

Society for Experimental Finance

The Effect of Price Signals on Effort and Productivity in a 'Hard' Task

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What are “ideas”?

Combinatorial

(Schumpeter, 1911)
in nature

“Ideas are the instructions that let us **combine limited physical resources in arrangements** that are ever more valuable.”

... the use of an idea by one person **does not limit its use** by someone else”

Non-rivalrous

(Samuelson, 1954)

Two Strategies for Economic Development:
Using Ideas and Producing Ideas
Paul Romer, 1993

Background

Discovering new ideas is essential for growth

Schumpeter, (1911)

Ideas are free to use, but costly to find (coordination problem)

Hayek (1945), Romer (1990); Romer (1993)

The institutions we use to incentivise discovery (i.e., patents) have some well-documented criticisms.

Fritz (1958); Usher (1964); Hall, et al., (2012)

Research question

How do we incentivise groups of individuals to commit the effort necessary to solve hard problems?



How should we (as a society) design our institutions?

Operationalising intellectual discovery

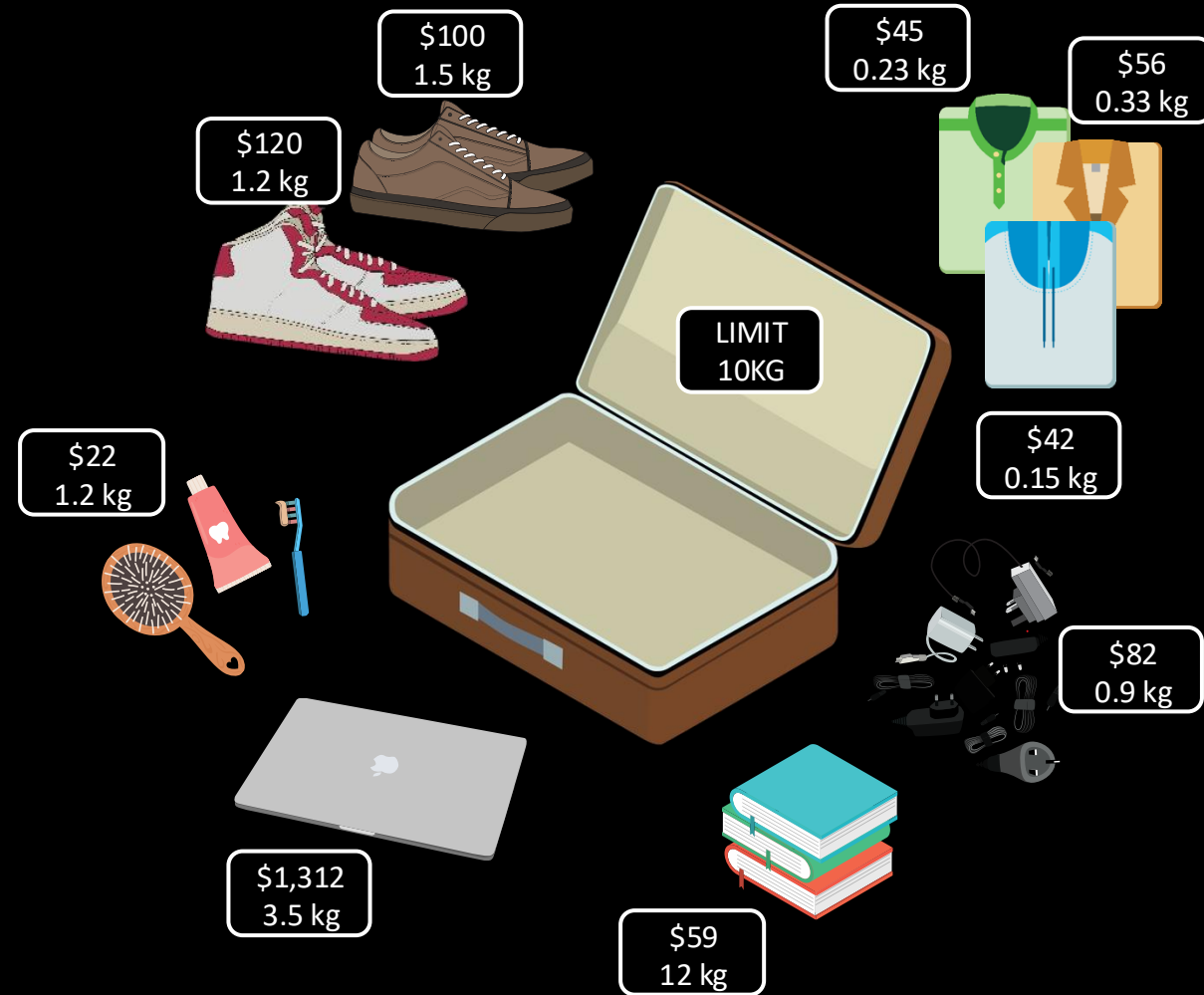
Mirror the (combinatorial) nature of discovery
in the real world

Romer (1990); Romer (1993)

Canonical, with a well-defined optimum

Allows us to precisely vary difficulty

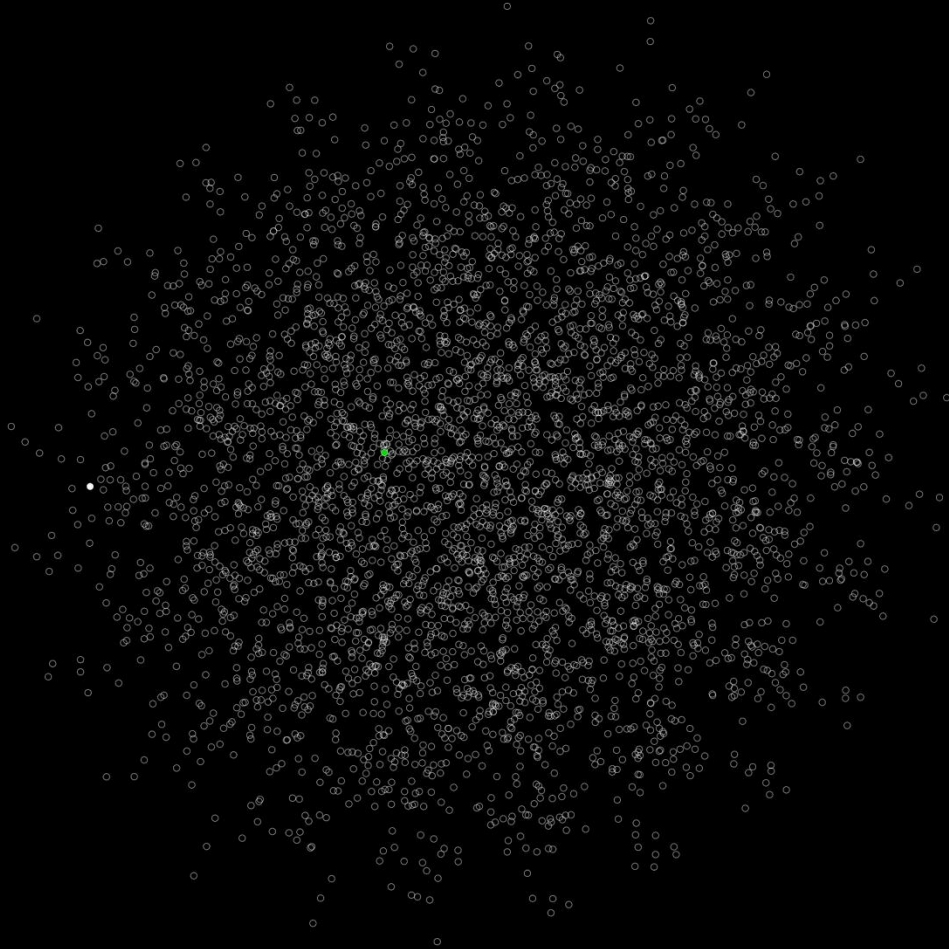
Our solution: **Knapsack Problem**



A real instance

Knapsack		Out of knapsack	
WEIGHT: 1135	VALUE: 2604		
CAPACITY: 1151	<input type="button" value="Submit"/>		

