

# Revisiting the Missing R&D-Patent Relation: Challenges and Solutions for Firm Fixed Effects Models

Hui-Ching Chuang   National Taipei University

**Po-Hsuan Hsu   National Tsing Hua University**

Chung-Ming Kuan   National Taiwan University

Jui-Chung Yang   National Taiwan University

# The prevailing use of firm fixed effects

- Researchers like to use fixed effects (FE) models because FEs **absorb** the influences of individual-specific, unobservable, and time-invariant effects (to mitigate endogeneity concerns)
- However, such a “by-default” use of FE regressions may fail to detect important **persistent explanatory variables**
- To illustrate such a bias, we need a very **convincing causal** relation:
  - The **R&D-patent relation** is perhaps the most intuitive example
  - Which factors contribute to corporate innovation has been an important topic (Ederer and Manso, 2011; He and Tian, 2018; Lerner and Seru, 2022)
  - Our review of **200 papers** in this field suggests that, while R&D is an important control variable, only **40%-50%** regressions/papers show insignificant or even negative coefficients on R&D.

# Example: Luong et al. (2017)

TABLE 2  
Baseline Regressions

Table 2 reports the regressions of firm innovation on institutional ownership. Columns 1 and 2 (3 and 4) show the pooled ordinary least squares (OLS) (Firm fixed effects) regression results. The dependent variable is shown as the column heading in columns 1–4. The main independent variable is foreign institutional ownership (FIO). All explanatory variables are lagged by 1 year. Variable definitions are in Appendix B. Standard errors are clustered at the firm level and reported in parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively.

Variables	ln(PATENT) 1	ln(CITEPAT) 2	ln(PATENT) 3	ln(CITEPAT) 4
FIO	0.010*** (0.003)	0.014*** (0.004)	0.008*** (0.003)	0.011*** (0.004)
DIO	−0.010*** (0.002)	−0.012*** (0.003)	−0.001 (0.001)	−0.001 (0.002)
INSIDE	−0.072 (0.063)	−0.054 (0.070)	0.062* (0.032)	0.084* (0.044)
ln(AGE)	0.062** (0.029)	0.062* (0.032)	0.086** (0.037)	0.118** (0.049)
HHI	0.396 (0.292)	0.400 (0.326)	−0.170 (0.274)	0.152 (0.347)
HHI <sup>2</sup>	−0.277 (0.277)	−0.280 (0.307)	0.152 (0.241)	0.050 (0.290)
RD	2.267*** (0.238)	2.637*** (0.288)	0.054 (0.132)	−0.232 (0.215)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Industry fixed effects	Yes	Yes	No	No
Country fixed effects	Yes	Yes	No	No

In columns (1) and (2) without firm FE, R&D effect is significant  
Once firm FEs are included in columns (3) and (4), R&D effect is gone!

# Why? and so what?

- **Why would R&D effect be missing?**
- Innovation economists have been aware of this issue and warned against FE regressions many decades ago (Hall et al., 2005):
  - A firm's R&D changes slowly over time; and is highly correlated with its individual effect -- which will be absorbed by FE regressions
  - FE regressions eliminate all cross-sectional variations in patents, and only inform us about how R&D explains a firm's time-series variations in patents, which weakens the R&D effect
- **So what?**
  - In fact, R&D is important in creating firm heterogeneity
  - Cross-sectional variation is more important than time-series variation (Hausman et al., 1984; Hall et al., 2005)
  - If R&D doesn't work, how much can we trust in other X variables?
- **Implications for empirical researchers:** This econometric issue applies to all persistent variables: ownership, culture, talent, etc.

# Feasible solutions for persistent X variables

- Solution 1:
  - present regression results without firm FEs for comparison
  - report within R-squared (which is readily available or easy-to-compute) in addition to R-squared
- Solution 2: Adjusted Hausman-Taylor estimator (1981)
- Solution 3: Machine-learning models to “shrink” parameters (i.e., select some informative firm dummies and drop unimportant ones)
  - Post-regularization LASSO (PRL) and Double machine-learning (DML)
  - These are easy to implement by STATA (or R/Python), and our codes available online: <https://github.com/hcchuang>
- These solutions can be useful to all empirical researchers

# Sample

- We first collect the financial and accounting data of all US public firms in CRSP/Compustat.
- We exclude financial and utility firms, and firms with negative and missing total asset and sales.
- Public firms' patent and citation are from the PatentsView patent database that is organized by the USPTO.
- As a result, we have 86,341 firm-year observations of 11,544 unique firms in 1976-2000 (to match most prior studies' sample period, which are based on the [1<sup>st</sup> version of NBER patent data](#)).
- We also consider [a patenting firm sample](#) with 45,913 firm-year observations of 4,312 unique firms with at least one patent during the sample period.

