Unveiling the J-curve: How Intangibles Drive Productivity Mismeasurement

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The emergence of intangibles

- Intangibles become increasingly important for production
- Intangibles have become more important than tangible investment Corrado&al.(12)
- Productivity measurement issues because intangible investments are not available on a balance sheet Brynjolfsson&al.(21) Goodridge&Haskel(23)
- Especially the case with GPTs as they tend to be correlated with intangibles Brynjolfsson&Hitt(03) Dhyne&al.(21)

Investment share of measured output
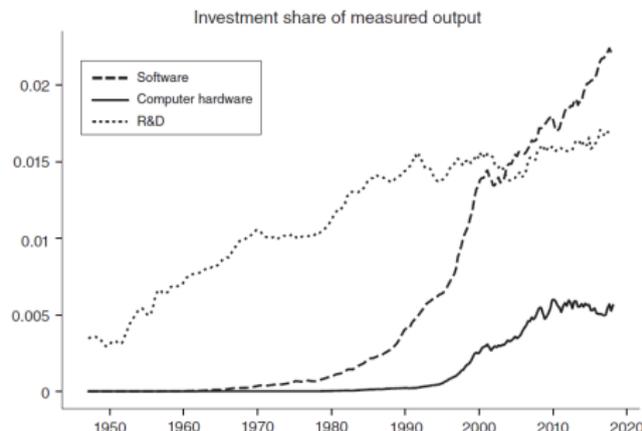
Source: Brynjolsson&al.(21)

Intangibles and productivity: emerging evidence

- **Macro-level evidence** on impact of intangible on aggregate productivity
  Corrado&al.(12), Goodridge&Haskel(23)
- **Micro-level evidence** on firm-level adoption of intangibles using survey/Compustat/balance sheet data
  - Positive impact on productivity Kaus&al.(24)
  - Larger firms do most of the investments Crouzet&Eberly(18,19)
- Challenges for micro-level evidence of intangibles on productivity:
  - measures of intangibles that is **comprehensive**
  - measures of intangibles that captures **all** intangibles
  - **Unbiased** measures of intangible capital

Contributions

1. Measure of **firm-level intangible investment** across sectors and firm size
2. Examine the **importance of intangibles in production**
3. **Event-study DiD design** leveraging the timing of intangible investment events
4. Examine whether the Solow Paradox can be explained by the complementarity between ICT & intangibles

Outline

Data

Data

1. **VAT customer listings**
   - Yearly customer listing in the value-added tax declarations of firms
   - All sales invoices above the amount of 250 Euro for all customers have to be reported.
   - Enables us to construct a measure on intangible investment Similar as Dhyne, Konings&al.(21) for ICT
   - Pervasive across time, sectors and firm sizes

Data

- Take the VAT customer listing of computer programmer X, active in NACE 6201
- From the VAT form of firm X, we know to which firms Y it sells and the value of the sales

Data

- Since we have the yearly VAT transactions of ALL X firms, we can deduce for each firm Y how much it purchases from type X firms. The sum of all intangible purchases in year t across type X firms, is our intangible investments measure of year t for firm Y

Data

Table: Intangibles selling industries

Intangible Asset Type	NACE Rev. 2 Code
	A. Computerized Information
(i) Software	6201, 6209, 6312
(ii) Database	6202, 6203, 6311
	B. Innovative Property
(i) R&D (Scientific)	7211, 7219, 7220
(ii) Entertainment & Artistic Originals	7410, 7420, 7430, 7911, 7912, 7990, 8810, 8891, 8899, 9001, 9002, 9003, 9004, 9311, 9312, 9313, 9319, 9321, 9329, 9604
(iii) Design & other new Product/Systems	7111, 7112, 7120
	C. Economic Competencies
(i) Advertising/Market Research	7311, 7312, 7320
(ii) Employer-provided Training/ Organizational Structures	7021, 7022, 7490, 7810, 7830, 8510, 8520, 8531, 8532, 8541, 8542, 8551, 8552, 8559, 8560

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2. Complemented by **in-house R&D expenditures** data from ECOOM Leuven

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3. **Annual accounts** (employment, tangible capital,...)
4. **VAT declarations** (sales, intermediates, tangible investment)
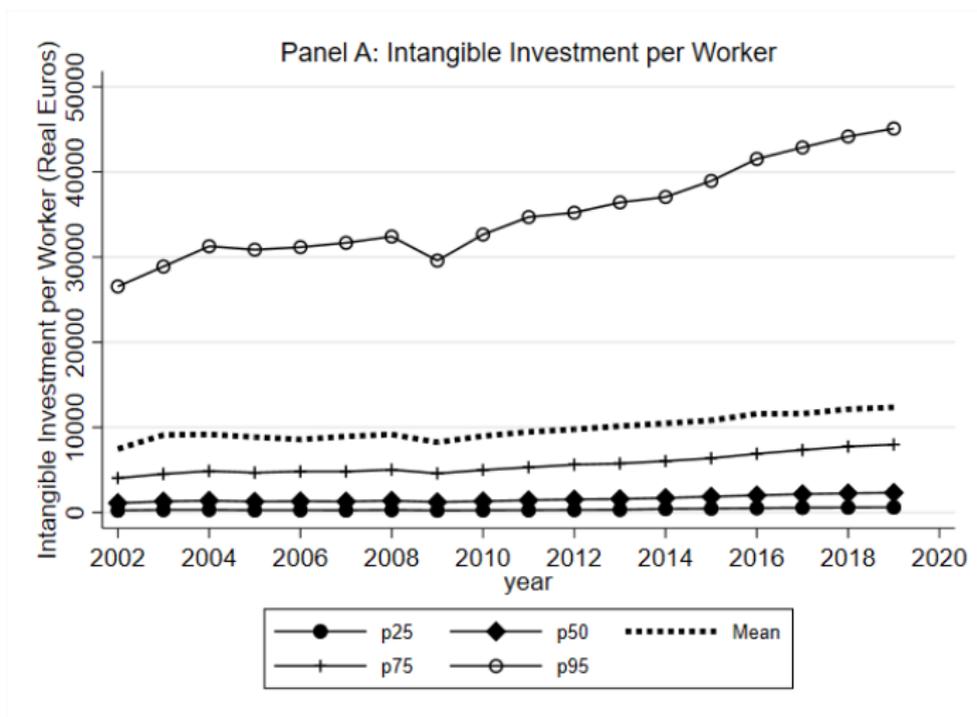5. Years **2002-2019**

Data

Data

Table: Intangibles by sector

| | Intangibles Value | Intangibles per Worker | | No. of Observations | |
	Mean	Mean	SD	Firms	Firms× Years
Manufacturing - High Tech	1,477,955	13,593	86,325	3,018	36,866
Manufacturing - Other	189,537	6,960	56,637	21,699	248,095
Utilities	1,468,334	25,386	157,610	1,032	11,480
Construction	42,763	6,831	73,095	37,863	383,032
Wholesale & Retail	110,622	11,942	86,354	69,485	734,766
Transport and Storage	155,526	10,582	410,797	10,174	108,734
Accommodation & Food Serv.	15,388	4,225	26,755	25,175	223,372
Information & Communication	1,066,337	46,998	174,328	2,474	22,352
Finance & Insurance	240,250	24,905	177,184	766	7,332
Real Estate	58,161	22,729	88,896	6,130	53,407
Prof., Scientific & Tech. Serv.	146,462	16,696	75,418	11,345	101,305
Admin. & Support Act.	107,295	16,746	175,693	10,323	96,039

Data

Table: Intangibles by firm size class

	Intangibles Value	Intangibles per Worker		No. of Observations	
	Mean	*Mean*	*SD*	*Firms*	*Firms×Years*
L ≤ 19	29,197	10,793	131,822	184,754	1,825,157
20 < L ≤ 49	269,815	9,613	71,270	9,628	129,268
50 < L ≤ 99	650,670	10,544	54,150	2,584	35,684
100 < L ≤ 199	1,454,252	11,808	49,769	1,352	19,641
200 < L ≤ 499	3,384,157	13,380	123,099	747	11,003
500 < L	19,661,221	13,119	30,773	358	5,749

