Appendix for Online Publication

Technological Progress and Ownership Structure

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Appendix A: Variable Description

Variable	Description
$ln(1+CITES_{s,t})$	The natural logarithm of 1 plus $CITES_{s,t}$. $CITES_{s,t}$ is the number of future citations received by the cohort of patents filed by firm s in year t. We count the future citations up to the end of 2010 and exclude all self-citations. Only those patents that are ultimately granted are included in our sample. Following Hall, Jaffe, and Trajtenberg (2001), we correct for the truncation in citation count based on the estimated empirical distribution of citation-lag. [Source: NBER Patent database and Kogan et al. (2014)]
$ln(1+N_{s,t})$	The natural logarithm of 1 plus the number of patents filed by firm s in year t. Only patents that are ultimately granted are included in our sample. [Source: NBER Patent database and Kogan et al. (2014)]
$ln(1+\overline{cites}_{s,t})$	The natural logarithm of 1 plus $\overline{cites}_{s,t}$. $\overline{cites}_{s,t}$ denotes the average future citations per patent for the cohort of patents filed by firm s in year t, calculated as $CITES_{s,t}$ divided by $N_{s,t}$. [Source: NBER Patent database and Kogan et al. (2014)].
$ln(1+R\&D\ Exp_{s,t})$	The natural logarithm of 1 plus *R&D Expenditure* (Compustat Mnemonic: XRD), which is based on the latest fiscal year-end value prior to the end of calendar year t and is measured in million U.S. dollars. [Source: Compustat-CRSP merged database]
$ln(1+cites_{p,t})$	The natural logarithm of 1 plus $cites_{p,t}$. $cites_{p,t}$ denotes the number of future citations received by patent p, which is filed in year t. The future citations are counted up to the end of 2010, and all self-citations are excluded. The truncation bias in citation count is adjusted based on the estimated empirical distribution of citation-lag. [Source: NBER Patent database and Kogan et al. (2014)]
$PSOL(p,p_u)$	Pairwise (institutional) shareholder ownership overlap between the downstream patent p and its upstream patent p_u at the end of year t. We first identify all the overlapped (institutional) shareholders between firm s and the assignee of patent p_u. For each overlapped shareholder i, we calculate the minimum ownership overlap $min[w_{i,O(p)}, w_{i,O(p_u)}]$. $w_{i,O(p)}$ denotes the shareholding of investor i (relative to the aggregate institutional ownership) in the corporate assignee of patent p. $w_{i,O(p_u)}$ is defined analogously. Then, we calculate the sum of $min(w_{i,O(p)}, w_{i,O(p_u)})$ over all of the overlapped institutional shareholders in the two firms. When calculating $PSOL$, we ignore any upstream patent p_u whose assignee is not a publicly listed firm or whose assignee is the same as the assignee of the downstream patent p. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database].
$sol_{p,t}$	Shareholder overlap for patent p, filed in year t. It is calculated as the importance-weighted average $PSOL(p,p_u)$ of all cited upstream patents p_u, with $u = 1, 2, .., N_p$. We measure the importance of an upstream patent p_u by its future citations relative to the aggregate future citations of all cited upstream patents. In cases in which multiple upstream patents are assigned to the same firm, we aggregate the citation count of these patents and treat them as one single upstream patent. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]
$SOL_{s,t}$	Shareholder overlap for firm s in year t. It is calculated as the importance-weighted average $sol_{p,t}$ of all patents filed by firm s in year t. We measure the importance of a patent p by its future citation count relative to the aggregate citation count of all patents filed by the firm in the year. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]
$SOL\_Dedicated_{s,t}$	Shareholder overlap contributed by dedicated investors. At the end of each year, we sort all institutional investors by the portfolio concentration (proxied by Herfindahl Hirschman Index (HHI)) in descending order and the portfolio turnover (proxied by churn ratio defined in Gaspar, Massa, and Matos (2005)) in ascending order, respectively, and define the combined rank as the sum of HHI rank and churn ratio rank. We label dedicated investors as those in the top tercile of the combined rank (high concentration and low turnover). $SOL\_Dedicated_{s,t}$ is constructed in a similar way to $SOL_{s,t}$ except that the former uses pairwise shareholder overlap from dedicated investors only. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]

