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ABSTRACT
Using the US patent data for the period 1977–2005, we find that there are inverted U-shaped relationships between the degree of industry-level technological imitation and industry-level innovation activities, and between the degree of industry-level technological imitation and the value of firm-level innovation. Our results suggest that positive externalities from the interactions among firms during the process of innovation dominate the negative effects of free-riding concerns on firms' innovation activities and incentives to innovate up to quite a high degree of technological imitation, while the free-riding concerns dominate the positive externalities when the level of technological imitation is extremely high.

KEYWORDS
Corporate innovation; technological imitation; value of innovation; clustering

1. Introduction

Corporate innovation is crucial in that it improves total factor productivity and allows firms to achieve higher potential output with lower manufacturing costs in a more efficient and environmentally friendly way (Schoonhoven, Eisenhardt, and Lyman 1990), as well as bringing new growth engines into different industries, thus enlarging demand in most developed economies (Brozen 1951; Huang and Rozelle 1996; Grossman and Helpman 1991). Although corporate innovation is very important to firms and economies as a whole, it is extremely costly in that it requires massive fixed investments at the early stage and may require substantial support for long-term capital and human resources from companies themselves or national institutions. Therefore, various determinants of corporate innovation such as hostile takeovers (Atanassov 2013), stock liquidity (Fang, Tian, and Tice 2014), corporate taxes (Mukherjee, Singh, and Zaldokas 2016), policy uncertainty (Bhattacharya, Hsu, Tian, and Xu 2015), and product market competition (Aghion, Bloom, Blundell, Griffith, and Howitt 2005; Greenhalgh and Rogers 2006; Im, Park, and Shon 2015) have been studied in the literature. In this paper, we investigate whether the degree of industry-level technological imitation decreases or increases industry-level innovation activities and firms' motivation to innovate.

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The relationship between technological imitation and corporate innovation has been studied by several scholars, but their theoretical predictions and empirical findings have not yet reached consensus. The first view is that technological imitation has a positive effect on corporate innovation due to the positive externalities in the process of innovation. Among others, Bessen and Maskin (2009) argue that if innovation is sequential (so that each successive innovation is made based on its predecessors' earlier innovations) and complementary (so that each potential innovator takes a different research line), technological imitation will enhance an inventor's prospective profits. In this case, patent protection (prohibition or hurdle against imitation) may not be useful for encouraging corporate innovation. Rather, creating innovation clusters like Silicon Valley in the United States and Shenzhen City in China and allowing different innovators to cooperate, imitate and compete with each other would be more effective in promoting corporate innovation.[1] The second view is that technological imitation has a negative effect on corporate innovation due to free-riding problems. For example, Zeng (2001) found that an increase in subsidies to technological imitation would increase investment in technological imitation and decrease investment in technological innovation. Given the assumption that innovation is independent, unlike the assumptions made by Bessen and Maskin (2009), technological imitation will obviously decrease the value of a firm's innovation outcomes, thereby reducing their incentives to innovate. The third view predicts an inverted U-shaped relationship between technological imitation and corporate innovation. Aghion, Harris, Howitt, and Vickers (2001) argue that a little imitation is almost always growth-enhancing as it promotes more frequent neck-and-neck competition, but extremely high imitation is unambiguously growth-reducing due to the free-riding problems.

In this study, we empirically investigate if the degree of industry-level technological imitation increases or decreases firms' innovation activities and their incentives to innovate by utilizing firm-level patent data of US firms between 1977 and 2005. First, we perform an industry-level analysis as in Aghion, Harris, Howitt, and Vickers (2001) by regressing an industry-average innovation measure (i.e., number of patents and number of citations) on a competitor–quick citation ratio for each industry-year as a measure of technological imitation. Second, we repeat the analysis sector-by-sector in order to investigate whether the relationship between technological imitation and corporate innovation is heterogenous across sectors. Finally, we investigate the impact of technological imitation on the value of firm-level innovation using the approach used by Im, Park, and Shon (2015), Faulkender and Wang (2006), and Dittmar and Mahrt-Smith (2007).

