



# Data Innovation Complementarity and Firm Growth

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## Cracking the Code: What Makes Firms Thrive in the Data Economy?

- ▶ There is a lot of heterogeneity across firms in how they adopt and benefit from data technologies.
- ▶ Question: what makes a company successful in the modern data economy?
  - ▶ Firm size (e.g. Babina et al., JFE 2024)
  - ▶ Labor composition (e.g., Eisfeldt et al., 2024)
  - ▶ Our paper: **Innovation complementarity**

## This paper

- ▶ Different firms differ in the complementarity between data-security innovation and other innovation
- ▶ There is a positive shock to data-security innovation
  - Technological
  - Policy: Data Breach Notification Laws (DBNLs): **this paper**
- ▶ Firms with high-complementarity benefit more from the shock in terms of overall innovation, profitability, and market share
- ▶ Analogy: research and teaching
  - High complementarity: Information frictions in macro & finance elective
  - Low complementarity: Finance 101

# Security to Success: Amazon's 1-Click Story



- ▶ Amazon's 1-click ordering: - Most cited patent in Amazon's history - Licensed by Apple for iTunes

United States Patent <sup>[19]</sup>		[11] Patent Number:	5,960,411
Hartman et al.		[45] Date of Patent:	Sep. 28, 1999
[54]	METHOD AND SYSTEM FOR PLACING A PURCHASE ORDER VIA A COMMUNICATIONS NETWORK	"Pacific Coast Software. Software creates virtual shopping cart." Sep. 6, 1996. M2 Communications Ltd. 1996.	
[75]	Inventors: Peri Hartman, Jeffrey P. Bezos, Shal Kaphan, Joel Spiegel, all of Seattle, Wash.	"Software Creates Virtual Shopping Cart." Sep. 5, 1996. Business Wire, Inc.	
[73]	Assignee: Amazon.com, Inc., Seattle, Wash.	Kunzle, William. "Java Electronic Commerce Framework." Computer Reader News, Sep. 23, 1996, CMP Media, Inc., 1996, pp. 126. <a href="http://www.edlibrary.com/id/101/101/guide.../publicid/0221098/Entry..._skidypoe-0-0k4dnta">http://www.edlibrary.com/id/101/101/guide.../publicid/0221098/Entry..._skidypoe-0-0k4dnta</a> . [Accessed Nov. 19, 1998].	

United States Patent <sup>[19]</sup>		[11] Patent Number:	5,727,163
Bezos		[45] Date of Patent:	Mar. 10, 1998
[54]	SECURE METHOD FOR COMMUNICATING CREDIT CARD DATA WHEN PLACING AN ORDER ON A NONSECURE NETWORK	Sullivan, E. "Firm Has Technology You Can Bank On." PC Week, pp. 42-46, Aug. 1994.	
[75]	Inventor: Jeffrey P. Bezos, Bellevue, Wash.	Peters, B. "Cafe of the Rain." Network Computing, pp. 33-36, Jan. 1995.	
[73]	Assignee: Amazon.com, Inc., Seattle, Wash.		

United States Patent <sup>[19]</sup>		[11] Patent Number:	5,715,399
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[75]	Inventor: Jeffrey P. Bezos, Bellevue, Wash.	"Web Page and CyberCash Team Up to Provide Secure Online Payment System." CyberCash News Release, Dec. 1994.	
[73]	Assignee: Amazon.com, Inc., Seattle, Wash.	Somargis, S. "How Would You Like to Pay for That? A Guide to Digital Cash and Carry Technology." Digital Media, v4, #7, p. 13, Dec. 1994.	

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- ▶ **Key insight:** Security innovation can catalyze broader advances—with the right organizational structure.