Variable	Description
$SOL\_Intermediate_{s,t}$	Shareholder overlap contributed by intermediate investors. Following the definition of dedicated investors above, we label intermediate investors as those in the middle tercile of the combined rank. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]
$SOL\_Transient_{s,t}$	Shareholder overlap contributed by transient investors. Following the definition of dedicated investors above, we label transient investors as those in the bottom tercile of the combined rank (low concentration and high turnover). [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]
$SOL\_Placebo1_{s,t}$	First placebo shareholder overlap measure. For each downstream innovator, we replace every firm cited as the true upstream patent owner with a placebo firm of similar characteristics. For any firm patent cohort, the placebo firms are matched to the true upstream firms based on the same four-digit SIC industry code and then on the minimal Euclidean distance of both firm total assets and firm patent filing counts in past five years, which are normalized by their respective industry average in the same year. The matched placebo firms aren't cited by any patent filed by the downstream innovator in respective year. If no matching firm is identified for an upstream firm, we then move up to three-digit SIC industry code and repeat the procedure above. [Source: NBER Patent database, Kogan et al. (2014), and Compustat-CRSP merged database]
$SOL\_Placebo2_{s,t}$	Second placebo shareholder overlap measure. For each downstream innovator, we replace every firm cited as the true upstream patent owner with a placebo firm of similar characteristics. For any firm patent cohort, the placebo firms are matched to the true upstream firms based on the technology proximity following Bloom, Schankerman, and Van Reneen (2013). If more than one of matching firms feature the same proximity with respect to a true upstream firm, we then follow the same methodology to find a closest matching firm as in the first placebo measure. The matched placebo firms aren't cited by any patent filed by the downstream innovator in respective year. [Source: NBER Patent database, Kogan et al. (2014), and Compustat-CRSP merged database]
$WHHI_{s,t}$	Weighted Herfindahl-Hirschman index of shareholder overlap concentration. First, we calculate the Herfindahl-Hirschman index of patent pair (p,p_u) for share overlap $min[w_{i,O(p)}, w_{i,O(p_u)}]$ of each investor $i \in I_{p,p_u}$, who jointly holds equity in downstream and upstream firms $O(p)$ and $O(p_u)$. $w_{i,O(p)}$ denotes the share holding of investor i (relative to the aggregate institutional ownership) in the corporate assignee of patent p. $w_{i,O(p_u)}$ is defined analogously. Second, we importance-weighted average HHI in the first step over all patent p's upstream patents p_u, with $d = 1, 2, .., N_p$, where we measure the importance of the upstream patent p_u by its future citations relative to the aggregate future citations of all patent p's peer upstream patents. In cases in which multiple upstream patents are assigned to the same firm, we aggregate the citation count of these patents and treat them as one single upstream patent. Lastly, we importance-weighted average the result obtained in the second step over all patents filed by firm s in year t, where we measure the importance of a patent p by its future citation count relative to the aggregate citation count of all patents filed by the firm in the year. [Source: NBER Patent database, Kogan et al. (2014), and Thomson Reuters 13F database]
$IO^{NOL}_{s,t}$	Non-overlapping institutional ownership of firm s at year t. It is calculated as the total number of shares held by non-overlapping institutional investors relative to total shares outstanding. [Source: Thomson Reuters 13F database and Compustat-CRSP merged database]
$ln(1 + MktCap_{s,t})$	The natural logarithm of 1 plus firm market capitalization , which is the product of share price and shares outstanding the end of calendar year t and is measured in thousand U.S. dollars. [Source: CRSP database]
$ln(1 + R\&D\ Stock_{s,t})$	The natural logarithm of 1 plus $R\&D\ Stock_{s,t}$, where $R\&D\ Stock_{s,t} = R\&D\ Expenditure_{s,t} + (1-\delta) \times R\&D\ Stock_{s,t-1}$. Following Hall, Jaffe, and Trajtenberg (2005), we set $delta = 0.15$ to represent the private depreciation rate of knowledge. $R\&D\ Expenditure$ (Compustat mnemonic: XRD) is based on the latest fiscal year-end value prior to the end of calendar year t and is measured in million U.S. dollars. [Source: Compustat-CRSP merged database]

Variable	Description
$ln(1+K/L_{s,t})$	The natural logarithm of 1 plus the ratio of *Capital* (Compustat Mnemonic: *PPEGT*) to *Labor* (Compustat Mnemonic: *EMP*). Both variables are based on the latest fiscal year-end values prior to the end of calendar year t. *Capital* is measured in million U.S. dollars and *Labor* in thousands. [Source: Compustat-CRSP merged database]
$ln(1+Sales_{s,t})$	The natural logarithm of 1 plus *Sales* (Compustat Mnemonic: *SALE*), which is based on the latest fiscal year-end value prior to the end of calendar year t and is measured in million U.S. dollars. [Source: Compustat-CRSP merged database]
PrivatePatentShare	Weighted share of cited upstream patents owned by private firms. For each patent filing in a given year, we calculate its share of upstream patents owned by private firms. We then importance-weighted average the private patent share over a cohort of patents filed by the downstream firm in the same year, where the importance is measured by the number of future citation count relative to the aggregate citation count of all patents in the same yearly patent cohort filed by the downstream firm.