# Our baseline regressions

$$Innov_{i,t+1} = \beta_0 + \beta_{R\&D} R\&D_{i,t} + \beta_2 X_{i,t} + \sum_{s \in S} \alpha_s dummy_{s,i} + u_{i,t}$$

- We consider **OLS** here and will discuss the **Poisson** regression later.  $Innov_{i,t+1}$  is one of innovation measures in  $\ln(1+y)$  format:  $\ln(1+Patent)$ ,  $\ln(1+Citation)$ , and  $\ln(1+AdjCitation)$ .
- $R\&D_{i,t}$  is 5-year R&D expenditures/total asset. (We also consider R&D/ME, or  $\ln(1+R\&D)$  for five years for robustness.)
- $X_{i,t}$  denotes firm characteristic controls: R&D missing dummy, capital level, firm age, K/L, Tobin's Q, ROA, leverage, cash divide by the total asset, Institutional ownership ratio, KZ index, Herfindahl-Hirschman index, and Herfindahl-Hirschman index square.
- **OLS model** includes none of the firm dummies, i.e.,  $S = \emptyset$ .
- **FE model** includes all of the firm dummies, i.e.,  $S = \{1, \dots, N\}$ .

# Solution 1: no-FE results + within R squared

Dependent: Patents	OLS model	FE model
R&D	0.593***	0.041
	(0.042)	(0.028)
Control	YES	YES
Firm dummies	NO	ALL
R2	0.362	0.853
Between R2		0.209
Within R2		0.034

- OLS model (no FE) suggest strong R&D effect
- FE model, however, suggests no R&D effect
- **Within R squared** is the R square from the regression of the de-entitled-meaned (i.e, within transformation) of y and de-meaned x.
- Within R-squared suggests that FE model explains 3.4% of patent variation in time-series
- R&D's explanatory power for cross-section is more important!



## Solution 2: Adjusted Hausman-Taylor (HT) methods

- Consider the simplified Hausman Taylor (1981) model

$$Y_{i,t+1} = \beta \mathbf{Z}_i + \boldsymbol{\beta}_2 \mathbf{X}_{i,t} + \alpha_i + \epsilon_{i,t}.$$

- HT allow arbitrary correlation between  $\mathbf{Z}_i$  (observable) and  $\alpha_i$  (unobservable), and can be estimated using moment conditions:

$$E[(\mathbf{X}_{i,t} - \bar{\mathbf{X}}_i)'(Y_{i,t+1} - \beta \mathbf{Z}_i - \boldsymbol{\beta}_2 \mathbf{X}_{i,t})] = \mathbf{0}.$$

$$E[\mathbf{X}_{i,t}'(Y_{i,t+1} - \beta \mathbf{Z}_i - \boldsymbol{\beta}_2 \mathbf{X}_{i,t})] = \mathbf{0}.$$

- For our purpose of R&D effect, we replace  $\mathbf{Z}_i$  with persistent  $R\&D_{i,t}$  and add an extra moment condition:
  - $E[(R\&D_{i,t} - \overline{R\&D}_i)(Y_{i,t+1} - \beta_{R\&D} R\&D_{i,t} - \boldsymbol{\beta}_2 \mathbf{X}_{i,t})] = 0.$
  - The correlation between individual effects ( $\alpha_i$ ) and  $R\&D_{i,t}$  arises from the firm's  $\overline{R\&D}_i$  (this is intuitive as R&D-innovation is a long-term effect); thus, deviations from  $\overline{R\&D}_i$  are unrelated to individual effects.
- Thus, we can identify  $\beta_{R\&D}$  by GMM using these moment conditions

## Solution 2: Adjusted Hausman-Taylor (HT)

Dependent: Patents	OLS model	FE model	Adj HT
R&D	0.593***	0.041	0.220***
	(0.042)	(0.028)	(0.027)
Control	YES	YES	YES
R2	0.362	0.853	
Between R2		0.209	
Within R2		0.034	

- Our adjusted Hausman-Taylor estimate also supports significant and important R&D effect
- The coefficient 0.220 is **smaller** than OLS estimates
  - ✓ This is reasonable given that adjusted Hausman-Taylor controls for **non-R&D individual effects**

## Solution 3: Machine learning

$$Innov_{i,t+1} = \beta_0 + \beta_{R\&D} R\&D_{i,t} + \beta_2 \mathbf{X}_{i,t} + \sum_{s \in \mathcal{S}} \alpha_s dummy_{s,i} + u_{i,t}$$

- Post-regularization LASSO (PRL) (Chernozhukov et al., 2015)
- Double machine-learning (DML) (Chernozhukov et al., 2018)
- By “shrinking” parameters, PRL and DML only use a subset of firm dummies, i.e.,  $\mathcal{S} \in \{1, \dots, N\}$ , while keep the valid inference of  $\beta_{R\&D}$ .
  - As important dummies have been selected to control for, we prevent the omitted-variable bias.
  - Since unimportant dummies are not selected, they will not bias our test for the role of persistent R&D.
- Intuition: unobserved heterogeneity exists in some firms but not all
  - Some firms have a strong, innovation-oriented culture or talented executives, while most do not.

