Revisiting the Patent Advantage: Global Evidence on Firm Age, Size, and Productivity

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October 2023

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Motivation

- Innovation is a main driver of long-term economic growth.
- Recently, empirical evidence in the U.S. economy documenting: increasing concentration, decreasing business dynamism and a slowdown in productivity growth.
  - Akcigit & Ates (2019, 2021): slowdown in knowledge diffusion from leaders to laggards (one channel: anti-competitive use of patents).
  - Olmstead-Rumsey (2022): declining innovativeness of laggard firms (drop in patent quality).
- However, the international evidence on concentration of patenting among market leaders is still unclear...
- ... and the characteristics of patenting firms and the role of size mostly limited to evidence based on US listed firms or single-country studies.

Our Contribution

- A new look at the patenting behavior of firms using
  - Detailed Firm-Level Data: ORBIS
  - Detailed Patent-Level Data: ORBIS IP
- Questions:
  1. What characterizes firms that patent (breakthrough innovations)?
  2. What are the (dynamic) effects of patenting and breakthrough innovations on sales, profits and productivity?
     - Results differ depending on firm size and age.
  3. What are the implications for aggregate productivity.

Literature

- Innovation and Growth: positive association between innovation, as measured by patenting activity, and economic growth. Acemoglu, Akcigit, Alp, Bloom and Kerr (2018); Akcigit and Kerr (2018).
- Technology Diffusion and Innovation: the role of patents in facilitating technology diffusion and knowledge spillovers. Aghion et al (2021), Akcigit and Ates (2019), Akcigit et al (2018), Bloom et al (2020), Olmstead-Rumsey (2022), Berkes, Manysheva and Mestieri (2022).
- Firm Dynamics and Patenting: Farre-Mensa, Hegde and Ljungqvist (2020) review.

Literature

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- Firm Dynamics and Patenting: Farre-Mensa, Hegde and Ljungqvist (2020) review.
- However, recent concerns about the potential negative effects of patents on innovation and growth: the importance of patent quality and firm size.

Literature

1. Patent Quality
   - Rather than patent counts, citations and novel approaches to measure patent value.
   - Kogan et al (2020) (U.S. listed) use event studies to estimate the excess stock market return realized on the grant date of U.S. patents assigned to public firms.
   - Kline et al (2019) (1st-time filers 9,000s U.S. firms) how patent rents are shared at innovative firms (top distribution of workers).

2. Firm Size
   - Argente et al (2022) (U.S. + retail products): as firm size increases, patent filings are less reflective of innovation in the market and are more likely to be used to deter competition.
   - Arora, Cohen, Lee and Sebastian (2023) (U.S. listed): average invention value rises with size while the average invention quality declines: larger firms superior ability to extract value through greater commercialization capabilities.
   - Braguinsky, Choi, Ding, Jo and Kim (2023) (U.S. Census): mega firms play an increasingly important role in generating new technological trajectories in recent years.

Outline

1. Description of World patents
2. Merge patents to firms
3. Description Patenting Firms
    3.1 Listed vs Private firms
    3.2 Age profiles
    3.3 Concentration
4. Patent Premia Results
5. Dynamic Effects
6. Aggregate Implications

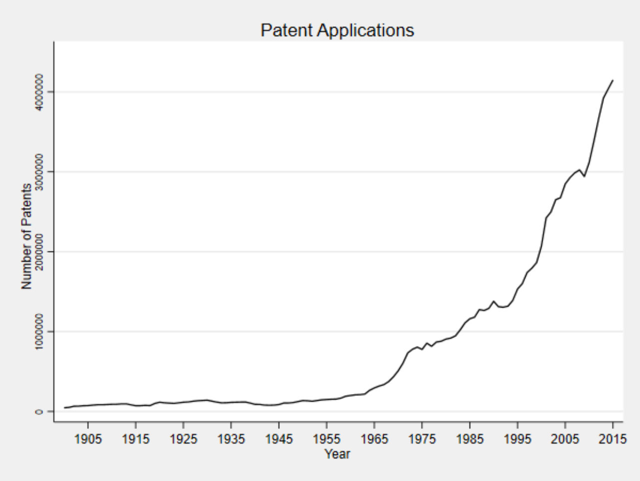
Data Sources

- Patents – Orbis IP (Moody's Bureau van Dijk)
  - 135 million patents sourced from POs around the globe.
  - It gives access to more than 80 million full text documents from 109 countries.
- Orbis (Financials) Global Database (Moody's Bureau van Dijk)
  - Standardized balance sheet and income statement information on 300 million companies (public and private) in more than 109 countries
  - Annual frequency: 1980's – 2018
- We match patents to firms using the "bridge" provided by BvD. Data Match

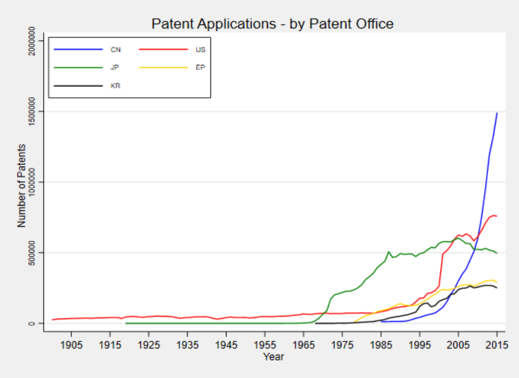
World Patenting Dynamics

- Over 4 million annual applications, driven by key main players. ▸ Online ▸ Grants ▸ Util.

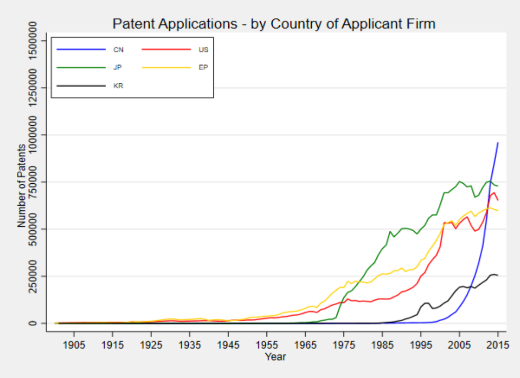
Figure: Number of Patent Applications by Application Year



Patent Applications: Regional Differences



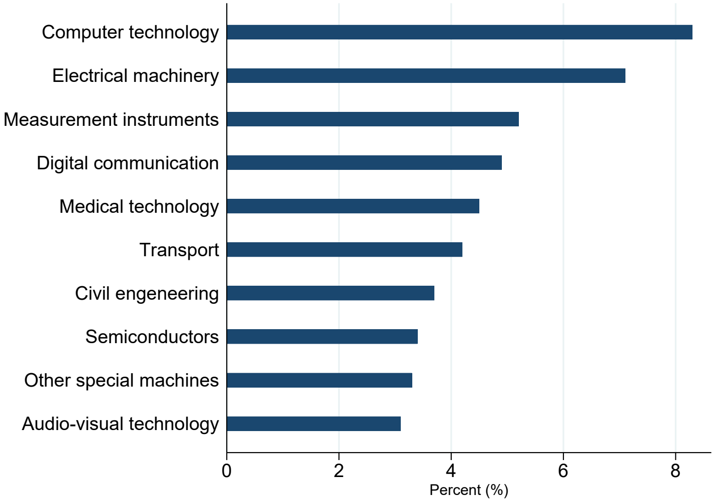
Applications in Big-5 PO



Applications by Firm Location

- Increasing importance of patent applications by foreign firms (e.g., USPTO acting like focal point with less than 50% domestic filings)

Patent Applications: by Top Tech Classes



- Top-10 tech classes account for almost 50% of patents (2010-20 avg.)
- Considerable cross-country variation

- CN—machine tools
- US—computer very high (14%), and semiconductors in top 5.
- EU—computers come in #4, (electrical machinery #1 and medical #2)
- JP—electrical machinery #1, furniture and games #2.
- KR—semiconductors #3

Breakthrough Patents

- The impact of patents is extremely asymmetric
  - Most have (close to) no economic value
  - A few are almost priceless

- We construct three measures of BT patents:
  1. Baseline: Fixed Effects Approach
  2. Kerr (2010): Top 1% of forward citations or Top 1% of ratio between forward and backward citations (adjusted by technological class).
  3. Truncation correction on both the forward and backward citation numbers using the Hall, Jaffe and Trajtenberg approach suggested by Lerner and Seru (2021)

Extensions

Breakthrough - Baseline - Fixed Effects

- First, we regress forward citations and ratio of forward citations over backward citations for some patent p on few controls and multiple FEs (year of application – t –, patent office – o –, WIPO tech field – f –):

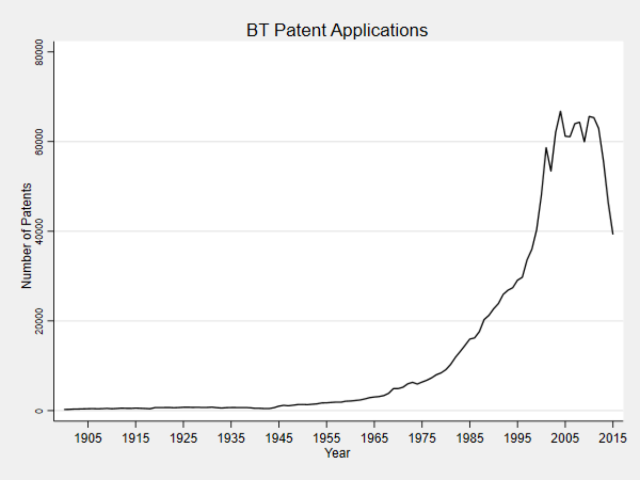
$$\ln\left(1 + \mathrm{Citations}_{poft}\right) = \lambda_t + \lambda_o + \lambda_f + \Gamma' X_{poft} + \varepsilon^{C}_{poft}$$
$$\ln\left(1 + \mathrm{Ratio}_{poft}\right) = \lambda_t + \lambda_o + \lambda_f + \Gamma' X_{poft} + \varepsilon^{R}_{poft}$$

  and we extract the residuals $\hat{\varepsilon}^{C}_{poft}$ and $\hat{\varepsilon}^{R}_{poft}$, computing their distributions.

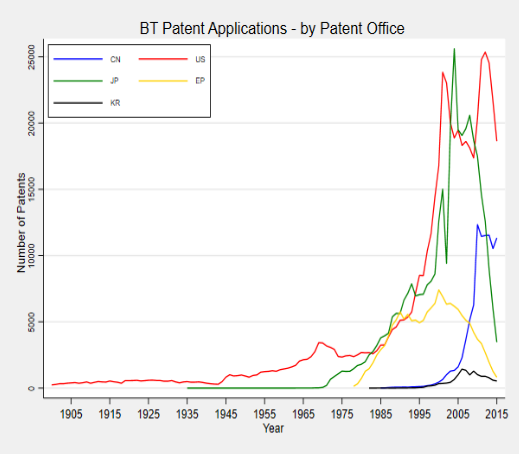
- Then, for each patent in each field, we check
  - if that patent's forward citation residuals belong to top 1% of the citation residuals across all patents in that field;
  - if that patent's ratio residuals belong to top 1% of the ratio residuals across all patents in that field;

  If either of these conditional statements are verified, a patent is deemed to be a breakthrough patent.

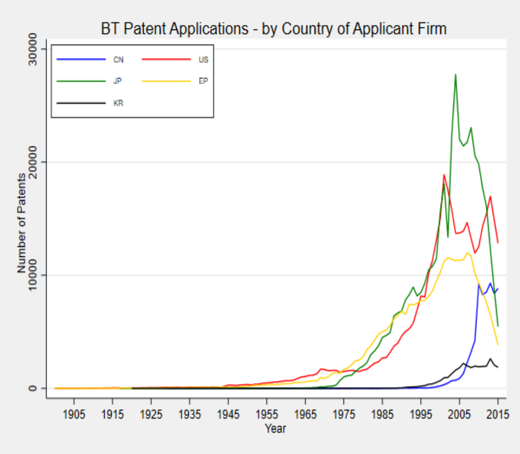
Breakthrough Patent Applications



Breakthrough Patents: Regional Differences



Applications in Big-5 PO



Applications by Firm Location

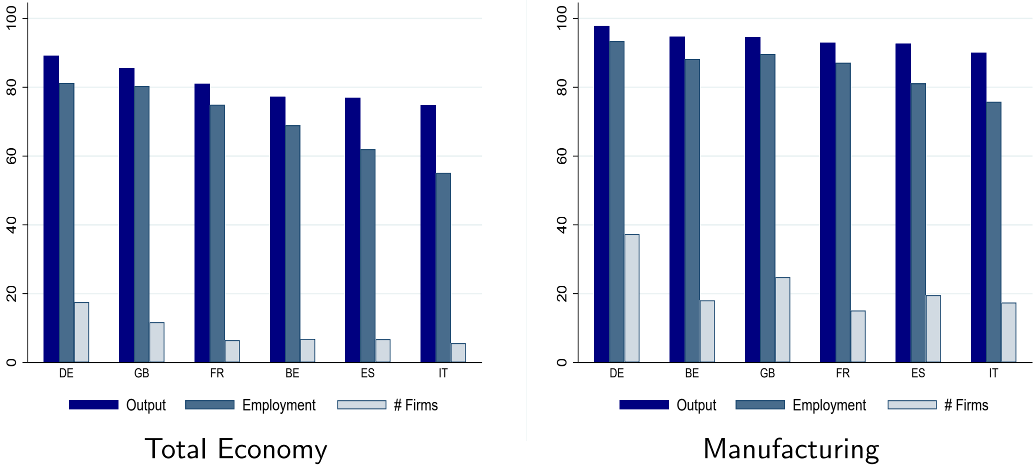
- BT patents mostly filed at USPTO. . . also by firms from other locations

Patent and Firm Coverage

- Sample of 19 countries (cover 95% of global patents): AU, BE, BR, CA, CH, CL, CN, DE, ES, FR, GB, IL, IN, IT, JP, KR, MX, RU, US.
- Matched firm-patents:
  1. FULL SAMPLE: 20,006,874 firms of which 2% patent.
  2. FINAL SAMPLE (+10 EMPL & Basic cleaning): 4,488,885 firms of which 6% patent.
- Our final sample of matched patent-firms covers 60% of the total Orbis-IP firms that patent and 40% of global patents.

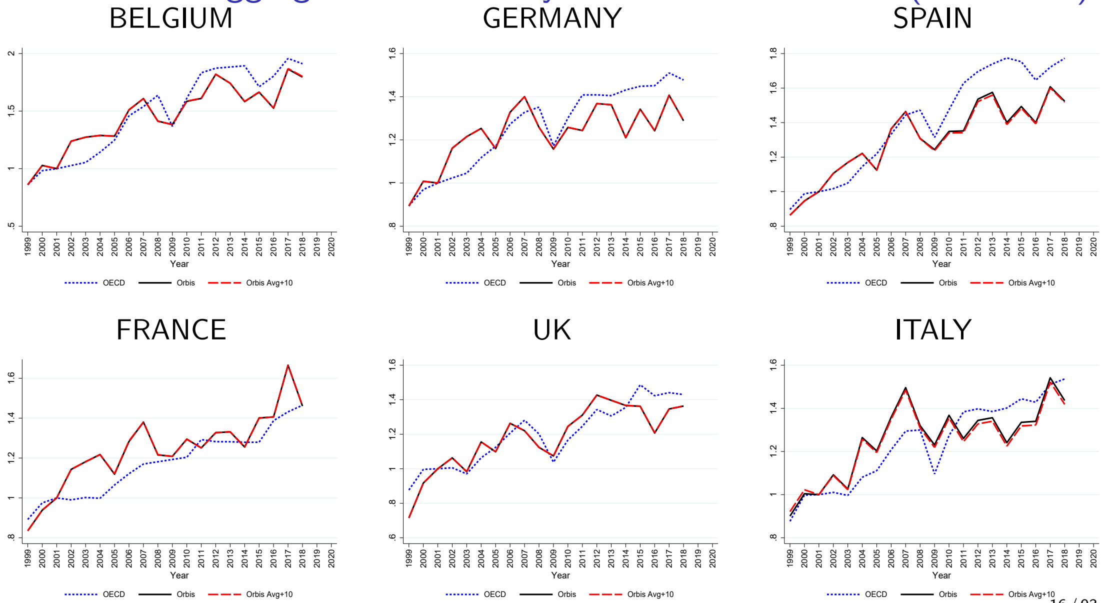
Importance of +10 Employee Sample (Official Data)

- Share of +10 empl. sample in total according to official OECD data (average 1999-2020)



- Less than 20% of firms account for over 70% of output and over 90% of manufacturing output. Aggregate productivity shifts will be explained by this sample.

OECD and Orbis Aggregate Productivity: MANUFACTURING (base 2001)



OECD and Orbis Aggregate Productivity: ECONOMY (base 2001)

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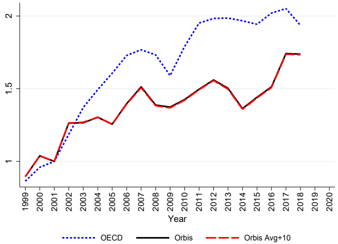

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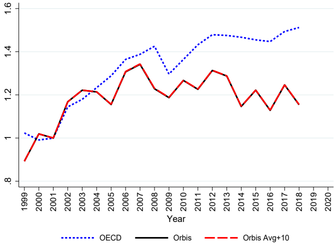

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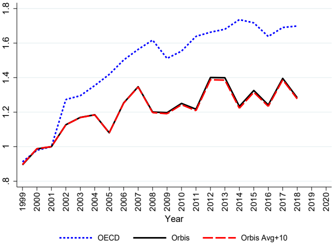

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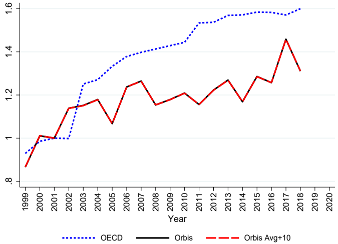

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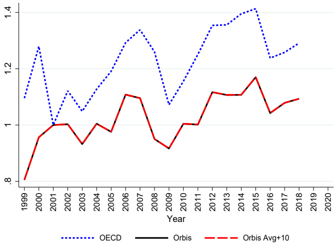

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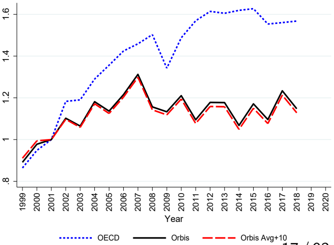
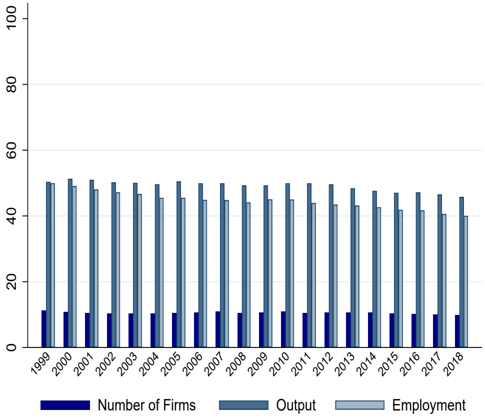
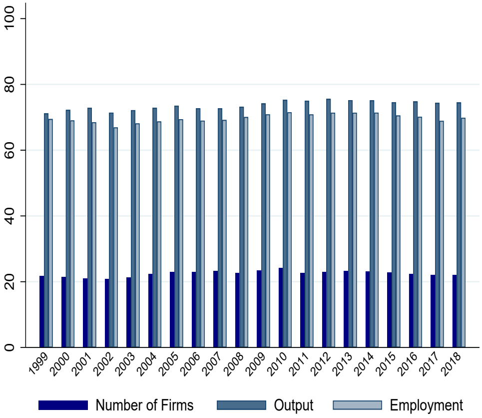


Share of Patenting Firms

- Contribution of patenting firms to aggreage outcomes (+10empl sample).