2. Sample selection and variable construction

We use data for returns to individual firms' stocks from the Center for Research in Security Prices (CRSP) and data for returns to the 25 portfolios formed on "Size" and "Book-to-Market" (5×5) from Kenneth French's data library (or industry average stock returns) to calculate excess stock returns. In addition, we use data from Compustat North America to construct variables based on the information contained

[1] An article in the South China Morning Post on 28th September 2016 introduces the success of Shenzhen City in promoting corporate innovation as follows: "*Beginning in 2013, Shenzhen funnelled more than 4 per cent of its annual GDP into research and development, putting it on par with South Korea and Israel. The city now accounts for almost half of the mainland's international patent filings–about 13,300 last year, even outpacing the UK or France. In the first six months of this year, Shenzhen filed 9,002 patent applications under the international patent system, 50 per cent up year on year, according to the municipal government.*"

in financial statements. Our key dataset is the latest version of the National Bureau of Economic Research (NBER) US Patent Citations Data File, which contains firms' patent-related information, including patent identifier, citing patent identifier, patent assignee names, the number of citations received by each patent, and a patent's application year over the period 1976–2006. We match this dataset with Compustat/CRSP data using a match table that contains a firm identifier (i.e., GVKEY) as well as patent assignee and patent identifier. Data truncation issues are handled by implementing the method of Hall et al. (2001, 2005). We exclude data before 1977 and in 2006 to further mitigate concerns arising from truncations.

As measures for firm-level innovation activities, we use *i)* the number of patents that firm i applied for in year t ($COUNT_{i,t}$) and *ii)* the number of citations of the patents that firm i applied for in year t ($CITE_{i,t}$). Similarly, to measure industry-average innovation activity, we use *i)* the within-industry average number of patents that firms in industry j applied for in year t ($\overline{COUNT}_{j,t}$) and *ii)* the within-industry average number of citations of the patents that firms in industry j applied for in year t ($\overline{CITE}_{j,t}$). As both firm-level and industry-average measures are skewed to the right, the natural logarithm of one plus each of the original measures is used in the industry-level fixed-effects regressions reported in Subsections 3.1 and 3.2 and firm-level regressions reported in Subsection 3.3.

To measure the intensity of technological imitation in industry j in year t, $IMI_{j,t}$, we use a *competitor–quick citation ratio* defined as "*Competitors' citations made within 5 years for the patents applied for by any firms in industry j in year t*" divided by "*Total number of citations for the patents applied for by any firms in industry j in year t*," where competitors are defined as all peers with the same Standard Industrial Classification (SIC) four-digit industry code. For example, $IMI_{j,t} = 0$ means that no patents applied for by any firms in industry j in year t has been cited by any competitors within five years after the granting of patents, implying that the degree of technological imitation is extremely low in industry j in year t. $IMI_{j,t} = 0.5$ means that the patents applied for by any firms in industry j in year t have been heavily cited by competitors within five years after the granting of patents, implying that the degree of technological imitation is extremely high in industry j in year t.

We exclude firms in the utilities and financial services sectors, and restrict the sample to firms whose common shares are publicly traded on the three major US stock exchanges (NYSE, NASDAQ, and AMEX). Our final sample is an unbalanced panel of 11,762 firms among 360 SIC four-digit industries over the period 1977–2005. All variables are winsorized at the 1st and 99th percentiles, and their definitions are reported in Appendices A and B. Table 1 reports summary statistics for those variables. Panel A is related to the industry-level analysis concerning the effect of imitation on corporate innovation (Subsections 3.1 and 3.2) and Panel B is related to the firm-level analysis regarding the effect of imitation on the market value of innovation. (Subsection 3.3).