## Why Focus on Innovation Complementarity?

- ▶ Amazon's case suggests organizational structure matters
- ▶ Key is an organizational structure that promotes **integration of security expertise**:
  - ▶ capturing firms' revealed preferences in resource allocation
  - ▶ patent inventors are rare and valuable → when a firm assigns its scarce security experts to non-security projects, it's making a meaningful organizational choice

## Measuring Innovation Complementarity

- ▶ Empirical challenge: measuring innovation complementarity is hard
- ▶ Our approach: Patent team composition analysis:
  - Identify security specialists
  - Track their involvement in non-security patents
- ▶ High complementarity: Security experts regularly on other innovation teams
- ▶ Low complementarity: Security expertise kept separate
- ▶ Intuitive measure: inventors working in both data-security and non-data-security patents can bring knowledge flows across both domains

## Identifying Causal Effects

### **Key Questions:**

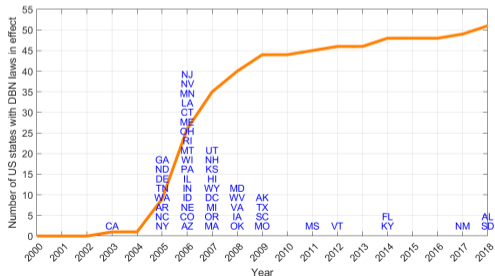
- ▶ Does increased data security salience affect innovation?
- ▶ Do high-complementarity firms respond differently?

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**Challenge:** Need exogenous variation in data security salience



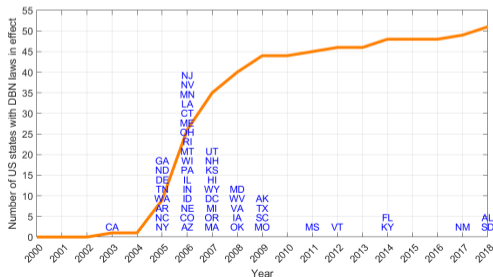
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- ▶ Penalties for non-compliance

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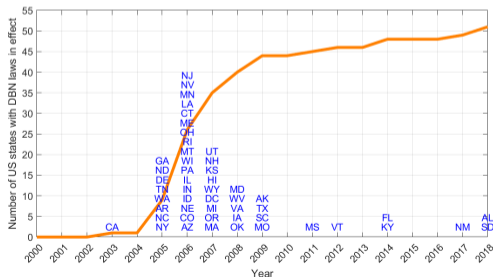
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- ▶ Staggered adoption (2003-2018) - Unrelated to firm innovation trends

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- ▶ ⇒ Clean identification

## Study Focus

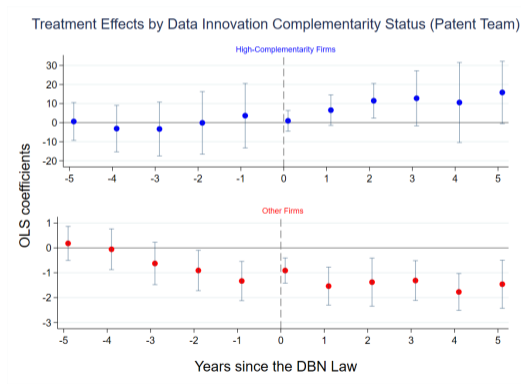
**Sample:** US Public Firms, 2000-2022

**Key Variables:**

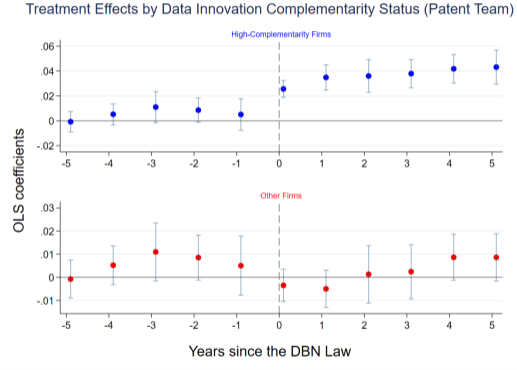
- ▶ Innovation: Citation-weighted patent count
- ▶ Performance: ROA, total assets
- ▶ Competition: change in market share, Hoberg-Phillips self-fluidity

# Result 1: Data security salience leads to **more overall innovation** by High-complementarity firms

Figure: Citation-weighted patent count by innovation complementarity



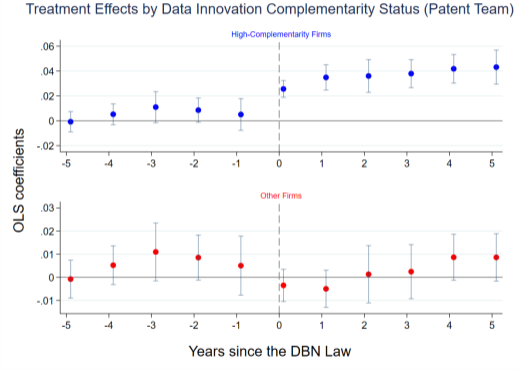
# Results 2 & 3: High-complementarity firms grow profitable, larger, and dominant in response to the data security salience