Approximation



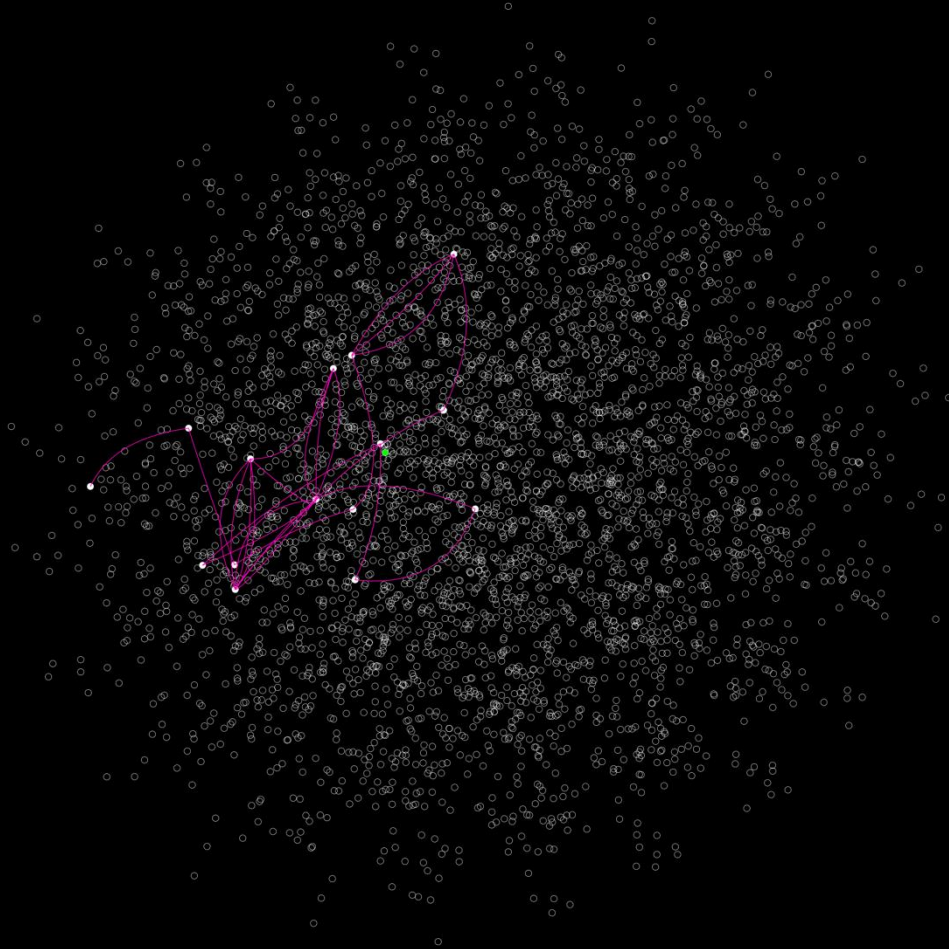
Problem: The total solution space is too vast to exhaustively explore.

Compromise: Individuals try to strike a balance between:

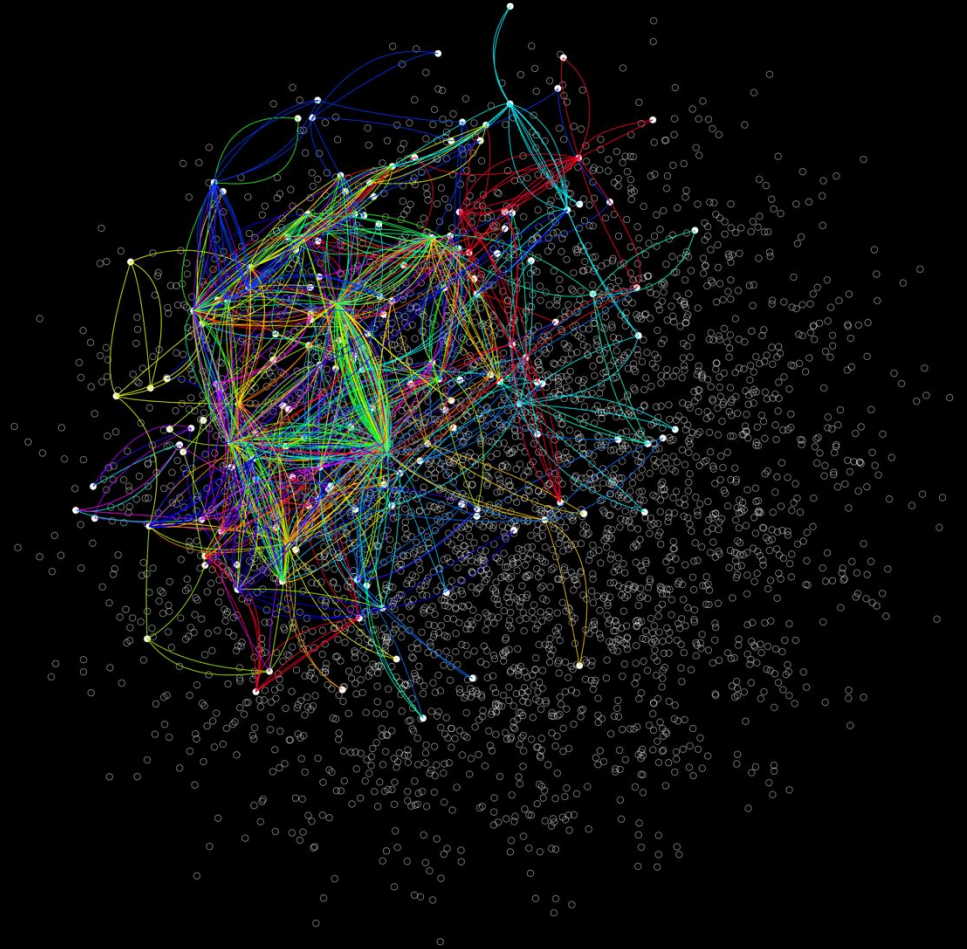
- **Solution quality** – the resulting solution should be within ϵ of the optimum.
- **Frugality** – computational cost should be minimised.

Result: Search over constrained subset of total solution space.

Collective problem-solving



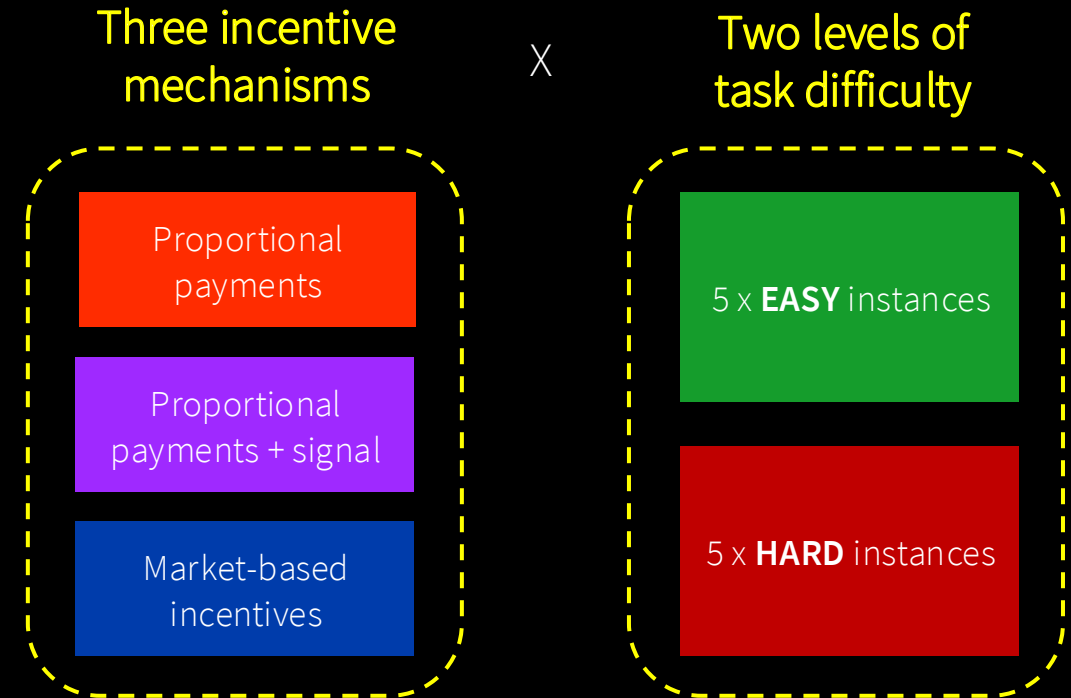
A single individual explores a small subset of the solution space.



A group of individuals collectively explore a large portion of the solution space.

Experiment design

- **Sample of N = 120**
Recruited from the University of Melbourne community, aged between 18 - 50. Mean age: 26; Gender: 78F, 41M, 1 prefer not to say.
- **3 (treatments) x 2 (difficulty)**
In each treatment, participants solved 10 instances of the knapsack problem (5 easy, 5 hard)
- **Within-subject design**
Six blocks of ~20 participants completed each treatment. Order of treatments was perfectly counterbalanced.



Treatments

- **Proportional payments**

Participants paid in proportion to their effort.

\$1.50 in proportion to submitted value

\$1.50 bonus for finding the optimal solution

- **Proportional payments + signal (signal)**

Identical to proportional payment treatment.

Except that participants were told the optimal value before attempting to solve the instance.

A



B



Treatments

- **Market treatment¹**

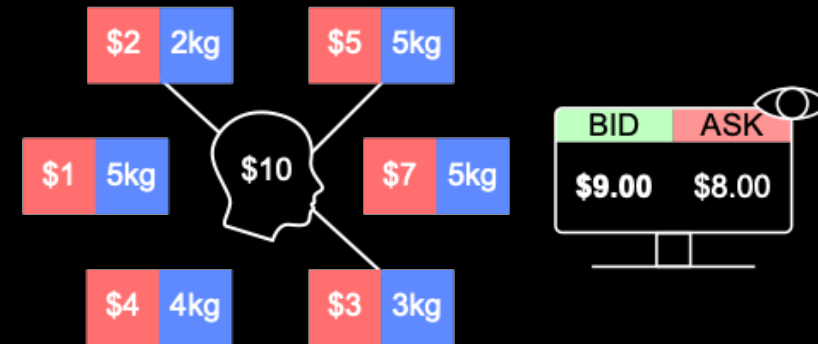
Participants trade experimental assets (“stocks”), while solving the knapsack problem.

The stock’s value equals the highest solution discovered by anyone.

Profit comes from:

- Buying stocks at prices below the final best solution, and
- Selling stocks at prices above the final best solution.