Table 1. Summary statistics

Panel A. Industry-average variables

Variable	Obs	Mean	S.D.	Min	Q1	Median	Q3	Max
$\overline{COUNT}_{j,t}$	6,696	7.256	15.845	0.000	0.275	1.368	5.800	88.394
$\overline{CITE}_{j,t}$	6,696	85.036	184.384	0.000	2.059	14.487	67.100	1009.677
$ln(1+\overline{COUNT}_{j,t})$	6,696	2.991	2.002	0.000	1.386	2.773	4.454	7.460
$ln(1+\overline{CITE}_{j,t})$	6,696	4.881	2.730	0.000	3.266	5.084	6.796	10.114
$\overline{Size}_{j,t-1}$	6,696	4.751	1.436	1.580	3.728	4.544	5.549	9.075
$\overline{ROA}_{j,t-1}$	6,696	-0.050	0.547	-4.230	-0.013	0.086	0.135	0.284
$\overline{R\&D}_{j,t-1}$	6,696	0.040	0.066	0.000	0.003	0.013	0.043	0.364
$\overline{PPE}_{j,t-1}$	6,696	0.300	0.136	0.056	0.202	0.272	0.369	0.770
$\overline{Lev}_{j,t-1}$	6,696	0.286	0.134	0.008	0.188	0.273	0.370	0.781
$\overline{Capex}_{j,t-1}$	6,696	0.066	0.036	0.008	0.043	0.059	0.080	0.262
$\overline{MB}_{j,t-1}$	6,696	2.479	5.109	0.455	0.928	1.302	2.012	42.707
$\overline{Age}_{j,t-1}$	6,696	2.187	0.385	0.896	1.917	2.169	2.431	3.383
$\overline{KZ}_{j,t-1}$	6,696	2.614	8.570	-32.735	0.430	1.613	3.251	61.104
$IMI_{j,t-1}$	6,696	0.087	0.130	0.000	0.000	0.039	0.107	0.696
$IMI^2_{j,t-1}$	6,696	0.024	0.070	0.000	0.000	0.002	0.011	0.484

Note: This table shows summary statistics for the variables used in Table 2 and Table 3.

Panel B. Firm-level variables

Variable	Obs	Mean	S.D.	Min	Q1	Median	Q3	Max
$r_{i,t}$	83,281	0.155	0.702	-0.856	-0.276	0.033	0.388	3.292
$r_{i,t}-R_{p,t}$	83,281	-0.005	0.689	-1.089	-0.422	-0.116	0.229	3.046
$r_{i,t}-R_{j,t}$	83,281	-0.022	0.622	-1.302	-0.379	-0.090	0.211	2.612
$ln(1+COUNT_{i,t})$	83,281	0.553	1.057	0.000	0.000	0.000	0.693	4.615
$ln(1+CITE_{i,t})$	83,281	1.133	2.002	0.000	0.000	0.000	2.097	7.153
$\Delta Earnings_{i,t}$	83,281	0.023	0.234	-0.985	-0.039	0.010	0.057	1.905
$\Delta Assets_{i,t}$	83,281	0.083	0.652	-4.186	-0.053	0.060	0.214	3.529
$\Delta R\&D_{i,t}$	83,281	0.001	0.030	-0.184	0.000	0.000	0.004	0.117
$\Delta Dividends_{i,t}$	83,281	0.000	0.014	-0.093	0.000	0.000	0.000	0.082
$Size_{i,t-1}$	83,281	4.412	2.064	-1.952	2.939	4.241	5.717	10.141
$Leverage_{i,t-1}$	83,281	0.578	1.309	0.000	0.021	0.181	0.584	15.524
$MB_{i,t-1}$	83,281	1.839	2.405	0.240	0.753	1.122	1.946	30.731
$Financing_{i,t}$	83,281	0.060	0.309	-1.224	-0.026	0.003	0.087	2.057
$\Delta Interests_{i,t}$	83,281	0.002	0.044	-0.386	-0.002	0.000	0.007	0.242

Note: This table shows summary statistics for the variables used in Table 4.

3. Empirical models and results

3.1. *Effects of technological imitation on corporate innovation: An industry-level analysis*

To examine the relationship between the degree of technological imitation and industry-average innovation activities, we estimate the following regression models:

$$\begin{aligned} y_{j,t} &= \beta_0 + \beta_1 IMI_{j,t-1} + \beta_2 IMI^2_{j,t-1} + \beta_{Controls} Controls \\ &\quad + Industry\ FE + Year\ FE + \epsilon_{i,t}, \end{aligned} \tag{1}$$

where $y_{j,t}$ is an industry-average innovation measure for industry j in year t, and $IMI_{j,t-1}$ is the competitor-quick citation ratio for industry j in year $t-1$. Control variables include industry-average values of the following measures: size, profitability, R&D intensity, assets tangibility, leverage, investment, market-to-book ratio, age, and a financial constraint measure. We also add industry and year fixed effects to capture unobserved heterogeneity across industries and years.