# Post-Regularization LASSO (PRL)

- **PRL** proceeds in the following 3 steps:
  - **Step1:** LASSO of  $Innov_{i,t+1}$  on firm dummies and force small coefficients of some dummies to 0 by BIC (estimate step). Then, Post LASSO: OLS of  $Innov_{i,t+1}$  on selected firm dummies, obtain the residuals,  $\hat{r}_{innov}$  (get residual step)
  - **Step2:**
    - a) LASSO of  $R\&D_{i,t}$  on firm dummies and force small coefficients of some dummies to 0. Then, Post LASSO: OLS of  $R\&D_{i,t}$  on selected firm dummies, obtain the residuals,  $\hat{r}_{R\&D}$ .
    - b) LASSO of  $X_{i,t}$  on firm dummies and force small coefficients of some dummies to 0. Then, Post LASSO: OLS of  $X_{i,t}$  on selected firm dummies, obtain the residuals,  $\hat{r}_X$ .
  - **Step3:** OLS of  $\hat{r}_{innov}$  on  $\hat{r}_{R\&D}$ ,  $\hat{r}_X$  and obtain the coefficient  $\hat{\beta}_{R\&D, PRL}$ .
- If a firm dummy is selected in either Step 1 or Step 2 (partialing-out/residualizing), it is considered **informative** to  $Innov_{i,t+1}$  and  $R\&D_{i,t}$ .

# Double Machine Learning (DML)

- **DML** generalizes the PRL to a general model selection (LASSO, random forests, gradient boosting, neural nets, etc.) and add the cross-fitting procedures to PRL.

- DML proceeds in the following steps:

- splits sample into random 5 folds,
- use only 4 folds to do LASSO
- use the reserved one to do Post LASSO
- stake all residuals from 5 times, use OLS to obtain  $\hat{\beta}_{R\&D,DML}$ .

1	2	3	4	5
	2	3	4	5
				1

- DML uses sample splitting to eliminates the dependence between the estimation steps, reduce the post-model-selection bias (or, **errors in estimated variables**) of PRL.
- However, as the cross-fit procedure reduces the sample size, DML also reduces the estimation efficiency.
- DML also takes longer in computation

# Patent regression: PRL and DML results

Dependent: Patents	OLS model	PRL	DML	FE model	Adj HT
R&D	0.593***	0.199***	0.213***	0.041	0.220***
	(0.042)	(0.018)	(0.014)	(0.028)	(0.027)
# of dummies		11,570	1,1570		
# of selected dummies		1,241 (10.73%)	1,737 (15.01%)		

- In PRL and DML, R&D effect is statistically significant
- The economic magnitude (0.199 and 0.213) is closer adjusted Huasman-Taylor (0.220)
- PRL and DML select about 10% to 15% of firm dummies to be included in estimation
- Bias from adding all firm dummies (FE) overpowers the bias from not adding any at all (OLS) and leads to “missing R&D effect”

# Robustness

- Alternative innovation measures:
  - Citations and adjusted citations
- Alternative R&D measures:
  - R&D/ME and  $\ln(1+R\&D)$  in addition to R&D/AT,
- Patenting firms only
  - Excluded firms without any patent for during its sample period.
- Handling missing R&D values
  - Remove firm-year observations with missing R&D
- Alternative specifications in HT, PRL, and DML methods
  - Different fold count from two to five in DML method

# Simulation Study

- Innovation outcome (patent, citations) equation:
  - $Innov_{i,t}$  negative binominal distribution with conditional mean
$$E(Innov_{i,t} | z_{i,t}, x_{i,t}) = \exp(\beta R\&D_{i,t} + x_{i,t})$$
  - and a over-dispersion parameter  $\alpha$ , larger value corresponds to a greater dispersion.
- R&D process:

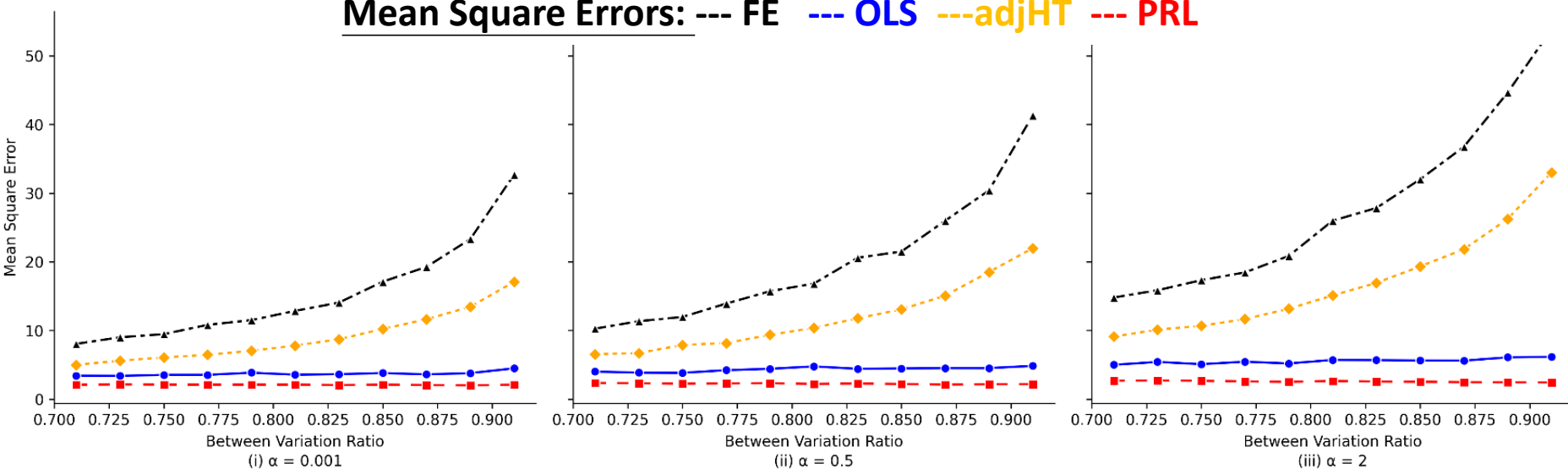
$$R\&D_{i,t} = 0.5 \eta_i + 0.5 v_{i,t}$$

- $\eta_i$  : time-invariant firm-fixed effect drawn from  $N(0, \sigma_\eta)$
  - $v_{i,t}$  : firm and time varying component drawn from  $N(0, \sigma_v)$
  - Between variation ratio  $= \frac{\sigma_\eta^2}{\sigma_\eta^2 + \sigma_v^2}$
- $x_{i,t}$  drawn from  $N(0, 2)$ , and  $N = 500, T = 10$ , Monte Carlo replicate 10,000.