Appendix B: A Model of Patent Hold-Up

B.1. Benchmark Case without Hold-Up Effects

A risk-neutral firm s can invest into a continuum of patent projects. Each project is represented by the index number p on the interval $[0, \infty)$, where a higher index number corresponds to higher patent development costs. For simplicity, we assume a continuous increasing convex cost function $C(p)$ with $C'(p) > 0$ and $C''(p) > 0$. The present value from commercialization of the patent project, $V_s(p)$, is proportional to the success of the patent proxied by the number of future citation counts $cites_s(p)$. Hence,

$$V_s(p) = \alpha \times cites_s(p), \tag{1}$$

where $cites_s(p)$ is a random variable with the expected value $E[cites_s(p)] = \mu_s$, and $\alpha > 0$ is a constant. The total expected firm value Π_s follows as

$$\Pi_s = \max_{\overline{p}} \int_0^{\overline{p}} [\alpha\mu_s - C(p)]\, dp, \tag{2}$$

where the interval $[0, \overline{p}]$ denotes the range of patent projects the firm pursues. Value maximization implies the first-order condition $\alpha\mu_s = C(\overline{p})$. For a convex cost function $C(p) = cp^b$ $(b > 1)$, we find that

$$\overline{p} = \left(\frac{\alpha\mu_s}{c}\right)^{\frac{1}{b}} \tag{3}$$

characterizes the optimal range of patent production. We summarize the model implications as follows:

Proposition 1: Patent Production without Patent Hold-up

A value maximizing firm optimally invests in the production of patents on the line interval $[0, \overline{p}]$. Given a patent-level expected citation count $E[cites_s(p)] = \mu_s$ that is proportional to each patent's expected value and a convex cost function $C(p) = cp^b$, we find for

(i) the (log) extensive margin of patent production

$$ln[\overline{p}] = \frac{1}{b} ln\frac{\alpha}{c} + \frac{1}{b} ln(\mu_s) \tag{4}$$

(ii) the firm-level (log) citation counts

$$ln[CITES_s] = ln\int_0^{\overline{p}} E[cites_s(p)]dp = \frac{1}{b} ln\frac{\alpha}{c} + \frac{b+1}{b} ln(\mu_s), \tag{5}$$

(iii) the (log) R&D expenditure

$$ln[R\&D\ Exp] = ln\int_0^{\overline{p}} cp^b dp = ln\frac{c}{1+b} + \frac{b+1}{b} ln\frac{\alpha\mu_s}{c}. \tag{6}$$

The firm-level (log) citation count in Eq. (5) is equal to the (log) extensive margin in Eq. (4) plus the (log) intensive margin $lnE[cites_s(p)] = ln(\mu_s)$. Empirically, we can approximate the intensive margin by the average citation count $\overline{cites}_s$ of a firm's patents.

B.2. The Patent Hold-Up Effect

Next, we enrich the model setting to account for hold-up problems with respect to the patent value $V_s(p)$. Suppose that commercialization of each patent p requires consent from the owners of upstream patents (p_u, $u = 1, 2, ...N_p$).[1] These upstream patents allow their owners to extract part of the value (through, e.g., license fees) so that the firm's expected patent value decreases. We denote the share of patent value lost to each upstream patent by $L_s(p, p_u)$ and the aggregate value loss by

$$L_s(p) = \sum_{u=1}^{N_p} L_s(p, p_u). \tag{7}$$

The share $L_s(p) \in [0, 1]$ and its component $L_s(p, p_u)$ depend on the "toughness" of bargaining by the owner of the upstream patent p_u. In the ideal case in which the institutional owners of firm s coincide with those of the firms owning (p_u, $u = 1, 2, ...N_p$), no rent extraction should take place so that $L_s(p) = L_s(p, p_u) = 0$. By contrast, maximal rent extraction occurs if there is no overlap in institutional ownership between the downstream innovating firm and the upstream firms. For simplicity, we assume that the ex-ante expectation for value loss is identical for all patents p produced by the same firm, with $E[L_s(p)] = \overline{L}_s$.