Both industry-average innovation measures, i.e., $\overline{COUNT}_{j,t}$ and $\overline{CITE}_{j,t}$, are skewed to the right, so either we employ panel Poisson regression models in which the dependent variable is $\overline{COUNT}_{j,t}$ or $\overline{CITE}_{j,t}$ as in Aghion, Bloom, Blundell, Griffith, and Howitt (2005) or we transform the dependent variable by adding one and taking the natural logarithm (i.e., $ln(1+\overline{COUNT}_{j,t})$ or $ln(1+\overline{CITE}_{j,t})$) when we use the fixed effects regression models as in Fang, Tian, and Tice (2014).

Table 2 presents the regression results. Columns (1) and (3) are the results from Poisson regressions with fixed effects, while Columns (2) and (4) show the results from fixed effects regressions. Regardless of the choice of the estimation method and dependent variable, we find an inverted U-shaped relationship between technological imitation and industry-average corporate innovation. Our main finding is robust to: *i)* using three-digit SIC codes to classify industries; *ii)* defining the degree of imitation as a competitor–citation ratio without the five-year restriction; *iii)* restricting the sample to the industry-years with at least 30 patents; and *iv)* controlling for product market competition as measured by (1-Lerner's index). We also find very similar results when firm-level variables are used instead of industry-average variables.

Table 2. Effects of technological imitation on corporate innovation: An industry-level analysis

	(1)	(2)	(3)	(4)
Estimation method	Poisson	Fixed effects	Poisson	Fixed effects
Dependent variable	$\overline{COUNT}_{j,t}$	$ln(1+\overline{COUNT}_{j,t})$	$\overline{CITE}_{j,t}$	$ln(1+\overline{CITE}_{j,t})$
$IMI_{j,t-1}$	4.389***	5.162***	5.865***	6.752***
	(0.631)	(0.450)	(0.754)	(0.657)
$IMI^2_{j,t-1}$	-5.564***	-7.273***	-7.631***	-9.444***
	(0.968)	(0.767)	(1.402)	(1.132)
$\overline{Size}_{j,t-1}$	0.099***	0.111***	0.061	0.149***
	(0.033)	(0.032)	(0.048)	(0.046)
$\overline{ROA}_{j,t-1}$	0.099*	-0.020	0.111*	0.014
	(0.055)	(0.043)	(0.062)	(0.075)
$\overline{R\&D}_{j,t-1}$	0.022	2.062***	0.141	2.425***
	(0.635)	(0.540)	(0.610)	(0.671)
$\overline{PPE}_{j,t-1}$	-0.615	-0.748*	-0.178	-1.073*
	(0.532)	(0.402)	(0.491)	(0.607)
$\overline{Lev}_{j,t-1}$	-0.436*	-0.442**	-0.413**	-0.760**
	(0.244)	(0.201)	(0.195)	(0.300)
$\overline{Capex}_{j,t-1}$	-0.519	-1.190	-0.956	-0.597
	(0.784)	(0.734)	(0.856)	(1.204)
$\overline{MB}_{j,t-1}$	0.008*	0.003	0.002	0.004
	(0.004)	(0.004)	(0.005)	(0.006)
$\overline{Age}_{j,t-1}$	0.265***	-0.251***	0.237**	-0.269**
	(0.080)	(0.089)	(0.094)	(0.136)
$\overline{KZ}_{j,t-1}$	-0.000	0.001	-0.000	0.002
	(0.002)	(0.001)	(0.002)	(0.002)
Constant		3.195***		5.222***
		(0.221)		(0.326)
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	6,620	6,689	6,605	6,689
R-squared		0.359		0.465
Number of industries	326	360	323	360

