Data, Privacy Laws, and Firm Production:

Growing Importance of Data for Firms & Privacy Laws

- **Data**

Growing Importance of Data for Firms & Privacy Laws

- **Data** plays an important and growing role in firm production
- New **privacy regulations** have emerged to govern data collection, storage, and analysis
- **EU's General Data Protection Regulation**: comprehensive and consequential privacy law
  - A□ected over **20M firms** across many countries that target EU residents (no min. size threshold)

Growing Importance of Data for Firms & Privacy Laws

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Production Approach: GDPR as Increased Cost of Managing Data

- These regulations increase the **cost of data** to firms and **a□ect their input choices**
  - Generate a wedge between the marginal product of data and its price (Hsieh and Klenow, 2009)
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- Requires a framework to analyze how firms use and process data

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This paper:

1. How do firms combine data and computation in production?
2. What is the cost of the GDPR for firms, and how do they adjust their data/computation inputs?

Data and Methods

- Confidential data from one of the largest **cloud computing providers**, 2016-2021
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  - Data directly targeted by regulation; computation a□ected through firm re-optimization/substitution

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- **Production function:** CES tech. to combine data and computation in information production
  - GDPR is ___ _

Preview of Results

1. **GPDR significantly changes data-compute input mix:** firms become less “data intensive”
   - Stored data ↓ 26%; computation ↓ 15% (both in EU relative to US)

2. **Data and computation are strong complements:** elasticity of substitution is 0.3-0.4
   -

Preview of Results

1.

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Contribution to the Literature

1. **The impact of the GDPR on firms**

   online tracking (Aridor et al., 2022; Lefrere et al., 2022; Lukic et al., 2023); business ventures (Jia et al., 2021); app development (Kircher and Foerderer, 2020; Janßen et al., 2021; Kircher and Foerderer, 2023); third-party ads (Johnson et al., 2022; Peukert et al., 2022); e-commerce revenue (Goldberg et al., 2023); e□ectiveness of targeted ads (Aridor et al., 2022; Matos and Adjerid, 2022); profits, and sales (Koski and Valmari, 2020; Chen et al., 2022); internet interconnectivity (Zhuo et al., 2021); + many others

   → Study the key margin targeted by privacy laws: data

   → Study firms' choices rather than outcomes using a production approach

Contribution to the Literature

1. **The impact of the GDPR on firms**

2. **Data as an input to the production of goods and services**

   (e.g., Jones and Tonetti, 2020; Cong et al., 2021; Farboodi and Veldkamp, 2022)

   → Empirical analysis of how firms use data and computation in a production approach

   → The first paper to incorporate and estimate both data and computation in firm production

Contribution to the Literature

1. **The impact of the GDPR on firms**

2. **Data as an input to the production of goods and services**

3. **Economics of privacy**

4. **Literature on misallocation**

   (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2017)

→ Model privacy regulation costs as a wedge to study GDPR compliance costs

Presentation Outline

1. Introduction
2. Institutional Setting
3. DiD Estimates of the Impact of GDPR
4. Production Function Framework
5. The Production Cost of GDPR
6. Conclusions

Introduction

2 Institutional Setting

DiD Estimates of the Impact of GDPR

Production Function Framework

The Production Cost of GDPR

Conclusions

2 Institutional Setting

2.1 The General Data Protection Regulation (GDPR)

2.2 Cloud Computing and Data

What is the General Data Protection Regulation (GDPR)?

- **Description:** Passed in April 2016 and went into e□ect in May 2018
  - Replaced and harmonized Data Protection Directive from 1995

- **Scope:** GDPR applies to firms located in EU or collecting “personal data” from EU residents
  - Protections apply to employee and customer data (e.g., IP addresses, location, shift schedules)

- **Enforcement:** Supervisory authorities in EU states enforce the regulation
  - Upon request, firms must be able to demonstrate their compliance

- **Compliance:** Heterogeneity in cost and timing of compliance
  -

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- Imposes a set of company obligations to protect data in addition to individual rights

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Firm Responsibilities under GDPR:	Fixed Costs	Variable Costs
1. Operational changes: privacy notices, employee training (Art. 25)	☐	
2. Designation / hiring of data protection o☐cers (Art. 37)	☐	☐
3. Handling customer delete/transfer requests expeditiously (Art. 14)	☐	☐
4. Records of processing activities, impact assessment and analysis (Art. 37)		☐
5. Data security: increase security requirements, breach notification (Art. 32)		☐
6. Increased liabilities with penalties up to 4% of *global* revenue (Art. 83)		☐