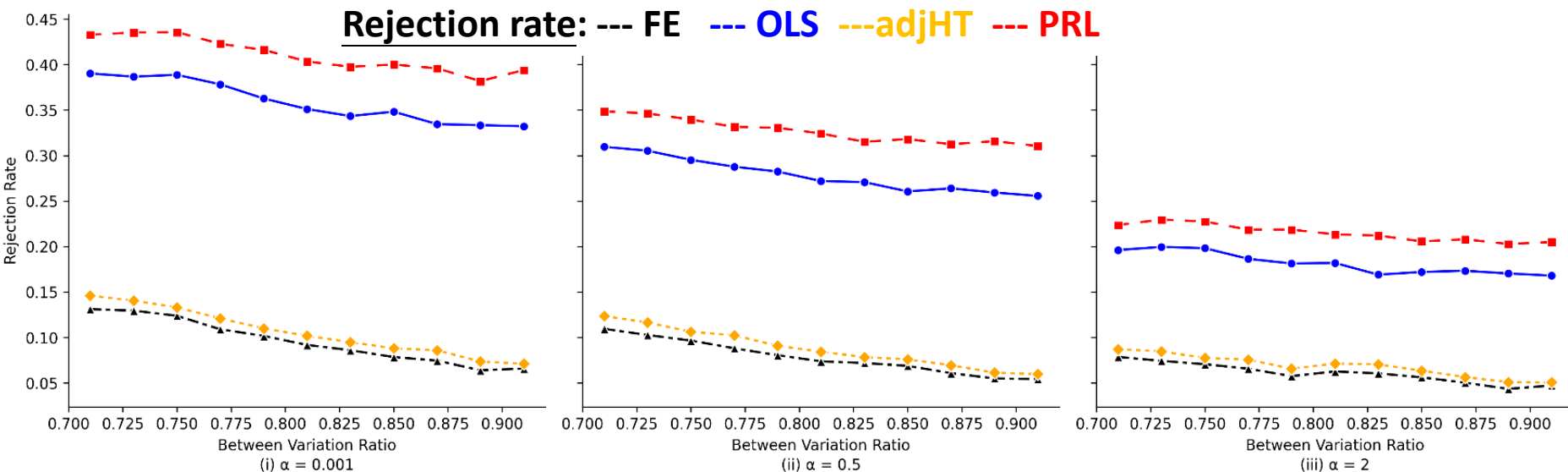


# Simulation Study (cont'd)

Mean Square Errors: --- FE --- OLS ---adjHT --- PRL



Rejection rate: --- FE --- OLS ---adjHT --- PRL



# Poisson regression

$$E(\text{Innov}_{i,t+1} | R\&D_{i,t}, x_{i,t}) = \exp(\beta_0 + \beta_{R\&D} R\&D_{i,t} + \beta_2 X_{i,t} + \sum_{s \in S} \alpha_s \text{dummy}_{s,i})$$

- Poisson regression includes none of the firm dummies, i.e.,  $S = \emptyset$ .
- Poisson fixed effect regression includes all of the firm dummies, i.e.,  $S = \{1, \dots, N\}$ .
- Adjusted Hausman-Taylor uses demeaned  $X_{i,t}$  and demeaned  $R\&D_{i,t}$  in GMM to identify  $\beta_{R\&D}$  of the rarely time-varying R&D.
- **PRL Poisson (Belloni, Chernozhukov and Wei, 2016)** and DML select some of the firm dummies, i.e.,  $S \in \{1, \dots, N\}$ .
  - PRL Poisson proceeds in the similar fashion as PRL, except it uses the post LASSO Poisson regression in Step 1 and use GMM in Step 3.
- DML follows the PRL Poisson steps with cross-fitting.

# PRL Poisson and DML

## Patent Counts

	Poisson	FE Poisson	PRL	DML
	Year Dummies only	All Firm and Year Dummies	Firm and Year Dummies	Firm and Year Dummies
R&D	2.305***	-0.248	2.407***	2.312***
	(0.187)	(0.255)	(0.161)	(0.120)
# of dummies			11,570	11,570
# of selected dummies			1,218 (10.53%)	2,484 (21.47%)

- In PRL and DML Poisson, R&D effect is statistically significant
- The economic magnitude (2.407 and 2.312) is close to Poisson without FE (2.305)
- PRL and DML select about 11% to 21% of firm dummies to be included in estimation
- Bias from adding all firm dummies (FE) overpowers the bias from not adding any at all (OLS) and leads to “missing R&D effect”

# Our recommendations

## Straightforward solutions:

1. Instead of only reporting FE model results, please also present the results **without FE** and discuss why the coefficient estimates vary
2. We recommend to report **within R-squared** in addition to total R-squared, and discuss the explanatory power in time series (and the rest for cross-section)

## Grab-and-go codes:

Use **adj. Hausman and Taylor, PRL and DML** for “second opinion”:

- easy to implement by **STATA** (or R/Python). We make our data and codes available online:

<https://github.com/hcchuang>

✓ These can be applied to many empirical questions in corporate finance, accounting, and economics



# Our contributions

- Corporate finance studies tend to solve firm-specific, time-invariant unobservables issues by using fixed effects models (e.g., Angrist and Pischke, 2009; Imbens and Wooldridge, 2009; Roberts and Whited, 2013)
- We illustrate the potential **biases** of such a practice by using the intuitive R&D-patent relation as our lab.
  - More importantly, we offer two **feasible and ready-to-use** methodologies to enable corporate finance researchers to analyze the effects of economic variables that are persistent in time, such as ownership structure and managerial capability.
  - In particular, we provide explanations that they may use to **justify** their choice of regression specifications without firm fixed effects (or with only a limited set of firm dummies).

## Our contributions (Cont.)

- We add to modern machine learning techniques in corporate finance research, for the selection of relevant covariates (e.g., Chinco et al., 2019; Feng et al., 2020; Gu et al., 2020; Erel et al., 2021).
- This study also adds to the economics literature by supporting and justifying prior studies' choice of not including firm fixed effects to estimate knowledge production functions (Pakes and Griliches, 1984; Blundell et al., 1995; Hall et al., 2007; Noel and Schankerman, 2013).