Note: This table reports the results of the regressions designed to estimate the impact of technological imitation on the level of industry-level innovation. Standard errors clustered by industry are reported in brackets. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

3.2. *Effects of technological imitation on corporate innovation: A sector-by-sector analysis*

In order to further examine whether the relationship between technological imitation and corporate innovation is heterogenous across sectors, we repeat the analysis sector-by-sector where sector is defined following Fama and French's (1997) 12-sector classification. Table 3 reports the regression results sector by sector. Each column represents the following sector: (1) Consumer nondurables; (2) Consumer durables; (3) Manufacturing; (4) Oil, gas, and coal extraction and products; (5) Chemicals and allied products; (6) Business equipment; (7) Telephone and television transmission; (8) Wholesale, retail, and some services; (9) Health care, medical equipment, and drugs; (10) Others. Note again that we exclude firms in the utilities and financial services sectors. In all sectors except chemicals and allied products, we find a clear inverted U-shaped relationship between technological imitation and corporate innovation as measured by the natural logarithm of 1 plus industry-average number of citations ($ln(1+\overline{CITE}_{j,t})$). We find similar results using the other specifications outlined in Subsection 3.1.

3.3. *Effects of technological imitation on market value of innovation: A firm-level analysis*

To further investigate the impact of technological imitation on the value of firm-level innovation, we follow the approach used by Im, Park, and Shon (2015), Faulkender and Wang (2006), and Dittmar and Mahrt-Smith (2007). To measure the market value of firm-level innovation, Im, Park, and Shon (2015) estimate the coefficient of a firm-level innovation measure in a regression model in which the dependent variable is excess (raw) stock returns. In this study, we model the coefficient as a quadratic function of technological imitation to investigate the effect of the degree of technological imitation on a firm's incentive to innovate as measured by the value of firm-level innovation.

The model is specified as follows:

$$r_{i,t} - R_{B,t} = \beta_0 + \beta_1 INN_{i,t-1} + \beta_{Controls} Controls + Industry\ FE + Year\ FE + \epsilon_{i,t}, \quad (2)$$

where

$$\beta_1 = \gamma_0 + \gamma_1 IMI_{j,t-1} + \gamma_2 IMI^2_{j,t-1}. \quad (3)$$

$r_{i,t}$ is the annualized stock return of firm i in year t, and $R_{B,t}$ is the annualized return of the benchmark portfolio in year t. The benchmark portfolios are Fama and French's Size and Book-to-Market 5×5 portfolios ($R_{p,t}$) and industry portfolio ($R_{j,t}$). $IMI_{j,t-1}$ is the lagged technological imitation measure, and $INN_{i,t-1}$ is the lagged value of a firm-level innovation measure. Both measures are defined in Section 2. Control variables include the ratio of change in earnings to market equity, ratio of change in total assets to market equity, ratio of change in R&D expenses to market equity, ratio of change in dividends to market equity, ratio of change in interest expenses to market equity, ratio of new financing to market equity, lagged leverage ratio, lagged natural logarithm of total assets, and lagged market-to-book ratio. We also add industry and year fixed effects to capture unobserved heterogeneity across industries and years.

Table 4 shows the regression results for the model specified in Equations (2) and (3). We use two different measures for firm-level innovation and three different spec-