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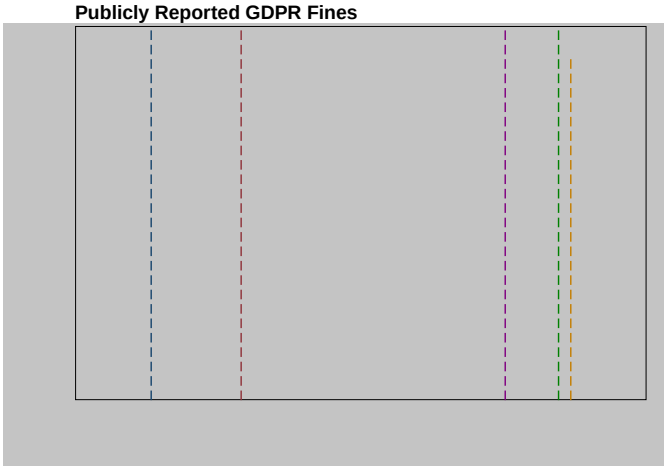
GDPR A□ects a Wide Range of Industries and Firms



2 Institutional Setting

2.1 The General Data Protection Regulation (GDPR)

2.2 Cloud Computing and Data

Our Data Source: Cloud Computing

- Cloud providers o□er **on-demand**

[1] Forbes (2022)

Our Data Source: Cloud Computing

- Cloud providers o□er **on-demand** access to scalable IT resources through the Internet
- Firms request **storage**

Some Examples of How Firms Use the Cloud

[1] Forbes (2022)

Data: Cloud Computing Usage from 2016 - 2021

1. **Cloud data**: detailed cloud usage from one of the largest service providers
   - Types: **storage** (gigabytes) and **computation** (number of cores × number of hours)
   - Unit of observation: firm−service−server location−month (e.g., MIT, Compute, East Coast, May/18)
   - Observe list prices and paid prices

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Limitations:

- We have limited knowledge on how firms use data stored in the cloud
- May not capture all data and computation: multi-cloud and traditional IT

Data: Cloud Computing Usage from 2016 - 2021

1. **Cloud data**: detailed cloud usage from one of the largest service providers

2. **Aberdeen/Harte-Hanks**: establishment level technology adoption (including cloud)
   - Observe □2.5 million US and □2 million EU establishments
   - Provides information on the extensive margin of cloud adoption and multi-homing
   - Wid29.ibBe0ssOtailedginxt

Data: Cloud Computing Usage from 2016 - 2021

1. **Cloud data**: detailed cloud usage from one of the largest service providers

2. **Aberdeen/Harte-Hanks**: establishment level technology adoption (including cloud)

3. **Duns & Bradstreet and Orbis**: information on industry classification and employment
   - Unit of observation: firm
   - Employment information available only for EU firms (fuzzy matching algorithm)

Summary Statistics: Top 8 Industries in Sample

Industry	Firms (%)	in EU (%)	Computation (%)	Storage (%)
Services	42.6	40.9	36.3	31.9
Software	25.4	59.8	17.6	20.8
Manufacturing	8.3	54.4	10.5	11.6
Retail Trade	5.8	46.9	5.2	5.4
Finance & Insurance	5.5	44.9	11.4	10.8
Wholesale Trade	5.2	52.3	3.7	4.5
Transportation	3.4	41.7	6.5	6.4
Construction	1.8	46.9	1.9	1.9

Main Empirical Specification

- **Challenge:** Lack of a natural control group due to regulation spillovers (Johnson, 2023)

- **Idea:** We observe the data centers firms use in addition to the country of origin
  - **Treated firms**: firms in the EU that store data only in EU data centers (domestic EU)
  - **Control firms**: firms in the US that store data only in US data centers (domestic US)

  → Eliminates multi-national firms

- **Sample:** EU and US firms who continuously use the cloud 24-13 months before the GDPR

- Use difference-in-differences with flexible trends by industry and pre-GDPR usage deciles