C



1. Adapted from experiment two in Bossaerts, Peter, et al. "Resource allocation, computational complexity, and market design." *Journal of Behavioral and Experimental Finance* 42 (2024): 100906.

Trading interface

×
FLEX-E-MARKETS beta

1395

SETTLED AVAILABLE

CASH \$10,000.00 \$10,000.00

STOCK 8 8

> STOCK <

ORDER BOOK			TRADE HISTORY	
UNITS	PRICE	MINE		
1	\$1,635.00		1	\$1,621.00 ↘ 12:12:15.653649
1	\$1,630.00		1	\$1,601.00 ↗ 12:11:40.076285
1	\$1,629.00		1	\$1,600.00 ↗ 12:11:33.408663
5	\$1,628.00		1	\$1,599.00 ↗ 12:11:32.055053
1	\$1,625.00		1	\$1,599.00 ↗ 12:11:31.449416
1	\$1,624.00		1	\$1,578.00 ↘ 12:11:29.961996
1	\$1,623.00		1	\$1,600.00 ↗ 12:11:29.591124
7	\$1,622.00		1	\$1,579.00 ↗ 12:11:23.832215
<i>spread</i> \$5.00 $\frac{1}{4}$			1	\$1,579.00 ↘ 12:11:20.677043
1	\$1,617.00		1	\$1,579.00 ↘ 12:11:19.880675
1	\$1,616.00		1	\$1,600.00 ↘ 12:11:19.860863
1	\$1,602.00		1	\$1,601.00 ↗ 12:11:18.852256
1	\$1,601.00		1	\$1,600.00 ↗ 12:11:09.014648
1	\$1,601.00		1	\$1,598.00 ↗ 12:11:01.493633
1	\$1,600.00		1	\$1,598.00 ↗ 12:10:58.571631
1	\$1,457.00		2	\$1,579.00 ↗ 12:10:44.022596
1	\$1,421.00		1	\$1,578.00 ↗ 12:10:40.072490
2	\$1,331.00		1	\$1,599.00 ↗ 12:10:03.885024

STOCK

BUY
SELL

UNITS

1

-

+

PRICE

\$1.00

-

+

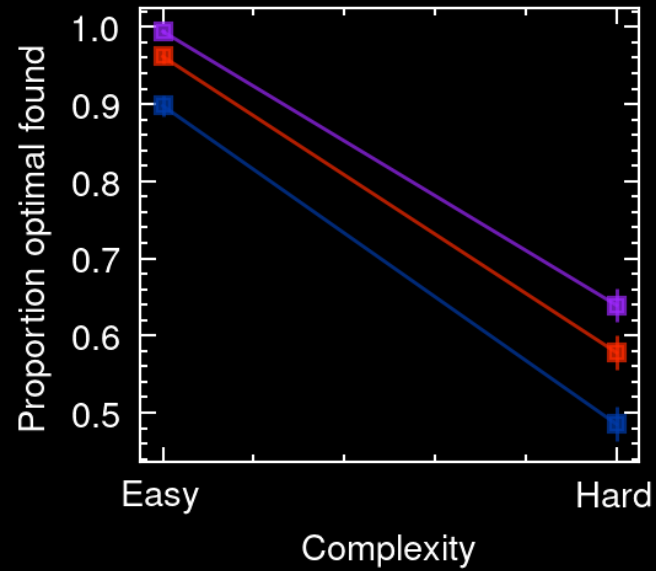
PLACE BUY ORDER

Outcome measures

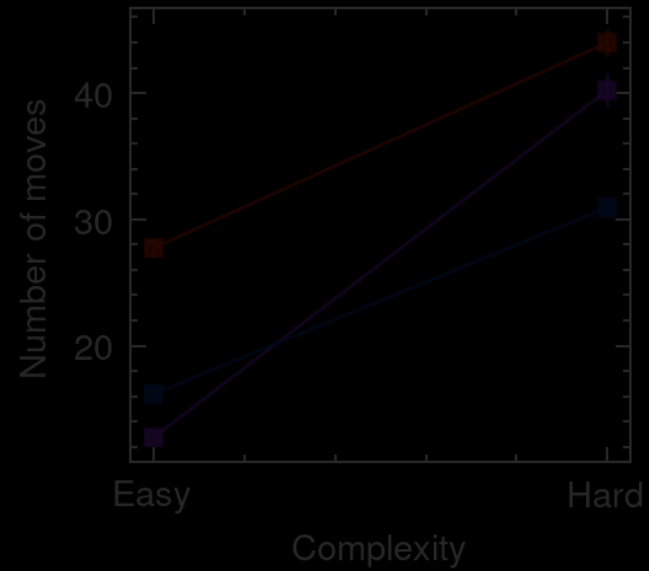
- 1. Quality**
Probability optimal solution attained
- 2. Effort**
Number of 'item moves'
- 3. Productivity**
Submitted value / number of moves
- 4. Price efficiency**
How well do prices aggregate knowledge?

Quality, effort, productivity

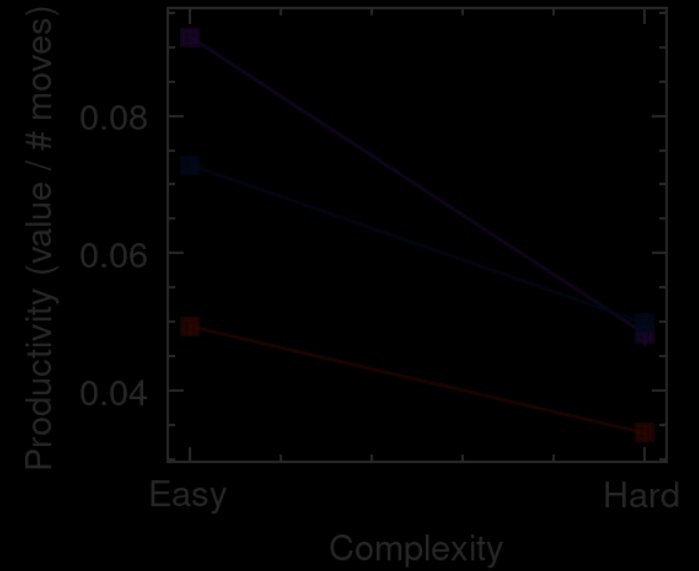
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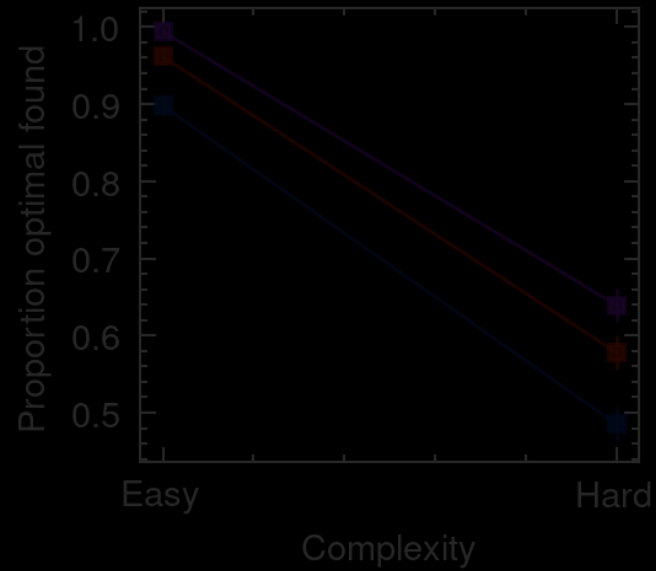
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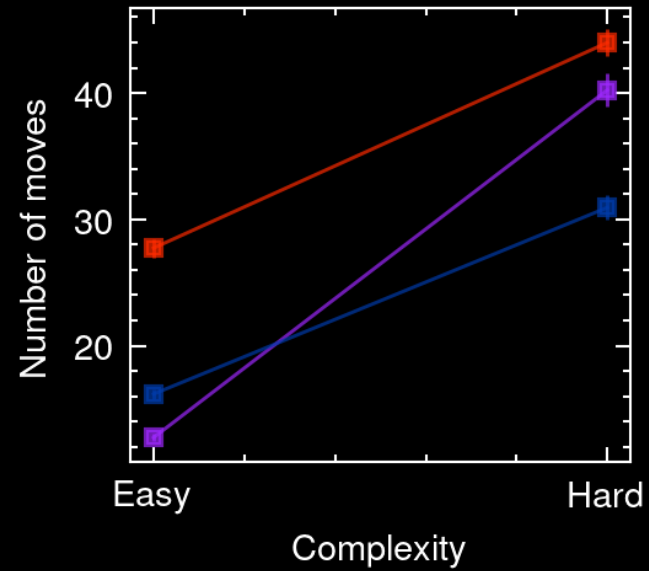
Prop. payments Signal Market