Table 3. Effects of technological imitation on corporate innovation: A sector-by-sector analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable	$ln(1+\overline{CITE}_{j,t})$									
$IMI_{j,t-1}$	6.294***	5.960**	6.722***	11.973**	6.395**	4.094**	8.559	6.577***	5.359***	7.698***
	(1.527)	(2.459)	(1.279)	(3.963)	(2.241)	(1.848)	(4.958)	(1.492)	(1.675)	(1.602)
$IMI^2_{j,t-1}$	-6.315***	-8.178*	-9.528***	-12.934*	-7.843	-7.041**	-33.462**	-9.124***	-4.874*	-10.944***
	(2.187)	(3.989)	(2.109)	(6.044)	(4.379)	(2.977)	(13.034)	(2.602)	(2.613)	(2.623)
$\overline{Size}_{j,t-1}$	-0.045	0.022	0.218***	0.231	0.023	0.088	0.456	0.032	0.488	0.111
	(0.066)	(0.234)	(0.083)	(0.180)	(0.096)	(0.098)	(0.382)	(0.244)	(0.434)	(0.163)
$\overline{ROA}_{j,t-1}$	-0.205	-0.128	-0.106	0.433	0.054	0.215**	-0.857	-0.017	-0.150	0.070
	(0.234)	(0.212)	(0.086)	(0.430)	(0.418)	(0.105)	(1.033)	(0.234)	(0.254)	(0.142)
$\overline{R\&D}_{j,t-1}$	2.047	4.387***	-0.102	2.227	-0.396	3.011**	9.345*	2.145	1.115	3.387***
	(1.991)	(1.398)	(1.332)	(3.981)	(1.388)	(1.235)	(4.314)	(3.017)	(1.824)	(1.243)
$\overline{PPE}_{j,t-1}$	1.143	0.892	0.439	-6.698**	-2.343**	-3.960*	17.414***	-0.925	3.858	-1.922*
	(1.578)	(3.607)	(1.023)	(2.269)	(1.027)	(2.117)	(4.160)	(2.359)	(2.404)	(1.149)
$\overline{Lev}_{j,t-1}$	-1.916***	-0.968	-0.206	-0.773	0.910	-0.215	-1.813	-0.603	-0.134	0.289
	(0.712)	(1.013)	(0.496)	(1.613)	(0.949)	(0.864)	(1.119)	(0.734)	(1.429)	(0.788)
$\overline{Capex}_{j,t-1}$	-2.434	2.239	1.325	3.107	4.630*	2.685	-21.299***	5.594	-1.808	-2.508
	(2.786)	(6.825)	(1.394)	(1.891)	(2.443)	(3.271)	(5.459)	(3.388)	(4.174)	(3.116)
$\overline{MB}_{j,t-1}$	-0.024	-0.020	-0.002	0.081	0.008	0.016*	0.033	0.009	-0.024*	0.000
	(0.018)	(0.021)	(0.010)	(0.055)	(0.029)	(0.009)	(0.093)	(0.025)	(0.013)	(0.014)
$\overline{Age}_{j,t-1}$	0.185	0.873	-0.432**	0.607	0.054	-0.518	-3.941**	-0.884**	0.292	-0.277
	(0.271)	(0.645)	(0.205)	(0.403)	(0.337)	(0.368)	(1.380)	(0.380)	(0.668)	(0.431)
$\overline{KZ}_{j,t-1}$	0.003	0.004	0.006*	-0.003	0.003	0.002	-0.002	-0.008	-0.008	0.004
	(0.007)	(0.013)	(0.003)	(0.011)	(0.007)	(0.005)	(0.011)	(0.007)	(0.009)	(0.006)
Constant	4.049***	4.438**	4.950***	7.102***	6.881***	7.186***	0.131	4.234***	2.304	3.748***
	(0.799)	(1.507)	(0.556)	(1.373)	(0.658)	(0.721)	(2.264)	(1.187)	(1.687)	(1.057)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	917	349	2,164	187	331	887	115	567	328	844
R-squared	0.327	0.604	0.501	0.736	0.888	0.761	0.685	0.223	0.705	0.275
Number of industries	48	16	96	9	12	33	8	55	17	66