▸ control definition details

Decrease in Data Storage and Computation

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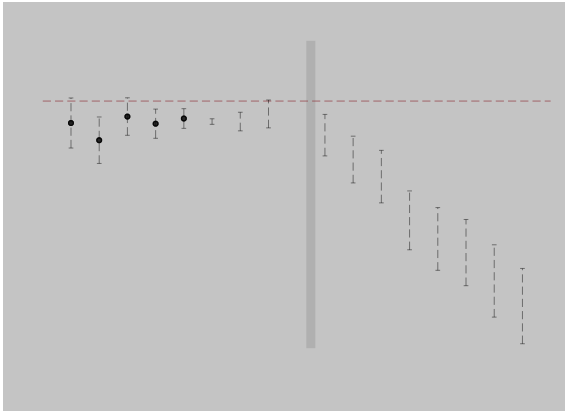

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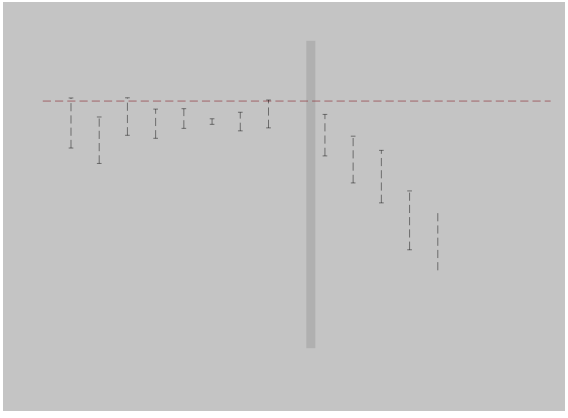
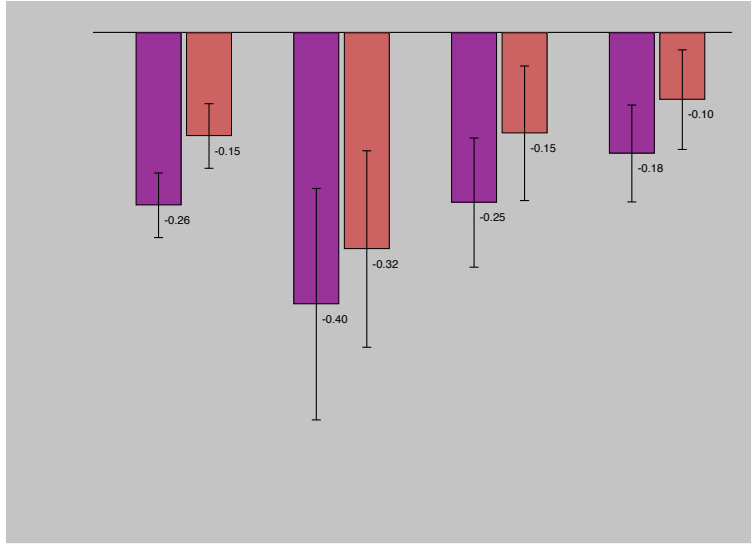


Estimated Long-run E

Estimated Long-run E□ects by Industry (Two Years After GDPR)

- Primary findings are the same across all industry groups
- Largest e□ect in manufacturing
- Suggestive that data and computation are less essential for manufacturing firms



Summary: GDPR Changes Firms' Data and Computation Input Choices

- **Additional Analyses:**
  1. Results not driven by differences in prices between US and EU
  2. Substitution (to other cloud providers, or in-house IT) unlikely to explain results
  3. Larger effect sizes, but not statistically significant wrt. country's enforcement strictness

     (Goldberg et al., 2023; Johnson, 2022)

- **Key Takeaways:**
  1. GDPR changed firms' data and computation input choices
  2. Results suggestive of a **wedge** between marginal product of storing data and its price

- **Next**: Model firms' input decisions using **production framework** to quantify the GDPR cost

CES Information Production Function with Data and Compute

- Firms produce information ( ) by using data ( ) and computing ( ) w/ CES tech:

$$= \quad (\quad) + \quad ^{1/}$$

  - : (unobserved) exogenous compute technology
  - $= 1/(1 -)$: the elasticity of substitution parameter, industry-specific

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Modeling The GDPR: A Wedge in the Production Function

- We model GDPR as an increase in the marginal cost of data storage by (1 +):