Total Economy

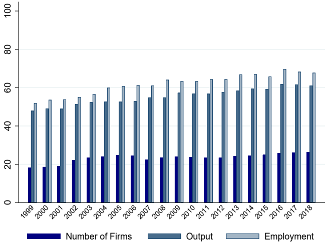


Manufacturing

- Contribution stable over time (plot the average). 50% in total economy and over 70% in manufacturing. Heterogeneity across countries (appendix if at all)

Share of Patenting firms: MANUFACTURING

BELGIUM



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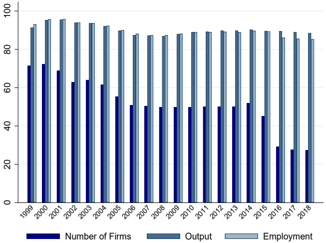

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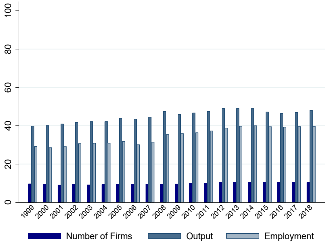

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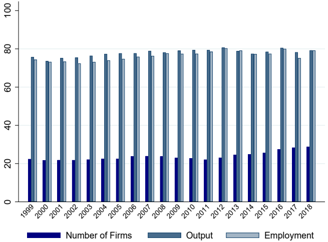

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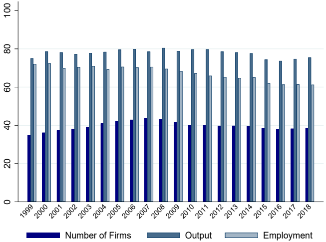

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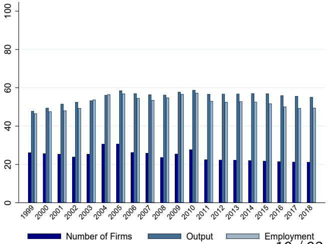
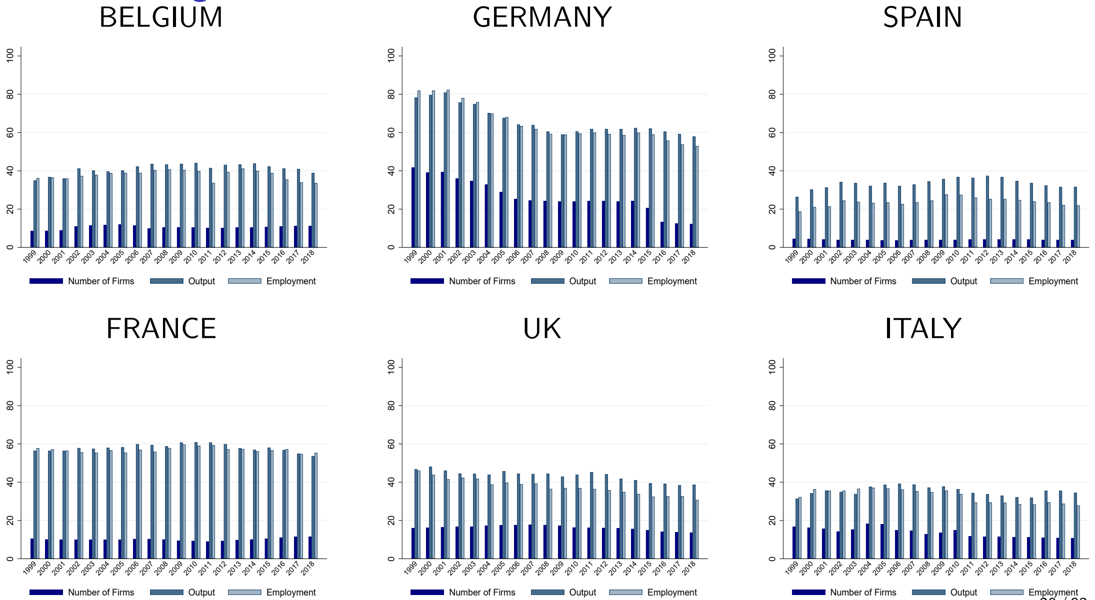
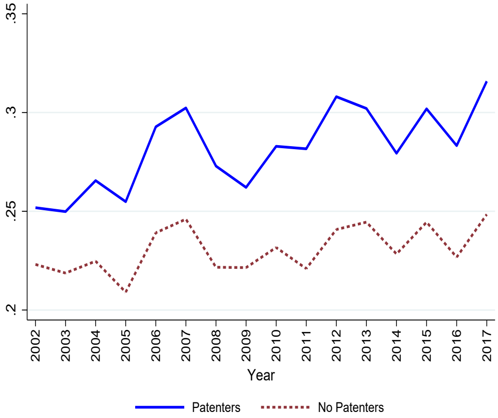


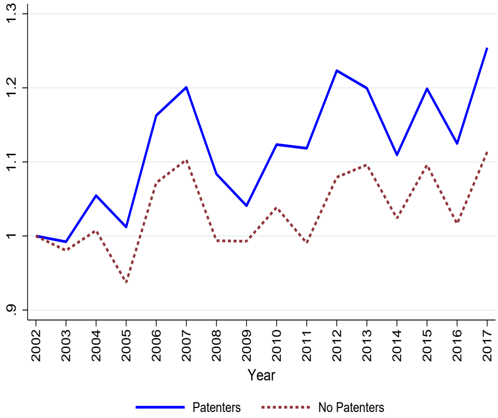
Share of Patenting firms: TOTAL



Labor Productivity of Patenting and Non-Patenting Firms



Level

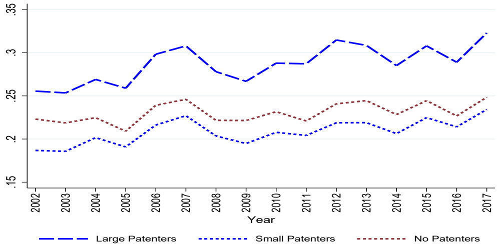


Growth

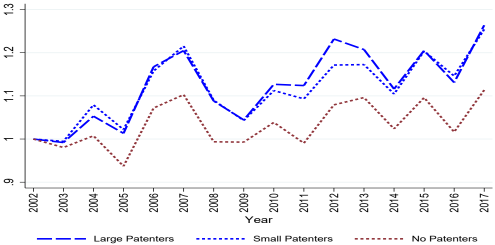
- Labor productivity of patenters higher than non-patenters. Higher growth of patenters and gap increased after GFC.)

Labor Productivity of Patenting Firms by Type

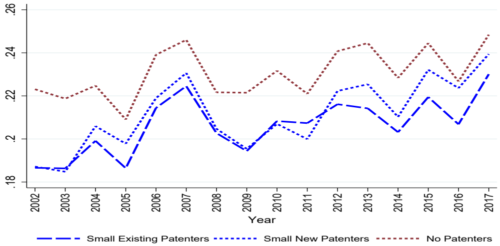
Large vs Small: Level

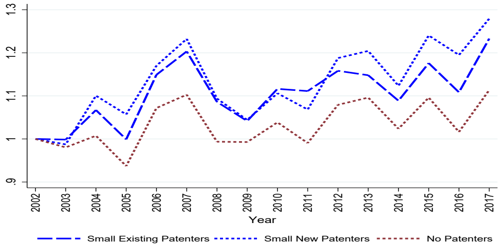


Growth



Within Small: Existing vs New Patenters



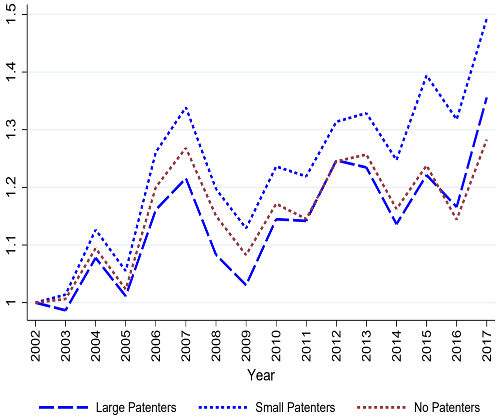


- Labor productivity growth of small patenters similar to that of large patenters. New small

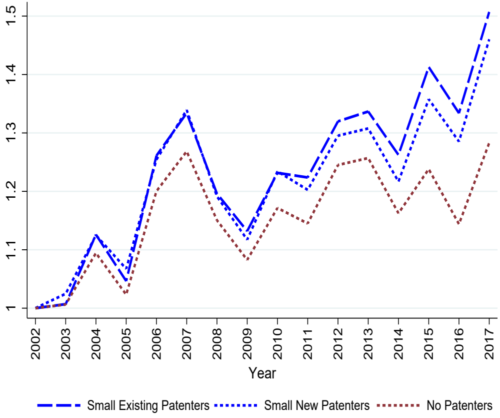
Points until here:

- Important contribution of the +10 employee sample to total so we can use for aggregate implications.
- Orbis+10 very good coverage. I dont show because ratios greater than 1.
- In terms of productivity trends, very good for manufacturing (similar to OCED) and we underestimate the Total Economy.
- The share of patenting firms to output and employment has slightly decreased in the Total Economy and is roughly fixed in manufacturing, over 70%. the drop for total seems to be driven by Germany I wouldn make much of it because composition of German sample changed over time.
- Labot productivity of patenters higher and grew more than that of non-patenters.
- Among patenters labor productivity gorwth of small and large firms almost identical.
- Within small patenters it is the new ones that grew faster.

Manufacturing slightly different



Growth



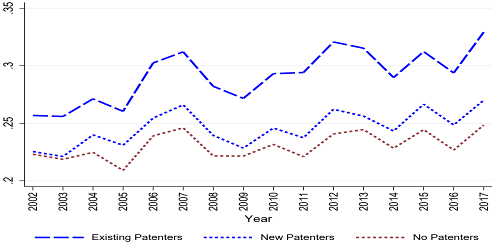
Growth

- Small patenters grew faster than large and no patenters. Within small patenters almost no difference between existing and new patenters.

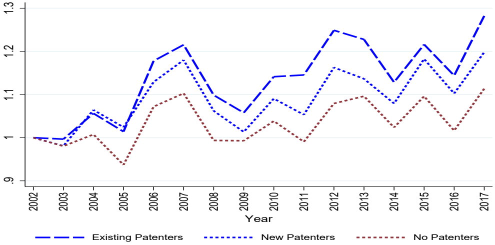
Labor Productivity of Patenting Firms by Type

New vs Existing

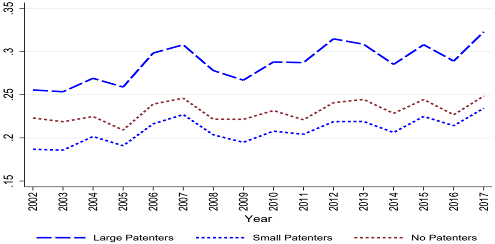
Level

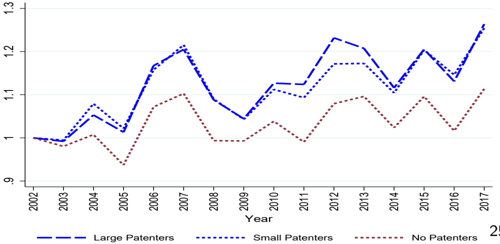


Growth

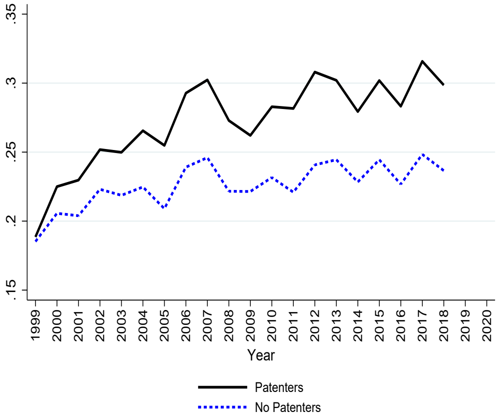


Large vs Small

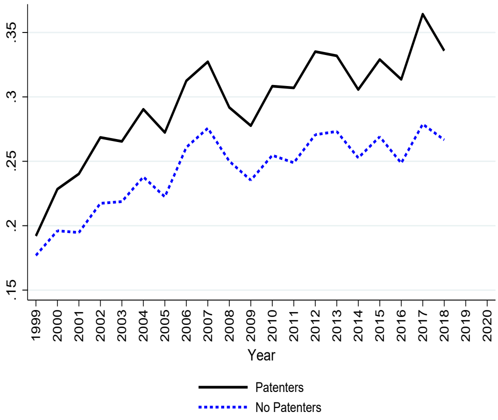




Labor Productivity of Patenting and Non-Patenting Firms



Total Economy



Manufacturing

- Labor productivity of patenters higher than non-patenters. Heterogeneity across countries, shows for ES and UK but not so clear in the rest. (we can't keep track of all countries)

Labor Productivity of Patenting and Non-Patenting Firms: MANUF

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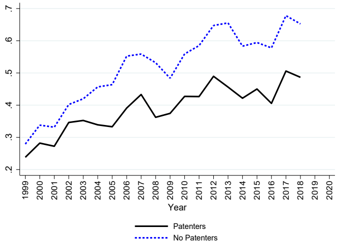

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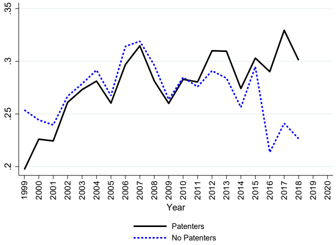

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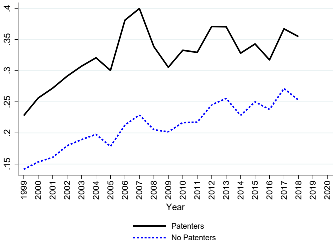

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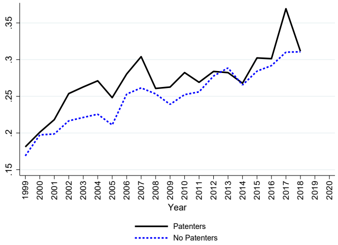

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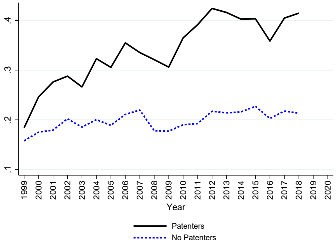

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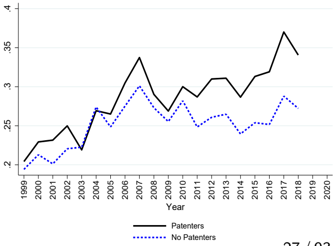
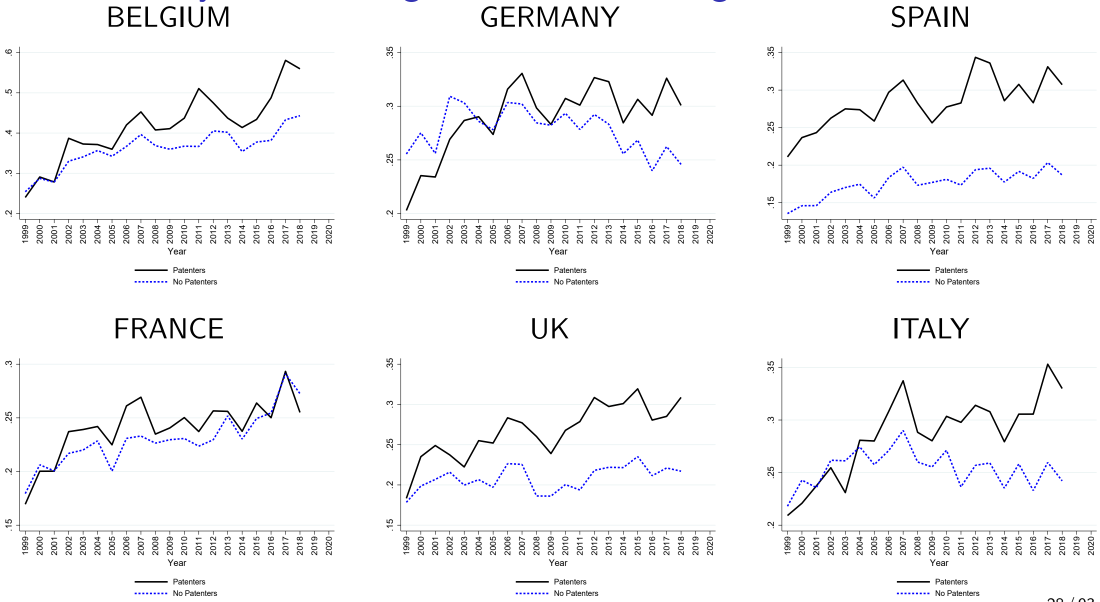
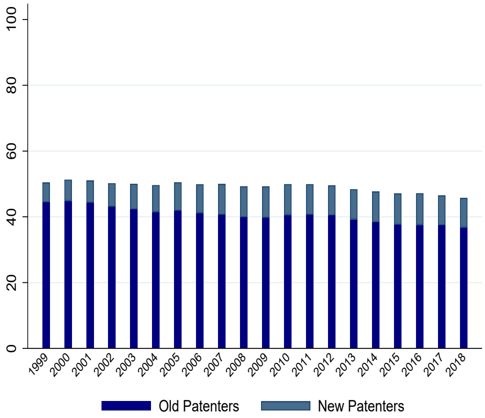


