Innovation: The Bright Side of Common Ownership?*

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Abstract

A firm has inefficiently low incentives to innovate when other firms benefit from its innovative activity and the innovating firm does not capture the full surplus of its innovations. We theoretically show under which conditions common ownership of firms can mitigate this impediment to corporate innovation. Common ownership increases innovation when technological spillovers are sufficiently large relative to product market spillovers. Otherwise, the business-stealing effect of innovation dominates and common ownership reduces innovation. Empirically, product market spillovers (as measured by Jaffe and Mahalanobis distance in product market space) decrease the effect of common ownership on innovation inputs and outputs whereas technology spillovers (distance in patent space) increase the effect. The sign and magnitude of relationship between common ownership and corporate innovation therefore varies considerably across the universe of firms. Our results inform the debate about the welfare effects of increasing common ownership among U.S. corporations.

JEL Codes: O31, L20, L40

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1 Introduction

Two secular trends have recently led to a spirited discussion among academics and policy makers regarding the competitiveness of the U.S. economy. First, increasing levels of product market concentration, as measured at the national industry level, have been accompanied by increasing profitability, a decline of the labor share of income, rising inequality, declining business dynamism, and, perhaps most importantly, declining innovation.[1] Second, in addition to rising product market concentration and declining innovation, common ownership has also increased: firms are increasingly commonly-owned by a decreasing number of institutional investors.[2] For example, Softbank's Vision Fund recently attracted the attention of a number of competition authorities by acquiring large stakes in rivals in the ride-hailing industry and exerting its influence to effectuate a lessening of competition in an alleged attempt to "dominate ride-hailing" (The Economist, 2018). As a result, competition authorities have begun investigations to study the competitive effects of common ownership of industry competitors by mutual funds, hedge funds, and other types of investment vehicles (e.g., Berkshire Hathaway) that pool resources from a large number of investors, but concentrate control over portfolio firms.[3] Although much attention has focused on the empirical investigation of anticompetitive effects of common ownership, much less work has been devoted to its procompetitive and potentially welfare-enhancing role.

We investigate, both theoretically and empirically, how corporate innovation depends on common ownership. We find that both the sign and the magnitude of the common ownership effect depends on the relative importance of technological spillovers and business-stealing repercussions of innovative activity: in the presence of technological spillovers, innovation in one firm not only generates benefits in the firm that generated the innovation, but also in technologically related firms. This surplus appropriability problem leads to inefficiently low ex-ante incentives to inno-

[1] CEA (2016) provides an early overview of these trends. See Philippon and Gutierrez (2017), Gutiérrez and Philippon (2017), De Loecker et al. (2020), and Akcigit and Ates (2021) for a formal quantification and analysis of their macroeconomic implications.

[2] Backus et al. (2020) provide a recent comprehensive analysis of common ownership of the largest U.S. corporations. See Azar (2012) for an earlier documentation of this trend and Schmalz (2021) for an update of the theoretical and empirical literature on common ownership.

[3] Mentions of the concerns and investigations by competition authorities and international institutions include, among many others, OECD (2017), European Competition Commission (2017), Federal Trade Commission (2018), and Vestager (2018).

vate (Bolton and Harris, 1999; Jones and Williams, 2000; Arora et al., 2020). Common ownership of technologically related firms mitigates this problem (provided that firms act in the interest of these common owners) and can even render innovative activity profitable that would have been unprofitable if it only benefited a single firm. When innovation lowers marginal costs in the industry so much as to increase industry output, common ownership may even increase welfare. Prior literature has suggested such beneficial knowledge transfers predominantly in the context of private firms (Lindsey, 2008; Eldar et al., 2020; González-Uribe, 2020) or among investors (Stein, 2008; Botelho, 2018), whereas we focus on public firms.