Data

- Relationship between intangibles per employee and the scale of firms:

$$Intangibles per employee_{it} = FE_{Size_{it}} + FE_{ind_{it}t} + FE_{age_{it}} + \zeta_{it}$$

- $FE_{Size_{it}}$ = size-class dummy
- $FE_{ind_{it}t}$ = flexible set of industry-time fixed effects (at the four-digit level)
- $FE_{age_{it}}$ = age dummies
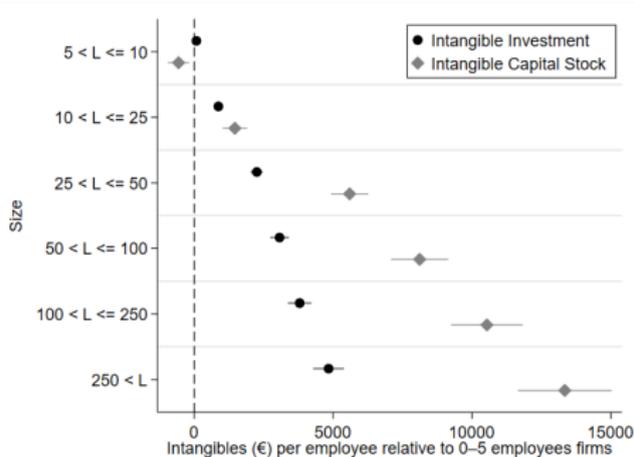
Data

- Next, we measure firm scale in terms of output (added value and sales) and intermediate inputs (excl. intangibles), and estimate the intangibles demand equation:

$$log(Intangiblesperemployee_{it}) = \eta log(Size_{it}) + FE_{ind_{it}t} + FE_{age_{it}} + \zeta_{it}$$

- $Size_{it}$ denotes firm added value, sales, or intermediate inputs
- The coefficient of interest is η, which measures the relationship between size and demand for intangibles
- As a next step, we also include firm fixed effect FE_i

Data

Table: Regressions of log intangibles per employee on log firm size

	Within-industry			Within-firm		
	(1)	(2)	(3)	(4)	(5)	(6)
A. Intangible Investment per Employee						
Size (Proxied by Added value)	0.3328***			0.2956***		
	(0.0009)			(0.0035)		
Size (Proxied by Sales)		0.3577***			0.2458***	
		(0.0009)			(0.0041)	
Size (Proxied by Inputs)			0.2977***			0.1157***
			(0.0008)			(0.0037)
Observations	1,425,022	1,425,022	1,424,876	1,425,022	1,425,022	1,424,876
A. Intangible Assets per Employee						
Size (Proxied by Added value)	0.4067***			0.0537***		
	(0.0009)			(0.0027)		
Size (Proxied by Sales)		0.4542***			0.0671***	
		(0.0009)			(0.0034)	
Size (Proxied by Inputs)			0.3880***			0.0325***
			(0.0008)			(0.0029)
Observations	1,638,584	1,638,584	1,638,346	1,638,584	1,638,584	1,638,346

Notes: This table shows the regression results of the intangibles demand equation. The dependent variable is the logarithm of intangibles per employee (Panel A considers intangible investments, while panel B takes intangible assets as outcome variable). The independent variable is the logarithm of firm size proxied by added value, sales, and inputs. The time period is 2002-2019. All columns include a full set of four-digit industry classification fixed effects interacted with year fixed effects, and within-industry results also include a full set of age fixed effects. An elasticity of 0.3 means that raising intermediates by a factor of 2 raises intangible investment per employee by 30 percent. Within-firm standard errors are clustered at the level of the firm. ∗p<0.10, ∗∗p<0.05, ∗ ∗ ∗p<0.01.

Production function estimation

Production function estimation

- We assume firms produce final output with a Cobb–Douglas technology

$$Y_{it} = M_{it}^{\beta_M} L_{it}^{\beta_L} K_{it}^{\beta_K} U_{it}^{\beta_U} A_{it}$$

- Log-linearized:

$$y_{it} = \beta_0 + \beta_M m_{it} + \beta_L l_{it} + \beta_K k_{it} + \beta_U u_{it} + \omega_{it} + \varepsilon_{it}$$

- where $y_{it} =$ log gross output, $m_{it} =$ log intermediates, $l_{it} =$ log labor (FTE), $k_{it} =$ log tangible capital, $u_{it} =$ log intangible capital, and $log A_{it} = \beta_0 + \omega_{it} + \varepsilon_{it}$, with ω_{it} denoting firm TFP and ε_{it} a residual

Production function estimation

MP = 0.0616/0.0630 = 0.98

Table: Production function estimation

	OLS		CWDL (2020)	
	(1)	(2)	(3)	(4)
Employment	0.2115***	0 2073***	0.1629***	0.1547***
	(0.0016)	(0.0016)	(0.0014)	(0.0019)
Tangible capital	0.0304***	0.0295***	0.0750***	0.0654***
	(0.0006)	(0.0006)	(0.0013)	(0.0012)
Intermediates	0.7424***	0.7367***	0.7369***	0.6915***
	(0.0015)	(0.0016)	(0.0010)	(0.0018)
Intangible capital		0.0089***		0.0616***
		(0.0005)		(0.0008)
No. of firms	150,008	150,008	138,647	132,195
No of observations	1,158,952	1,158,952	933,165	839,188

Notes: This Table shows the production function estimation results using ordinary least squares (OLS) and the estimation technique by CWDL. ∗p<0.10, ∗∗p<0.05, ∗ ∗ ∗p<0.01.

MP tangibles = 0.16,
MP intermediates = 0.82,
MP labor = 0.23

Productivity mismeasurement

How does intangibles lead to productivity mismeasurement?

How does intangibles lead to productivity mismeasurement?

- New innovations require complementary intangible investments
- Firms must create new business processes, develop managerial experience, train workers, patch software, and build other intangibles.
- TFP growth will initially be underestimated: capital and labor are used to accumulate intangible capital stocks
- Later: Measured productivity growth is overestimated because intangible capital generates output.
- Brynjolfsson&al.(21) call this the productivity J-curve

How does intangibles lead to productivity mismeasurement?

Toy economy: The productivity growth mismeasurement J-curve
Calculation of capital share as $1 - (wL/Y)$
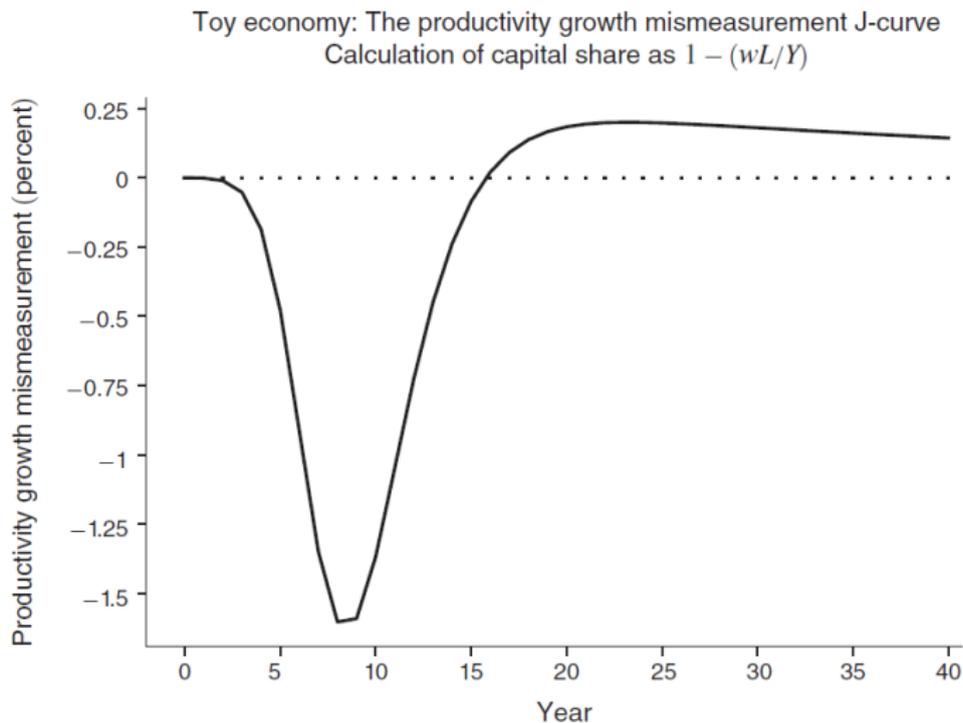
How does intangibles lead to productivity mismeasurement?