(a) ROA

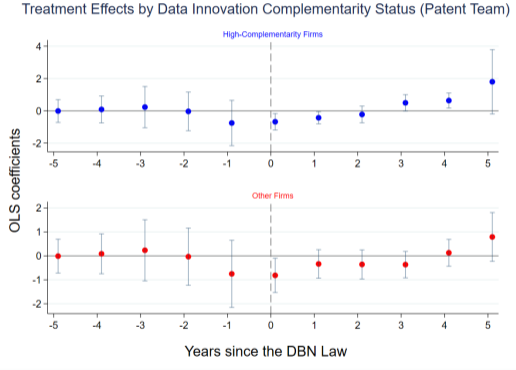
▶ Total Assets

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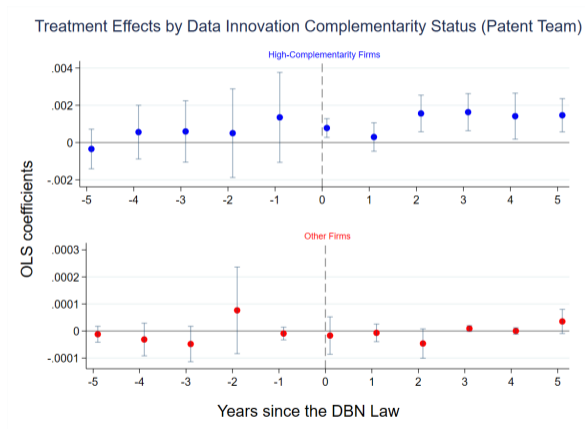
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(b) Market share growth

▶ Hober-Phillips Self-fluidity

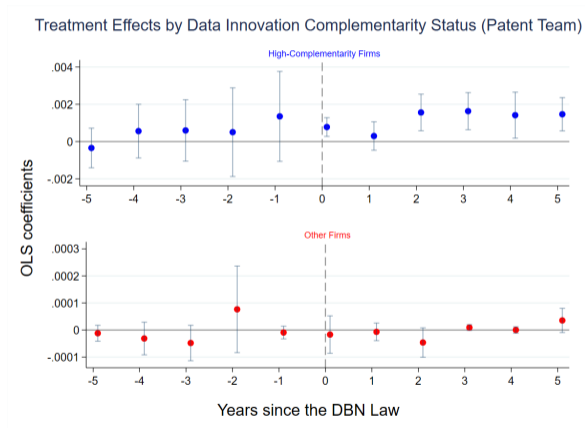
# Mechanism: High-complementarity firms are more effective in knowledge transfer from security to innovation



- ▶ High-complementarity firms:
  - Increase citations of their own data security patents in non-data-security innovations

Share of self-data security patent citations in non-data security patents

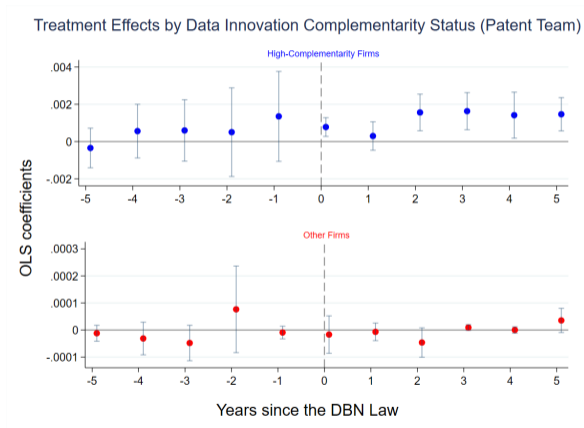
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- ▶ Low-complementarity firms show no such effect
- ▶ Security expertise becomes input into broader innovation

▶ Mechanism: integration of security expertise

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## Protection to Progress: Who Wins When Security Matters More?

### **Key Results:**

- ▶ High-complementarity firms turn protection into progress:
  - Innovation (+58%), profits (+4% ROA), market power
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### **Broader Implications:**

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Thank You!