Labor Productivity of Patenting and Non-Patenting Firms: TOTAL

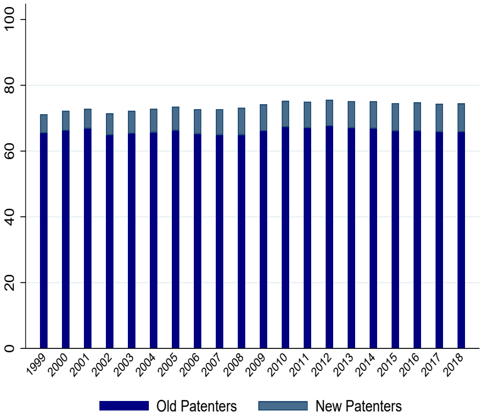


Contribution of Existing and New Patenters to Output

- New patenter: filed for the first time in the 2000s



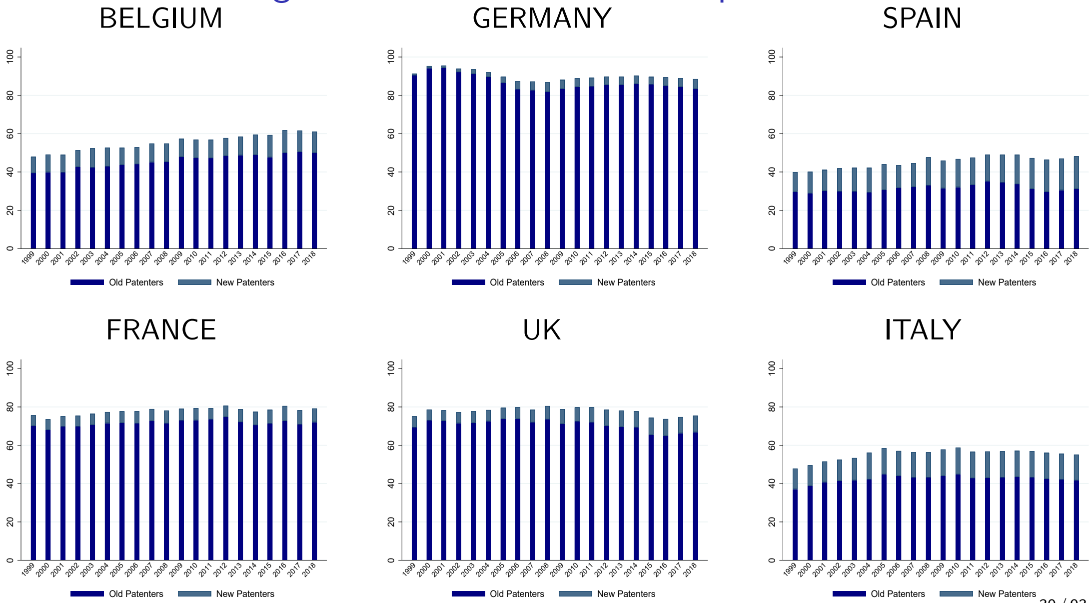
Total Economy



Manufacturing

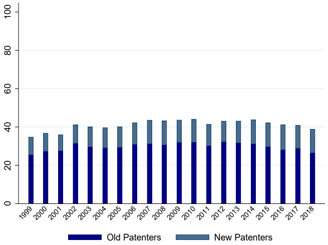
- Contribution of new patenters to output has increased over time.
- New patenters contribute little to aggregate output but notice small number.

Contribution of Existing and New Patenters to Output: MANUF



Contribution of Existing and New Patenters to Output:: TOTAL

BELGIUM



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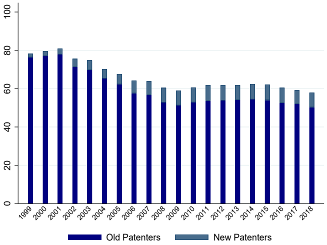
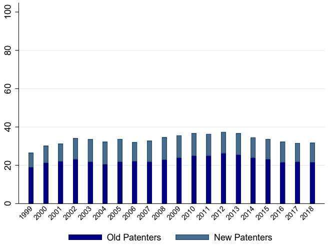


SPAIN



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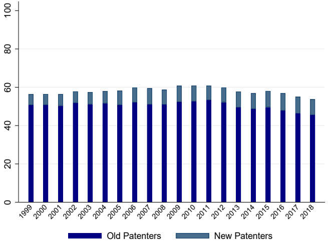

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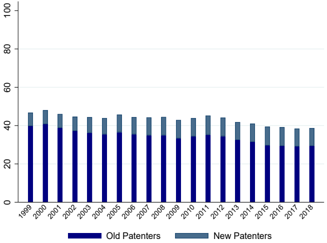

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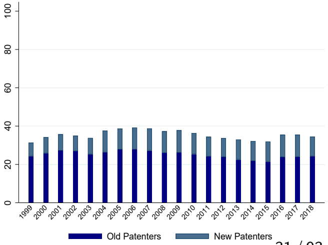
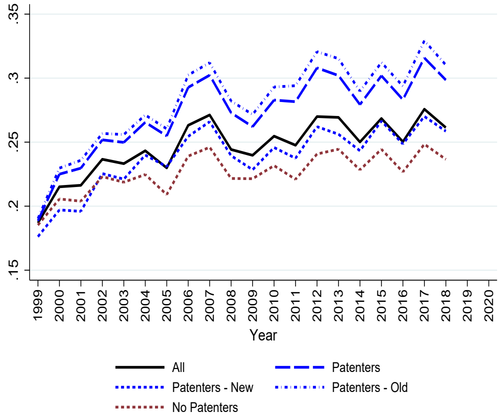
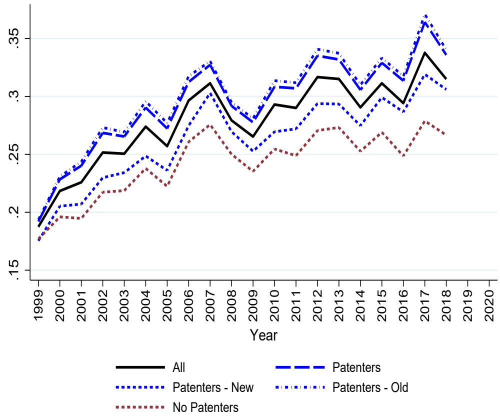


LP of Existing and New Patenters



Total Economy

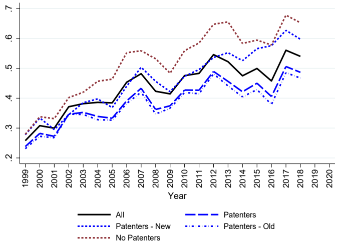


Manufacturing

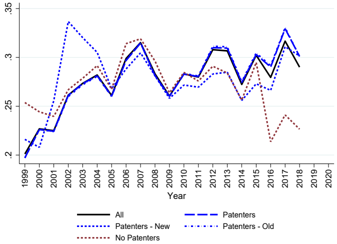
- LP of existing has increased while the non-patenters has flattened since GFC.
- New patenters above the non-patenters but below the existing patenters. Heterogeneity across countries (appendix if at all)

LP of Existing and New Patenters: MANUF

BELGIUM



GERMANY



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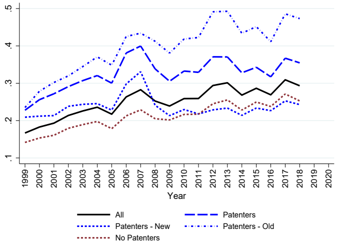

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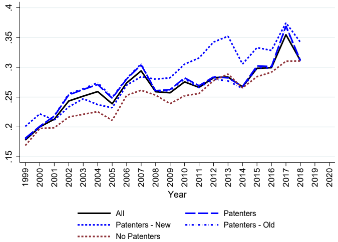

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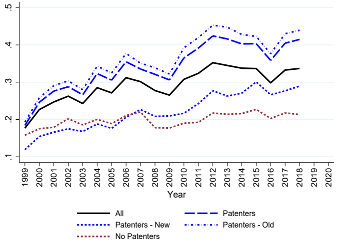

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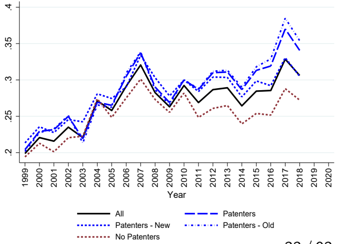
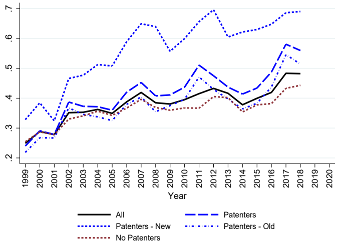


LP of Existing and New Patenters: TOTAL

BELGIUM



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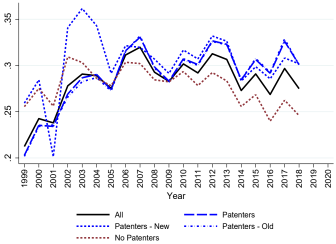

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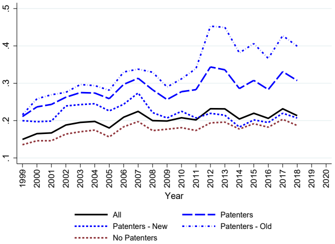

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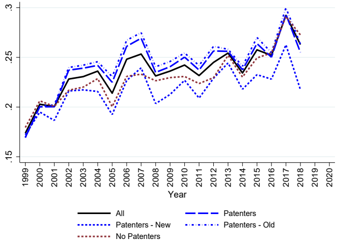

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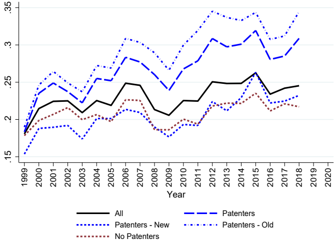

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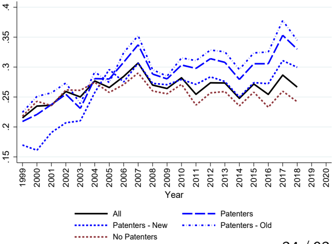
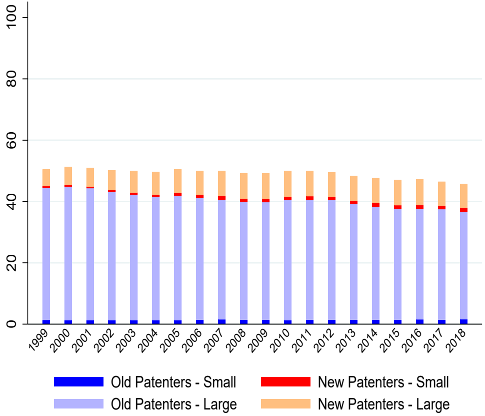
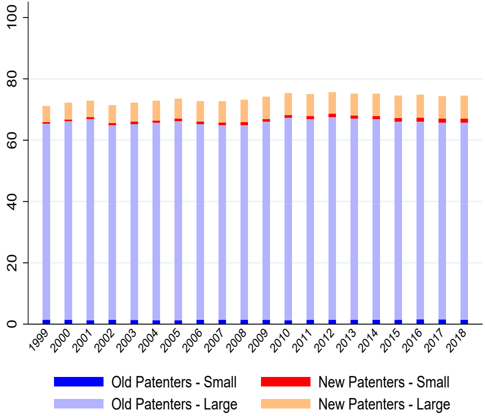


Contribution of Existing and New Patenters by SIZE to Output

- Small: if market share three years prior to filing below 90th percentile



Total Economy

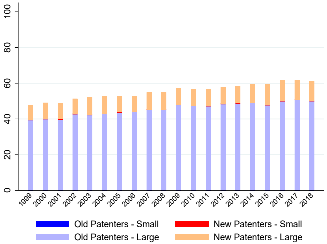


Manufacturing

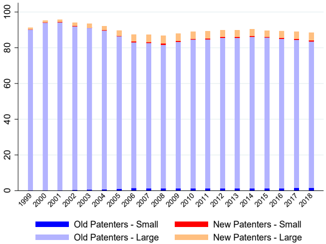
- Contribution stable over time (plot the average).
- Small patenters contribute little. Heterogeneity across countries (appendix if at

Contribution of Existing and New Patenters by SIZE to Output: MANUF

BELGIUM



GERMANY



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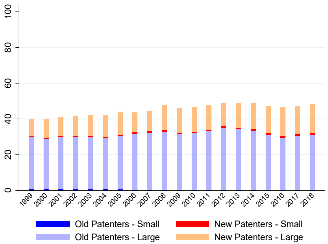

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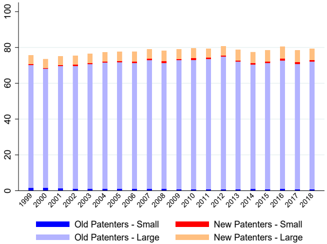

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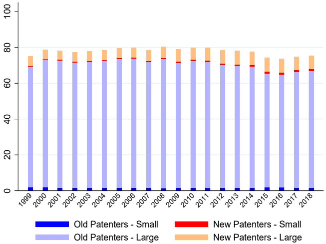

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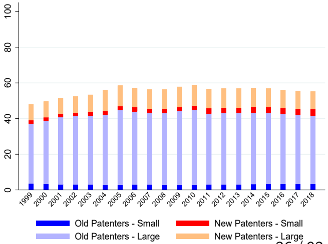
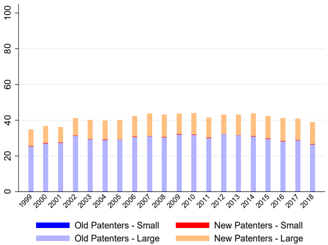


Contribution of Existing and New Patenters by SIZE to Output: TOTAL

BELGIUM



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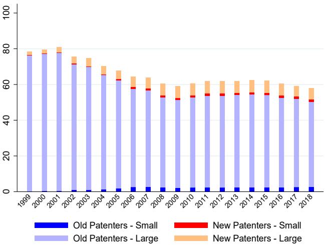

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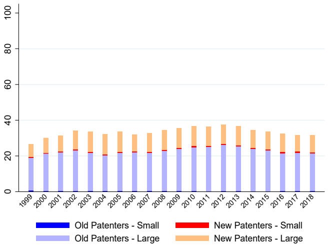

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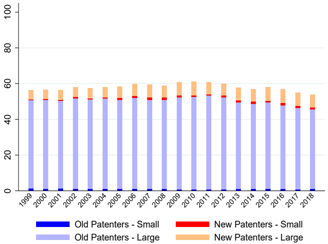

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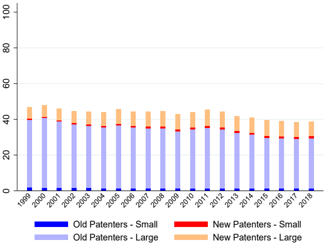

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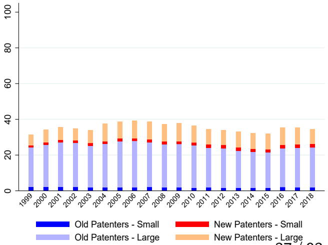
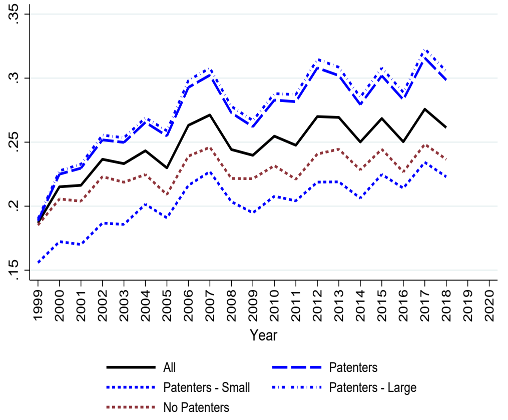
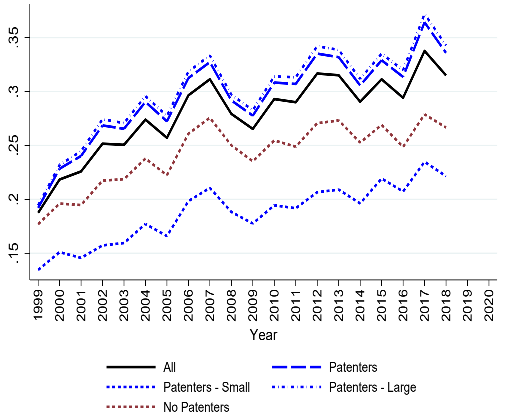


LP of Patenters by SIZE



Total Economy

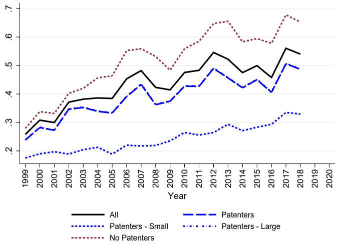


Manufacturing

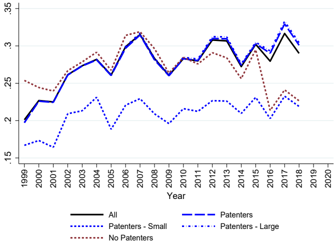
- LP of large patenters has increased.
- Small patenters below non-patenters but high growth. Heterogeneity across countries (appendix if at all)

LP of Patenters by SIZE: MANUF

BELGIUM



GERMANY



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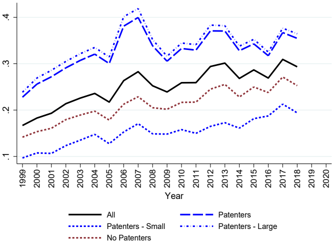

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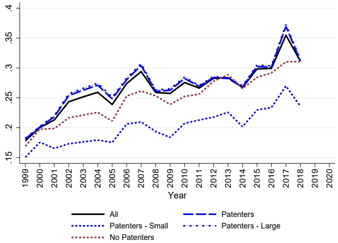

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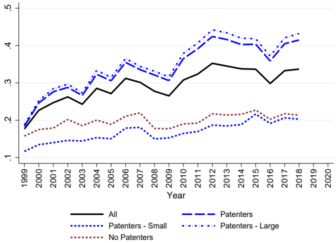

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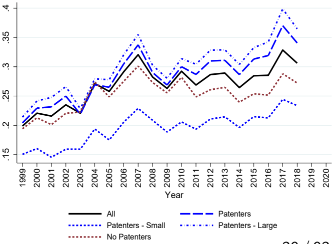
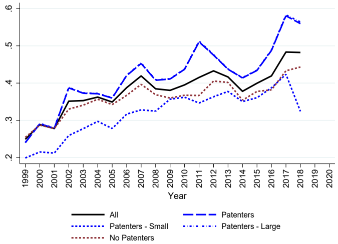