Note: This table reports the results of the sector-by-sector regressions designed to estimate the impact of technological imitation on the level of industry-level innovation in each sector. Each column represents the following sector: (1) Consumer nondurables; (2) Consumer durables; (3) Manufacturing; (4) Oil, gas, and coal extraction and products; (5) Chemicals and allied products; (6) Business equipment; (7) Telephone and television transmission; (8) Wholesale, retail, and some services; (9) Health care, medical equipment, and drugs; (10) Others. Note that we exclude firms in utilities and financial services sectors. Standard errors clustered by industry are reported in brackets. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4. Effects of technological imitation on the market value of innovation: A firm-level analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	$INN_{i,t-1} = ln(1 + COUNT_{i,t-1})$			$INN_{i,t-1} = ln(1 + CITE_{i,t-1})$		
Dependent variable	$r_{i,t} - R_{p,t}$	$r_{i,t}$	$r_{i,t} - R_{j,t}$	$r_{i,t} - R_{p,t}$	$r_{i,t}$	$r_{i,t} - R_{j,t}$
$INN_{i,t-1}$	0.012***	0.013***	0.013***	0.009***	0.009***	0.009***
	(0.004)	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)
$INN_{i,t-1} \times IMM_{j,t-1}$	0.196***	0.183***	0.119***	0.120***	0.121***	0.077***
	(0.038)	(0.038)	(0.036)	(0.022)	(0.023)	(0.021)
$INN_{i,t-1} \times IMM^2_{j,t-1}$	-0.340***	-0.390***	-0.273***	-0.182***	-0.232***	-0.165***
	(0.067)	(0.068)	(0.066)	(0.042)	(0.042)	(0.040)
$\Delta Earnings_{i,t}$	0.651***	0.643***	0.539***	0.651***	0.642***	0.539***
	(0.020)	(0.019)	(0.018)	(0.020)	(0.019)	(0.018)
$\Delta Assets_{i,t}$	0.251***	0.259***	0.215***	0.251***	0.259***	0.215***
	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)	(0.008)
$\Delta R\&D_{i,t}$	1.052***	1.021***	0.909***	1.045***	1.015***	0.904***
	(0.121)	(0.119)	(0.113)	(0.121)	(0.119)	(0.113)
$\Delta Dividends_{i,t}$	1.183***	1.114***	0.934***	1.185***	1.115***	0.934***
	(0.277)	(0.270)	(0.248)	(0.277)	(0.270)	(0.248)
$Size_{i,t-1}$	-0.018***	-0.018***	-0.016***	-0.019***	-0.019***	-0.017***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
$Leverage_{i,t-1}$	0.035***	0.036***	0.029***	0.036***	0.036***	0.030***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$MB_{i,t-1}$	-0.021***	-0.032***	-0.028***	-0.022***	-0.033***	-0.029***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
$Financing_{i,t}$	0.097***	0.082***	0.075***	0.097***	0.081***	0.074***
	(0.016)	(0.016)	(0.015)	(0.016)	(0.016)	(0.015)
$\Delta Interests_{i,t}$	-1.811***	-1.847***	-1.504***	-1.807***	-1.843***	-1.501***
	(0.108)	(0.106)	(0.095)	(0.108)	(0.106)	(0.095)
Constant	-0.113**	0.283***	0.015	-0.110**	0.287***	0.018
	(0.047)	(0.046)	(0.040)	(0.048)	(0.047)	(0.041)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	68,103	68,103	68,103	68,103	68,103	68,103
Adjusted R-squared	0.144	0.212	0.112	0.145	0.212	0.112

Note: This table reports the results of the regressions designed to estimate the impact of technological imitation on the value of firm-level innovation. Standard errors clustered by industry are reported in brackets. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

ifications to measure the value of innovation. Columns (1) through (3) are based on ($ln(1 + COUNT_{i,t-1})$) as a firm-level innovation measure ($INN_{i,t-1}$), while Columns (4) through (6) are based on ($ln(1 + CITE_{i,t-1})$). We use three dependent variables: $r_{i,t} - R_{p,t}$ is the excess return based on Fama and French's 5×5 portfolios, $r_{i,t} - R_{j,t}$ is the excess return based on industry portfolios, and $r_{i,t}$ is the raw return. Regardless of specifications, the relationship between technological imitation and the market value of innovation has an inverted-U shaped relationship, suggesting that a firm's incentive to innovate increases with the intensity of technological imitation up to a certain point, beyond which it starts to decrease with the intensity of technological imitation. Our main finding is robust to: *i)* using three-digit SIC codes to classify industries; *ii)* restricting the sample to the industry-years with at least 30 patents; *iii)* including firm-fixed effects; and *iv)* controlling for the effect of product market competition.