# *Appendix*

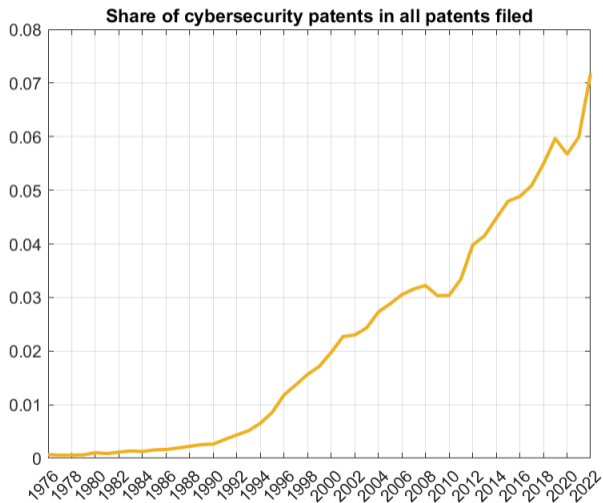
# Data security patents

[back CS](#)

[back overall](#)

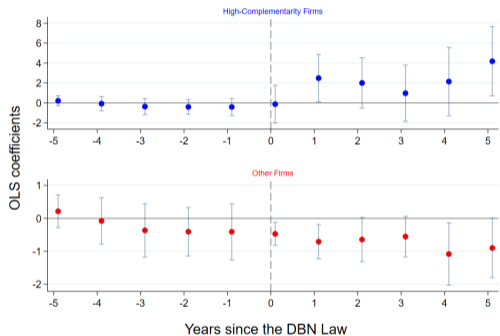
Identifying CS patent based on USPTO Cooperative Patent Classification (CPC) codes.  
Example classification codes:

- ▶ G06F 21/ : "Security arrangements for protecting computers, components thereof, programs or data against unauthorised activity"
- ▶ H04L 9/00 "arrangements for secret or secure communications; Network security protocols."



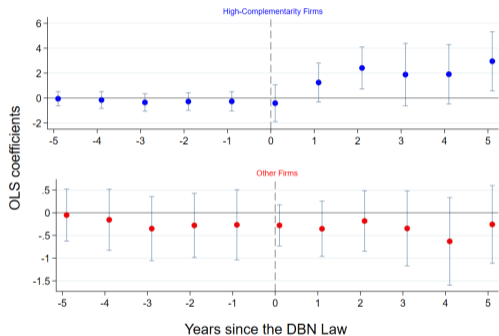
## Result 2: Impact on Product vs. Process Innovation

Treatment Effects by Data Innovation Complementarity Status (Patent Team)



(a) Product Patents

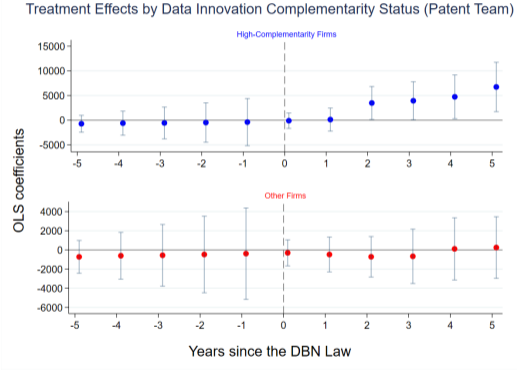
Treatment Effects by Data Innovation Complementarity Status (Patent Team)



(b) Process Patents

► [Back to Overall Results](#)

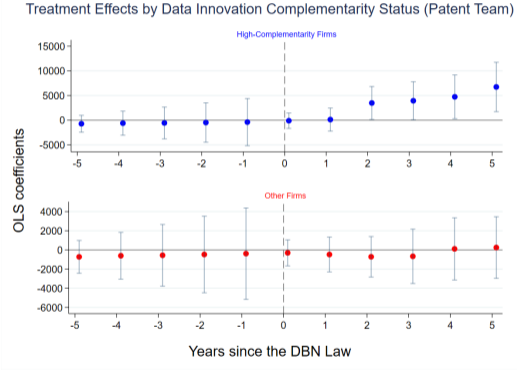
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(a) Total Assets