LP of Patenters by SIZE: TOTAL

BELGIUM



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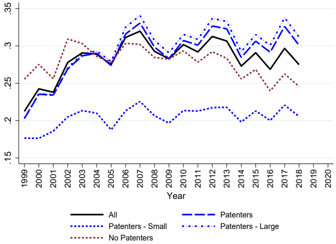

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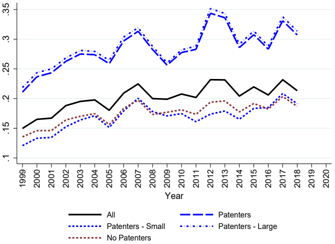

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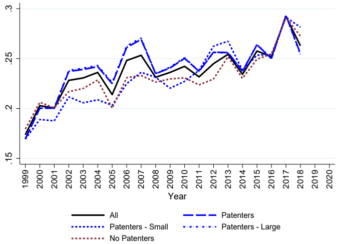

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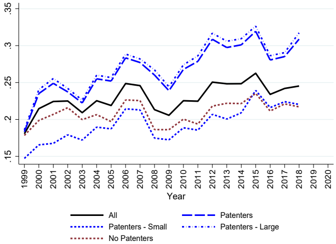

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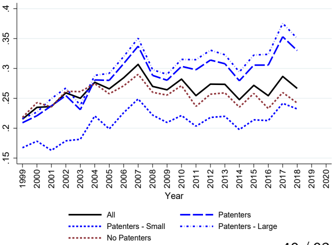
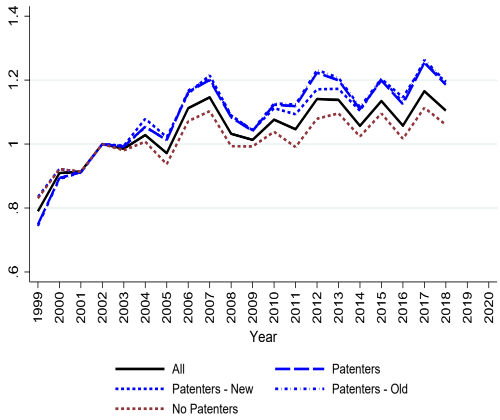
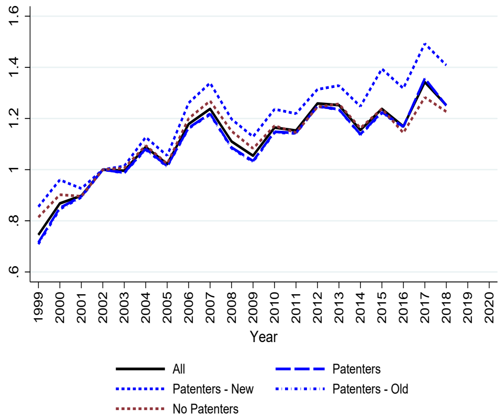


LP GROWTH (base 2002) of Existing and New Patenters by SIZE



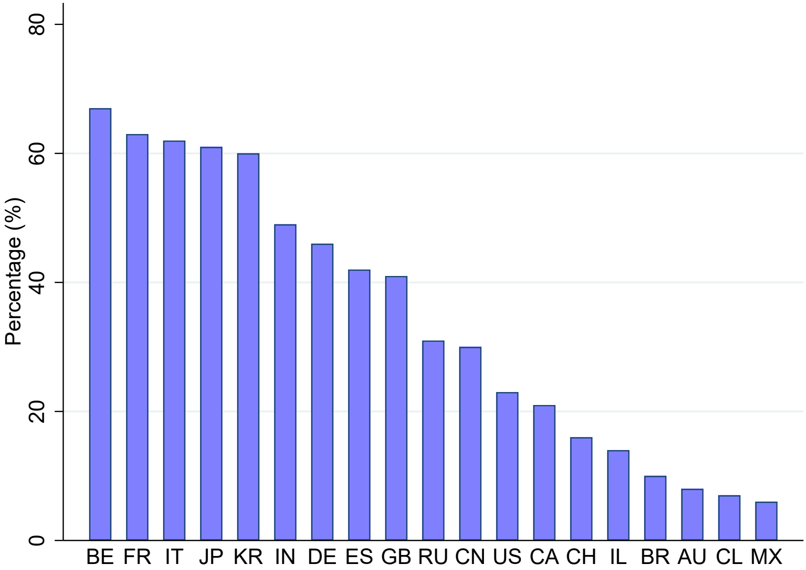
Total Economy



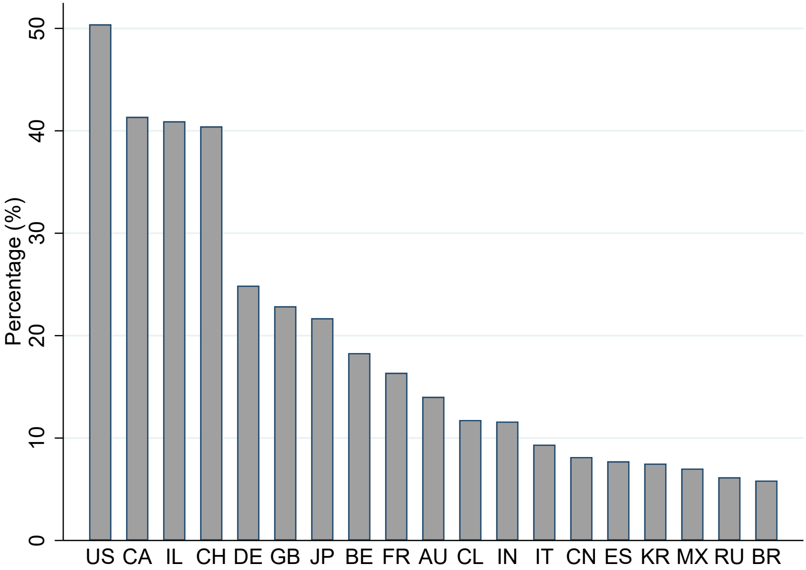
Manufacturing

- (check this slide and how it is constructed)

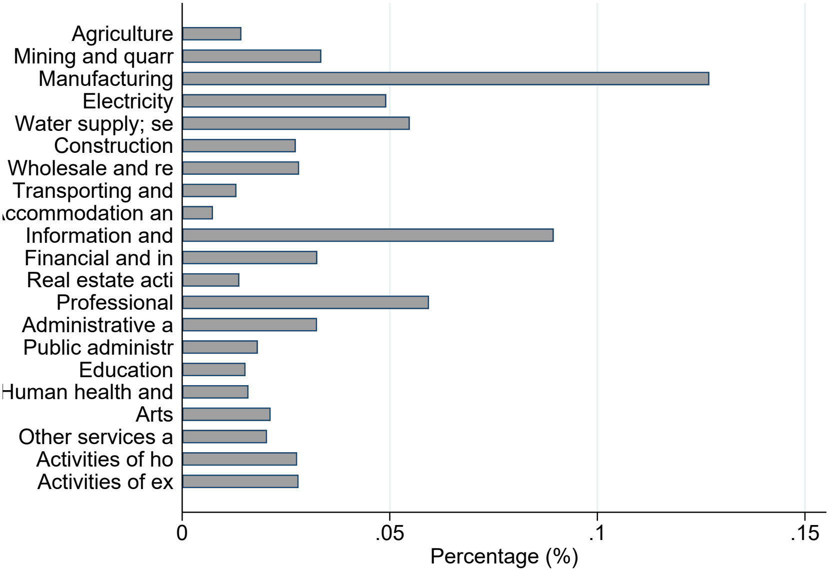
Patent Coverage by Country



Distribution of BT Patenting Firms in total Patenting Within Countries



Patenting Firms Distribution by Sector



Facts on Patenting and BT Patenting Firms

1. Listed vs Private
2. Age Profile
3. Concentration

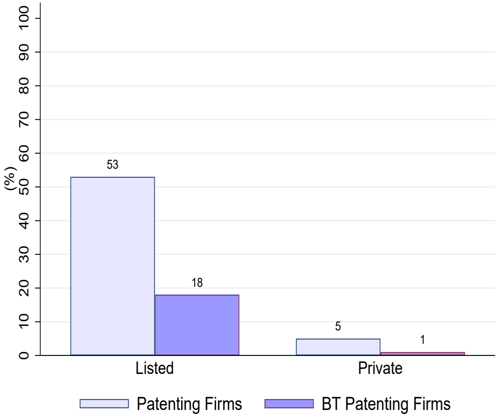
Facts on Patenting and BT Patenting Firms

1. Listed vs Private
2. Age Profile
3. Concentration

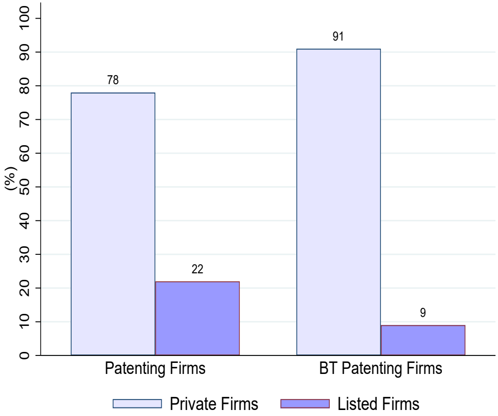
Listed vs Private

- Key advantage of the dataset is that it includes private firms. Only 1% of firms are listed (heterogeneity across countries).
- Patenting is a rare event among private firms:
  - Among private firms 5% patent and 1% patent BT.
  - Among listed firms 53% patent and 18% patent BT.
- However, the sample of patenting firms are dominated by private firms:
  - In our sample, 91% of the firms that patent are private.
  - And importantly, 78% of BT patenting firms are private.

Listed and Private firms



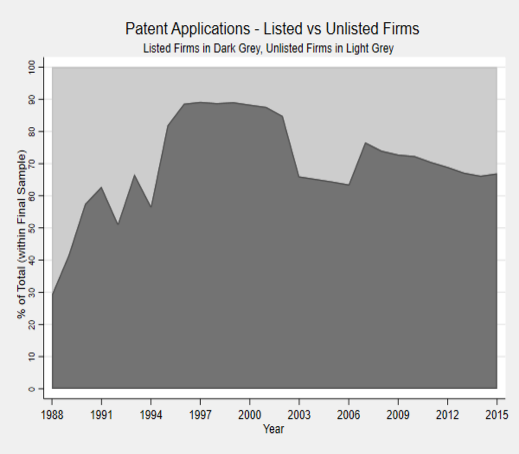
Total Sample

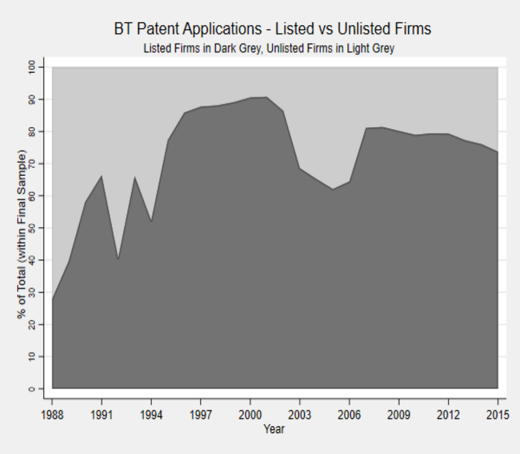


Patenting Sample

- In the full sample, 53% of listed firms patent and only 5% of private firms patent.
- In the patenting sample, 78% of firms are private and 91% of BT firms are private.

Quantitatively



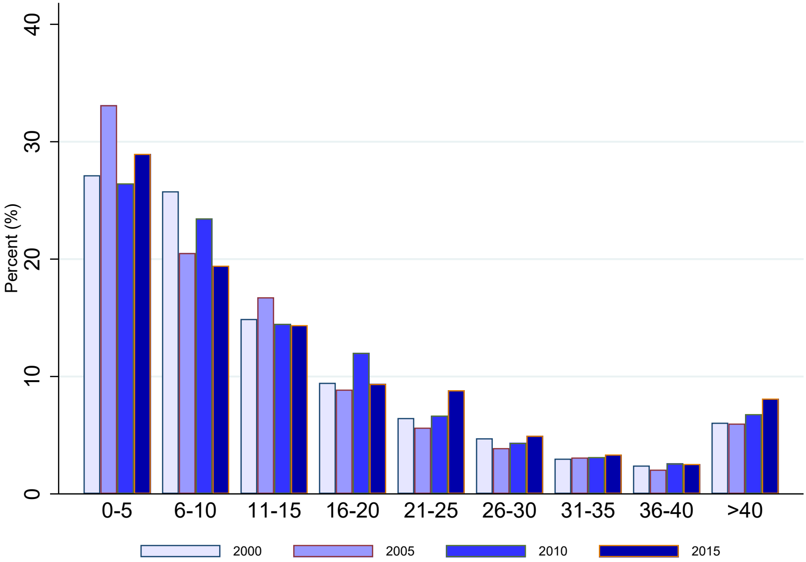


- Quantitatively: still the vast majority of patents (75%) done by listed firms.

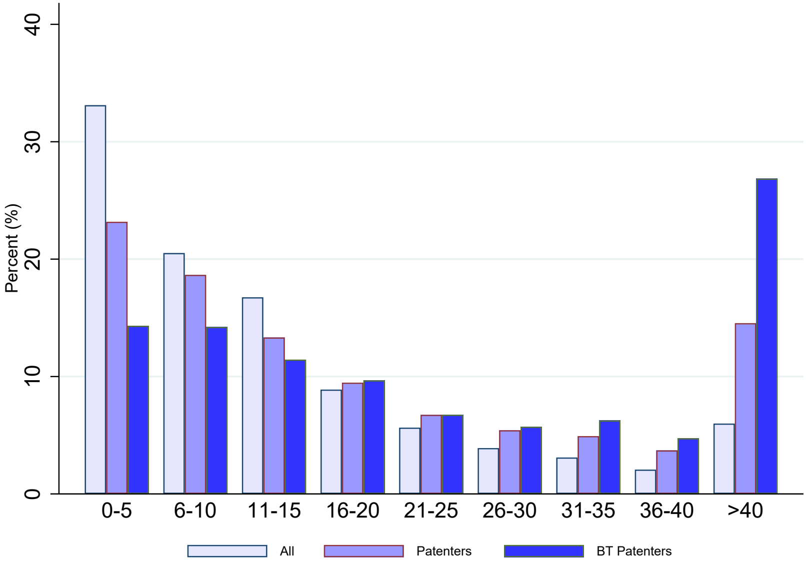
Facts on Patenting and BT Patenting Firms

1. Listed vs Private
2. Age Profile
3. Concentration

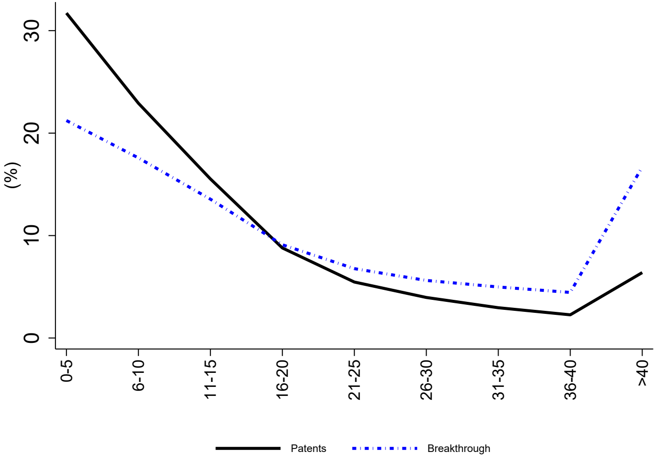
Firm Age Distribution from Different Data Cohorts



Firm Age Distribution of Ever Patenting Firms (2005 Cohort)



Firm Age at filing of first patent and first BT patent



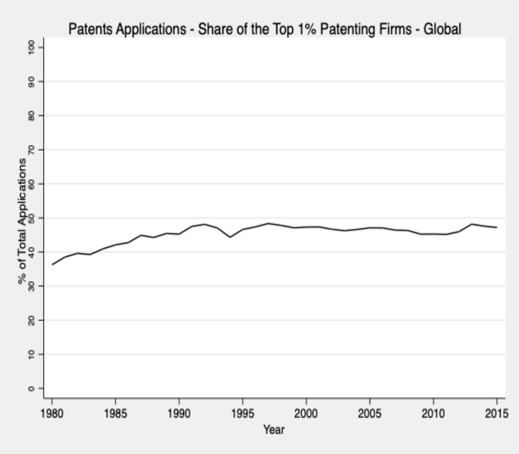
- (Most) innovative firms are so from the beginning
- But for some, BT patents come with age

Facts on Patenting and BT Patenting Firms

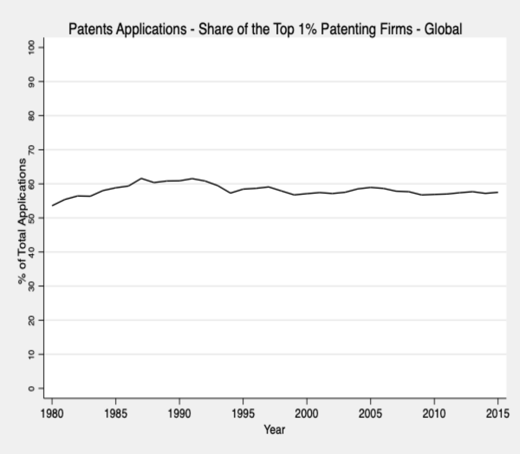
1. Listed vs Private
2. Age Profile
3. Concentration

Patent Concentration: Global

- Share of applied patents by the top 1% of innovating firms with the largest patent stocks.