Pre-GDPR: ˜ =

Post-GDPR: ˜ = (1 +) ·

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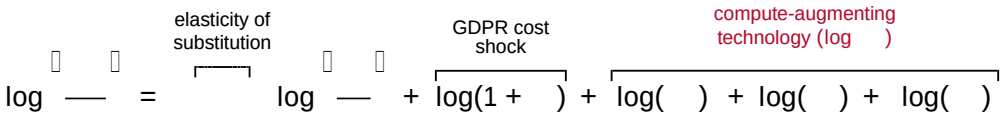
  (Doraszelski and Jaumandreu, 2018; Raval, 2019; Demirer, 2020)



- Use equation to identify and using US/EU, pre/post GDPR variation + shift-share design

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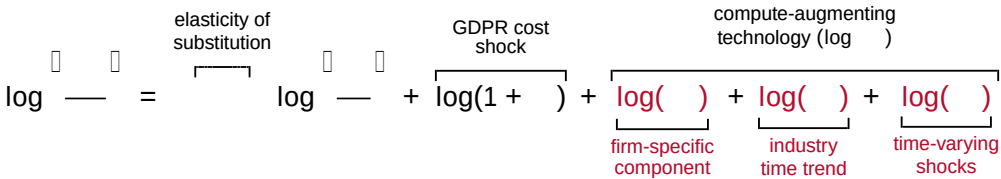

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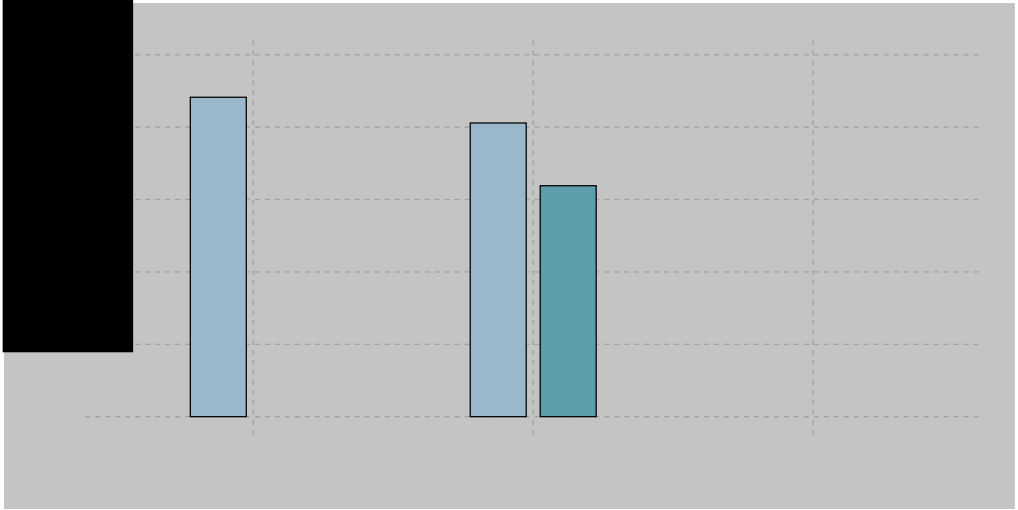
4 Production Function Framework

4.1 Estimation Results

Result[redacted]sticity of Substitution for EU Firms

Compute [redacted]strong complements; more so than “traditional inputs”