Besides the direct value loss due to rent extraction, the hold-up situation might also reduce the total value prospect of each individual patent itself. For example, patent litigation may retard the commercial adoption of a patent and jeopardize its long-run success. We assume that the expected number of citations diminishes according to

$$E\left[cites_s(p)\right] = \mu_s[1 - \overline{L}_s]^\gamma, \tag{8}$$

where γ denotes the elasticity of the expected patent success (measured by future citation count) to the retained value share, $1 - \overline{L}_s$, with $\gamma \geq 0$. In the special case $\gamma = 0$, patent hold-up does not compromise the overall long-term patent success and instead amounts to only a simple redistribution of future rents. The expected net value from patent p follows as

$$E[V_s(p)] = \alpha[1 - \overline{L}_s]\ E\left[cites_s(p)\right] = \alpha\mu_s[1 - \overline{L}_s]^{1+\gamma}. \tag{9}$$

The optimal investment policy in the hold-up case requires maximization of the expected present value function

$$\max_{\overline{p}_L} \Pi_s = \int_0^{\overline{p}_L} \left[\alpha\mu_s[1 - \overline{L}_s]^{1+\gamma} - C(p)\right] dp, \tag{10}$$

where the optimal patent range $[0, \overline{p}_L]$ has the upper limit

$$\overline{p}_L = \left(\frac{\alpha\mu_s}{c}[1 - \overline{L}_s]^{1+\gamma}\right)^{\frac{1}{b}}. \tag{11}$$

[1] Note that p_u does not include any expired patents because they do not pose any threat to the commercialization of the citing patent.

Proposition 2: Patent Production in the Patent Hold-up Case

A firm accounting for an expected value loss $\overline{L}_s$ per patent optimally invests in the production of patents on the line interval $[0, \overline{p}_L]$. Given a patent-level (ex-ante) expected citation count $E[cites_s(p)] = \mu_s[1-\overline{L}_s]^\gamma$, which is proportional to the expected patent value, a convex cost function $C(p) = cp^b$, and an (ex-ante) expected value loss $\overline{L}_s = E[L_s(p)]$ for each patent due to patent hold-up, we find for

(i) the (log) extensive margin of patent production

$$ln[\overline{p}_L] = \frac{1}{b} ln\frac{\alpha}{c} + \frac{1}{b} ln(\mu_s) + \frac{1+\gamma}{b} ln[1-\overline{L}_s] \tag{12}$$

(ii) the firm-level (log) citation count

$$ln[CITES_s] = \frac{1}{b} ln\frac{\alpha}{c} + \frac{b+1}{b} ln(\mu_s) + \frac{1+\gamma+b\gamma}{b} ln[1-\overline{L}_s], \tag{13}$$

(iii) the (log) R&D expenditure

$$ln[R\&D\ Exp] = ln\frac{c}{1+b} + \frac{b+1}{b} ln\frac{\alpha\mu_s}{c} + (1+\gamma)\frac{b+1}{b} ln[1-\overline{L}_s]. \tag{14}$$

Eqs. (12)–(14) are exactly the same as Eqs. (4)–(6) except for the third term. The third term in Eqs. (12)–(14) features the same (log) loss term $ln[1-\overline{L}_s] < 0$ and captures how the hold-up problem reduces, respectively, the extensive margin, the overall patent success, and R&D expenditure. The hold-up problem also affects the *intensive margin* $E[cites_s(p)]$ of patent production if $\gamma > 0$.

B.3. Patent Hold-Up and Shareholder Overlap

The model estimation has to define empirical proxies for the patent-specific hold-up loss $L_s(p)$ and its unconditional expected value $E[L_s(p)] = \overline{L}_s$. We assume that shareholder overlap influences $\overline{L}_s$ through two channels: First, a *transfer internalization channel* implies that management of the downstream firm will only account for the portion of the transfer payments received by the overlapping shareholders but not the portion paid to the upstream firms' other shareholders in its value maximization. Second, a *transfer reduction channel* suggests that if the rent extraction by upstream firms involves frictions that generate costs for overlapping shareholders without a commensurate benefit, overlapping investors would exercise their influence over the upstream firms in favor of swift conflict resolution and therefore reduce the overall patent transfer payments by the downstream firm. Both channels imply that $\overline{L}_s$ should decrease in *shareholder overlap* either because of a smaller proportion of transfer payments that are not accounted for, or because of the reduction of overall monetary transfers, or both.

We can formalize the role of shareholder overlap as follows: Let $O(p)$ be an ownership function that assigns a patent p to a (single) firm owner at time t. The *pairwise (institutional) shareholder overlap* between the downstream patent p and an upstream patent p_u (listed in the patent filings) can be defined as

$$PSOL(p, p_u) = \sum_i \min[w_{i,O(p)}, w_{i,O(p_u)}], \tag{15}$$

where $w_{i,O(p)}$ and $w_{i,O(p_u)}$ are the ownership share (relative to the total institutional ownership of the respective firm) of institutional investor i in, respectively, firms $O(p)$ and $O(p_u)$ at time t. Without loss of clarity, we omit the time index t from all variable expressions in this subsection. We assume the following reduced form for the distributive value loss function associated with the upstream patent p_u cited by patent p:

$$L_s(p, p_u) = \delta w(p_u) \left[1 - PSOL(p, p_u)\right], \tag{16}$$

where weight function $w(p_u)$ measures the importance of the upstream patent p_u relative to all other upstream cited patents of the follow-up patent p. The parameter $\delta \in [0, 1]$ denotes the degree to which separate asset ownership translates into patent revenue sharing; a larger value for δ implies more rent redistribution due to ownership separation. The total redistributed rents to the N_p upstream patent holders aggregate to a redistributive loss for patent p, given by

$$\begin{aligned} L_s(p) &= \sum_{u=1}^{N_p} \delta w(p_u) \left[1 - PSOL(p, p_u)\right] \\ &= \delta \left[1 - \sum_{u=1}^{N_p} w(p_u) PSOL(p, p_u)\right]. \end{aligned} \tag{17}$$

We can define *patent-level shareholder overlap* as

$$sol_p = \sum_{u=1}^{N_p} w(p_u) PSOL(p, p_u). \tag{18}$$

For the N_s patents filed by firm s at year t, we can approximate the average hold-up loss as

$$\begin{aligned} \overline{L}_s &= \sum_{p=1}^{N_s} w(p) L_s(p) \\ &= \delta \left[1 - \sum_{p=1}^{N_s} \sum_{u=1}^{N_p} w(p) w(p_u) PSOL(p, p_u)\right], \end{aligned}$$

where the weight $w(p)$ denotes the relative importance of patent p. The *firm-level shareholder overlap* can be defined as

$$SOL_s = \sum_{p=1}^{N_s} \sum_{u=1}^{N_p} w(p) w(p_u) PSOL(p, p_u), \tag{19}$$

which captures shareholder commonality between firm s and all other firms owning the upstream patents. The hold-up loss term in Proposition 2 can be approximated by

$$ln(1 - \overline{L}_s) \simeq -\overline{L}_s = \delta[SOL_s - 1], \tag{20}$$

and substitution makes the model directly testable. The expression δSOL_s captures the hold-up attenuation through firm-level shareholder overlap relative to a total (non-attenuated) hold-up effect embodied by δ.

A final measurement issue concerns the choice of weights reflecting the relative importance of any patents p and p_u. Empirically, we measure the relative importance by the relative (log) citation count as follows:

$$w(p) = \frac{ln[1 + cites_s(p)]}{\sum_{p=1}^{N_s} ln[1 + cites_s(p)]} \quad \text{and} \quad w(p_u) = \frac{ln[1 + cites(p_u)]}{\sum_{u=1}^{N_p} ln[1 + cites(p_u)]}. \tag{21}$$

In the robustness section (Section 7), we show that an alternative weighting scheme using a (non-parametric) rank measure of future citations $rank(p)$ in Eq. (21) delivers very similar results. The results are also robust to using equal weights.

Appendix C: Robustness Tests

Table C1: Firm Level Citation Counts by Adjustment Method

Reported are summary of sample statistics for (the number of) firms, (approved) patents per firm and the firm level subsequent citation count by year of patent filing. We report two measures of adjusted future citations that correct for the truncation. Hall et al. (2001) addresses the truncation issue in citation counts by estimating the shape of citation-distribution. Relative citation count is proposed by Lerner et al. (2011). A patent's relative citation count is calculated as the number of future citation the patent receives in the grant year and three-year thereafter relative to the average number of future citations received, over the same period, by patents that are assigned to the same USPTO technology class and that are applied in the same year. The firm-level relative citation count measure reported below is the sum of relative cites of all patents filed by a firm in a given year.

			Firm level citation count (*Cites*)								
			No adjustment			Hall et al. (2001)			Lerner et al. (2011)		
	Firms	Patents per firm	Mean	Median	STD	Mean	Median	STD	Mean	Median	STD
1992	920	26	471	62.5	2,062	581	79	2,468	26	3.8	98
1993	1,065	23	443	55	1,886	563	72	2,317	24	3.5	88
1994	1,206	23	453	57	2,215	589	74	2,772	25	3.6	99
1995	1,313	26	473	59	2,334	637	85	3,019	27	3.9	113
1996	1,281	26	469	55	2,382	649	79	3,175	27	3.8	119
1997	1,457	28	487	49	2,829	703	74	3,920	30	3.6	145
1998	1,412	28	421	42	2,531	636	70	3,673	29	3.9	149
1999	1,399	30	363	36	2,177	585	61	3,357	30	3.8	156
2000	1,347	34	314	29	1,680	542	53	2,783	34	4.1	167
2001	1,377	35	234	25	1,148	442	47	2,098	35	4.4	166
2002	1,338	38	178	18	807	371	40	1,611	37	4.4	155
2003	1,232	38	122	12	550	287	31	1,245	37	4.2	158
2004	1,123	38	80	7	344	217	21	896	36	3.4	151
2005	1,067	36	49	5	210	159	18	652	32	3.7	149
2006	971	31	27	3	107	115	13	429	25	0.9	98
2007	807	24	15	2	65	90	11	357	17	0.0	71
Total	2,964	30	300	26	1,805	468	48	2,562	30	3.7	137