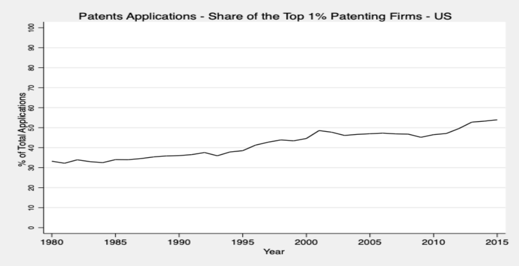


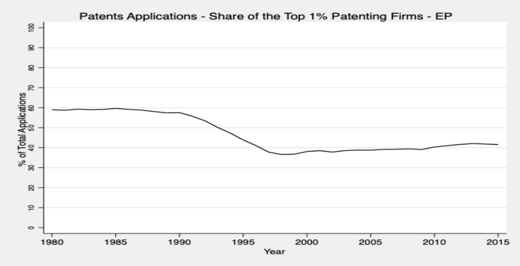
Full Sample

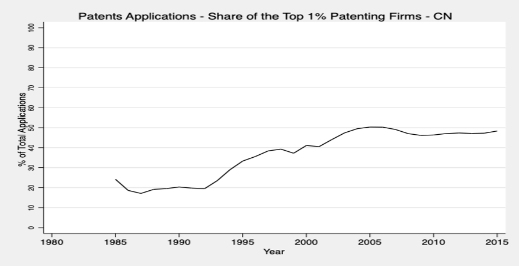


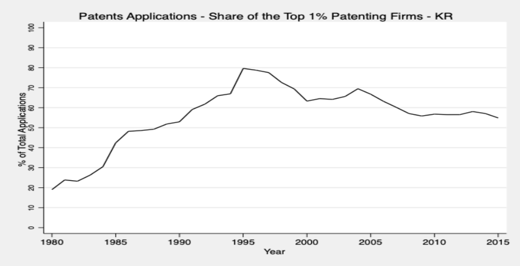
Matched Sample

Patent Concentration by Country



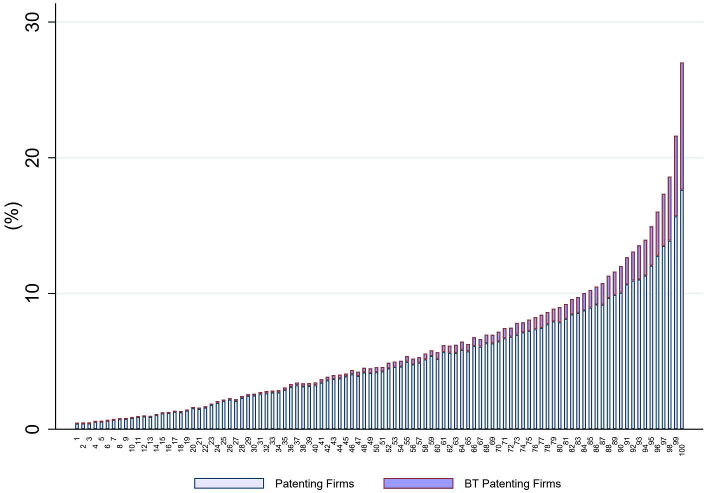






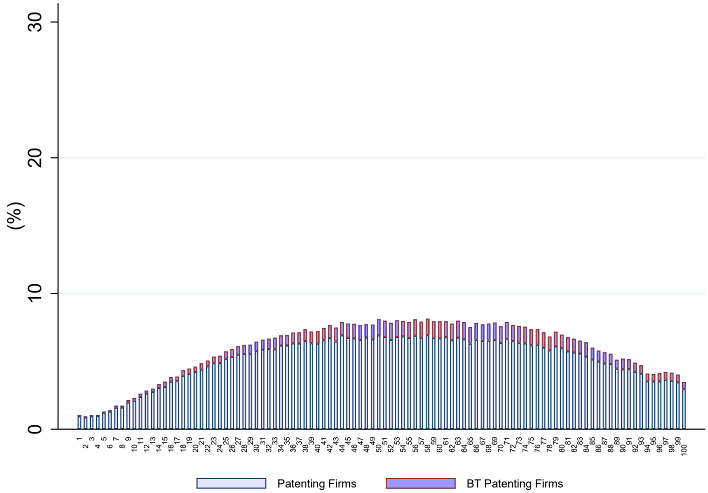
US evidence

Share of Patenting Firms Across Percentiles of Market Share Distribution



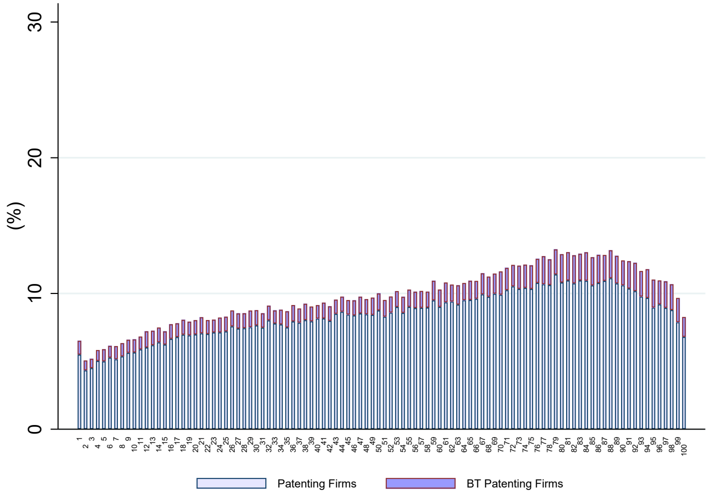
- Market share (ms_{it}): firm operating revenue in a given country-four digit sector-year.
- Average ms_{it} per firm $\rightarrow$ Distribution.
- Share of patenters larger among firms with higher average market shares.

Share of Patenting Firms Across Percentiles of Productivity Distribution



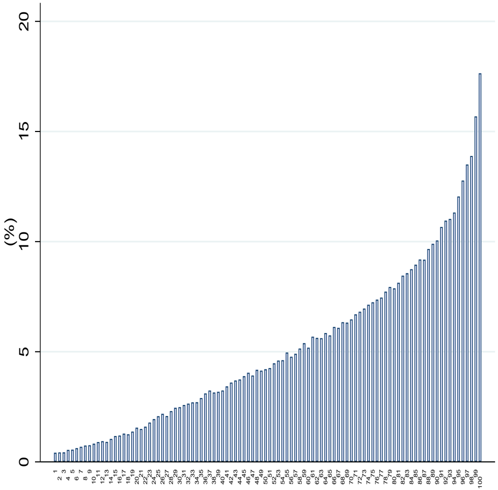
- Demeaned log Y/ EMPL (country-sec4)

Share of Patenting Firms Across Percentiles of TFP Distribution

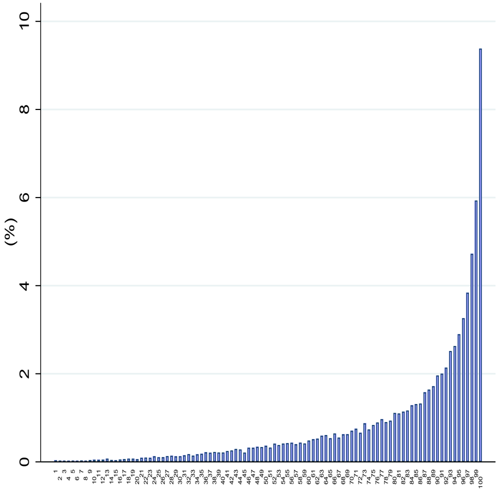


- Demeaned TFP (country-sec4)

Share of Patenting Firms Across Percentiles of Market Share Distribution

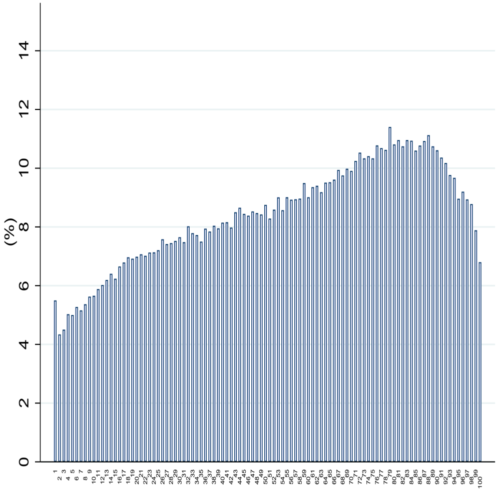


Patenters (but NO BT)

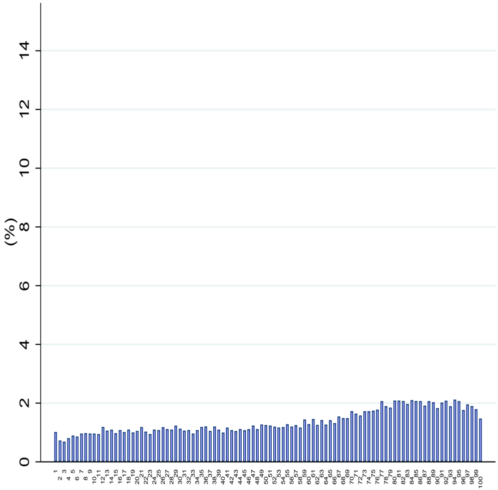


BT Patenters

Share of Patenting Firms Across Percentiles of TFP Distribution

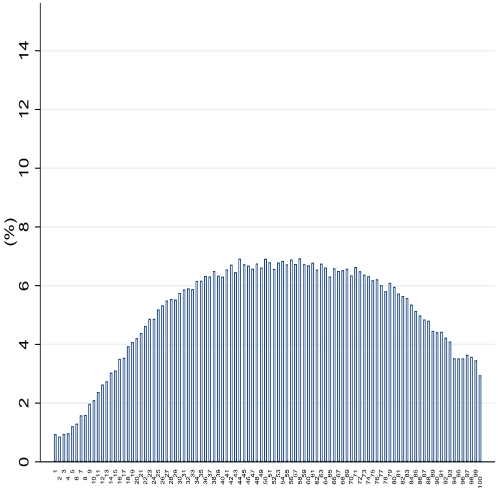


Patenters (but NO BT)

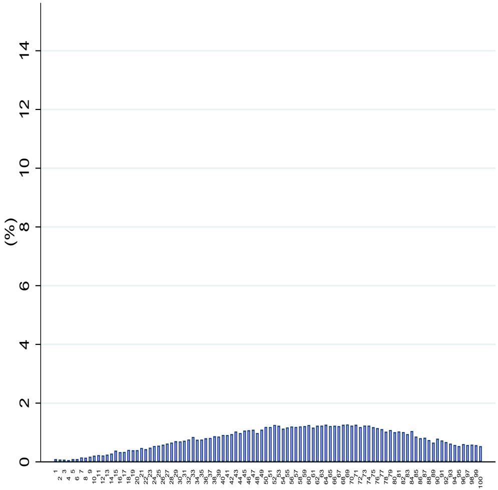


BT Patenters

Share of Patenting Firms Across Percentiles of Productivity Distribution



Patenters (but NO BT)



BT Patenters

Characterizing Patenting Firms (Cross-sectional Differences)

Patenting and BT Patenting Premia

- The first step is understanding what differentiates firms that patent and breakthrough patent from the rest.

- We run the following regressions:

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent_i) + \delta_{c,s4,t} + u_{it}$$

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent_i) + \beta_2 \mathbb{1}(BTPatent_i) + \delta_{c,s4,t} + u_{it}$$

- where y_{it} is the variable of interest: Output, Profits and Productivity.
- $\mathbb{1}(Patent_i)$ dummy equal one if the firm ever patented.
- $\mathbb{1}(BTPatent_i)$ dummy equal one if the firm ever patented BT.
- $\delta_{c,s4,t}$ refer to country, sector four-digit and year fixed effects.

Patent Premia Results

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent_i) + \beta_2 \mathbb{1}(BTPatent_i) + \delta_{c,s4,t} + u_{it}$$

	(1)	(2)	(3)	(4)	(5)	(6)
	$\log(Y)$	$\log(\Pi)$	$\log(Prod)$	$\log(Y)$	$\log(\Pi)$	$\log(Prod)$
$\mathbb{1}(Patent)$	1.003***	1.044***	0.256***	0.873***	0.928***	0.237***
	(0.004)	(0.004)	(0.002)	(0.004)	(0.004)	(0.002)
$\mathbb{1}(BTPatent)$				0.995***	0.893***	0.138***
				(0.011)	(0.012)	(0.005)
Age	0.020***	0.022***	0.002***	0.020***	0.021***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs.(million)	26	12.6	21.5	26	12.6	21.5
R^2	.51	.55	.57	.52	.55	.57

Patent and Size Premia

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent_i) \times \mathbb{1}(Size_i) + \beta_2 \mathbb{1}(Patent_i) + \beta_3 \mathbb{1}(Size_i) + \delta_{c,s4,t} + u_{it}$$

where:

- $\mathbb{1}(Patent_i)$: indicator patent firm.
- $\mathbb{1}(Size_i)$: indicator size variable based on average total assets.
- $\delta_{c,s4,t}$: country-sector4digit-year fixed effects.
- y_{it}:Output, Profits and Productivity.
- Size: Compute average market share by firm (country-sec4-year). Large if firm above the 90th percentile of the mean market share distribution. SizeCommon SizeContinuous

Patent and Size Premia Results

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent_i) \times \mathbb{1}(Size_i) + \beta_2 \mathbb{1}(Patent_i) + \beta_3 \mathbb{1}(Size_i) + \delta_{c,s4,t} + u_{it}$$

	(1) $\log(Y)$	(2) $\log(\Pi)$	(3) $\log(Prod)$
$\mathbb{1}(Patent) \times \mathbb{1}(Small)$	-0.001	0.257***	0.278***
	(0.007)	(0.009)	(0.004)
$\mathbb{1}(Patent)$	0.656***	0.553***	-0.059***
	(0.006)	(0.008)	(0.004)
Small	-2.348***	-2.379***	-0.906***
	(0.003)	(0.005)	(0.002)
Age	0.012***	0.013***	-0.001***
	(0.000)	(0.000)	(0.000)
Observations	26 million	12.6 million	21.5 million
R^2	.59	.61	.59

BT Patent and Size Premia Results

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(BTPatent_i) \times \mathbb{1}(Size_i) + \beta_2 \mathbb{1}(BTPatent_i) + \beta_3 \mathbb{1}(Size_i) + \delta_{c,s4,t} + u_{it}$$

	(1) $\log(Y)$	(2) $\log(\Pi)$	(3) $\log(Prod)$
$\mathbb{1}(BTPatent) \times \mathbb{1}(Small)$	-0.370***	-0.096***	0.074***
	(0.016)	(0.018)	(0.009)
$\mathbb{1}(BTPatent)$	0.760***	0.633***	0.024***
	(0.013)	(0.014)	(0.006)
Small	-2.324***	-2.086***	-0.612***
	(0.007)	(0.009)	(0.005)
Age	0.012***	0.013***	-0.001***
	(0.000)	(0.000)	(0.000)
Obs.	2,559,245	1,620,717	2,066,085
R^2	.58	.57	.53

Characterizing Patenting Firms (Intensive and Extensive Margins)

Intensive Margin: What is the effect of one extra patent?

- Y (output); Π (profits); Prod: Productivity

$$y_{it} = \beta_0 + \beta_1 \log(PatStock + 1)_{t-1} + \alpha_i + \delta_{c,s4,t} + u_{it}$$

	Patenting Firms			Patenting Firms (Excl. Acquisitions)		
	(1)	(2)	(3)	(4)	(5)	(6)
	$\log(Y)$	$\log(\Pi)$	$\log(Prod)$	$\log(Y)$	$\log(\Pi)$	$\log(Prod)$
$\log(PatStock + 1)_{t-1}$	0.051***	0.047***	0.001	0.055***	0.052***	0.006***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Observations	2,156,825	1,338,970	1,769,694	1,624,934	1,032,826	1,319,871
R^2	0.920	0.903	0.874	0.904	0.886	0.880
$FE : id$	✓	✓	✓	✓	✓	✓
$FE : cs4y$	✓	✓	✓	✓	✓	✓

Extensive Margin: Impact after first patent

- Y (output); Π (profits); Prod: Productivity

$$y_{it} = \beta_0 + \beta_1 \mathbb{1}(Patent)_{t-1} + \alpha_i + \delta_{c,s4,t} + u_{it}$$

	(1)	(2)	(3)
	$\log(Y)$	$\log(\Pi)$	$\log(Prod)$
$\mathbb{1}(Patent)_{t-1}$	0.057***	0.053***	0.008***
	(0.002)	(0.003)	(0.002)
Observations	2,156,825	1,338,970	1,769,694
R^2	0.919	0.917	0.874
$FE : id$	✓	✓	✓
$FE : cs4y$	✓	✓	✓

Extensive Margin: Impact after first patent

- Static TWFE

$$y_{it} = \alpha_i + \delta_t + \beta^{TWFE} D_{it} + u_{it}$$

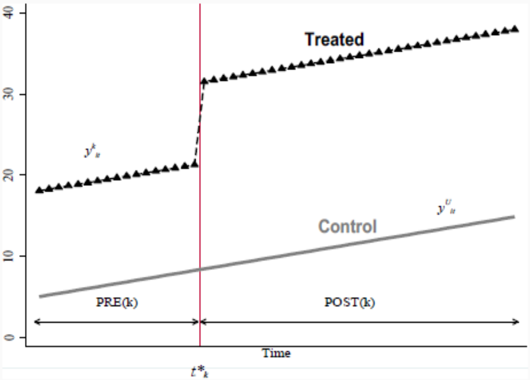
- Event-study (distributed lags) TWFE

$$y_{it} = \alpha_i + \delta_t + \sum_{m=-Q}^{M} \beta_m^{TWFE} D_{it-m} + u_{it}$$

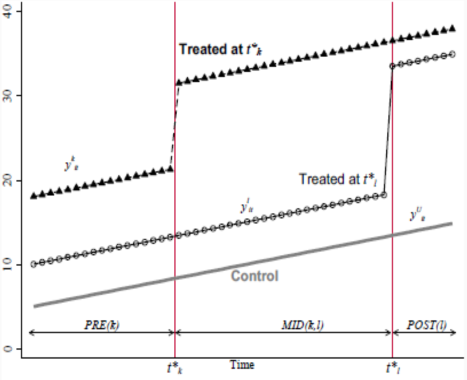
- Correct in a 2x2 setting (one treated-control group and units enter treatment at the same time).
- Biased even under parallel trends with staggered treatment, if treatment effects are dynamic and heterogeneous.

DiD Setting

2x2 Setting



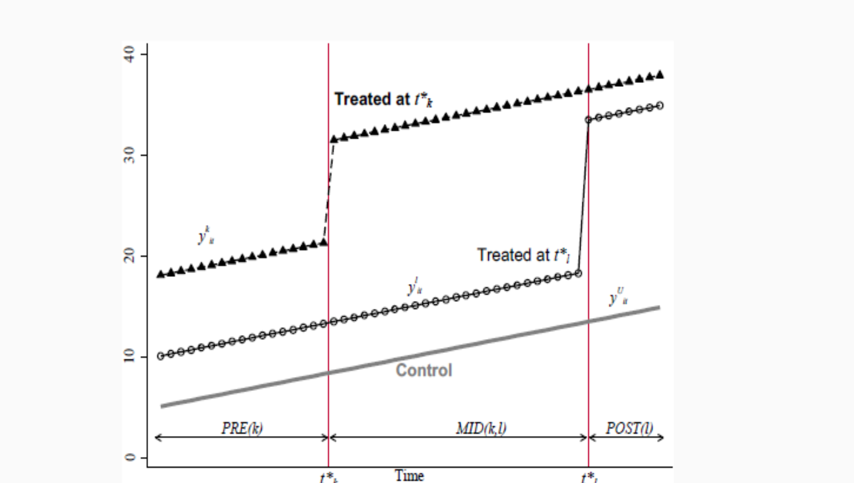
Staggered Setting



Note: Figures from Goodman-Bacon (2021)

Problems with TWFE in the staggered setting

- TWFE as weighted-average of 2x2 comparisons (Goodman-Bacon 2021)
  1. Newly treated vs Never treated;
  2. Newly treated vs Not-yet treated;
  3. Newly treated vs Earlier treated.