Quality, effort, productivity

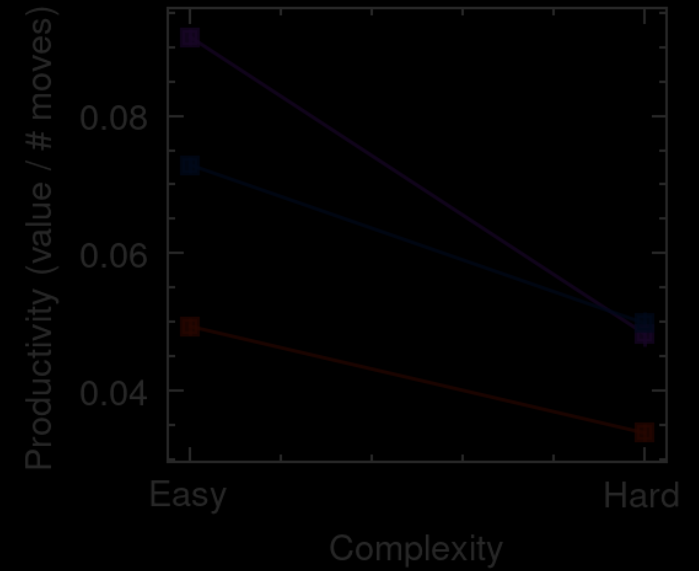
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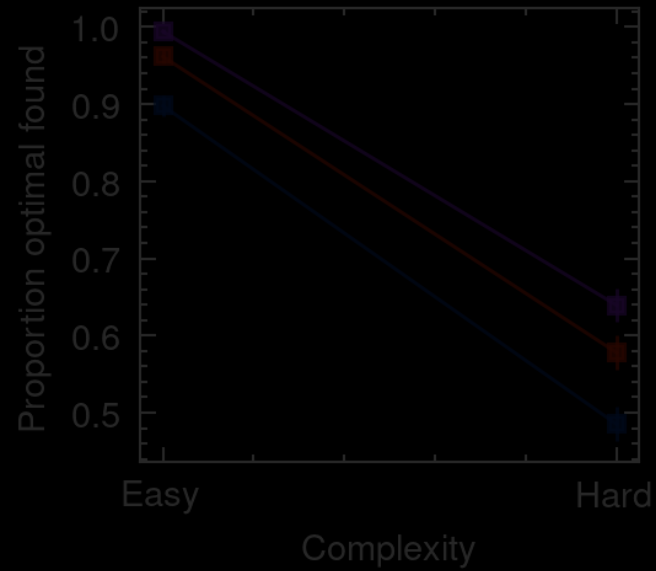
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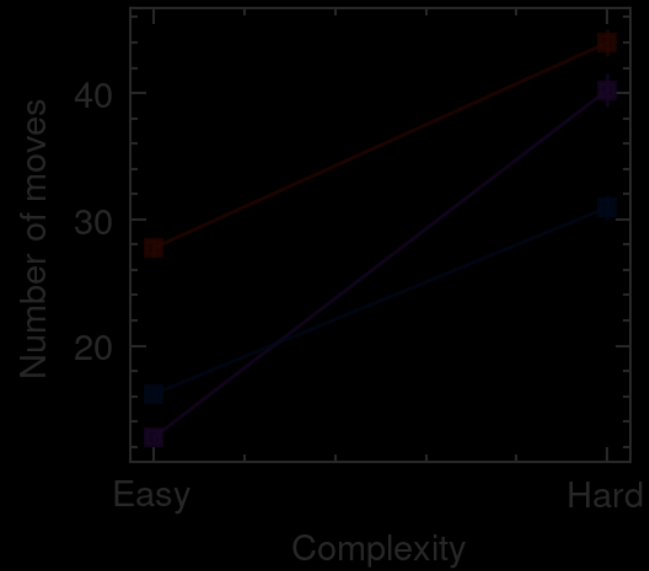
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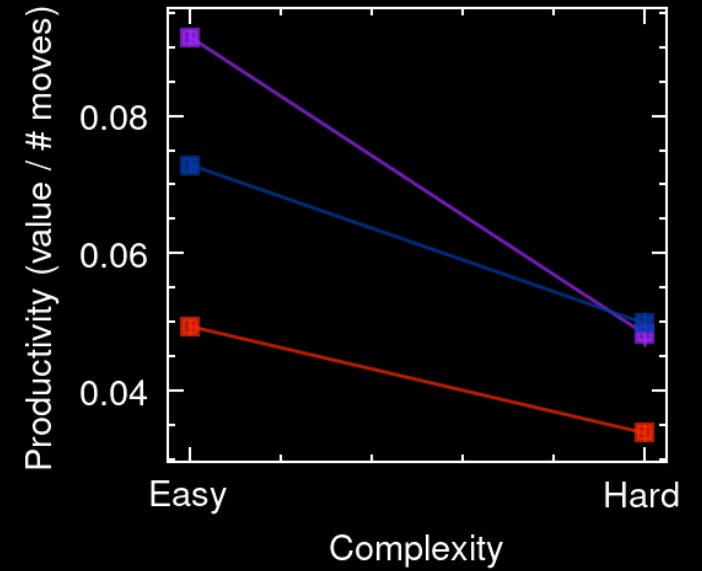
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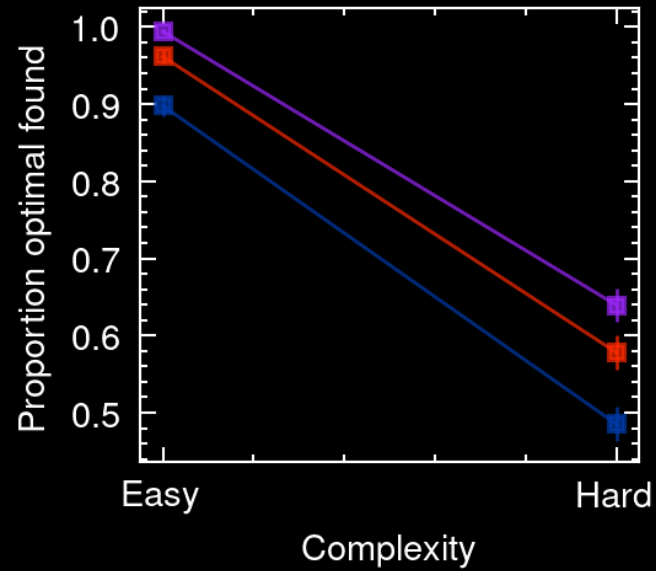
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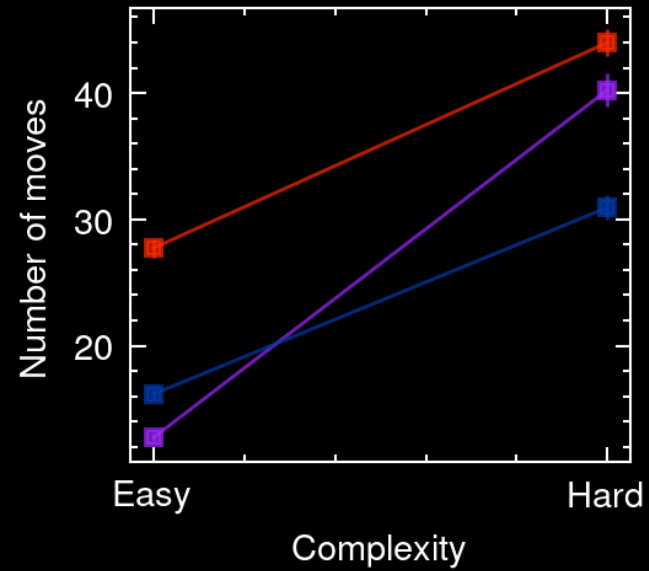
Prop. payments Signal Market

Quality, effort, productivity

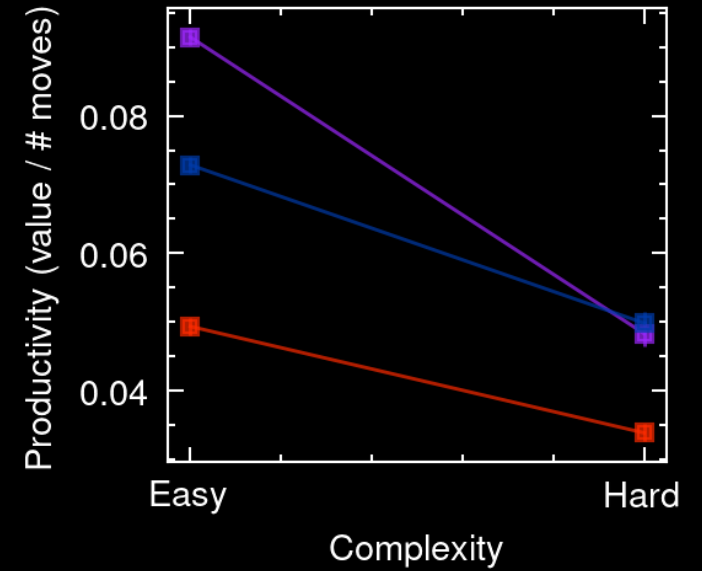
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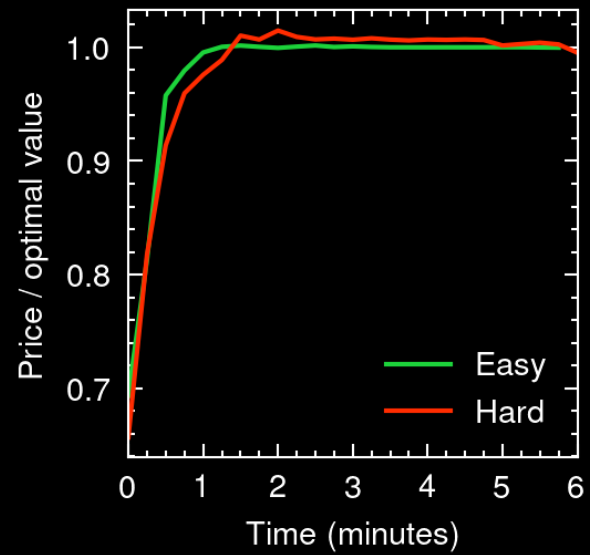
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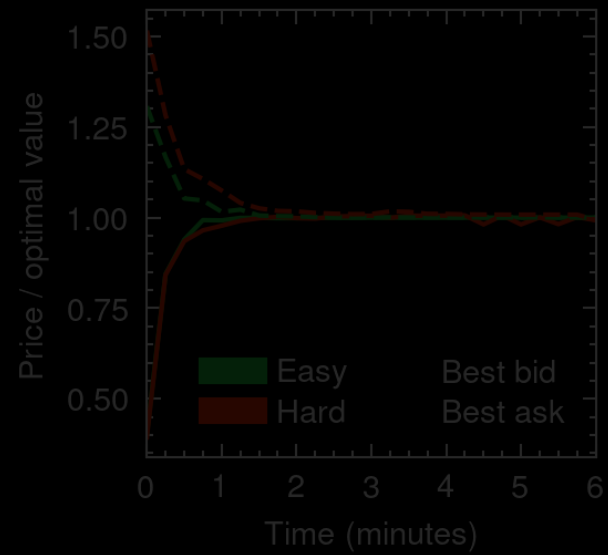
Prop. payments Signal Market