# Thank you!

## Questions? Comments?

[pohsuanhsu@mx.nthu.edu.tw](mailto:pohsuanhsu@mx.nthu.edu.tw) (Po-Hsuan Hsu)

Codes and data: <https://github.com/hcchuang>

Chuang, Hui-Ching and Hsu, Po-Hsuan and Kuan, Chung-Ming and Yang, Jui-Chung, Revisiting the Missing R&D-Patent Relation: Challenges and Solutions for Firm Fixed Effects Models (2024). Available at SSRN: <https://ssrn.com/abstract=4636846>

# Thank you!

## Questions? Comments?

hcchuang@gm.ntpu.edu.tw (Hui-Ching Chuang)

Chuang, Hui-Ching and Hsu, Po-Hsuan and Kuan, Chung-Ming and Yang, Jui-Chung, Revisiting the Missing R&D-Patent Relation: Challenges and Solutions for Firm Fixed Effects Models (2024). Available at SSRN: <https://ssrn.com/abstract=4636846>

[https://github.com/hcchuang/Revisiting-the-Missing-RD-Patent-Relation\\_Challenges-and-Solutions-for-Firm-Fixed-Effects-Models](https://github.com/hcchuang/Revisiting-the-Missing-RD-Patent-Relation_Challenges-and-Solutions-for-Firm-Fixed-Effects-Models)



# Example:

TABLE 2  
Baseline Regressions

Table 2 reports the regressions of firm innovation on institutional ownership. Columns 1 and 2 (3 and 4) show the pooled ordinary least squares (OLS) (Firm fixed effects) regression results. The dependent variable is shown as the column heading in columns 1–4. The main independent variable is foreign institutional ownership (FIO). All explanatory variables are lagged by 1 year. Variable definitions are in Appendix B. Standard errors are clustered at the firm level and are in parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively.

Variables	ln(PATENT) 1	ln(CITEPAT) 2	ln(PATENT) 3	ln(CITEPAT) 4
FIO	0.010*** (0.003)	0.014*** (0.004)	0.008*** (0.003)	0.011*** (0.004)
DIO	-0.010*** (0.002)	-0.012*** (0.003)	-0.001 (0.001)	-0.001 (0.002)
INSIDE	-0.072 (0.063)	-0.054 (0.070)	0.062* (0.032)	0.084* (0.041)
ln(AGE)	0.062** (0.029)	0.062* (0.032)	0.086** (0.037)	0.111** (0.049)
HHI	0.396 (0.292)	0.400 (0.326)	-0.170 (0.274)	0.152 (0.247)
HHI <sup>2</sup>	-0.277 (0.277)	-0.280 (0.307)	0.152 (0.241)	0.050 (0.290)
RD	2.267*** (0.238)	2.637*** (0.288)	0.054 (0.132)	-0.232 (0.132)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	Yes	Yes
Industry fixed effects	Yes	Yes	No	No
Country fixed effects	Yes	Yes	No	No

Dependent variables: innovation output

**ln(PATENT):** Natural logarithm of the number of patents filed by each firm in a year plus 1.

**ln(CITEPAT):** Natural logarithm of the number of citations received by each firm's patents in a year plus 1.

Our focus:

**RD:** Research and development expenditures scaled by total assets.

Does R&D explain

# Selected Top 30 Firms

1	INTL BUSINESS MACHINES	11	XEROX HOLDINGS CORP	21	FORD MOTOR CO
2	LUCENT TECHNOLOGIES	12	AT&T INC	22	HONEYWELL INTERNATIONAL INC
3	GENERAL ELECTRIC	13	TEXAS INSTRUMENTS INC	23	CBS CORP -OLD
4	APTIV PLC	14	3M CO	24	RAYTHEON TECHNOLOGIES CORP
5	EASTMAN KODAK	15	RCA CORP	25	PROCTER & GAMBLE CO
6	MOTOROLA SOLUTIONS	16	BROADCOM CORP	26	SUN MICROSYSTEMS INC
7	GENERAL MOTORS CO	17	NORTH AMERICAN PHILIPS CORP	27	QUALCOMM INC
8	DU PONT (E I) DE NEMOURS	18	EXXON MOBIL CORP	28	MOBIL CORP
9	AT&T CORP	19	HP INC	29	CONOCOPHILLIPS
10	DUPONT DE NEMOURS INC	20	MERCK & CO	30	MICRON TECHNOLOGY INC

# Alternative R&D measures: Patent regression

	Fixed Effects (Firm and Year Dummies)	OLS (Year Dummies)	adjHT (Year Dummies)	PRL (Firm and Year Dummies)	DML (Firm and Year Dummies)
<b>R&amp;D/ME</b>	0.026	0.502***	0.139***	0.112***	0.123***
	(0.018)	(0.035)	(0.018)	(0.015)	(0.012)
<b>Ln(R&amp;D)</b>	0.023***	0.140***	0.071***	0.032***	0.035***
	(0.003)	(0.004)	(0.003)	(0.001)	(0.001)

Firm cluster standard errors in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , and \*\*\* $p < 0.01$ .  
We suppress the year and firm characteristics variables to save space.