Dynamic Effects: Difference-in-Difference

- Central concern in DiD literature:
  - Different units enter treatment at different dates (staggered treatment adoption)
  - Treatment effects can occur gradually over time and be heterogenous
- Intuition: bias in FE because previously treated units, which might still be experiencing lagged time-varying and heterogeneous treatment effects, are used as controls for newly treated units.
- Extensive literature documenting the bias from fixed-effects estimation and proposing estimators with different weighting schemes (Borusyak, Jaravel, and Spiess (2021); de Chaisemartin and D'Haultfoeuille (2020); Goodman-Bacon (2021); Callaway and Sant'Anna (2020); Sun and Abraham (2020))

New Approach: A Local Projections Diff-in-Diff Estimator (LP-DiD)

- Recent literature shows that the TWFE implementation of DiD (static or distributed lags) can be severely biased.
  - Estimate is an average with possibly negative weight
- A new regression-based framework: LP-DiD: **Dube, Girardi, Jorda and Taylor (2022)**
  - Basically, local projections (Jorda 2005) + clean controls (Cengiz et al 2019).

Dynamic Effects: Difference-in-Difference

- LP-DiD combines:
  - applied microeconomists challenges: estimating dynamic, heterogenous, staggered treatment effects.
  - applied macroeconomists challenges: estimating dynamic impulse-responses in time-series or panel data.
- Extends DiD settings from the perspective of estimation via local projections (Jorda (2005)).
- Contribution over DiD new estimation methods:
  - Simplicity of implementation
  - Ability to control for pre-treatment values of the outcome and other covariates
  - Flexibility to define the appropriate set of treatment and controls units.

Dynamic Effects: Difference-in-Difference

- Two simulations:
  - Simulation 1 (Treatment timing is exogenous): LP-DiD performs as well as Sun and Abraham (2020) and Callaway and Sant'Anna (2020) (while being computationally simpler and faster).
  - Simulation 2 (probability of entering treatment depends on lagged outcome dynamics): the ability of LP-DiD to match on pre-treatment outcomes allows it to outperform other estimators.

- LP-DiD performs well in plausible scenarios and there is a class of settings (those in which matching on pre-treatment outcome dynamics or other pre-determined covariates is appropriate and important) in which LP-DiD is particularly suited.

A Local Projections Diff-in-Diff Estimator (LP-DiD)

- **Dube, Girardi, Jorda and Taylor (2022)**

A Local Projections Diff-in-Diff Estimator (LP-DiD)

No Covariates, Outcome Lags

$$
\begin{aligned}
y_{i,t+k} - y_{i,t-1} = \quad & \beta^{k\ LP-DiD} \Delta D_{it} && \} \text{ treatment indicator} \\
& + \delta_t^k && \} \text{ time effects} \\
& + e_{it}^k \, ; && \quad \text{for } k = 0, \ldots, K \, .
\end{aligned}
$$

restricting the sample to observations that are either:

$$
\begin{cases}
\text{treatment} & \Delta D_{it} = 1 \, , \\
\text{clean control} & \Delta D_{i,t+h} = 0 \text{ for } h = -H, \ldots, k \, .
\end{cases}
$$

A Local Projections Diff-in-Diff Estimator (LP-DiD)

- **Dube, Girardi, Jorda and Taylor (2022)**

$$
\begin{aligned}
y_{i,t+k} - y_{i,t-1} = \; & \beta^{k\ LP-DiD} \Delta D_{it} && \} \text{ treatment indicator} \\
& + \textstyle\sum_{p=1}^{P} \gamma_{0,p}^{k} \Delta y_{i,t-p} && \} \text{ outcome lags} \\
& + \textstyle\sum_{m=1}^{M} \sum_{p=0}^{P} \gamma_{m,p}^{k} \Delta x_{m,i,t-p} && \} \text{ covariates} \\
& + \delta_t^k && \} \text{ time effects} \\
& + e_{it}^k \; ; && \text{for } k = 0, \ldots, K \, .
\end{aligned}
$$

restricting the sample to observations that are either:

$$
\begin{cases}
\text{treatment} & \Delta D_{it} = 1 \, , \\
\text{clean control} & \Delta D_{i,t+h} = 0 \text{ for } h = -H, \ldots, k \, .
\end{cases}
$$

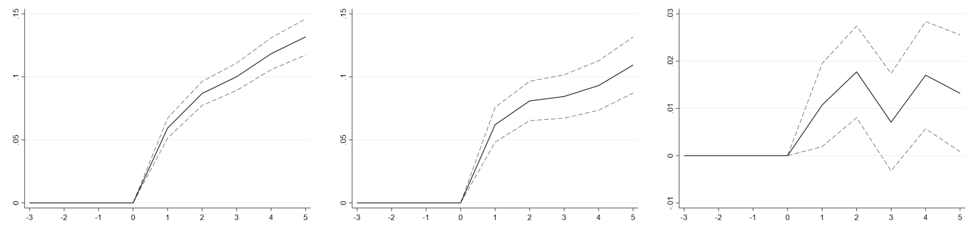
Treatment and Control groups

- Timing: $t = 0$ the year in which the firm first apply for a patent in the period 2000-2018. (Farre-Mensa, Hegde, and Ljungqvist (2017) and Kline et al (2019)).
- Exercise 1: Compare regular patenting firms (those without BT patents) to non-patenting firms.
- Exercise 2: Compare BT patenting firms to regular patenting firms.

Patents: Average Effects

Excl.Acquisitions

PANEL A: REGULAR PATENTERS VS NON-PATENTERS

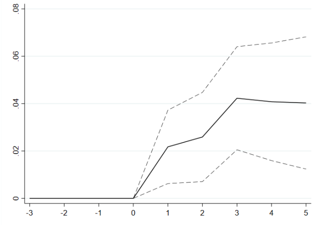


(a) $\log(Y)$ (b) $\log(\Pi)$ (c) $\log(Prod)$

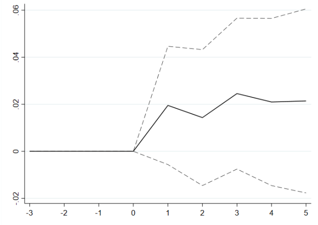
BT Patents: Average Effects

Excl.Acquisitions

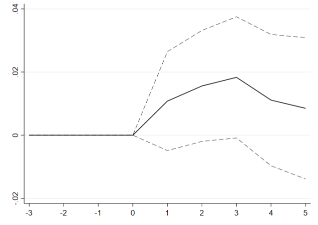
Panel B: BT Patenters vs Regular Patenters



(a) $\log(Y)$



(b) $\log(\Pi)$

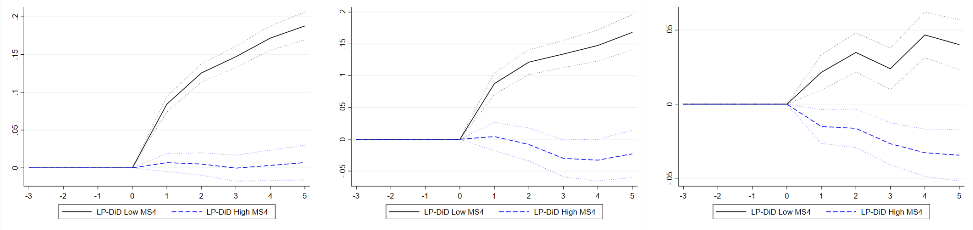


(c) $\log(Prod)$

Regular Patents: The Role of Size

▸ Excl.Acquisitions

Panel A: The Role of Size

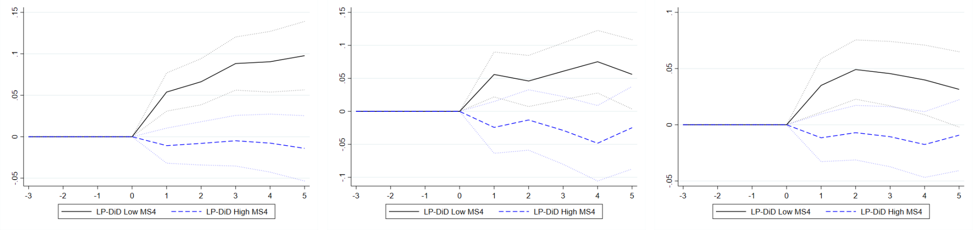


(a) $\log(Y)$ (b) $\log(\Pi)$ (c) $\log(Prod)$

BT Patents: The Role of Size

▸ Excl.Acquisitions

Panel A: The Role of Size

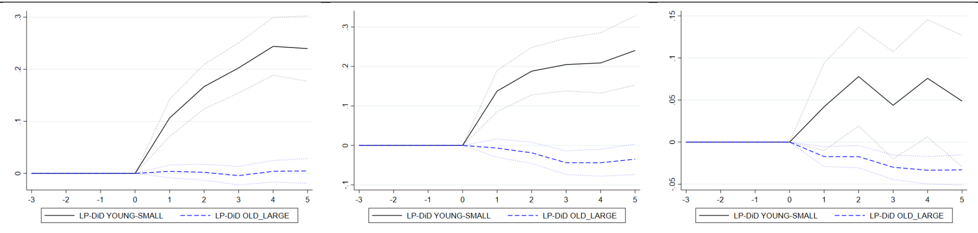


(a) $\log(Y)$ (b) $\log(\Pi)$ (c) $\log(Prod)$

Regular Patents: The Role of Size and Age

▸ Excl.Acquisitions

Panel B: The Role of Size & Age

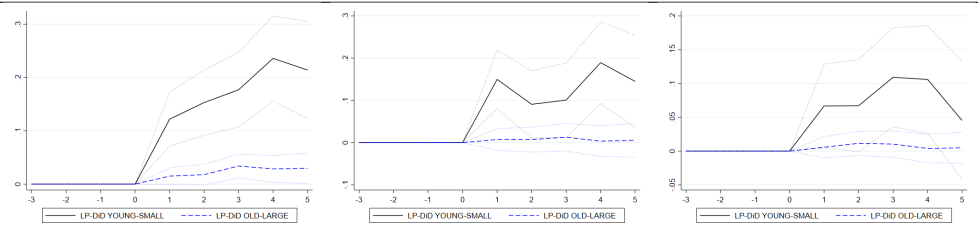


(a) $\log(Y)$ (b) $\log(\Pi)$ (c) $\log(Prod)$

BT Patents: The Role of Size and Age

Excl.Acquisitions

Panel B: The Role of Size & Age



(a) $\log(Y)$ (b) $\log(\Pi)$ (c) $\log(Prod)$

Summary

1. What characterizes firms that patent (breakthrough innovations)?
   - Most patenting firms are private (although most patents are from listed).
   - The likelihood of patenting is higher among younger firms. But some breakthrough innovations come with age.
   - Increasing shares of patenting firms as market shares increase; not so clear trend with productivity.
2. Firm size plays a very important role:
   - Large firms do benefit from patents in terms of sales (and also profits); but in terms of productivity, it is the small firms that benefit the most.
3. We use LP DiD methodology (Dube, Girardi, Jorda, and Taylor 2022: staggered treatment + clean controls) to measure the "causal" impact of the first patent on firm's output (10-15%), profits (10%), productivity (1-2%)
   - We find significant difference along the firm distribution, with much greater impact (twice+ as large) for young and small firms.

Aggregate Effects

- Through out the paper it has been made clear the important role of firm size and age to reap productivity benefits from patenting.
  - Young, small patenting firms account for a (small but) outsized share of growth (grow faster) $\rightarrow$ Today's small-young firms will mature into tomorrow's larger firms.

- The contribution of patenting firms to aggregate labor productivity growth during the period 2000-2016 has significantly increased.

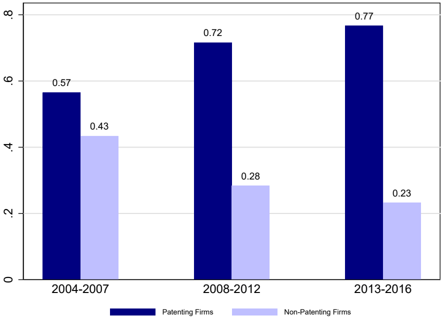
LP Growth Decomposition

Total labor productivity is the weighted sum of the firm labor productivity levels, weighted by firm level employment shares, as follows:

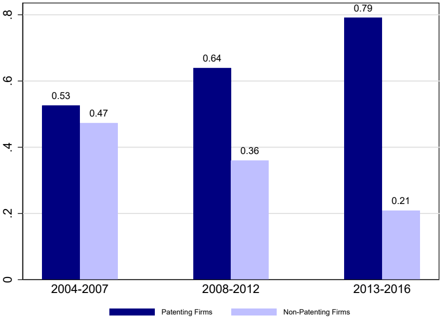
$$LP_t = \frac{Y_t}{L_t} = \sum_{i=1}^{n} \frac{Y_{it}}{L_{it}} \times \frac{L_{it}}{L_t} = \sum_{i=1}^{n} LP_{it} s_{it} \tag{1}$$

- LP_t, Y_t and L_t represent respectively aggregate labor productivity, output and employment in period t.
- LP_{it}, Y_{it} and L_{it} represent respectively firm labour productivity, output and employment ($i = 1, ..., n$) in period t.
- s_{it}: employment share of firm i in the total employment in period t.

Contribution of Patenters to LP Growth



(a) Full Sample



(b) Europe

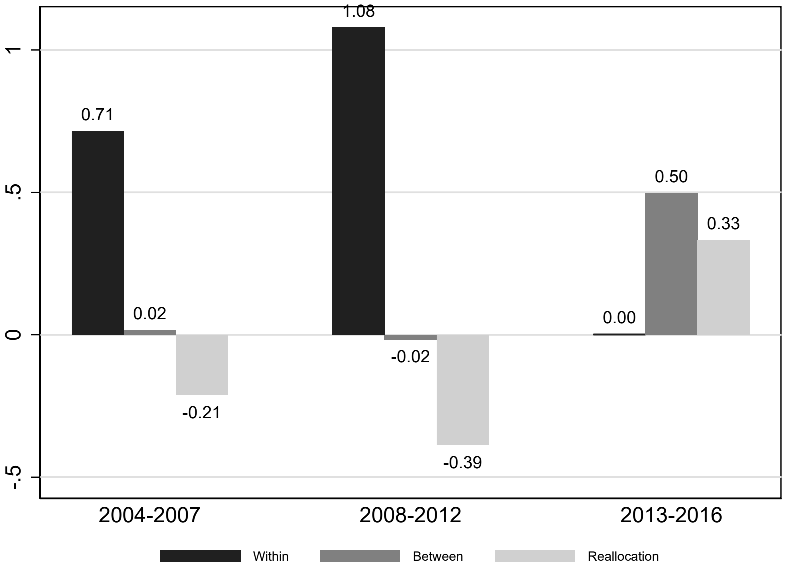
Shift-Share Decomposition

- The difference in aggregate labor productivity levels at time 0 and time T:

$$LP_T - LP_0 = \underbrace{\sum_{i=1}^{n}(LP_{iT} - LP_{i0})s_{i0}}_{Within} + \underbrace{\sum_{i=1}^{n}(s_{iT} - s_{i0})LP_{i0}}_{Between} + \underbrace{\sum_{i=1}^{n}(LP_{iT} - LP_{i0})(s_{iT} - s_{i0})}_{Reallocation}$$

- WITHIN: captures change in aggregate labor productivity driven by within firm changes in labor productivity;
- BETWEEN: captures changes driven by changes in firm size and;
- REALLOCATION: captures changes driven by the interaction between firm productivity and firm size changes.

Shift-Share Decomposition (Patenting Firms)



Thank You

Appendix

Data

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1. Patent Information
   - Start with 134.4 million patents.
   - Drop utility models (patents with minor economic-innovative content): left with 108.3 million patents.
   - Drop patents without application dates and patents with application dates before 1800 or after 2016: left with 88.9 million patents.
2. Orbis IP: Patents matched to firms
   - Start with 148.4 million matches between patents (patpublnr) and firms (bvdid_directmatch).
   - Multiplicity of ownership: multiple levels for the same patent, patents owned by different firms even at the same level → we only keep relevant matches, i.e. those at level == 0 (Direct ownership)
   - Final: 95.7 million matches kept.
3. Match Patents and Firms

Data

3. Match Patents and Firms
   - Match patents with firms using the "bridge" provided by Orbis IP.
     - There are duplicates at this stage, since some patents are owned by multiple entities even at level 0.
   - Matched sample: 67.4 million pairs (firm-patent) out of the 95.7 million.
   - Unmatched sample:
     - 28.2 million pairs (utility models + dates)
     - 25.4 million patents (patents that cannot be matched to BvDID)
   - To characterize the evolution of patents and define BT patents we keep 67.4 + 25.4 = 92.871 million patents.
   - Since our final dataset requires financial information, we will have at most 67.4 million patents matched to firms.

Data

- Number of firms in the raw firm-patent matched sample: 20,006,874 firms show up at least once
- Number of firms in the final matched sample: 4,551,005 firms show up at least once
- Number of patents in the raw firm sample: 20,030,583 patents (total could be up to 67.4 million)
- Number of patents in the final matched sample: 17,979,770 patents (total could be up to 67.4 million)

Matched Patents to BvD IDs - Orbis IP

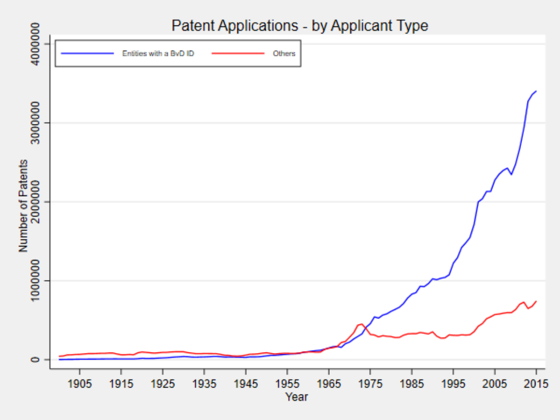


Figure: Number of Patent Applications Matched

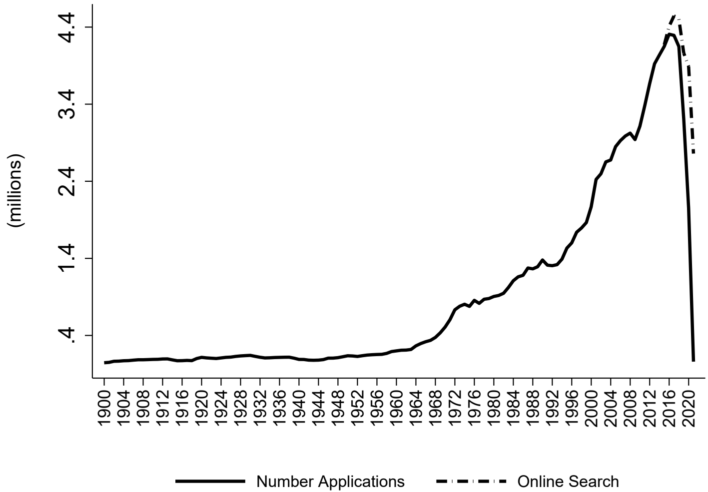
- Note: "Matched" filers with a BvD ID, "Unmatched" captures all other filers (including individuals).

