



Implications for managers: Focus on the process

37

- Be humble.

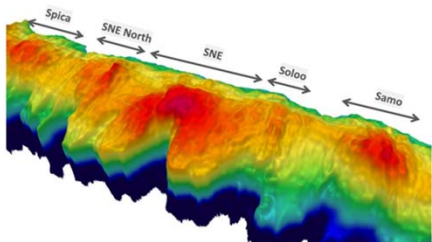


Ensure the long run!!

- Reduce the role of luck in exploration:
 - ▣ Maximize company's exposure to opportunities.
 - ▣ Enable geoscientists with data, technology and knowledge.
 - ▣ Deploy consistent and unbiased process of opportunities evaluation.
 - ▣ Keep track record of forecasts versus results, use learnings in new evaluations.

Implications for individual explorers: Being wrong is expected

38

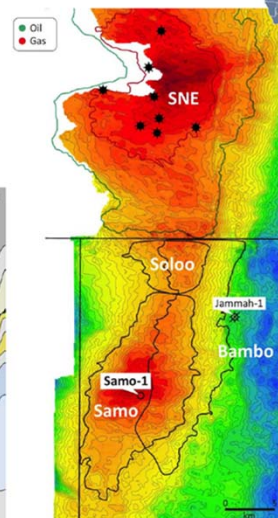
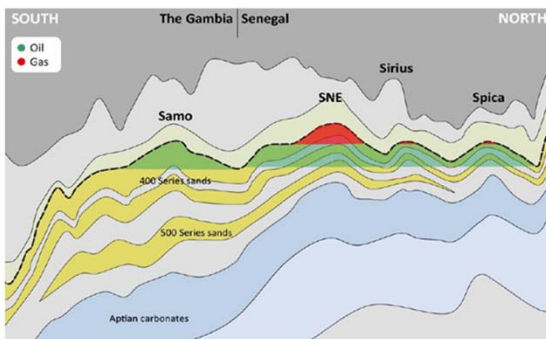


- On trend with SNE
- Key reservoir drilled by 9 wells with 100% success
- 50% geol. PoS

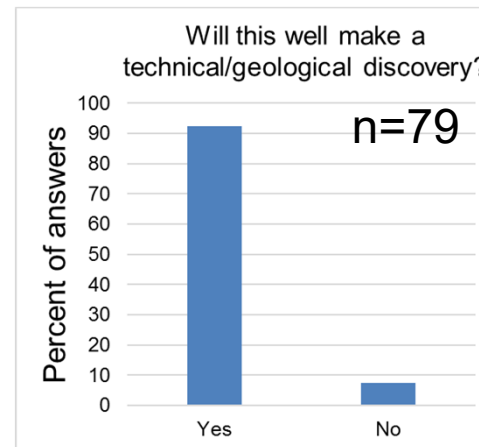


Samo Prospect Volumes*	Low estimate (P90)	Best estimate (P50)	High estimate (P10)
	335	825	1,713

Source: FAR



- Exploration, especially in the frontier areas, is the business of being mostly wrong.
- ▣ Factors beyond your visibility and control.



Offshore

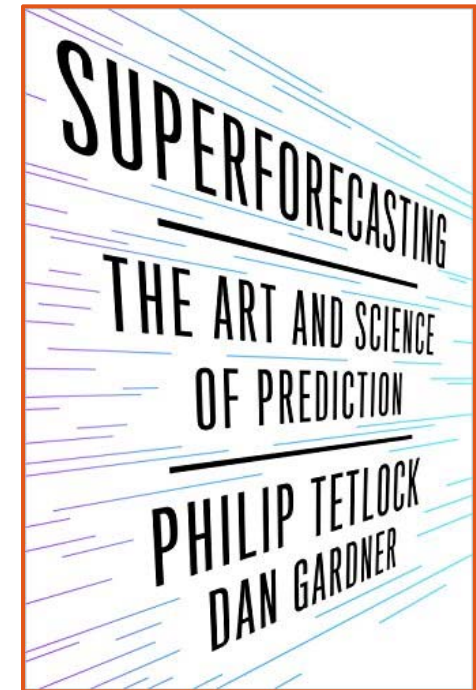
Offshore The Gambia well fails to deliver



Implications for individual explorers: Be better forecasters

39

- Focus less on the binary outcomes of each well.
- Compare your predictions of well results with the outcomes.
- Good long run forecasting is a true measure of skill.
- Forecasting abilities can be developed and cultivated.



Main takeaways

- Recognize the role of luck in petroleum exploration.
- Focus on the process. Ensure the long run.
- Hone your forecasting skills.

Property + People + Process + Luck

Questions / comments?

41

amilkov@ines.edu