# Alternative R&D measures: Citation regression

	Fixed Effects (Firm and Year Dummies)	OLS (Year Dummies)	adjHT (Year Dummies)	PRL (Firm and Year Dummies)	DML (Firm and Year Dummies)
<b>R&amp;D/ME</b>	-0.024	1.040***	0.286***	1.015***	1.001***
	(0.040)	(0.064)	(0.040)	(0.064)	(0.038)
<b>Ln(R&amp;D)</b>	0.036***	0.286***	0.176***	0.285***	0.285***
	(0.007)	(0.006)	(0.006)	(0.006)	(0.003)

Firm cluster standard errors in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , and \*\*\* $p < 0.01$ .  
We suppress the year and firm characteristics variables to save space.

# Alternative R&D measures: AdjCitation regression

	Fixed Effects (Firm and Year Dummies)	OLS (Year Dummies)	adjHT (Year Dummies)	PRL (Firm and Year Dummies)	DML (Firm and Year Dummies)
<b>R&amp;D/ME</b>	0.021	0.506***	0.135***	0.119***	0.117***
	(0.019)	(0.037)	(0.019)	(0.016)	(0.012)
<b>Ln(R&amp;D)</b>	0.022***	0.143***	0.071***	0.035***	0.035***
	(0.003)	(0.004)	(0.003)	(0.001)	(0.001)

Firm cluster standard errors in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , and \*\*\* $p < 0.01$ .  
We suppress the year and firm characteristics variables to save space.

# Patenting firms (Observation: 45,913)

	Fixed Effects (All Firm and Year Dummies)	OLS (Year Dummies)	adjHT (Year Dummies)	PRL (Firm and Year Dummies)	DML (Firm and Year Dummies)
--	---	-----------------------	-------------------------	-----------------------------------	-----------------------------------

## Patent regression

R&D/AT	0.035	0.448***	0.161***	0.406***	0.399***
	(0.031)	(0.045)	(0.030)	(0.044)	(0.025)

## Citation regression

R&D/AT	-0.061	0.777***	0.317***	0.738***	0.740***
	(0.079)	(0.087)	(0.075)	(0.084)	(0.054)

## AdjCitation regression

R&D/AT	0.033	0.419***	0.175***	0.369***	0.377***
	(0.036)	(0.049)	(0.034)	(0.047)	(0.028)

Firm cluster standard errors in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , and \*\*\* $p < 0.01$ .

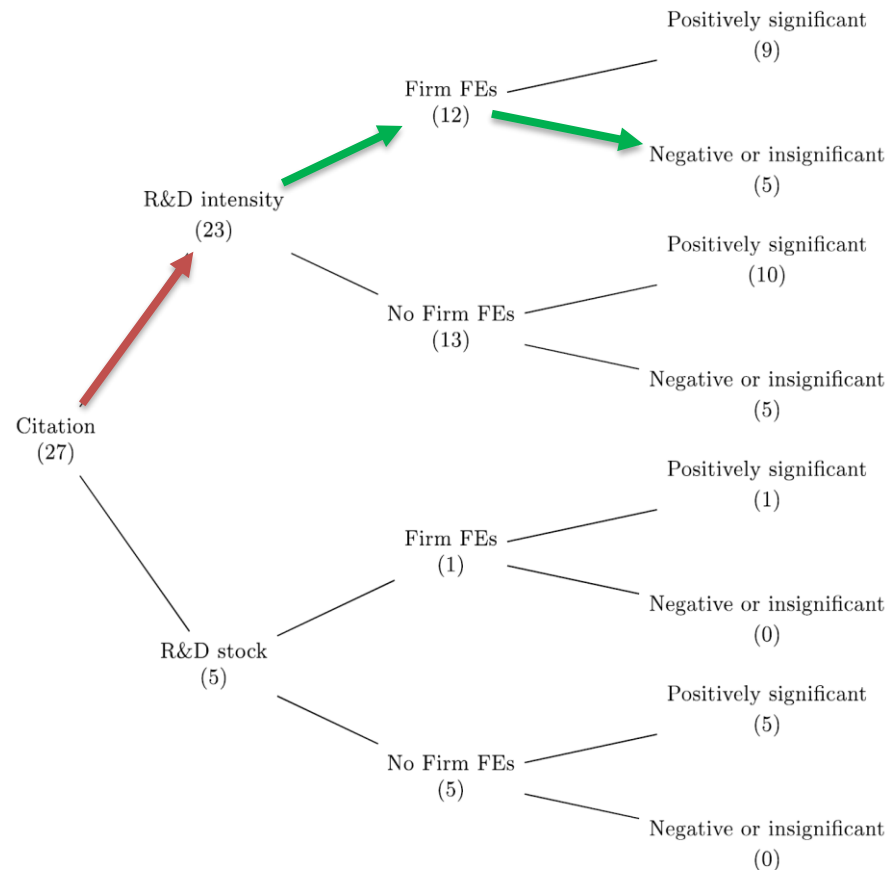
We suppress the year and firm characteristics variables to save space.