Table C2: Shareholder Overlap by Weighting Method

Reported are the summary statistics for the patent pairs between owners of upstream and downstream patents and three measures for shareholder overlap. Patent pairs denotes the number of distinct pairs formed by our sample firms and listed firms owning precursory complementary patents. Three measures of shareholder overlaps are i) Cites weighted shareholder overlap (SOL), where the importance weight is based on patent future citation count, ii) Rank weighted shareholder overlap (SOL_rank), where the importance weight is based on the rank of patent future citation count relative to those patents that are assigned to the same USPTO technology class and are applied in the same year, and iii) Equally weighted shareholder overlap (SOL_equal), where we no longer leverage overlapped ownership by importance weight.

Year	Firms	Patent pairs (p, p^u)		Shareholder overlap (SOL) by weights ($\times 100$)								
		All Firms	Listed Firms	Cites weighted			Rank weighted			Equally weighted		
				Mean	Median	STD	Mean	Median	STD	Mean	Median	STD
1992	920	199,152	73,348	5.59	4.18	5.40	5.56	4.20	5.33	15.65	14.41	11.08
1993	1,065	234,780	87,013	5.15	3.55	5.23	5.16	3.62	5.13	14.39	13.11	10.69
1994	1,206	276,445	104,365	5.36	4.00	5.31	5.34	3.85	5.24	15.13	13.97	10.66
1995	1,313	344,000	138,967	5.43	3.79	5.30	5.41	3.78	5.23	14.80	13.26	10.43
1996	1,281	317,550	137,229	5.66	4.09	5.51	5.65	4.10	5.44	15.10	14.33	10.74
1997	1,457	437,927	192,251	5.44	3.74	5.57	5.46	3.82	5.55	14.88	13.62	11.07
1998	1,412	428,224	188,161	5.61	4.06	5.65	5.62	4.19	5.60	15.07	13.75	11.32
1999	1,399	473,645	201,186	5.70	3.78	5.83	5.72	3.82	5.85	15.53	13.70	11.33
2000	1,347	608,761	255,724	6.07	3.99	6.44	6.16	4.18	6.47	16.57	15.51	12.42
2001	1,377	657,902	271,328	6.35	4.46	6.64	6.42	4.55	6.66	17.73	17.32	12.34
2002	1,338	713,064	292,714	6.86	4.66	7.01	6.94	4.76	7.03	19.14	19.62	12.78
2003	1,232	700,752	275,324	6.82	5.15	6.71	6.94	5.19	6.74	19.18	19.59	12.86
2004	1,123	697,338	284,849	7.48	5.40	7.36	7.59	5.70	7.31	20.85	22.00	12.67
2005	1,067	587,137	236,380	7.27	5.27	7.09	7.37	5.63	7.10	19.93	20.66	12.53
2006	971	459,526	180,050	7.43	5.76	7.07	7.59	5.98	7.12	21.11	21.85	12.49
2007	807	307,457	115,216	7.37	5.31	7.11	7.45	5.54	7.02	21.93	23.08	12.78
Total	2,964	7,443,660	3,034,105	6.17	4.34	6.26	6.22	4.43	6.25	17.10	16.24	12.01

Table C3: Robustness to Log Transformation of Dependent Variable

We repeat the main specifications in Table 2 but proxy the patent success in dependent variable with $ln(CITES_{s,t})$. Column 1-3 report full sample results and Column 4-6 results of subsample based on top three R&D-intensive industries. Industry fixed effects are based four-digit SIC codes. All regressions report robust standard errors clustered at firm and year levels in parentheses.