World Patenting Dynamics

▸ Back

- Over 4 million annual applications, driven by key main players.

Figure: Number of Patent Applications by Application Year



World Patenting Dynamics: Grants

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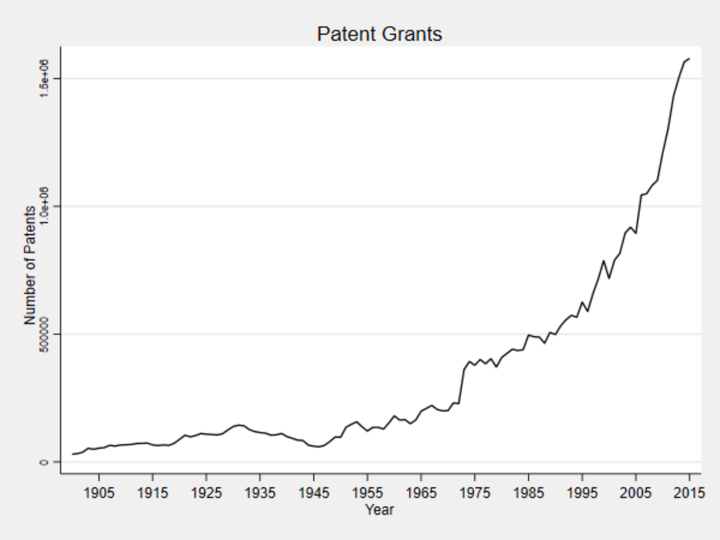
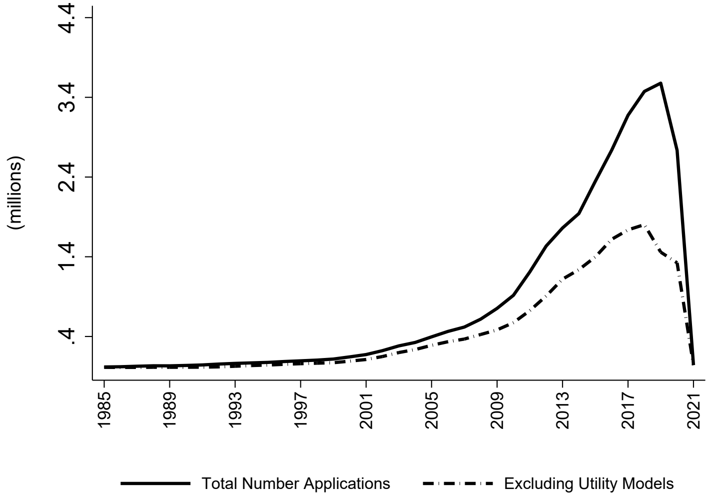


Number of Applications excl. Utility Models ▸ Back



Breakthrough Definition: Extensions

Back

- Truncation
- Account for technology class and year
- Word count
- Correlated with other measures:
  - Kelly et al (2018): BT patents where the patent's text differs from the text of past patents but is similar to the text of future patents.
  - Kogan et al (2017): excess returns in a window around patent approval dates to infer the market value the patent.

Breakthrough - Alternative 1 - Kerr (2010)

- First, for each WIPO tech field, we compute the empirical distribution of forward citations and the empirical distribution of the ratio between forward and backward citations.

- Then, for each patent in each field, we check
  - if that patent's forward citations belong to top 1% of the forward citation all patents in that field;
  - if that patent's ratio belong to top 1% of the ratio across all patents in that field;

  If either of these conditional statements are verified, a patent is deemed to be a breakthrough patent.

Breakthrough - Alternative 2 - Kerr (2010) + HJT (2001, 2005)

- First, for each patent in the sample, we perform a truncation correction on both the forward and backward citation numbers using the Hall, Jaffe and Trajtenberg approach suggested by Lerner and Seru (2021):

$$\text{HJT Forward Citations}_{ipft} = \frac{\text{Forward Citations}_{ipft}}{\left[\sum_i \text{Forward Citations}_{ipft} / N_{p,f,t}\right]}$$

$$\text{HJT Backward Citations}_{ipft} = \frac{\text{Backward Citations}_{ipft}}{\left[\sum_i \text{Backward Citations}_{ipft} / N_{p,f,t}\right]}$$

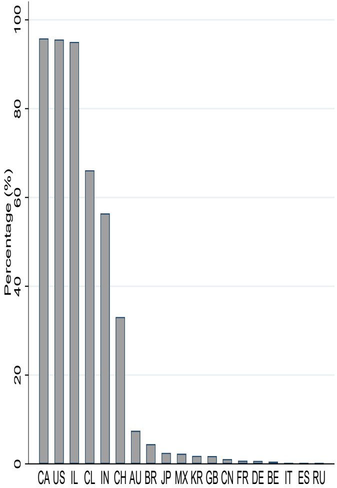
Breakthrough - Alternative 2 - Kerr (2010) + HJT (2001, 2005)

- Second, for each WIPO tech field, we compute the empirical distribution of forward HJT corrected citations and the empirical distribution of the ratio between, both HJT corrected, forward and backward citations.

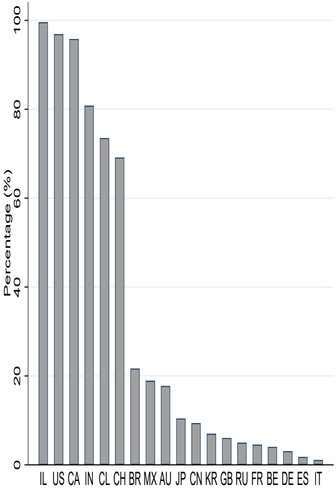
- Then, for each patent in each field, we check
  - if that patent's HJT corrected forward citations belong to top 1% of the HJT corrected forward citation all patents in that field;
  - if that patent's HJT corrected ratio belong to top 1% of the HJT corrected ratio across all patents in that field;

  If either of these conditional statements are verified, a patent is deemed to be a breakthrough patent.

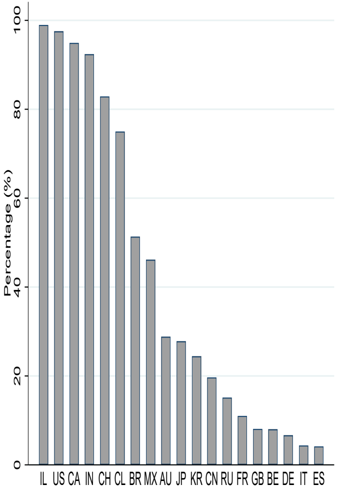
Distribution of Listed & Patenting Firms by Country



% of Listed in Total

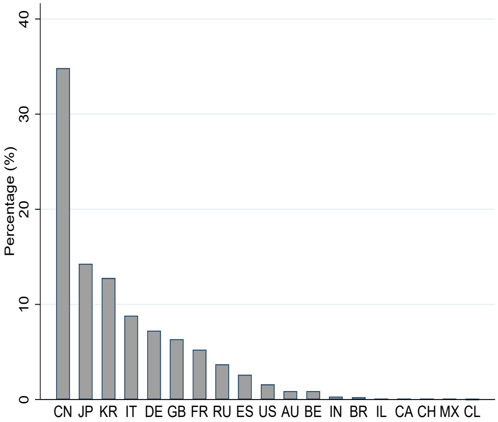


% of Listed in Patenting

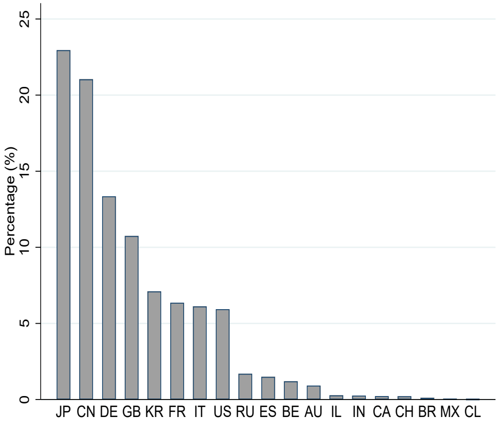


% of Listed in BT

Distribution of Patenting Firms Across Countries

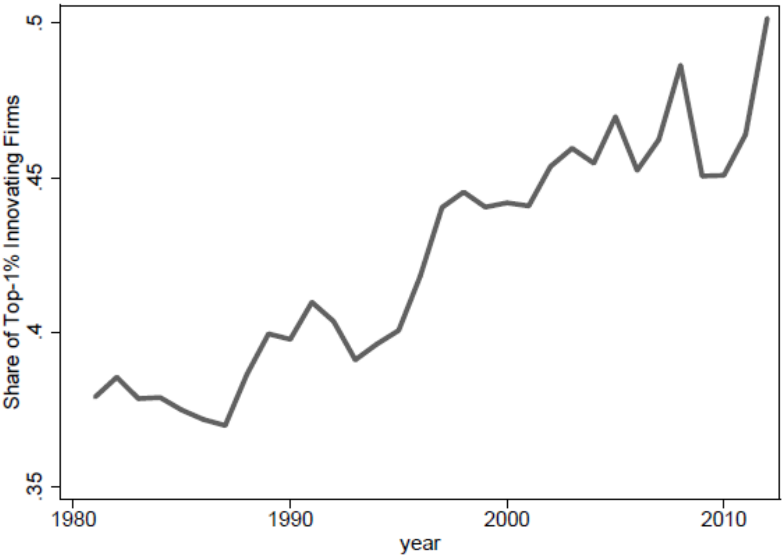


Share Patenting Firms



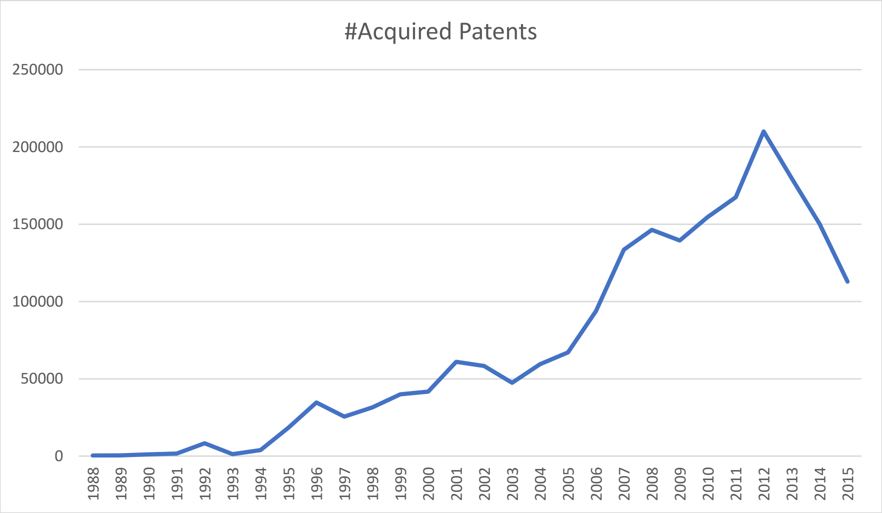
Share BT Patenting Firms

US Evidence Patent Concentration (Ackcigit and Ates (2020)) ▸ Back



Acquired Patents

Back



Premia Regressions with Common Size Threshold

▸ Back

Table: Patent and Size Premia: Size Common Threshold

	log(RevenueWorker)			log(L)			log(Wage)			log(K_L)			log(Leverage)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
$\mathbb{1}(Size)$	0.717***	0.687***	0.784***	2.007***	1.895***	1.809***	0.260***	0.239***	0.270***	1.134***	1.072***	1.226***	-0.236***	-0.219***	-0.231***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)	(0.006)	(0.002)	(0.002)	(0.003)	(0.005)	(0.005)	(0.007)	(0.003)	(0.003)	(0.005)
$\mathbb{1}(Patent)$		0.129***	0.167***		0.484***	0.450***		0.108***	0.122***		0.270***	0.331***		-0.071***	-0.075***
		(0.002)	(0.002)		(0.003)	(0.002)		(0.002)	(0.002)		(0.003)	(0.003)		(0.002)	(0.002)
1(Size) $\times \mathbb{1}(Patent)$			-0.249***			0.223***			-0.099***			-0.397***			0.029***
			(0.006)			(0.009)			(0.004)			(0.009)			(0.006)
Obs.(million)	21,4	21.4	21.4	21.5	21.5	21.5	10.6	10.6	10.6	17.8	17.8	17.8	23.9	23.9	23.9
R^2	.62	.62	.62	.43	.44	.44	.43	.43	.43	.48	.48	.48	.22	.22	.22

- Size: Compute average total assets per firm. Large if average total assets greater than official 43 million euro by EC.

Premia Regressions based on continuous log assets

▸ Back

Table: Patent and Size Premia: Size Continuous

	log(RevenueWorker)			log(L)			log(Wage)			log(K_L)			log(Leverage)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
logTotAssets	0.341***	0.346***	0.359***	0.392***	0.383***	0.357***	0.117***	0.116***	0.124***	0.485***	0.489***	0.510***	0.028***	0.032***	0.042***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
$\mathbb{1}(Patent)$		-0.166***	1.896***		0.310***	-3.758***		0.022***	0.742***		-0.116***	2.093***		-0.136***	1.142***
		(0.002)	(0.016)		(0.002)	(0.019)		(0.002)	(0.014)		(0.003)	(0.025)		(0.002)	(0.016)
$\mathbb{1}(Patent) \times logTotAssets$			-0.129***			0.254***			-0.045***			-0.138***			-0.080***
			(0.001)			(0.001)			(0.001)			(0.002)			(0.001)
Obs.(million)	21.4	21.4	21.4	21.5	21.5	21.5	10.6	10.6	10.6	17.8	17.8	17.8	23.9	23.9	23.9
R^2	.72	.72	.72	.58	.59	.6	.46	.46	.46	.57	.57	.57	.22	.22	.22

- Size: log firm average total assets.

What does LP-DiD identify? **Dube, Girardi, Jorda and Taylor (2022)**

- A variance-weighted average effect:

$$E(\hat{\beta}^{k\ LP-DiD}) = \sum_{g \neq 0} \omega_{g,k}^{LP-DiD} \tau_g(k)$$

  - $\tau_g(k)$ = k-periods forward ATT for treatment-cohort g.

- Weights are always positive and depend on subsample size & treatment variance

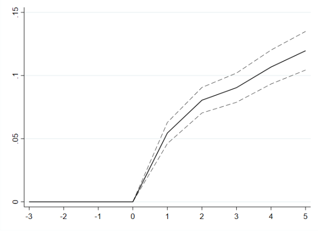
$$\omega_{g,k}^{LP-DiD} = \frac{N_{CCS_{g,k}}[n_{gk}(n_{c,g,k})]}{\sum_{g \neq 0} N_{CCS_{g,k}}[n_{g,k}(n_{c,g,k})]},$$

where

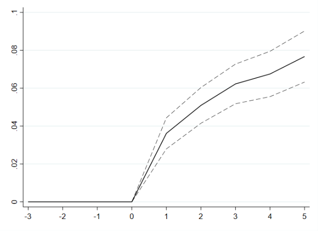
  - $CCS_{g,k}$ is a subsample including group g and its 'clean controls'.