- This framework only considers the aggregate impact of intangibles when new GPT's are introduced
- But does the productivity J-curve also exist at the firm level?
- And if so, which firms drive these results?
- Important since new technologies are generally adopted first by bigger firms before smaller firms are able to (financial constraints etc.)

Leveraging intangible investment spikes in a DiD setting

- Firms have **spikes in intangible cost shares over time**
- Firm j has an intangible cost share spike in year τ if

$$spike_{j\tau} = \mathbf{1}\left\{ \frac{I_{j\tau}}{TK_j} \geq 3 \times \frac{1}{T-1} \sum_{t\neq\tau}^{T} \left(\frac{I_{jt}}{TK_j} \right) \right\}$$

- Of 200K firms, 97K have at least 1 spike, 67K have exactly 1 spike
- A firm's **first spike is its intangible investment event**
- Similar to Aghion&al.(20) and Bessen&al.(22) for automation
- Intangibles are fixed and irreversible investments $=>$ spikes in intangible cost shares within firms over time Haltiwanger(99), Doms&Dunne(98)

Leveraging intangible investment spikes in a DiD setting
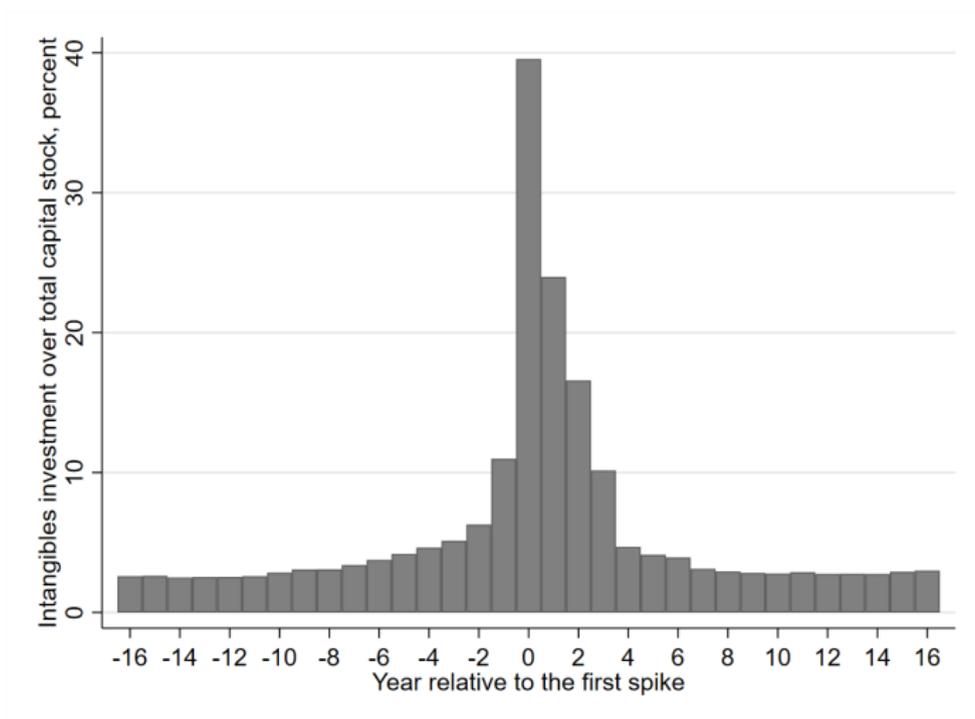
Leveraging intangible investment spikes in a DiD setting

- Consider event window of 3 yrs before and 7 yrs after
- For each year $2005 \leq t \leq 2012$, create 8 group-specific data sets of firms treated in t and control firms treated at least 7 yrs later
- We have excluded forbidden comparisons Borusyak&al.(23), Goodman-Bacon(21)
- Stack 8 group-specific data sets into a single stacked data set

Leveraging intangible investment spikes in a DiD setting

- Using stacked data, regress standard TWFE event-study DiD specification:

$$y_{it} = \alpha + \sum_{\tau=-3}^{-2} \delta_\tau \times I_\tau \times Treat_i + \sum_{\tau=0}^{6} \delta_\tau \times I_\tau \times Treat_i + \lambda_{st} + \eta_i + \epsilon_{it},$$

- $\lambda_{st} =$ industry-year FE,
- $\eta_i =$ set of cohort by firm fixed effects
- I_t are the leads and lags in event time, with $\tau = -1$ as the reference category.
- $Treat_i$ is the dummy variable indicating treatment
- $y_{it} =$ log measured TFP - log adjusted TFP

Productivity mismeasurement
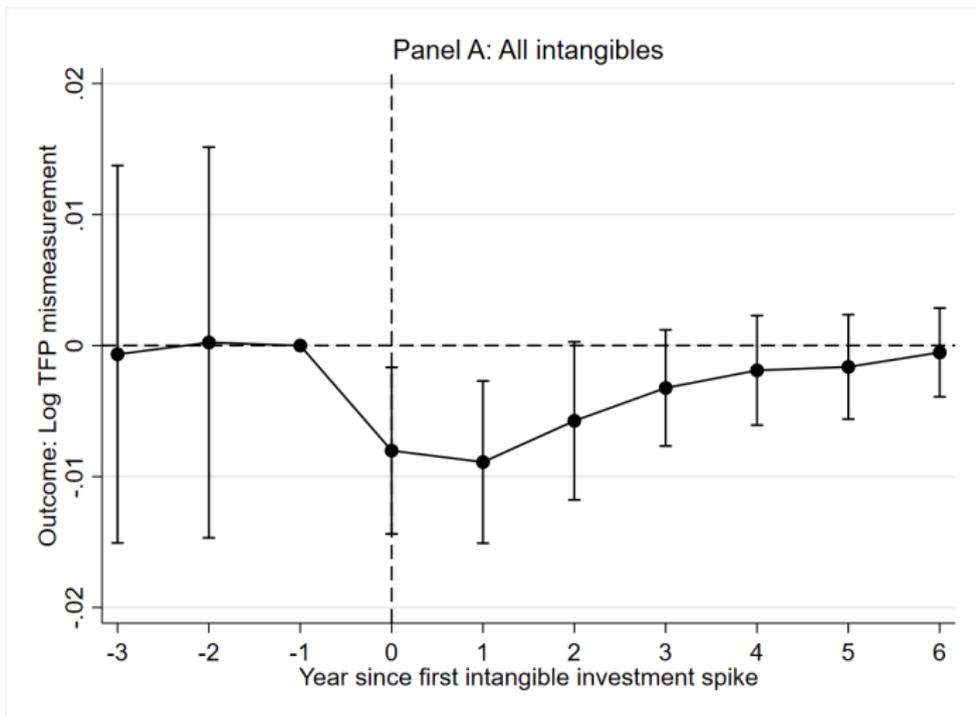
Effect heterogeneity

The Productivity J-curve is:

1. Larger for smaller firms
2. Larger for younger firms
3. Larger for less-skilled firms
4. Larger for less capital-intensive firms ▸ more

Additional analyses

1. Placebo events (investment in other material fixed assets) ▶ more
2. Dropping outliers ▶ more
3. Changing the definition of a 'spike' ▶ more
4. Robustness for spike intensity ▶ more
5. Other definitions of intangibles ▶ more
6. Matching ▶ more