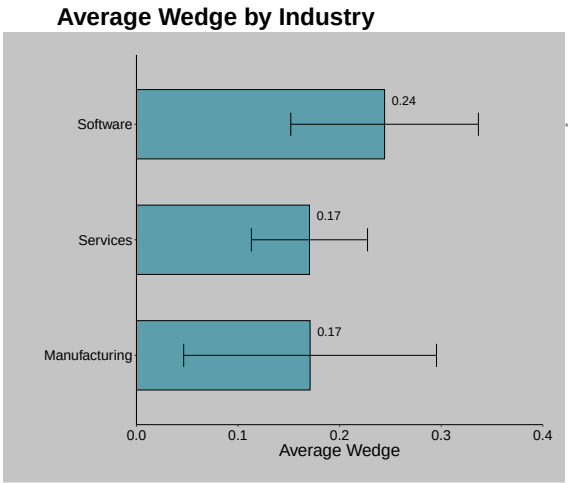


5 The Production Cost of GDPR

5.1 Changes in the Cost of Data Storage

5.2 Changes in the Cost of Information Production

Average GDPR Wedge is 20% with Important Heterogeneity



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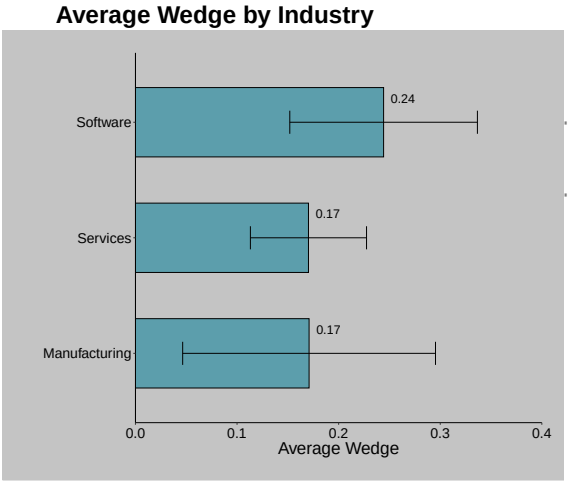

- GDPR 20% tax on price of storing data
- Firms where information is likely more important face larger costs:
  - Software (24%) vs Manufacturing (17%)

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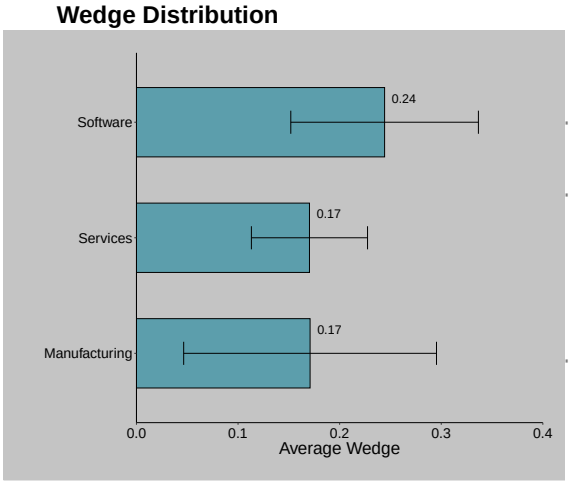
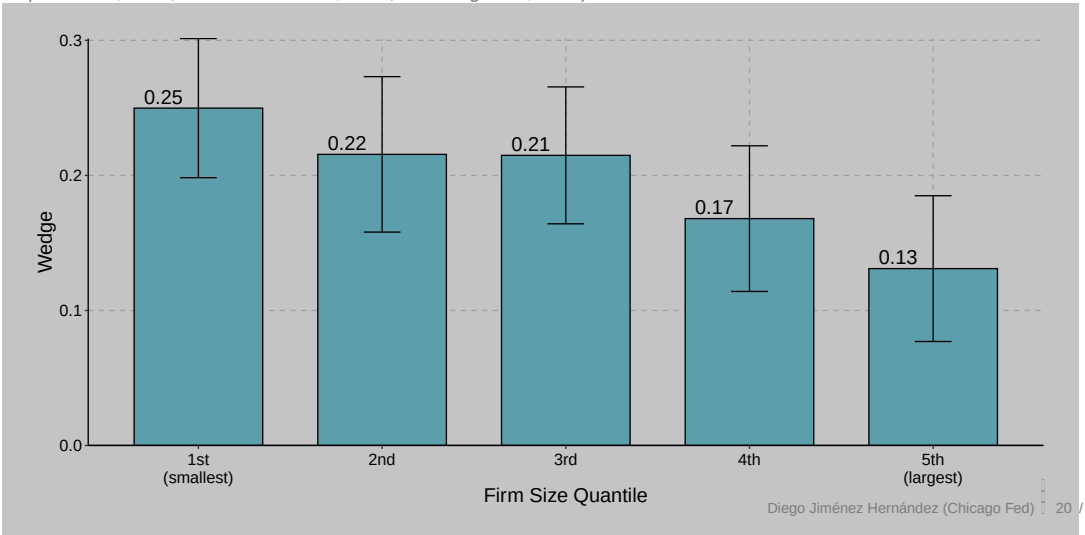


- GDPR ⇒ 20% tax on price of storing data
- Firms where information is likely more important face larger costs:
  - Software (⇒ 24%) vs Manufacturing (⇒ 17%)
- What explains the large cost heterogeneity?