4. Conclusion

This study examines the relationship between technological imitation and firms' innovation activities and their incentives to innovate using US firm-level patent data for the period 1977–2005, finding that there are inverted-U-shaped relationships between technological imitation and industry-average innovation activities and between technological imitation and market value of firm-level innovation. The results are driven by the trade-off of two different effects. The first effect is positive externalities from the interactions among firms during the process of technological innovation. Particularly when innovation is sequential and complementary, interactions among innovative firms can enhance firms' innovation activities and incentives to innovate. The second effect is the negative effect of free-riding problems on firms' innovation activities and incentives to innovate. This effect may be quite significant when innovation outcomes can be easily extended or imitated by competing firms, and imitators can extract some parts of the benefits that would have been enjoyed by the original innovators. Our results suggest that the first effect dominates the second effect up to quite a high level of technological imitation, while the second effect dominates the first effect when the level of technological imitation is extremely high. This suggests that creating innovation clusters like Silicon Valley in the United States and Shenzhen City in China and allowing different innovators to cooperate, imitate and compete with each other would be very effective in promoting corporate innovation. However, too high a level of technological imitation lowers firms' incentives to innovate.

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Appendix A. Definition of industry-average variables

The following table shows definitions of the within-industry-average variables used in Table 2 and Table 3.

Variable	Definition
Dependent variables	
$\overline{COUNT}_{j,t}$	Industry-average number of patents applied for by any firms in industry j in year t
$\overline{CITE}_{j,t}$	Industry-average number of citations of the patents applied for by any firms in industry j in year t
$ln(1+\overline{COUNT}_{j,t})$	Natural logarithm of 1 plus $\overline{COUNT}_{j,t}$
$ln(1+\overline{CITE}_{j,t})$	Natural logarithm of 1 plus $\overline{CITE}_{j,t}$
Control variables	
$\overline{Size}_{j,t}$	Industry-average value of natural logarithm of market capitalization
$\overline{ROA}_{j,t}$	Industry-average return on assets (ROA)
$\overline{R\&D}_{j,t}$	Industry-average ratio of R&D expenditures to total assets
$\overline{PPE}_{j,t}$	Industry-average ratio of net property, plant and equipment (PP&E) to total assets
$\overline{Lev}_{j,t}$	Industry-average market leverage ratio
$\overline{Capex}_{j,t}$	Industry-average ratio of capital expenditures to total assets
$\overline{MB}_{j,t}$	Industry-average market-to-book ratio
$\overline{Age}_{j,t}$	Industry-average age of firms
$\overline{KZ}_{j,t}$	Industry-average Kaplan-Zingales Index
$IMI_{j,t}$	Technological imitation for industry j in year t defined as the ratio of citations made by industry peers within five years after the granting of patents to total citations of the patents applied for by any firms in industry j in year t

Appendix B. Definition of firm-level variables

The following table shows definitions of the firm-level variables used in Table 4.

Variable	Definition
Dependent variables	
$r_{i,t}$	Firm i's stock returns in year t
$r_{i,t} - R_{p,t}$	Firm i's stock returns in year t in excess of returns to the 5×5 Fama and French portfolios formed on "Size" and "Book-to-Market"
$r_{i,t} - R_{j,t}$	Firm i's stock returns in year t in excess of industry-average stock returns for industry j to which firm i belongs in year t
Firm-level innovation measures	
$ln(1 + COUNT_{i,t})$	Natural logarithm of 1 plus the number of patents applied for by firm i in year t
$ln(1 + CITE_{i,t})$	Natural logarithm of 1 plus the number of citations of the patents applied for by firm i in year t
Control variables	
$\Delta Earnings_{i,t}$	A ratio of change in earnings to market capitalization
$\Delta Assets_{i,t}$	A ratio of change in total assets to market capitalization
$\Delta R\&D_{i,t}$	A ratio of change in R&D expenditures to market capitalization
$\Delta Dividends_{i,t}$	A ratio of change in dividends to market capitalization
$Size_{i,t}$	Natural logarithm of book total assets
$Leverage_{i,t}$	A ratio of total debt to market capitalization
$MB_{i,t}$	A ratio of market capitalization to total assets
$Financing_{i,t}$	A ratio of new financing to market capitalization
$\Delta Interests_{i,t}$	A ratio of interest expenditures to market capitalization