# Summary statistics

	Obs.	Mean	Median	Std. dev.	P25	P75
ln(1+Patent)	86,341	0.53	0.00	1.11	0.00	0.69
ln(1+Citation)	86,341	1.25	0.00	2.27	0.00	2.20
ln(1+AdjCitation)	86,341	0.54	0.00	1.16	0.00	0.34
R&D/Asset	86,341	0.13	0.00	0.26	0.00	0.14
ln(ME)	86,341	11.13	10.95	2.07	9.60	12.51
R&D Missing Dummy	86,341	0.43	0.00	0.50	0.00	1.00
ln(1+Age)	86,341	2.48	2.48	0.75	1.95	3.09
ln(K/L)	86,341	10.00	9.85	1.29	9.18	10.64
Tobin Q	86,341	1.76	1.22	1.66	0.94	1.85
ROA	86,341	0.10	0.13	0.18	0.06	0.19
Leverage	86,341	0.23	0.21	0.18	0.07	0.35
Cash/Asset	86,341	0.14	0.07	0.17	0.02	0.18
KZ Index	86,341	-3.42	-0.54	10.77	-3.48	1.03
Institutional ownership	86,341	0.23	0.15	0.24	0.01	0.40
HH Index	86,341	0.25	0.20	0.20	0.11	0.30
HH Index Square	86,341	0.10	0.04	0.18	0.01	0.09

# Our survey of the corporate innovation literature

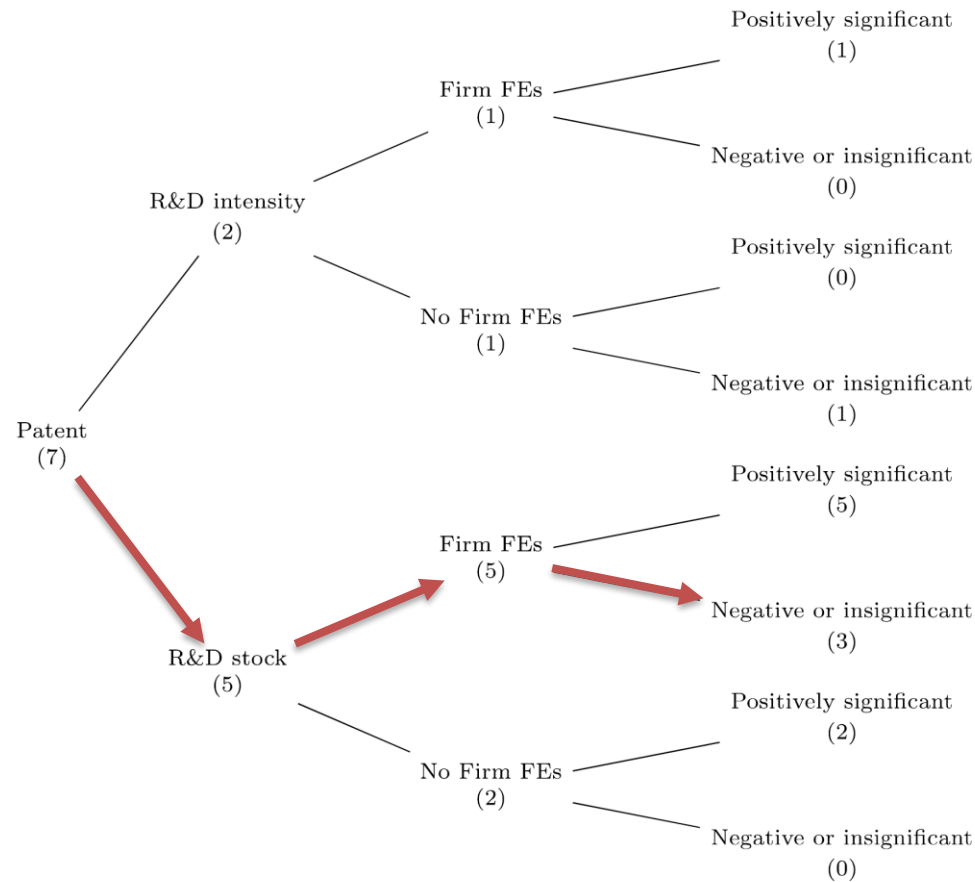
## Least square approach on Citation (paper #)





# Our survey of the corporate innovation literature

## Poisson and negative binominal approach on Patent



# Our survey of the corporate innovation literature

## Poisson and negative binominal approach on Citation