Dependent Variables:	$ln(CITES)$					
	Full Sample			Top 3 R&D-Intensive Industries		
	(1)	(2)	(3)	(4)	(5)	(6)
SOL	3.489	1.270	2.138	3.510	1.958	3.463
	(0.363)	(0.369)	(0.289)	(0.667)	(0.688)	(0.527)
Controls:						
$ln(1+MktCap)$	0.283	0.136		0.362	0.156	
	(0.011)	(0.015)		(0.020)	(0.026)	
$ln(1+R\&D\ Stock)$	0.304	0.119		0.249	0.174	
	(0.009)	(0.024)		(0.020)	(0.048)	
$ln(1+K/L)$	0.024	-0.086		0.119	-0.070	
	(0.018)	(0.030)		(0.032)	(0.052)	
$ln(1+Sales)$	-0.007	0.026		0.014	0.018	
	(0.010)	(0.020)		(0.017)	(0.031)	
$Private\ Patent\ Share$	0.265	-0.028		0.321	-0.124	
	(0.091)	(0.092)		(0.154)	(0.159)	
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	NO	NO	YES	NO	NO
Firm FE	NO	YES	YES	NO	YES	YES
Obs.	17,864	17,864	17,864	5,539	5,539	5,539
Adj. R^2	0.502	0.721	0.717	0.537	0.738	0.733

Table C4: Cites Adjustment and Different Importance Weights of Shareholder overlap

This table presents the regression results of the firm-level patent success on shareholder overlap. Column 1-4 report the regression results by repeating baseline regressions for rank-weighted shareholder overlap, SOL_Rank, and equally-weighted shareholder overlap, SOL_Equal. We adopt the adjusted cites measure proposed by Lerner et al., 2014 and report the regression results in Column 5-6, where both dependent variable and the importance weight of shareholder overlap are adjusted accordingly. Industry fixed effects are based on four-digit SIC codes. All regressions report robust standard errors clustered at the firm and year levels in parentheses.

Dep. Variable:	$ln(1+CITES)$				$ln(1+CITES\_Rel)$	
	(1)	(2)	(3)	(4)	(5)	(6)
SOL_Rank	3.906	2.096				
	(0.373)	(0.286)				
SOL_Equal			2.916	2.544		
			(0.164)	(0.142)		
SOL_Rel					2.787	1.521
					(0.256)	(0.190)
Controls:						
$ln(1+MktCap)$	0.297		0.254		0.204	
	(0.012)		(0.012)		(0.008)	
$ln(1+R\&D\ Stock)$	0.318		0.308		0.262	
	(0.009)		(0.009)		(0.006)	
$ln(1+K/L)$	0.035		0.028		0.046	
	(0.019)		(0.019)		(0.014)	
$ln(1+Sales)$	-0.008		-0.025		0.035	
	(0.010)		(0.010)		(0.007)	
$Private\ Patent\ Share$	0.435		0.056		0.259	
	(0.093)		(0.074)		(0.063)	
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	NO	YES	NO	YES	NO
Firm FE	NO	YES	NO	YES	NO	YES
Obs	19,315	19,315	19,315	19,315	19,315	19,315
Adj. R^2	0.524	0.721	0.530	0.727	0.509	0.717

Table C5: Robustness to Different Time Lags for Shareholder Overlap

We repeat the baseline regressions in Table 2, Columns 1-2, for different time lags of ownership measurement in the computation of SOL. The variables $SOL(-k)$ is similar to $SOL_{s,t-1}$ in the baseline regression except that the former is based on institutional ownership at the end of year $t-k$ instead of $t-1$. Industry fixed effects are based on four-digit SIC codes. All regressions report robust standard errors clustered at firm and year levels in parentheses.

Dependent Variable:	$ln(1+CITES)$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$SOL(-2)$	3.651	1.723						
	(0.375)	(0.297)						
$SOL(-3)$			3.348	1.190				
			(0.393)	(0.317)				
$SOL(-4)$					2.776	0.639		
					(0.428)	(0.338)		
$SOL(-5)$							2.184	−0.106
							(0.402)	(0.330)
Controls:								
$ln(1+MktCap)$	0.302		0.306		0.310		0.322	
	(0.012)		(0.013)		(0.014)		(0.015)	
$ln(1+R\&D\ Stock)$	0.317		0.319		0.328		0.325	
	(0.009)		(0.010)		(0.011)		(0.011)	
$ln(1+K/L)$	0.046		0.082		0.087		0.096	
	(0.021)		(0.023)		(0.024)		(0.026)	
$ln(1+Sales)$	−0.001		0.006		0.013		0.014	
	(0.012)		(0.013)		(0.014)		(0.015)	
$Private\ Patent\ Share$	0.363		0.274		0.132		0.033	
	(0.098)		(0.106)		(0.116)		(0.114)	
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	NO	YES	NO	YES	NO	YES	NO
Firm FE	NO	YES	NO	YES	NO	YES	NO	YES
Obs.	17,259	17,259	15,055	15,055	13,058	13,058	12,028	12,028
Adj. R^2	0.533	0.730	0.545	0.739	0.557	0.749	0.558	0.753