Intangible capital type heterogeneity
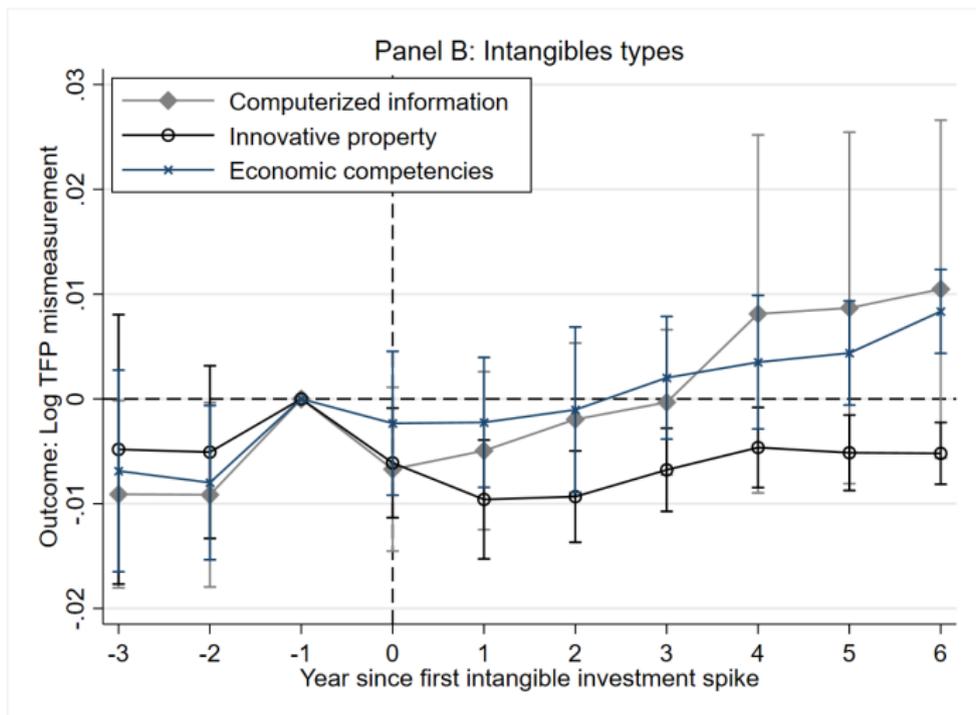
A tangible example: ICT and the Solow Paradox

- Brynjolfsson&al.(21) argues that general-purpose technologies are complemented by intangibles
- Can the Solow Paradox be explained by intangible correlates?
- Literature indicates that ICT and intangibles are correlated Brynjolfsson&Hitt(03) Dhyne&al.(21)

A tangible example: ICT and the Solow Paradox

ICT investment spike

$$spike_{j\tau} = \mathbf{1}\left\{ \frac{I_{j\tau}^{ICT}}{\bar{T}K_j} \geq 3 \times \frac{1}{T-1} \sum_{t \neq \tau}^{T} \left(\frac{I_{jt}^{ICT}}{\bar{T}K_j} \right) \right\} \tag{1}$$

We additionally require that

$$\frac{I_{j\tau}}{TK_{j\tau}} \geq 2 \times \frac{I_{j\tau-1}}{TKj\tau - 1} \tag{2}$$

implying intangible capital deepening goes up with a significant amount at the moment of an ICT spike.

A tangible example: ICT and the Solow Paradox

Panel A: ICT investment spikes

A tangible example: ICT and the Solow Paradox
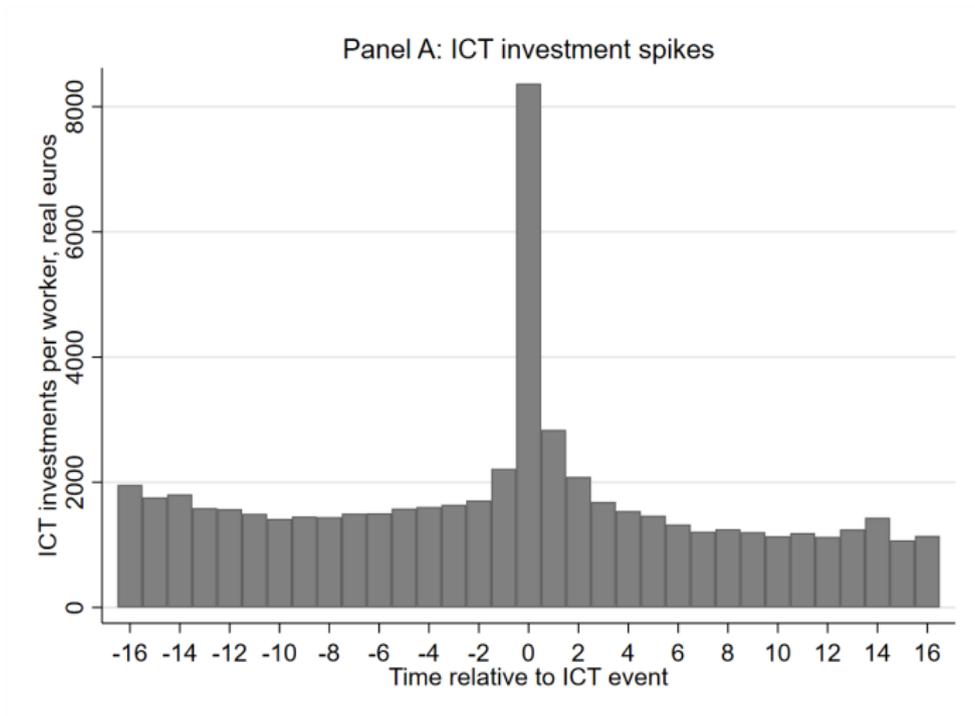
Panel B: ICT and the Solow Paradox
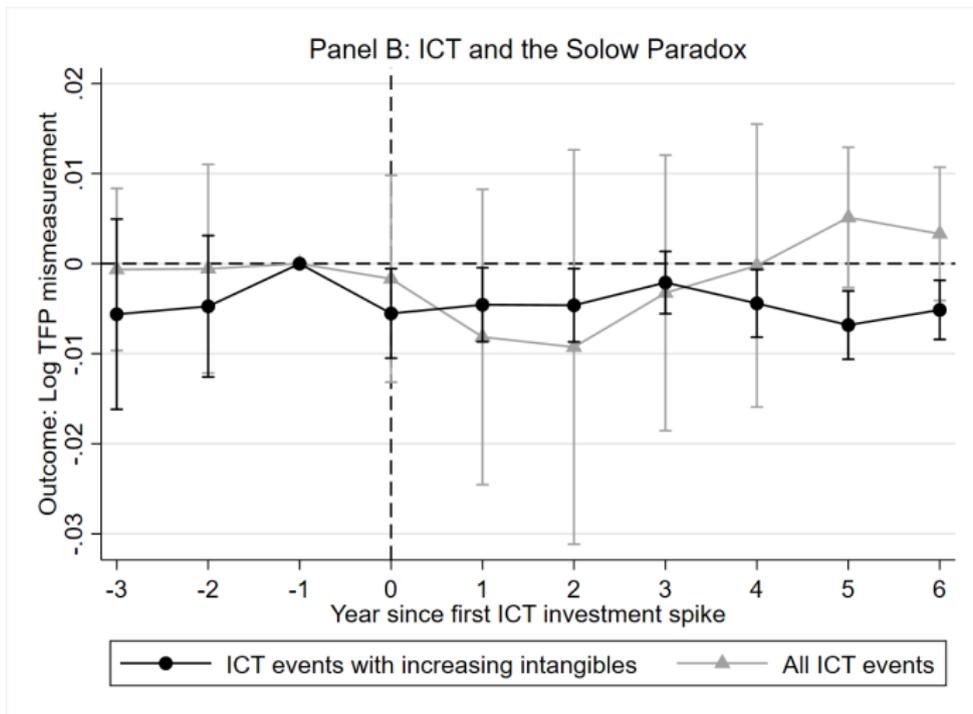
Conclusions

Conclusions

1. Intangibles have become more important over time
2. Important for the production of firms (MP of 0.98, higher than other production factors)
3. Intangible investments lead to a productivity J-curve at the firm level
4. Mainly due to innovative intangibles
5. Small, low-skilled, young firms experience this J-curve (they need time to adapt)
6. The Solow Paradox can be explained by the complementarity between ICT and intangibles

Thank you!