Patent vs the Rest (Excluding Acquisitions)

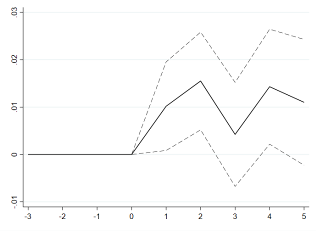
Back



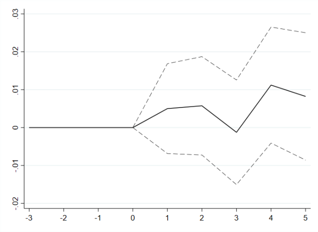
(a) log *output*



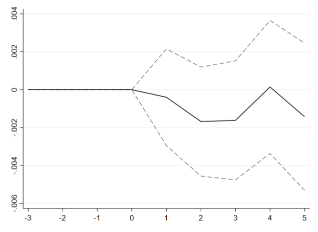
(b) log *employment*



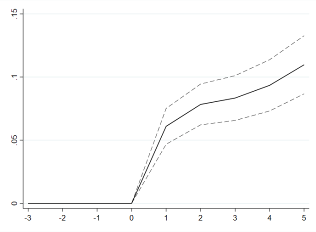
(c) log *Productivity*



(d) log *VA*/*L*



(e) log *TFP*

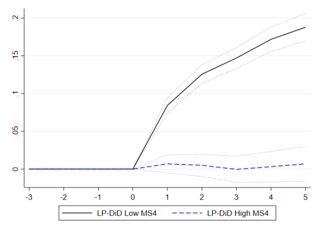


(f) log *GrossProfit*

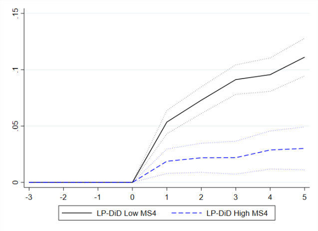
Figure: Patents vs the Rest: Excluding Acquisitions

Patent vs The Rest: SIZE

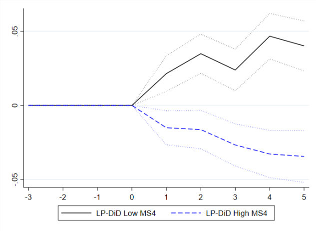
Back



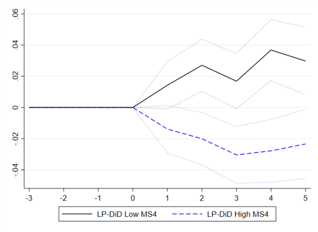
(a) log *output*



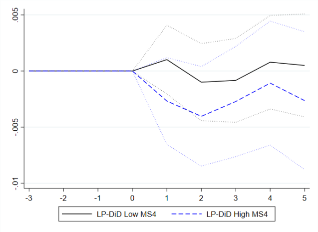
(b) log *employment*



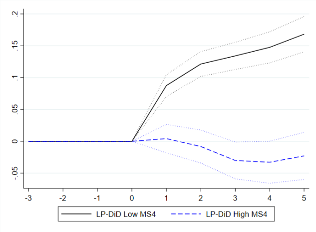
(c) log *Productivity*



(d) log *VA*/*L*



(e) log *TFP*

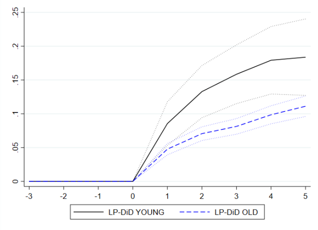


(f) log *GrossProfit*

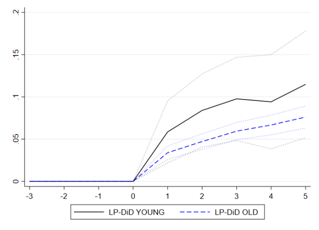
Figure: Patents vs The Rest: SIZE

Patent vs The Rest: Age

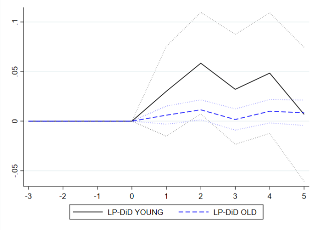
Back



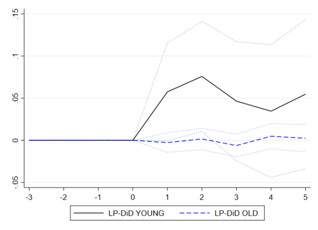
(a) log *output*



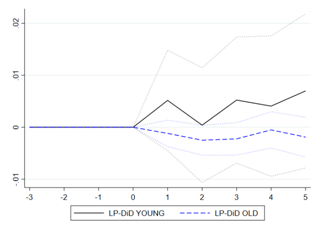
(b) log *employment*



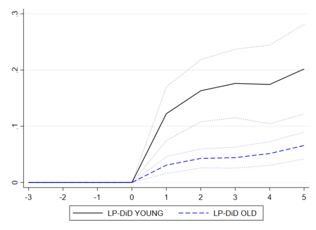
(c) log *Productivity*



(d) log *VA*/*L*



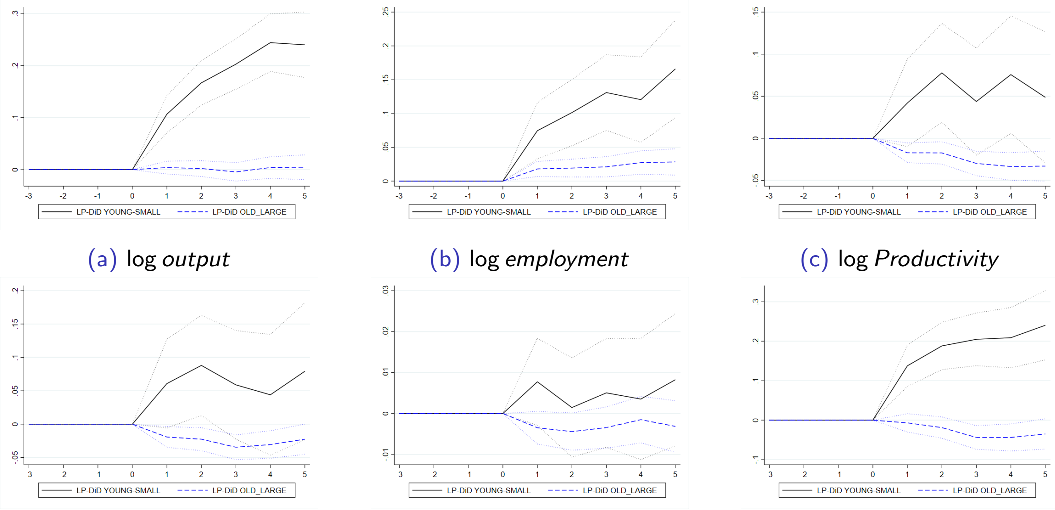
(e) log *TFP*



(f) log *GrossProfit*

Figure: Patents vs The Rest: Age

Patent vs The Rest: Age & Size ▸ Back

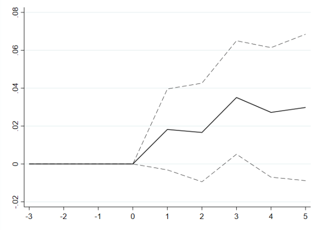


(a) log *output* (b) log *employment* (c) log *Productivity*

(d) log *VA*/*L* (e) log *TFP* (f) log *GrossProfit*

Figure: Patents vs The Rest: Age & Size

BT vs Patent (Excluding Acquisitions) ▸ Back



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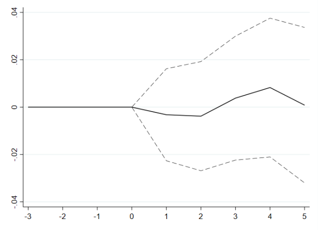
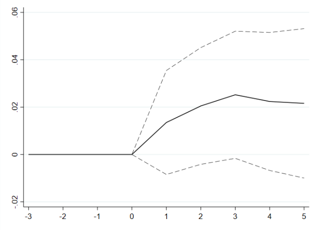
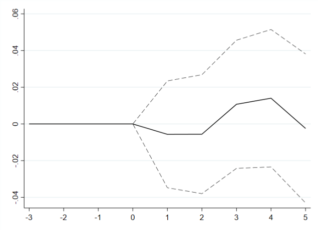


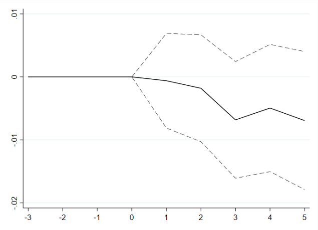
(b) log *employment*



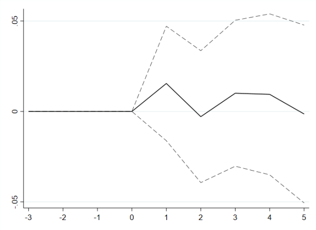
(c) log *Productivity*



(d) log VA/L



(e) log *TFP*

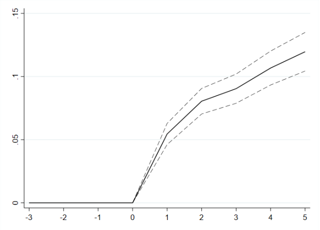


(f) log *GrossProfit*

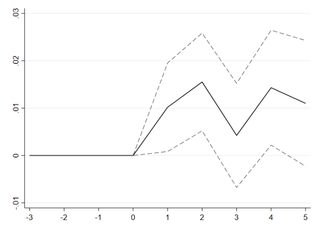
Figure: BT vs Patent: Excluding Acquisitions

Patents: Average Effects (excluding Acquisitions)

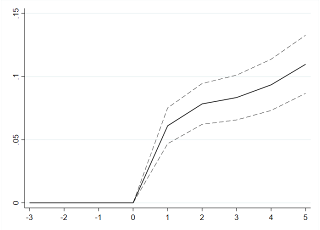
Panel A: Patents vs the Rest



(a) log *Output*

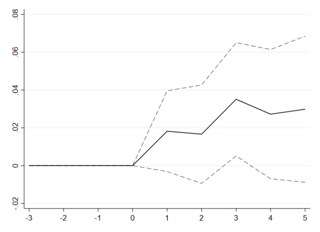


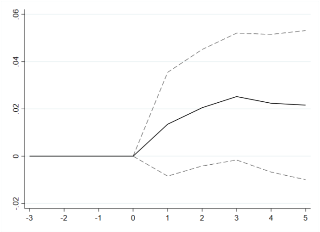
(b) log *Productivity*

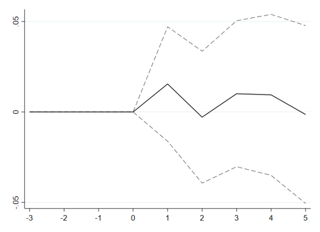


(c) log *GrossProfit*

Panel B: BT patents vs Patents

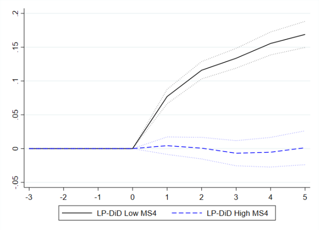




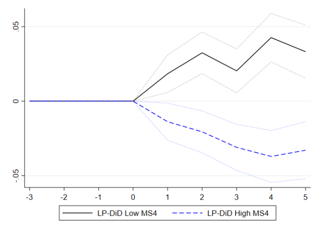


Patents: Size Effects (Excluding Acquisitions) ▸ Back

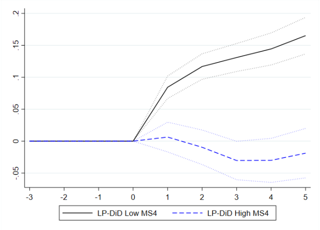
Panel A: Patents vs the Rest



(a) log *Output*

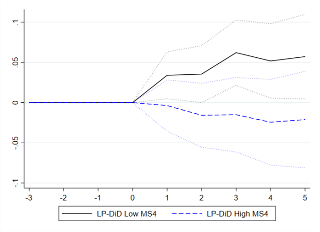


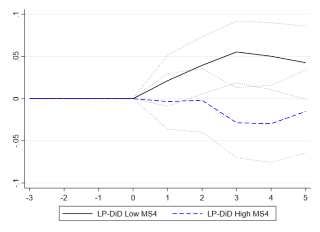
(b) log *Productivity*

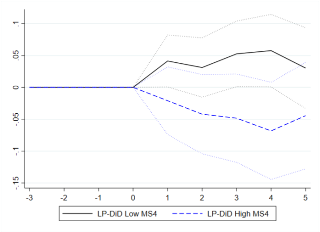


(c) log *GrossProfit*

Panel B: BT patents vs Patents

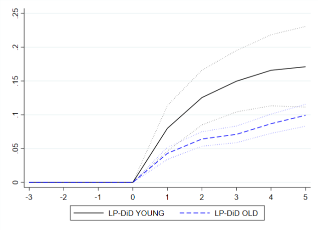




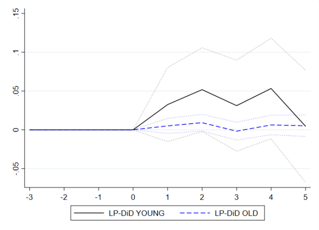


Patents: Age Effects (Excluding Acquisitions) ▸ Back

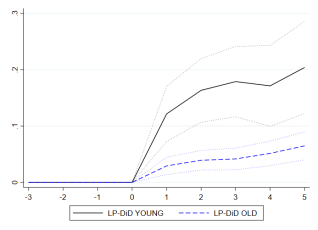
Panel A: Patents vs the Rest



(a) log *Output*

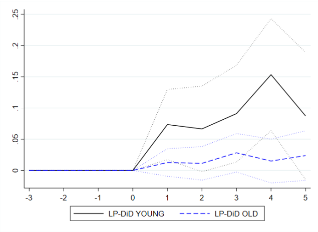


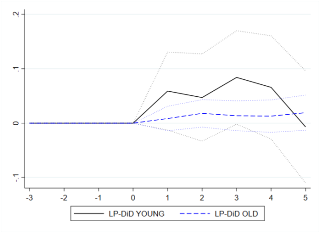
(b) log *Productivity*

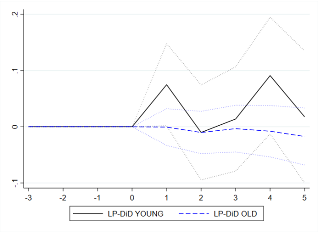


(c) log *GrossProfit*

Panel B: BT patents vs Patents



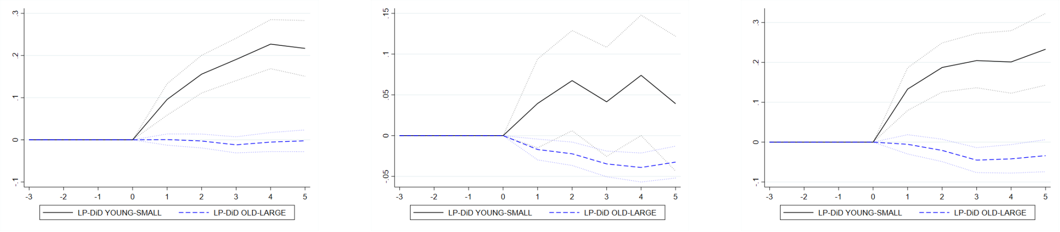




Patents: Size & Age Effects (excluding Acquisitions)

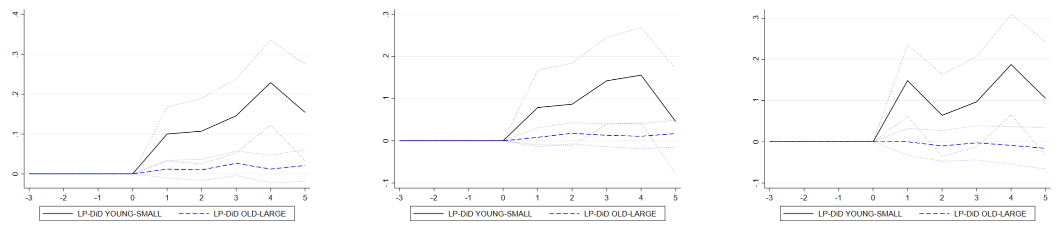
Back

Panel A: Patents vs the Rest



(a) log *Output* (b) log *Productivity* (c) log *GrossProfit*

Panel B: BT patents vs Patents

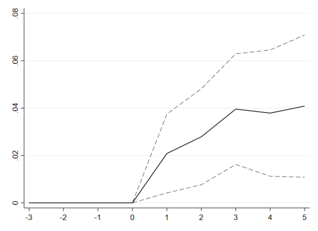


ROBUSTNESS I: DROPPING OPPOSING AND OPPOSED FIRMS

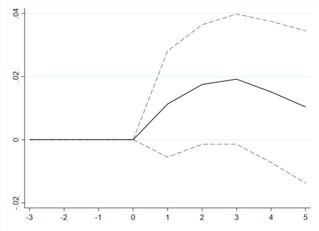
BT patents vs Patents (Dropping Opposing and Opposed)

▸ Back

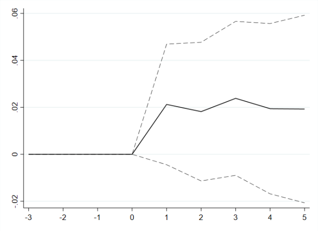
Panel A: BT vs Patents



(a) log *Output*

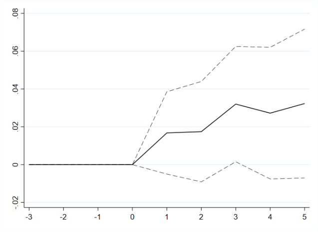


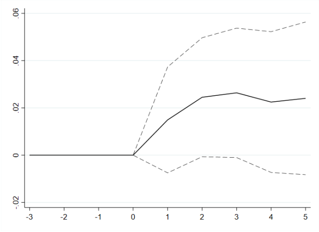
(b) log *Productivity*

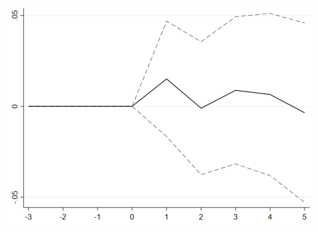


(c) log *GrossProfit*

Panel B: BT patents vs Patents (excluding acquisitions & opposing and opposed firms)

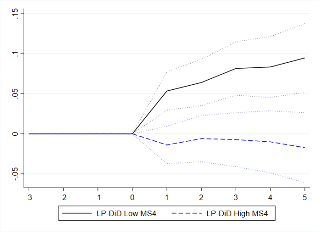




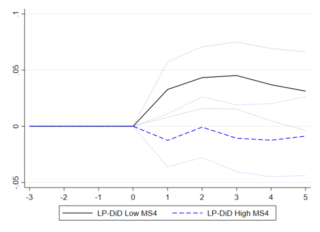


BT patents vs Patents (Dropping opposing and opposed firms): SIZE

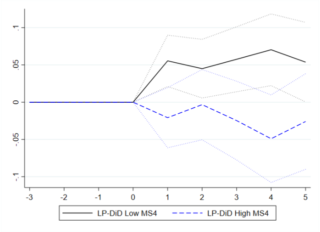
Panel A: BT vs Patents



(a) log *Output*

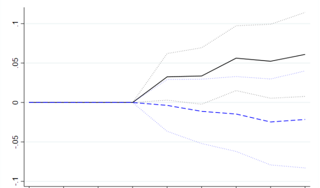


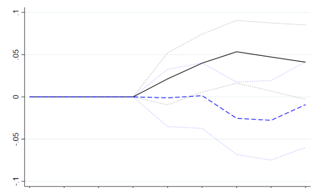
(b) log *Productivity*

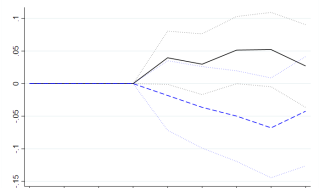


(c) log *GrossProfit*

Panel B: BT patents vs Patents (excluding acquisitions & opposing and opposed firms)

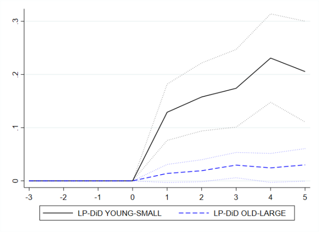




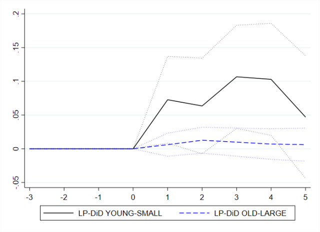


BT patents vs Patents (Dropping opposing and opposed firms): AGE & SIZE ▸ Back

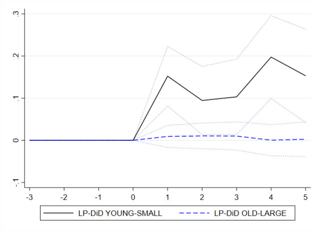
Panel A: BT vs Patents



(a) log *Output*



(b) log *Productivity*



(c) log *GrossProfit*

Panel B: BT patents vs Patents (excluding acquisitions & opposing and opposed firms)