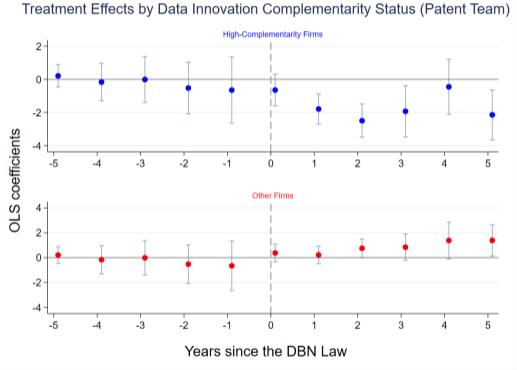
▶ Back to Results 2 & 3

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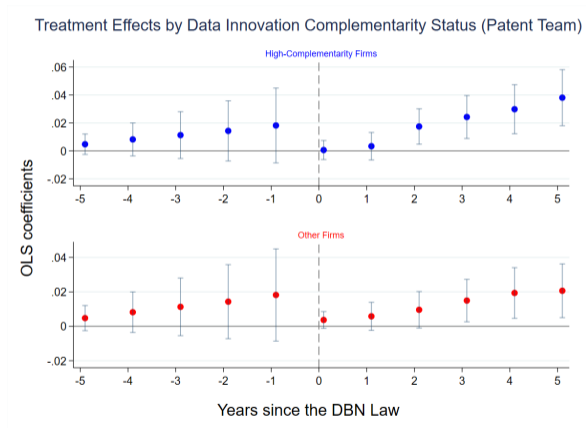


(b) Hoberg-Phillips Self-fluidity

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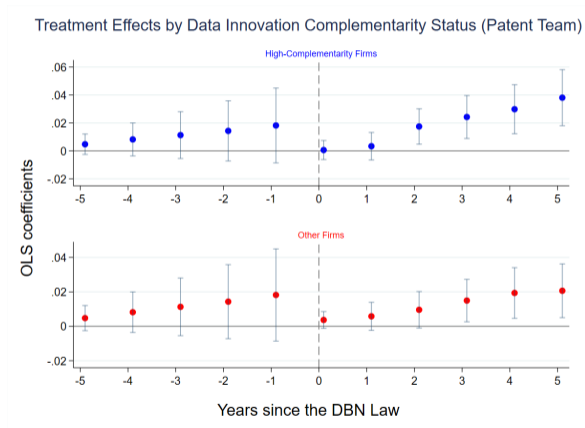
# Mechanism: High-complementarity firms are more successful in integration of security expertise

- ▶ Post-DBNL: All firms integrate more security experts



Share of security experts in non-security patent teams

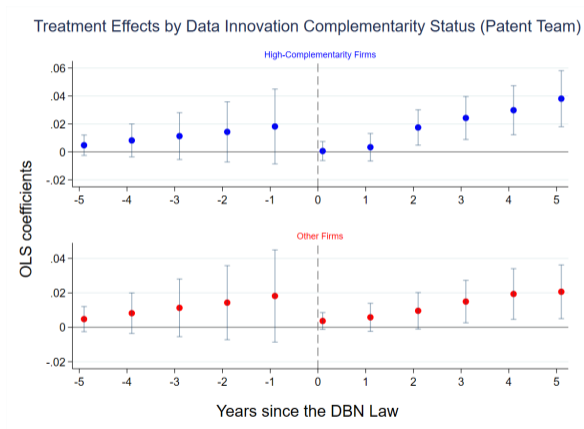
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- ▶ Post-DBNL: All firms integrate more security experts
- ▶ But effect twice as large for high-complementarity firms
- ▶ Combining with the previous result implies that only high type firms turn integration into innovation advantages
  - Pre-existing infrastructure and experience in knowledge transfer matters

▶ [Back to Mechanism](#)

## Rationalize findings with a theoretical model

We build a **growth model of the data economy** and perform some comparative statics

- Firms maximize profits
- Data is information extracted from the relation with customers
- Data allows to accumulate knowledge
- Knowledge lowers uncertainty and improves efficiency in production

### **Cyber risk:**

- Threatens data availability and, indirectly, the accumulation of knowledge
- Diverts resources from innovation to damage control