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Back-up Slides

Data description: B2B

- The B2B data reports information from the customer listings of firms
- firms have to report the VAT number and associated revenues it obtained from each of its customers
- Indirectly, this also learns how much each customers buys
- We exploit this information to obtain intangible purchases for each customer
- More specifically, we use the customer listings of firms that are active in NACE codes of intangible services industries
- From their customer listings, we deduce how much intangible goods and intangible services each of its customers bought
- For each customer, we sum its intangible purchases across all intangible producing firms

Data description: In-house R&D

- R&D expenditures are from ECOOM (KU Leuven), collected through a bi-annual survey covering all firms which are known to have R&D projects.
- These are identified by a number of different approaches, including firms which have reported R&D costs in their annual company accounts, applied for patents, have received tax credits for R&D expenditures, received R&D subsidies; as well as including a list of R&D-active firms provided by technology employer federations, and a search in the general media.
- In addition, a stratified random sample of the general population of firms is included to detect other potential R&D-active firms.

Data description: Skilled labor

- The number of employees, by level of education (university, higher education, secondary education, primary education), are sourced from the NBB social accounts data (a supplement to the annual financial accounts).
- We define the fraction of skilled workers as the number of employees with college education or higher as a share of the total reported employees (full-time equivalent).
- These data are only available from 2008 onwards, so we average these over 2008 to 2019.

Construction of intangible capital stock

- We construct real intangible capital using the Perpetual Inventory Method (PIM). This method allows us to optimally exploit our unique data on intangible purchases. The formula of the PIM is the following:

$$K_{it}^U = K_{it-1}^U \times (1 - \delta_U) + I_{it}^U \tag{3}$$

- In which K_{it}^U refers to the real intangible capital stock of firm i in year t, δ_U refers to the depreciation rate for intangible capital and I_{it}^U refers to real intangible investments.
- We rely on data of the EU KLEMS initiative to turn the nominal values from our data set into real values.

Construction of intangible capital stock

- The first step in applying the PIM is calculating the initial intangible capital stock.
- This is necessary because intangible capital is not reported in annual accounts in a sufficient way.
- To obtain the initial stocks, we predicted the firm's intangible capital intensity and use this to obtain its share in initial nominal total assets.
- First, we obtain nominal intangible investments from:

$$I_{it}^U = \textit{Intangible Purchases}_{it} \tag{4}$$

Construction of intangible capital stock

- Next, we take the average of the real investment flows from the first 3 years the firm is in the sample.

$$K_{i0}^U = \frac{1}{3} \times \sum_{t=1}^{3} \frac{I_{it}^U}{g_{it}^U + \delta^U} \tag{5}$$

- With I_{it}^U the real intangible investment of the firm, g_{it}^U the constant average past growth rate of real intangible investments and δ^U the intangible capital depreciation rate.

Descriptives

Table: Descriptive statistics

|	Mean	Median	SD
Measured Value Added (X1,000 EUR)	877	137	12,077
Corrected Value Added (X1,000 EUR)	964	147	13,030
Tangible Capital (X1,000 EUR)	935	129	16,039
Intangible Capital (X1,000 EUR)	268	14	3,988
Employment	10,55	2	159
Tangible investment (X1,000 EUR)	146	18	2,717
Intangible Investment (X1,000 EUR)	88	4	1,331
Sales (X1,000 EUR)	4,889	538	153,059
Wage Bill (X1,000 EUR)	530	72	7,222
Measured Intermediate inputs (X1,000 EUR)	3,557	341	74,598
Corrected Intermediate inputs (X1,000 EUR)	3,467	328	74,048

Descriptives
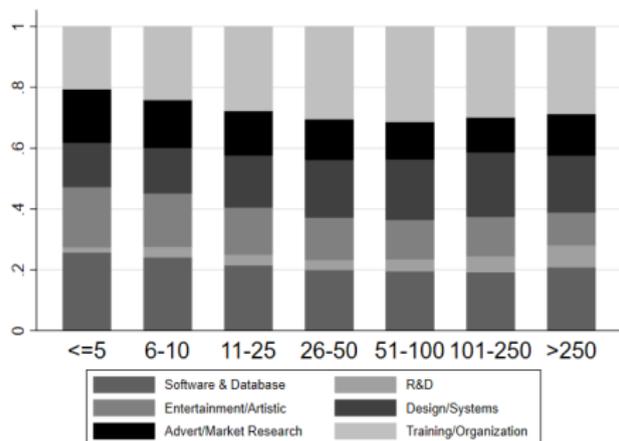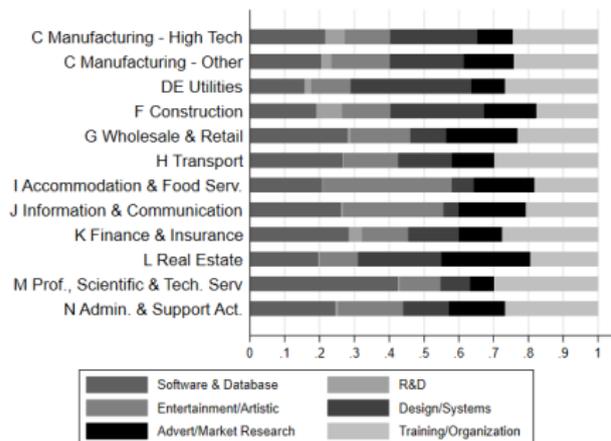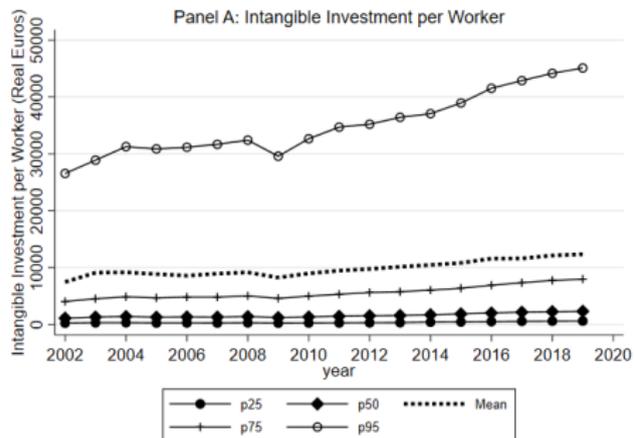
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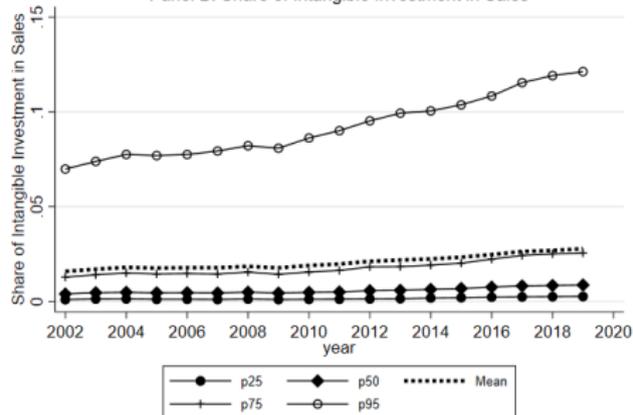
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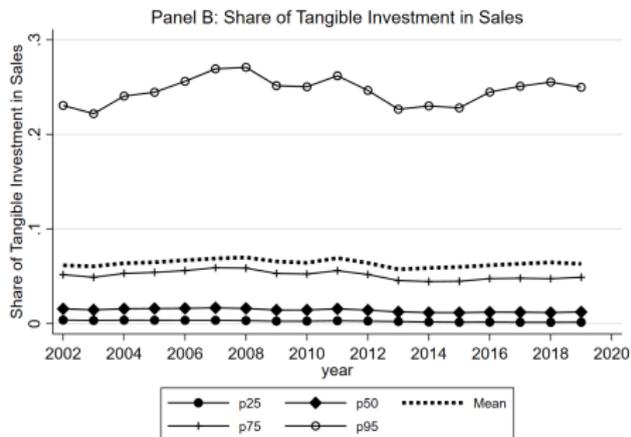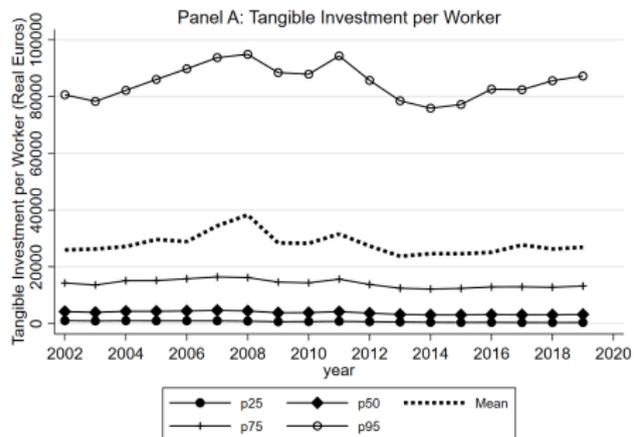
Effect heterogeneity   ◄ Back