Price efficiency and returns

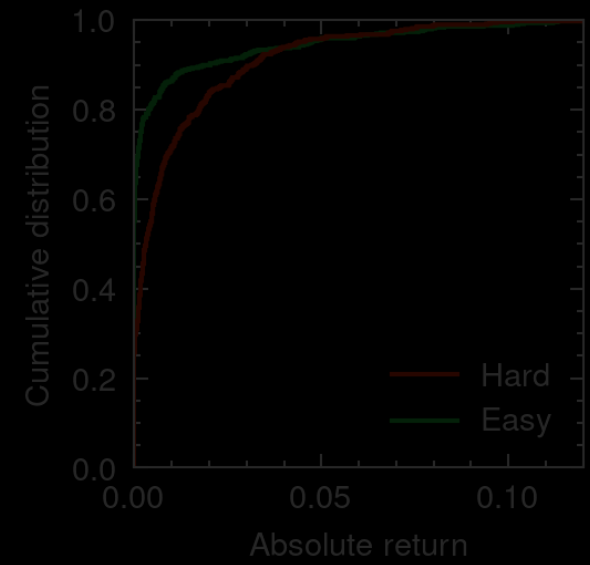
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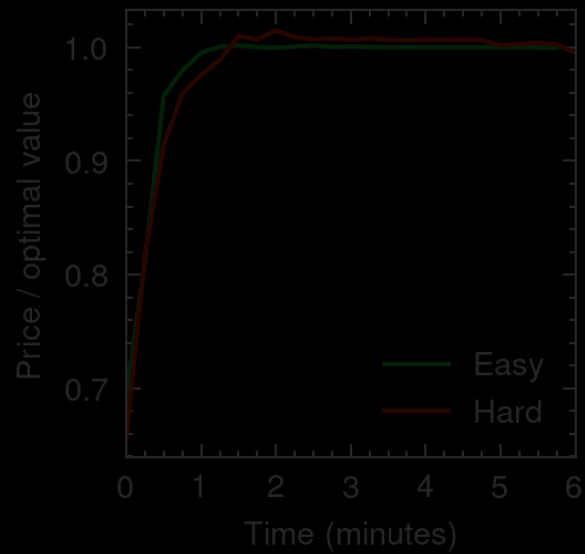


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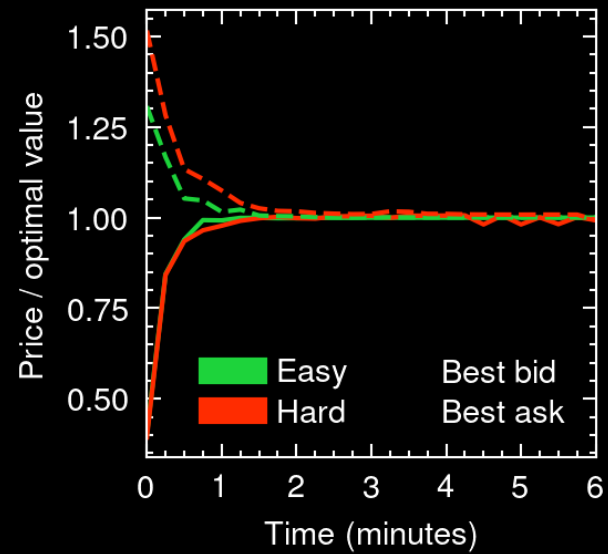


Price efficiency and returns

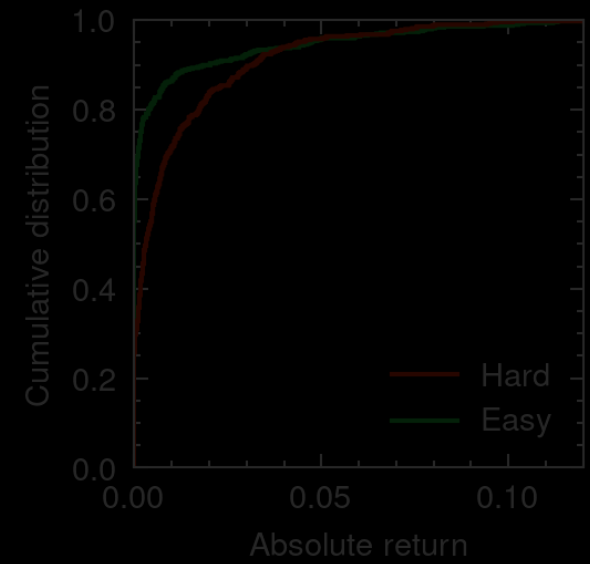
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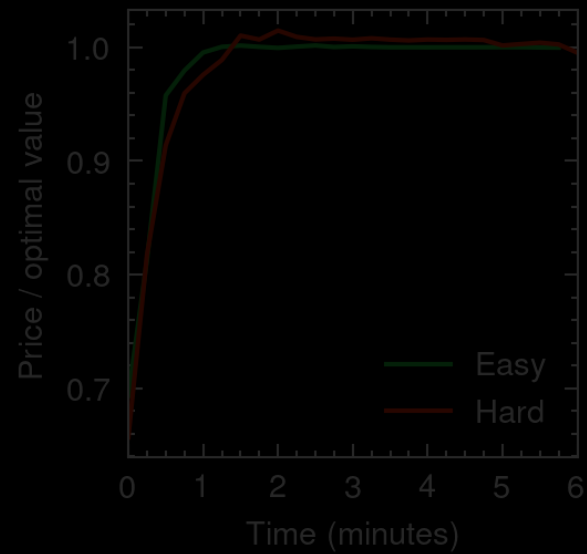


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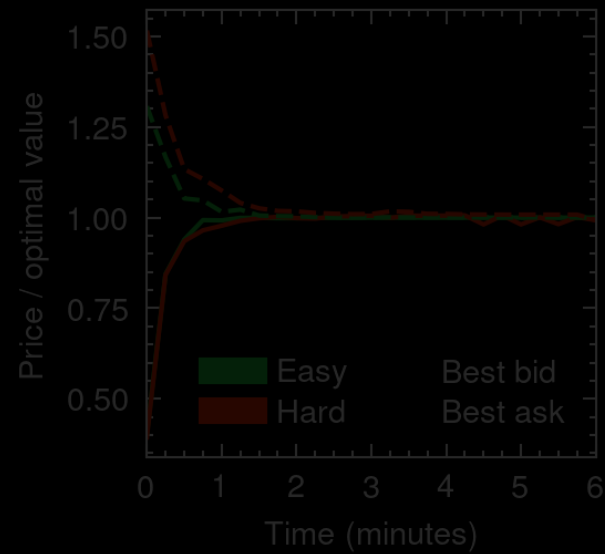


Price efficiency and returns

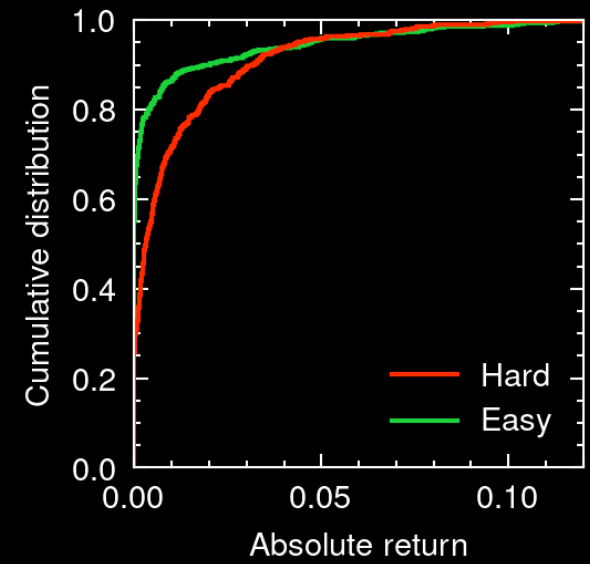
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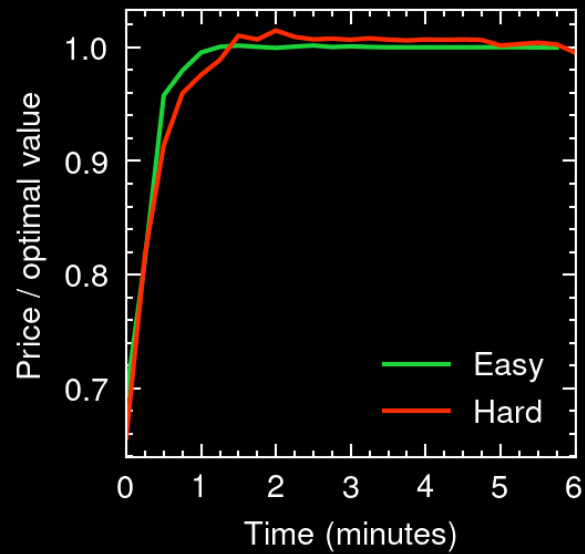