## Basic building blocks: heterogeneous firms

### **Firm heterogeneity:**

- Some firms are **high-capability** and develop security in-house [H-type firms]
- Other firms are **low-capability** and outsource (buy protection from the market) [L-type]

### **H-firms invest in cyber security** in order to:

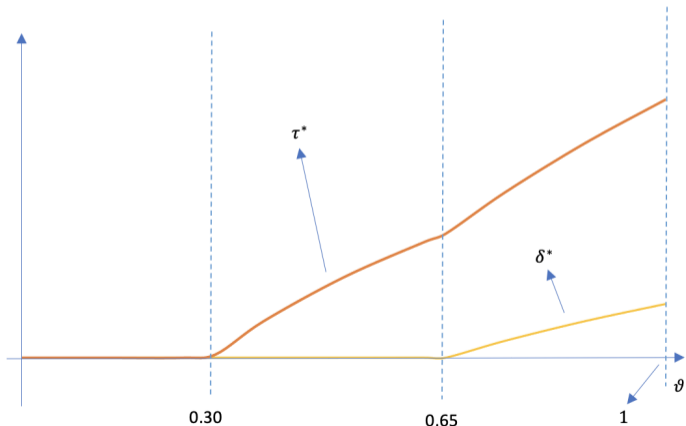
- Lower the impact of cyber risk over the availability of data
- **Foster innovation**, counteracting the resource diversion effect of cyber risk

### **L-firms acquire cyber security** from H-firms:

- It secures their data and allows them to accumulate knowledge
- But they **cannot use the security resources to innovate** (they can use the program, but they don't know the code)

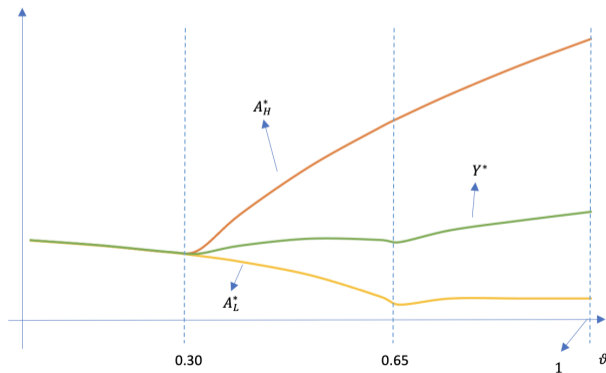
## Graphical results (1): Investment in cyber security for different levels of cyber risk

- ▶ *H*-types start investing in data protection at a lower level of cyber risks than the *L*-types



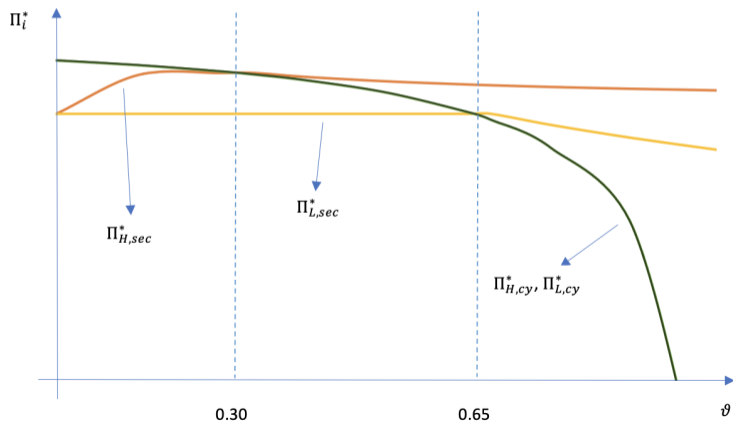
## Graphical results (2): Output for different levels of cyber risk

- ▶ H-type (orange) use protection to innovate,  $\uparrow$  quality & quantity of production.
- ▶ L-type do not have this positive spillover; they use security only for protection.
- ▶ The evolution of steady state aggregate  $Y^*$  gains momentum when  $L$ -type start protecting as well.



## Graphical results (3): Profits for different levels of cyber risk

- ▶ Without protection, the profits (green) of  $H$ -type equal profits of  $L$ -type's.
- ▶ With protection, profits of  $H$ -type (orange) always higher than  $L$ -type's (yellow).
- ▶ As data risk increases, the profits of  $H$ -type decrease by less than  $L$ -type's.



# Bibliography