Table: Effect heterogeneity

	Small firms	Big firms	Low capital-intensive firms	High capital-intensive firms	Low-Skilled firms	High-Skilled firms	Young firms	Old firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2+ yrs before	-0.0035	0.0057	0.0002	-0.0016	-0.0025	0.0009	0.0078	-0.0065
	(0.0058)	(0.0132)	(0.0087)	(0.0070)	(0.0041)	(0.0196)	(0.0110)	(0.0083)
Yr of event	-0.0058	-0.0043	-0.0057	-0.0080**	-0.0067***	0.0157	-0.0081	-0.0032
	(0.0045)	(0.0068)	(0.0040)	(0.0033)	(0.0025)	(0.0112)	(0.0060)	(0.0038)
1 yr after	-0.0067**	-0.0066	-0.0086**	-0.0018	-0.0068***	0.0061	-0.0108**	-0.0030
	(0.0028)	(0.0065)	(0.0040)	(0.0030)	(0.0019)	(0.0106)	(0.0046)	(0.0033)
2+ yrs after	-0.0061***	0.0013	-0.0024	-0.0003	-0.0037*	0.0086	-0.0087***	0.0016
	(0.0012)	(0.0035)	(0.0018)	(0.0035)	(0.0019)	(0.0058)	(0.0023)	(0.0023)
No. of firms	54,298	13,633	45,623	15,697	59,184	2,148	29,816	31,502

Intangible vs. tangible investment spikes [◄ Back]

- As a further robustness check, we construct events for firm-level investments which we expect to be neutral to productivity mismeasurement:
- Spikes in "material fixed assets" (furniture, shelving, silos, containers, pellets, buildings, land, means of transportation, machines, communication equipment, and computers)
- We construct spikes in material fixed assets analogously
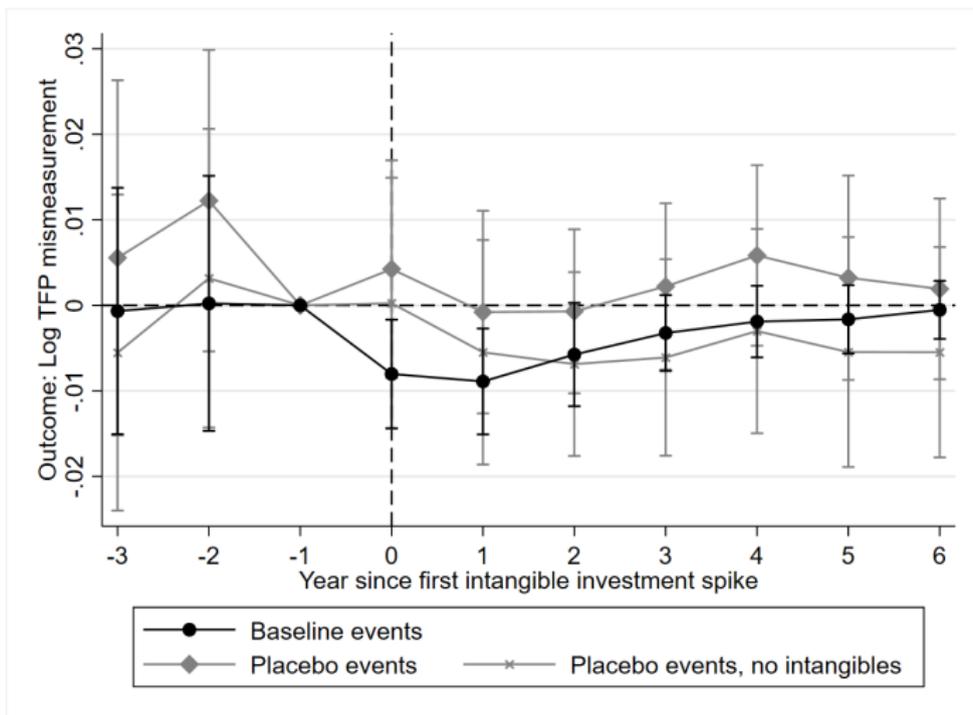
Intangible vs. tangible investment spikes ◂ Back
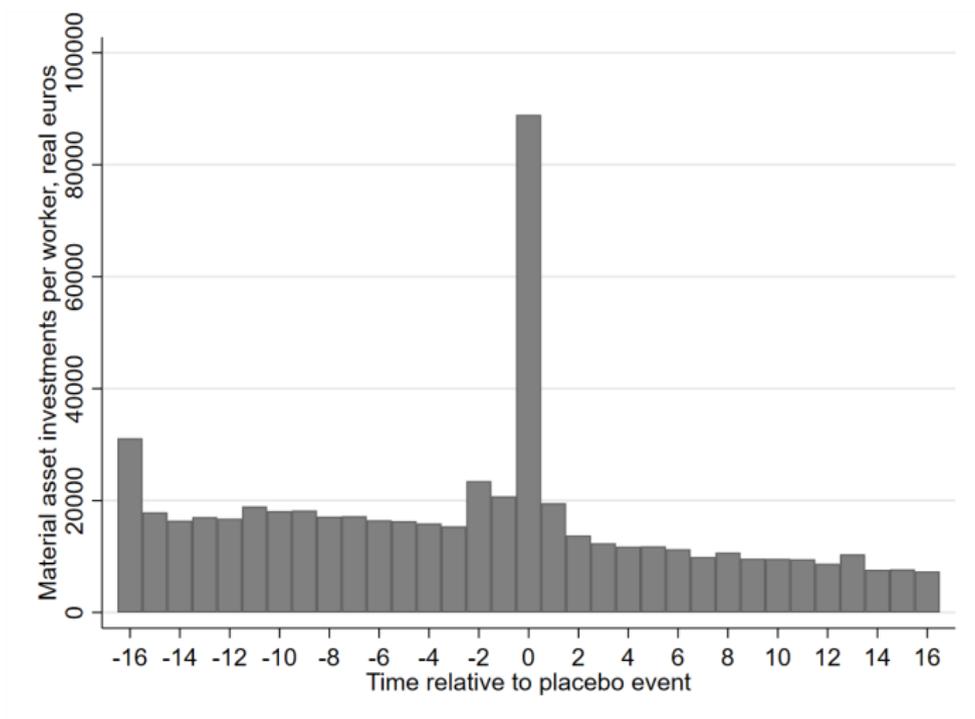
Intangible vs. tangible investment spikes ◂ Back