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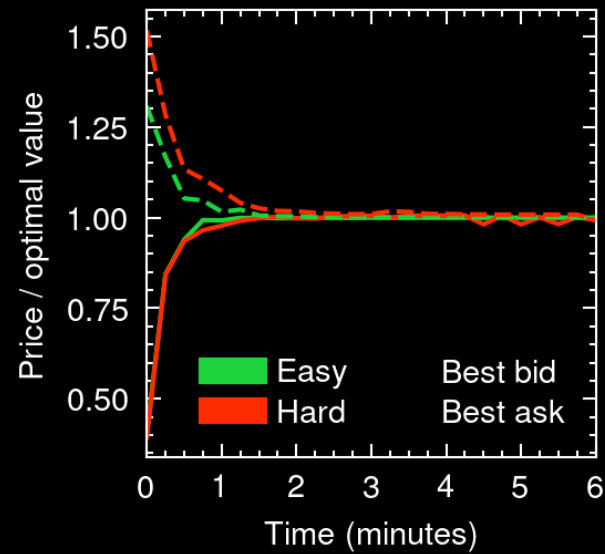


Price efficiency and returns

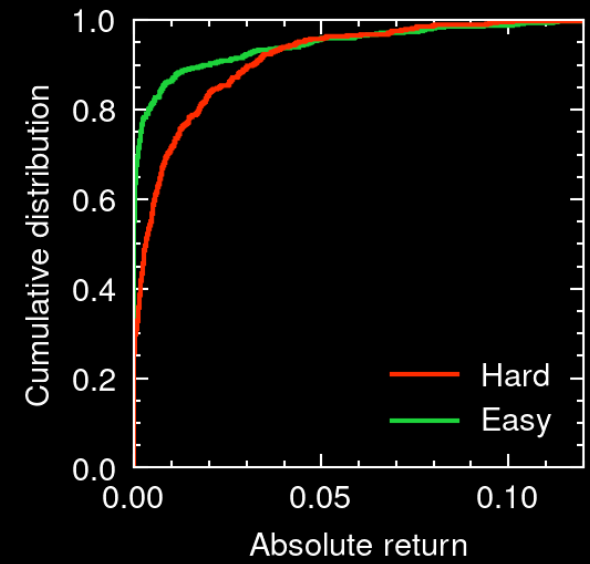
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Summary

1. Complexity matters

Higher problems reduce performance but markets and signals can mitigate this.

2. Markets enable coordination

Groups explore larger portions of the solution space, trading shares information and reduces redundant effort.

3. Market efficiency degrades with complexity

Prices are less efficient when it is computationally difficult to estimate fundamental

Questions?

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Website

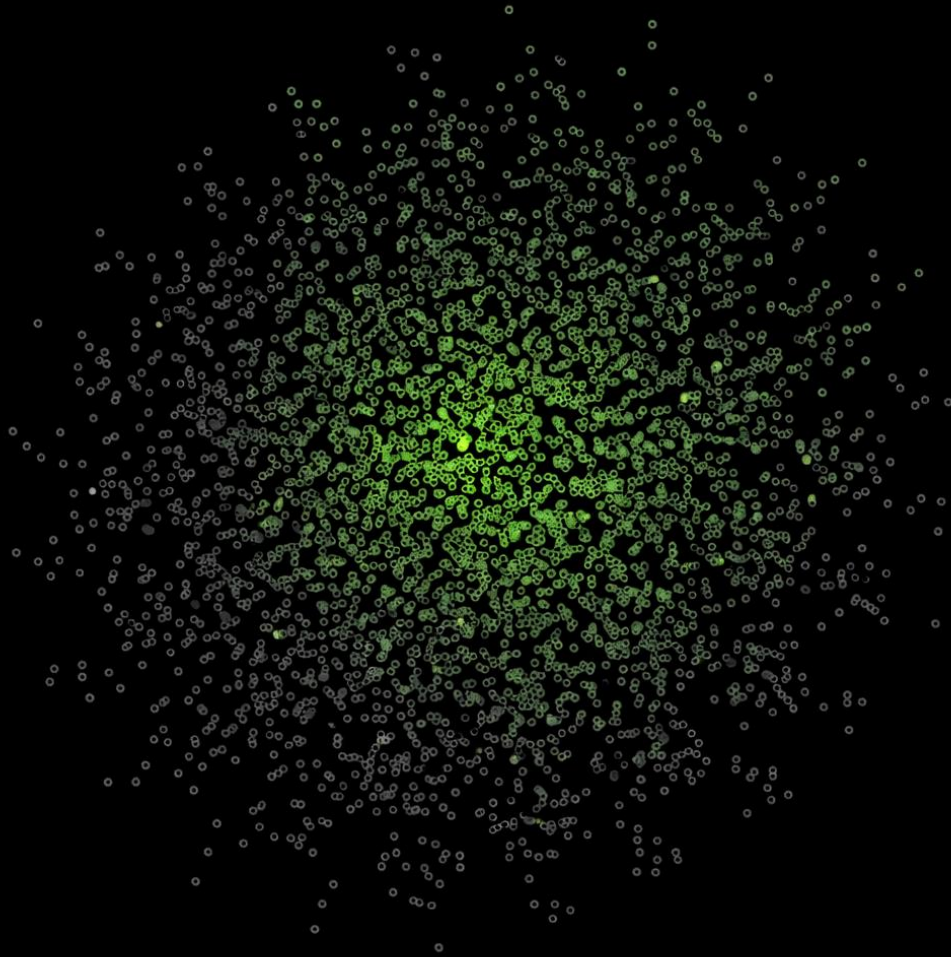
<https://hassan.andra.bi>



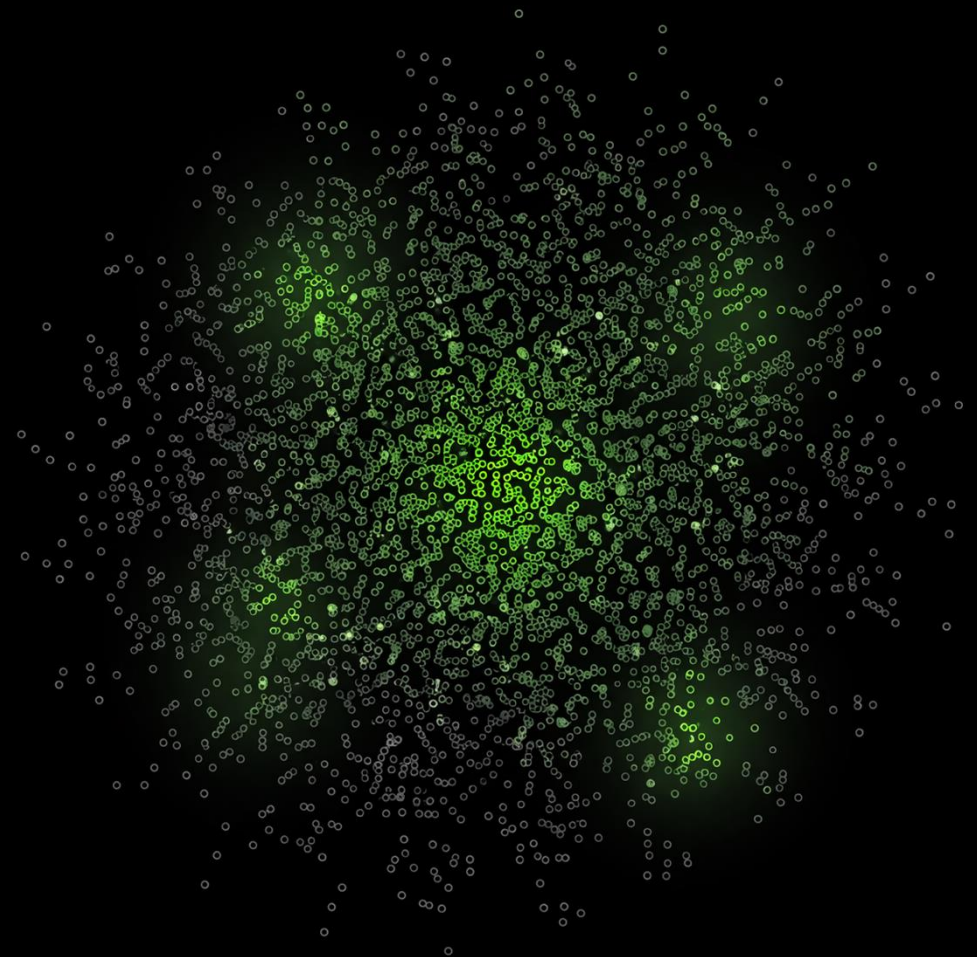
References

1. Schumpeter, J. A. (1911). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Harvard University Press.
2. Hayek, F. A. (1945). The use of knowledge in society. *The American Economic Review* 35(4), 519–530.
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4. Usher, Dan. "The welfare economics of invention." *Economica* 31.123 (1964): 279-287.
5. Hall, Bronwyn H., and Dietmar Harhoff. "Recent research on the economics of patents." *Annu. Rev. Econ.* 4.1 (2012): 541-565.
6. Bossaerts, Peter, et al. "Resource allocation, computational complexity, and market design." *Journal of Behavioral and Experimental Finance* 42 (2024): 100906.