Table C6: Filtering Citation Counts

Reported are OLS regressions of patent success measured on the lagged *shareholder overlap* for the sample period 1992 − 2007. Patent success is proxied by $ln(1 + cites_{s,t})$ as the (log) future citation count received by firm s filed in year t excluding self-citations. The first filtered version of the citation count, $cites^{F1}_{s,t}$ excludes in addition citations coming from all firms quoted in the patent application of patent p. The second filtered citation measure, $cites^{F2}_{s,t}$, excludes in addition citations coming from all firms that firm s has ever quoted previously. We sum up the patent-level filtered citation counts $cites^{F1}_{s,t}$ and $cites^{F2}_{s,t}$ to achieve firm-level filtered citation count $CITES^{F1}$ and $CITES^{F2}$, respectively. Industry fixed effects are based four-digit SIC codes. All regressions report robust standard errors clustered at firm and year levels in parentheses.

Dependent Variables:	$ln(1+CITES^{F1})$		$ln(1+CITES^{F2})$		$ln(1+cites^{F1})$	$ln(1+cites^{F2})$
	(1)	(2)	(3)	(4)	(5)	(6)
SOL	3.538	1.830	3.328	1.821	0.087	0.063
	(0.372)	(0.283)	(0.365)	(0.280)	(0.018)	(0.018)
sol						
Controls:						
$ln(1 + MktCap)$	0.300		0.301			
	(0.012)		(0.011)			
$ln(1 + R\&D\ Stock)$	0.317		0.302			
	(0.009)		(0.009)			
$ln(1 + K/L)$	0.035		0.018			
	(0.019)		(0.019)			
$ln(1 + Sales)$	−0.007		−0.014			
	(0.010)		(0.010)			
$Private\ Patent\ Share$	0.466		0.466			
	(0.093)		(0.092)			
Year FE	YES	YES	YES	YES	NO	NO
Industry FE	YES	NO	YES	NO	NO	NO
Firm FE	NO	YES	NO	YES	NO	NO
Tech. FE	NO	NO	NO	NO	YES	YES
Year × Firm FE	NO	NO	NO	NO	YES	YES
Obs.	19,315	19,315	19,315	19,315	582,032	582,032
Adj. R^2	0.519	0.718	0.504	0.706	0.323	0.291

Table C7: Alternative Explanatory Variables

We compare three potential determinants of innovation success, namely (i) *shareholder overlap* ($SOL_{s,t-1}$) between an innovating firm and upstream firms owning complementary patents as a proxy for attenuation of a patent hold-up problem; (ii) *institutional ownership* ($IO_{s,t-1}$) as advocated by Aghion, Van Reenen and Zingales (2013) as a proxy for investor patience; and (iii) *shareholder innovation focus* ($SIF_{s,t-1}$) as a proxy for a firm's shareholders focus on research intensive portfolio investments. Columns 1–3 use the full sample period $1992-2007$, and Columns 4–5 use the sample of Aghion, Van Reenen and Zingales (2013), which spans the shorter period from 1991 to 1999. The dependent variable $ln(1+CITES_{s,t})$ is the (log) number of total future citations received by the cohort of patents successfully filed by firm s in year t. The first three regressions adopt the same dependent and control variables as in the previous tables. The last two regressions are based on data set provided by Aghion, Van Reenen and Zingales (2013). Industry fixed effects are based four-digit SIC codes. Robust standard errors are reported in parentheses.

Dependent Variables:	$ln(1+CITES)$ Full Sample			$ln(CITES)$ ARZ Sample	
	(1)	(2)	(3)	(4)	(5)
SOL	3.726	3.682	3.558		4.823
	(0.373)	(0.373)	(0.374)		(0.951)
IO		−0.680	−0.674	0.546	0.270
		(0.058)	(0.058)	(0.186)	(0.219)
SIF			1.024		
			(0.270)		
Controls:					
$ln(1+MktCap)$	0.300	0.339	0.331		
	(0.012)	(0.012)	(0.012)		
$ln(1+R\&D\ Stock)$	0.318	0.313	0.312	0.337	0.334
	(0.009)	(0.009)	(0.009)	(0.040)	(0.049)
$ln(1+K/L)$	0.035	0.039	0.037	0.261	0.271
	(0.019)	(0.019)	(0.019)	(0.085)	(0.093)
$ln(1+Sales)$	−0.008	0.013	0.012	0.310	0.262
	(0.010)	(0.010)	(0.010)	(0.045)	(0.053)
$Private\ Patent\ Share$	0.411	0.397	0.373		
	(0.093)	(0.093)	(0.093)		
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	NO
Obs	19,315	19,315	19,315	4,025	3,390
Adj. R^2	0.524	0.528	0.528	0.611	0.628