- We estimate firm-level difference-in-differences models for the overlapping sample of firms (both intangibles and tangible spikes)
- Next, we estimate the impact of tangible spikes, but deleting firms with also an intangible spikes
- Fixed material assets do not have any impact on productivity mismeasurement
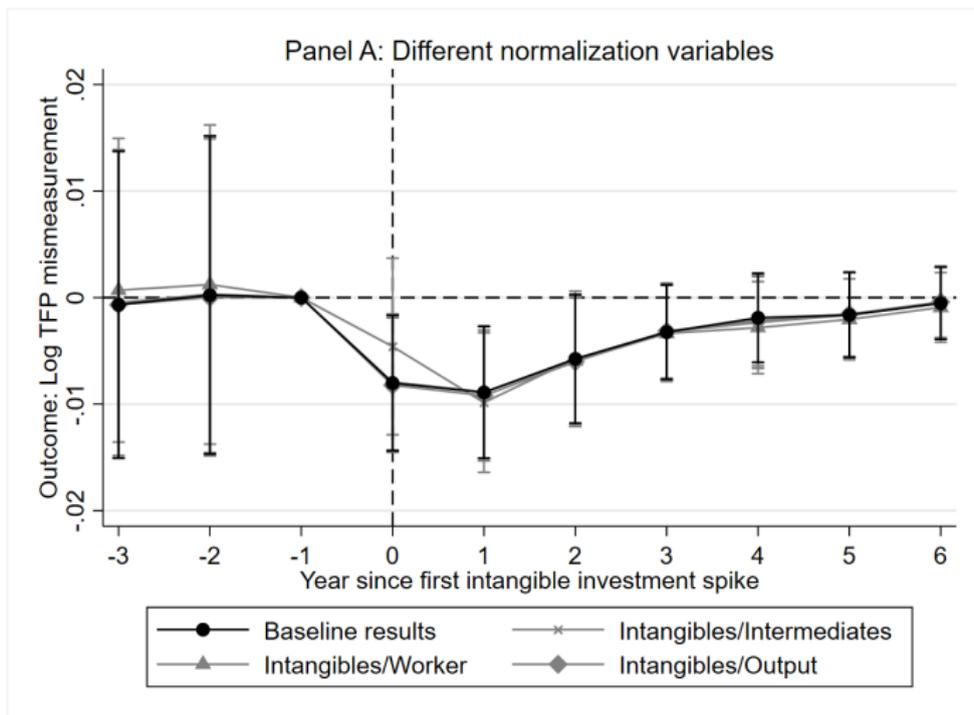- Not a mechanical outcome of constructing firm-level events the way we do
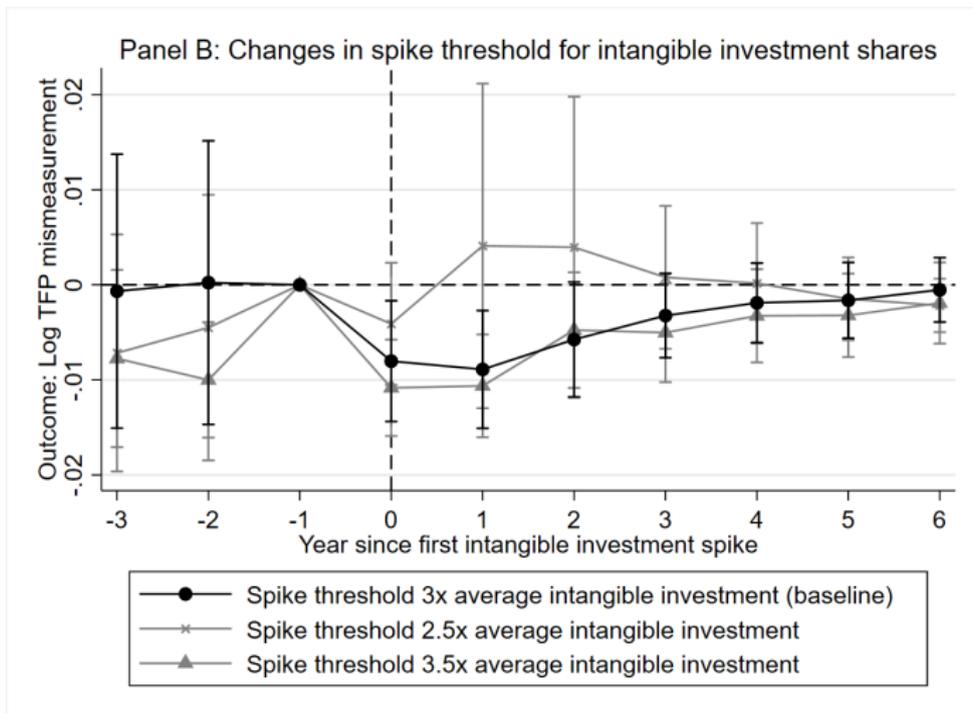
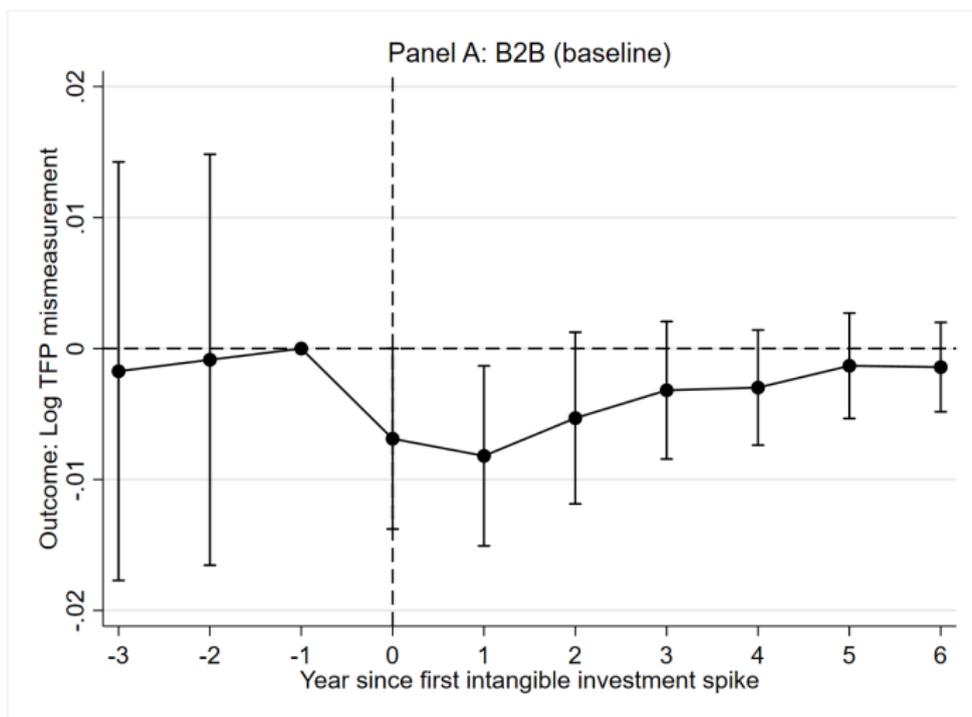# Intangible vs. tangible investment spikes ◀ Back

Dropping outliers ◂ Back

Changing the definition of a 'spike' ◂ Back

Panel A: Different normalization variables
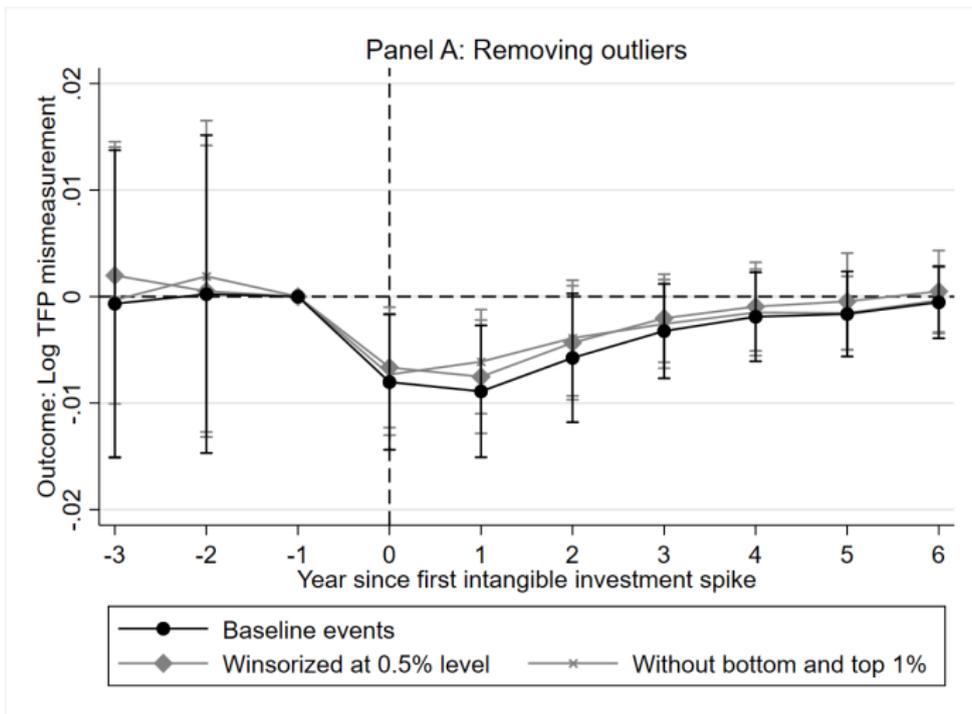
Other spike intensity ◂ Back