Modulating complexity



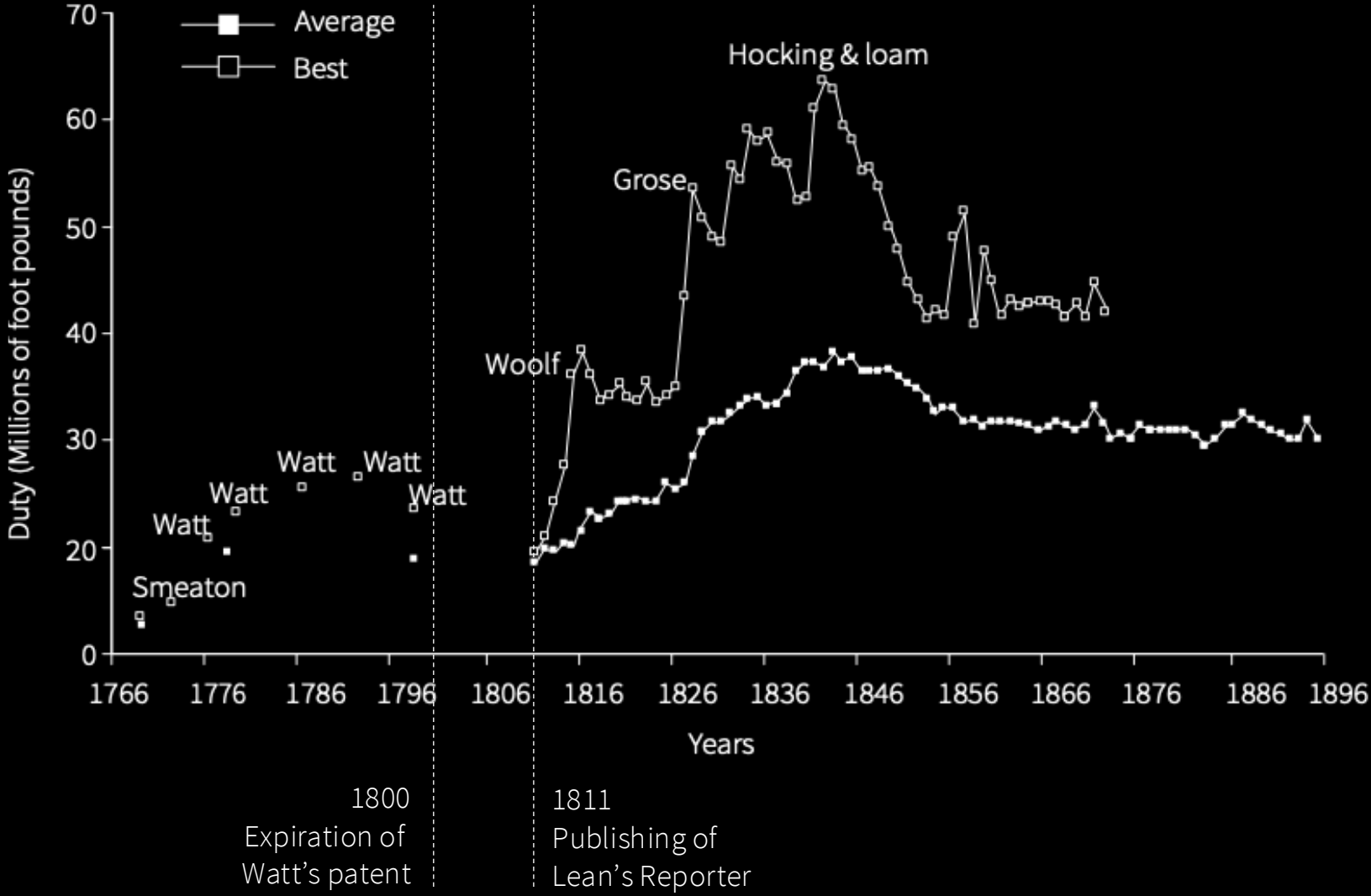
Smooth landscape = **easy** instance



Rugged landscape = **hard** instance

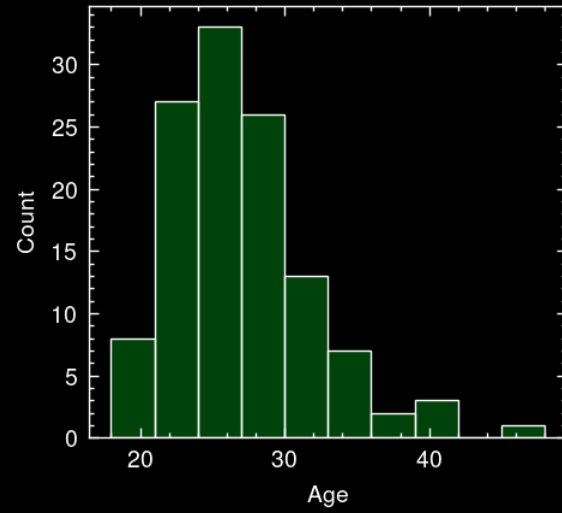


Historical case study: Cornwall

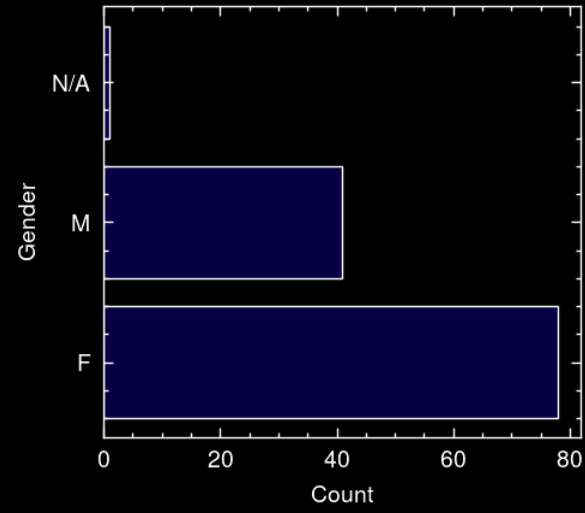


Demographics

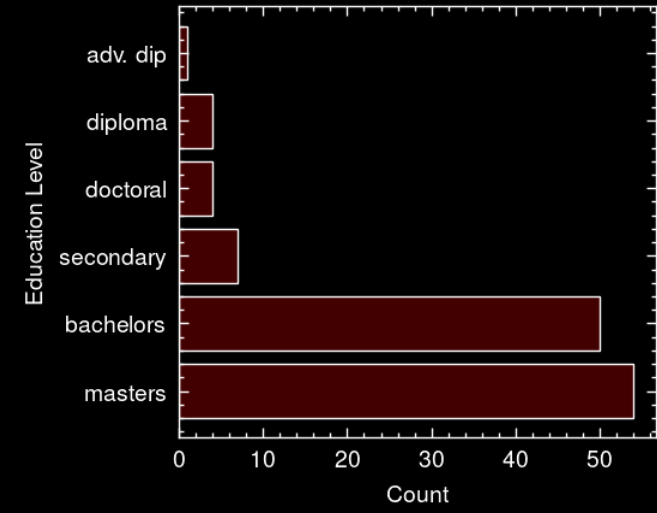
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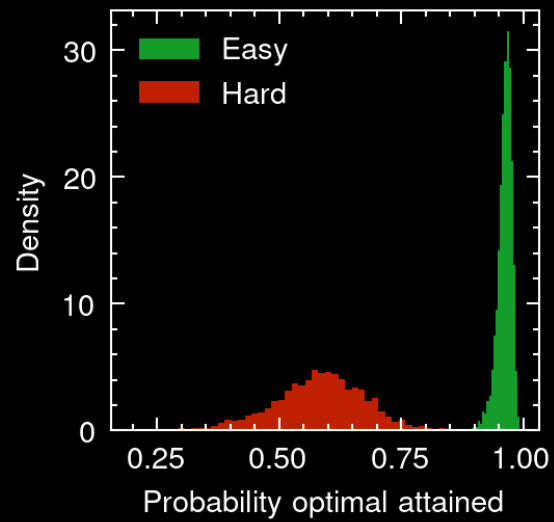