Wedges Negatively Correlated with Firm Size (Employment)

- Larger firms face lower wedges, consistent with the literature
  (Campbell et al., 2015; Koski and Valmari, 2020; Goldberg et al., 2023)



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How Much Does GDPR Increase the Cost of Producing Information?

- From CES production function, the cost of producing a unit of information (without subscripts):

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$$(\ ,\ \ ,\ \ ) = (\ \ )\ (\ \ )^{1-} + (1 + \ \ )^{1-} \ ^{1/(\ \ -1)}$$

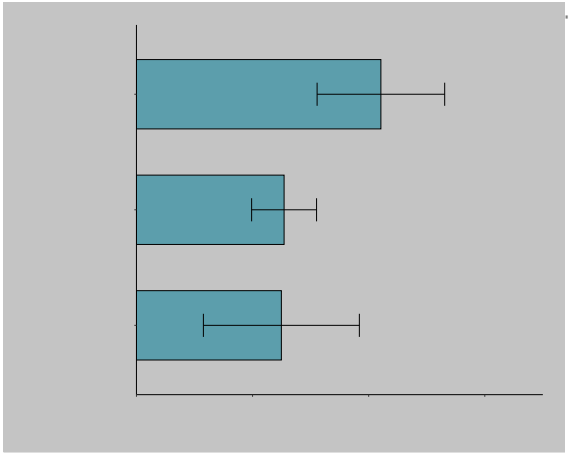
heterogeneity depends on prices, compute productivity, elasticity of substitution, and wedges

- Calculate <u>counterfactual information cost</u> without GDPR ($= 0$)

With GDPR: $(\ ,\ \ ,\ \ =\ \ )$ **Without GDPR:** $(\ ,\ \ ,\ \ = 0)$

Average Increase in Information Cost is Only 3.7%

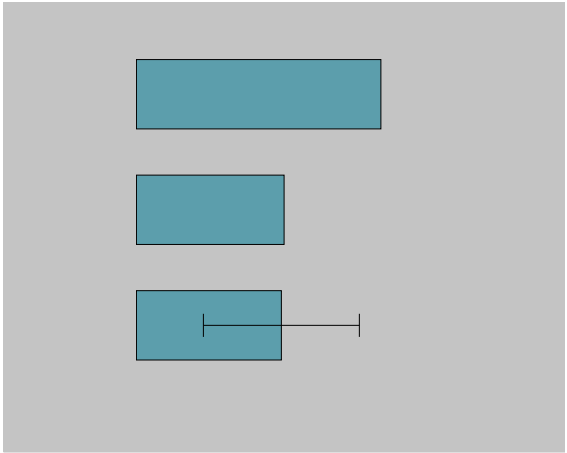
Avg. Increase in Information Cost by Industry



- Information cost increases only by 3.7% on average, with important heterogeneity

Average Increase in Information Cost is Only 3.7%

Avg. Increase in Information Cost by Industry



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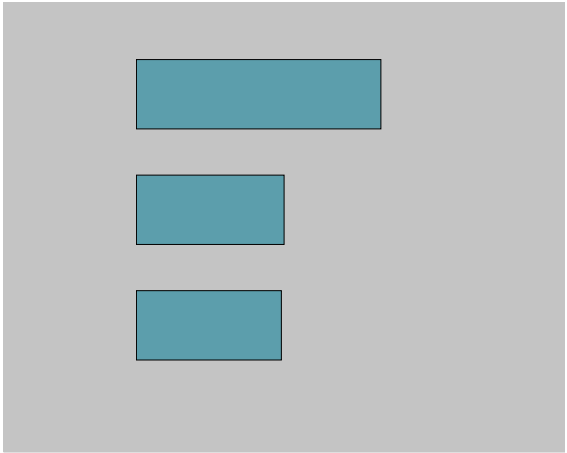

Conclusion

What We Do:

- Use a production approach to study the e□ects on GDPR on data and computation

Results:

- DiD estimates suggest that GDPR reduced firm demand for data and computation:
  - Firm storage declined by 26%; computing declined by 15%
- Data and computation are strong complements in production function
- Production function framework estimates GDPR □ 20% tax on data storage:
  - This leads to only 4% increase in the cost of information because it targets cheaper input
  - Total production costs are lower (≤ 1%) since information expenditure shares tend to be low