Panel B: Changes in spike threshold for intangible investment shares

Legend:
- Spike threshold 3x average intangible investment (baseline)
- Spike threshold 2.5x average intangible investment
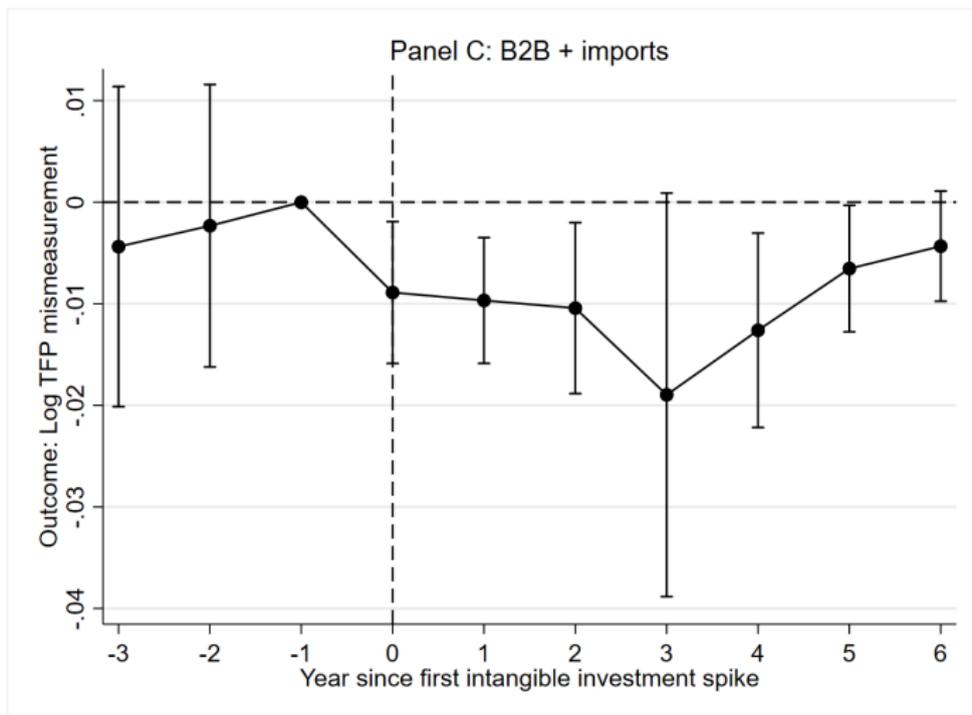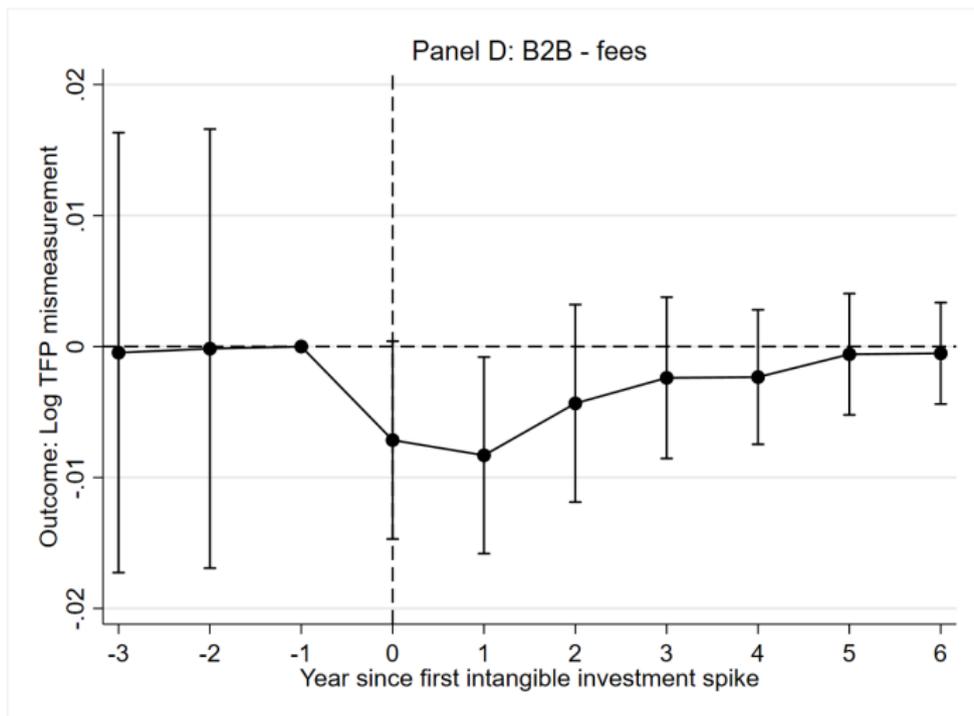- Spike threshold 3.5x average intangible investment

Other definitions of intangibles ◄ Back

Other definitions of intangibles ◂ Back

Other definitions of intangibles ◀ Back

Panel C: B2B + imports
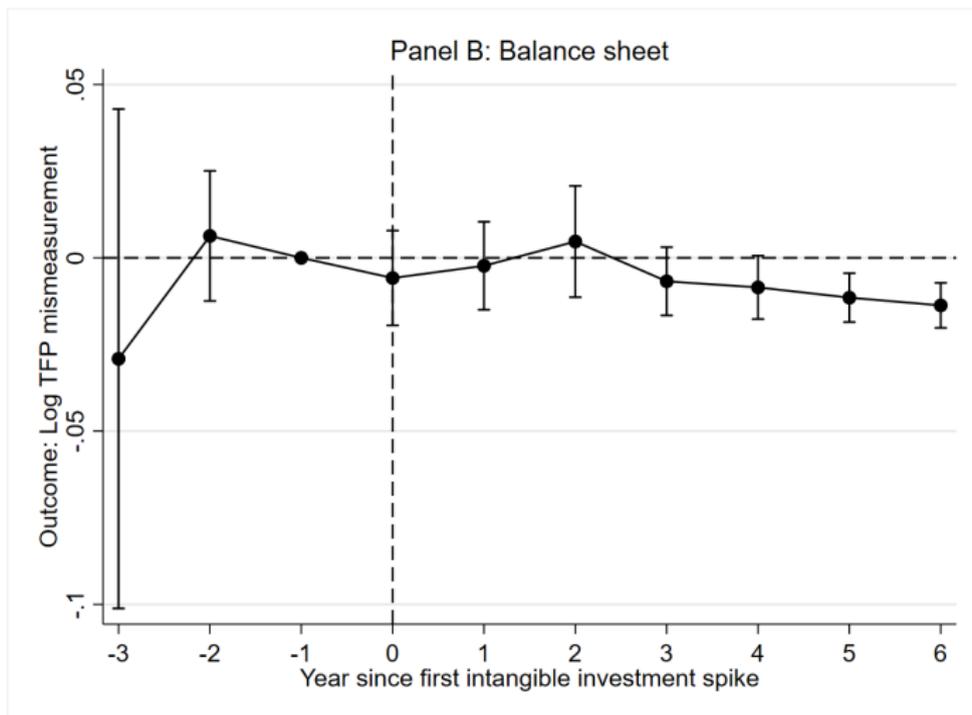
Other definitions of intangibles ◀ Back

Matching ◄ Back