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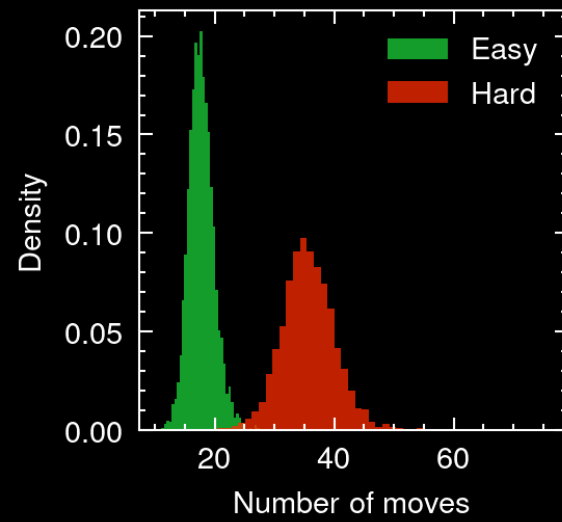


Effectiveness of complexity manipulation

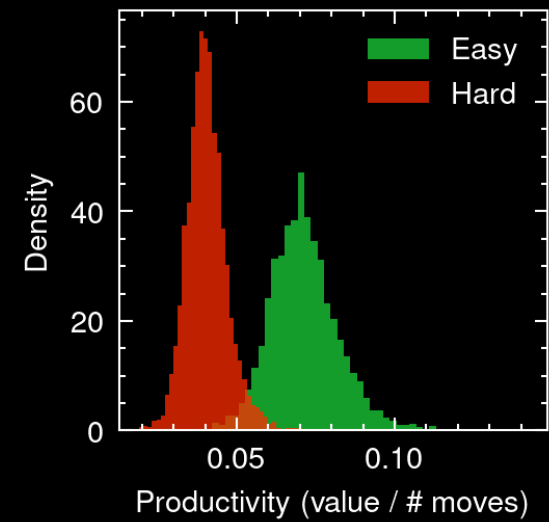
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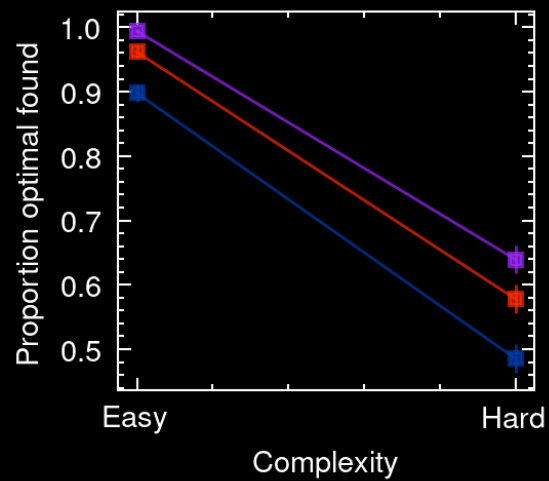
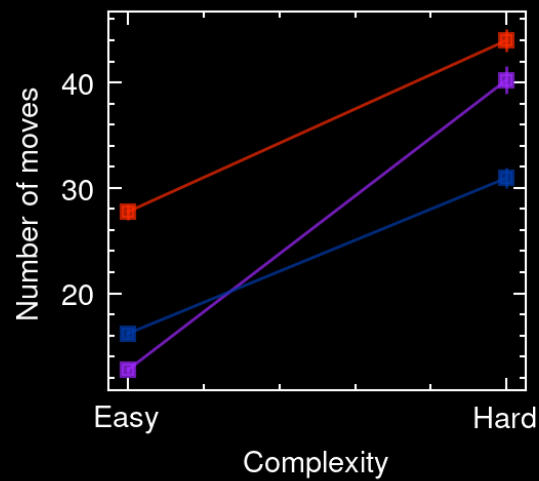
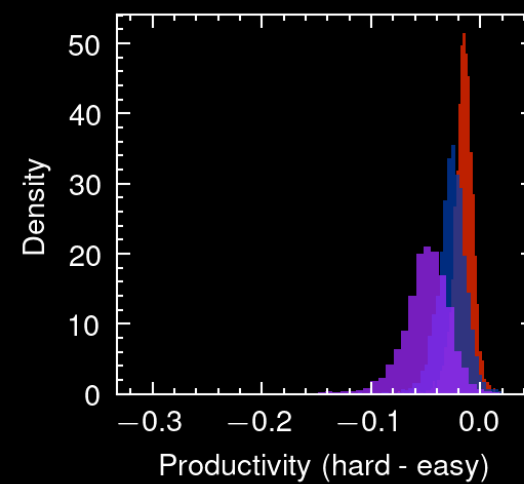
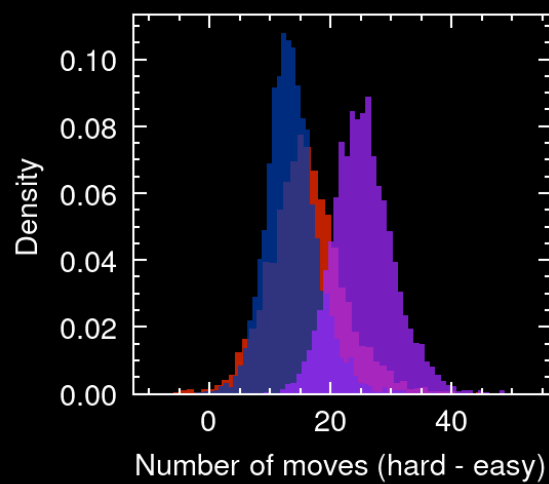
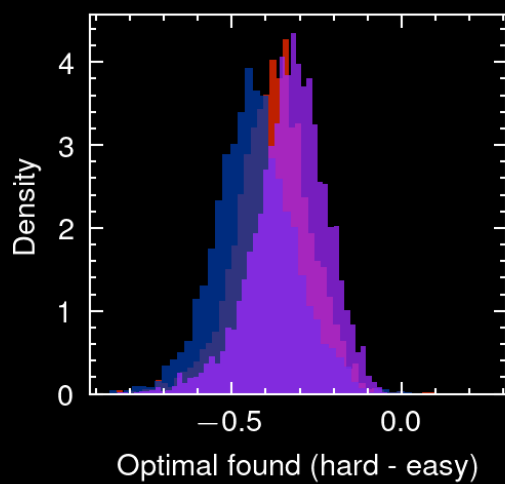
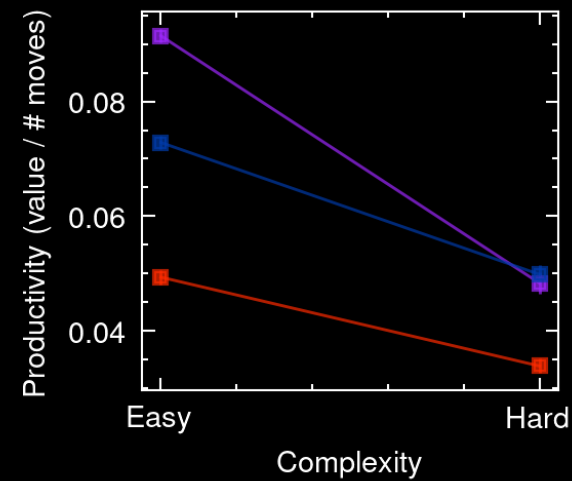


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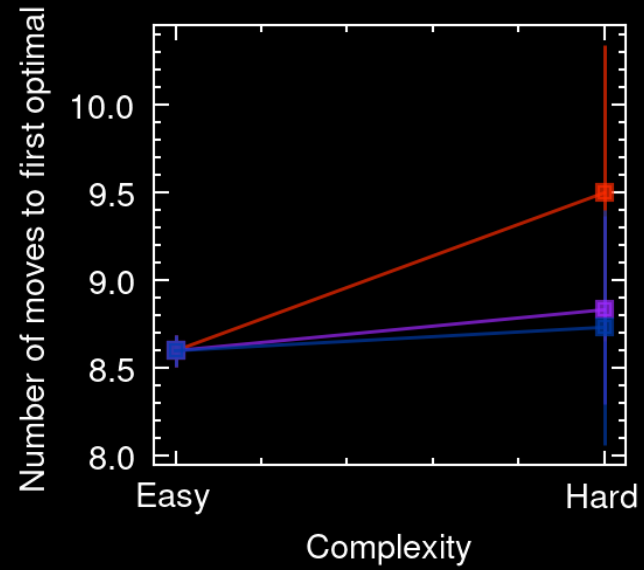


A**B****C**

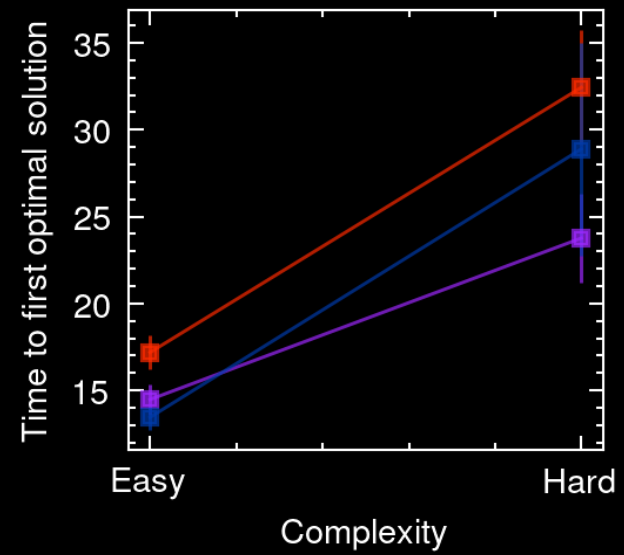
■ Prop. payments
 ■ Signal
 ■ Market

Speed of discovery

A



B



Prop. payments Signal Market