However, there is a second dimension affecting the firm's innovation decisions, which concerns the interaction between innovation and product market competition. Innovations resulting from R&D expenditures naturally lead to the innovator stealing market share and profits from firms competing in the same or related product markets (Bloom et al., 2013). When the competitors are predominantly owned by separate groups of shareholders, this procompetitive effect of innovation is desirable for the innovating company's shareholders. However, when shareholders own both the innovator as well as its product market competitors, such business stealing is less desirable.[4] Consistent with this idea, González-Uribe (2020) shows that technological spillovers amongst companies sharing common VCs are more substantial between portfolio companies that are not in direct competition for the VCs' resources because different funds finance them. Hence, common ownership can reduce the incentives to innovate when the business-stealing effect is stronger than the aforementioned technological spillover effect. Our theoretical framework combines both of these effects and provides conditions when each of them dominates.

Including both dimensions is of first-order importance for understanding the effect of common ownership on innovation not just in the theory, but also in our empirical implementation. To illustrate, Table 1 reports the ownership shares of four technology firms (IBM, Intel, Motorola, and Apple) that are technologically related, but over our sample period compete to a varying extent in the same product markets. First, the four companies are closely technologically related over the sample period. The technological distances, as measured by firms' patent issuances across different patent classes in Bloom et al. (2013), of IBM-Intel, IBM-Motorola, and IBM-Apple are 0.76, 0.46,

[4]We abstract away from the potential role of common *debtholders* in inducing reduced competition which is the focus of empirical work by Saidi and Streitz (2021).

and 0.64, respectively—much larger than the sample average of 0.038. However, whereas IBM is close to Apple in product market space (product market distance of 0.65, compared to the sample average of 0.015), IBM is not close to Intel and Motorola (product market distance of 0.01). As shown in Table 1, these four firms also have a significant degree of common ownership, particularly towards the end of our sample period in 2015. BlackRock, Vanguard, and State Street are all represented among the top owners of each of the four companies. It is thus likely that common ownership could not only affect the innovation decisions of these firms, but vary according to firms' technological and product market proximity. Our central theoretical prediction is that, depending on their distance in technology and product market space, common ownership can have innovation effects of opposite sign.

IBM	*[%]*	*Intel*	*[%]*
Berkshire Hathaway	8.35	BlackRock	6.14
Vanguard	6.06	Vanguard	6.00
State Street	5.12	Capital Research	5.56
BlackRock	5.06	State Street	3.98
State Farm	1.72	Wellington	2.18
BNY Mellon	1.46	Northern Trust	1.26
Fidelity	1.29	UBS	1.10
Northern Trust	1.14	Harris Associates	1.09
Norges Bank	0.94	BNY Mellon	1.01
Geode Capital	0.75	Norges Bank	0.96

Motorola Solutions	*[%]*	*Apple*	*[%]*
ValueAct	10.11	Vanguard	5.79
BlackRock	8.67	BlackRock	5.65
Capital Research	7.93	State Street	3.90
Orbis	7.61	Fidelity	2.79
Vanguard	5.31	Northern Trust	1.27
Parnassus Investments	4.97	BNY Mellon	1.22
State Street	3.83	T. Rowe Price	0.90
Metropolitan West	2.26	Norges Bank	0.86
Janus Capital	2.09	Invesco	0.85
Neuberger Berman	2.06	J.P. Morgan	0.84

Table 1. Examples of commonly-owned firms that are close in product market and/or technology space.
The table shows the ten largest owners and their ownership percentage in 2015 of the four technology companies discussed in the text.

Whether the theoretical predictions about the relationship between common ownership and innovation are indeed helpful in organizing the data is a question that requires more than just anecdotal evidence. It is principally an empirical question, as is the question which of the two effects dominates. We use the methodology pioneered by Bloom et al. (2013) and Lucking et al. (2018) to measure technology and product market spillovers, and extend their data from 2001 to 2013.[5] We combine these data with information about the ownership of firms, in particular to which extent the largest owners of one firm also hold shares in other firms using the "kappa" measure advocated by Backus et al. (2020). In accordance with our theoretical framework, using panel regressions we document an ambiguous relationship between common ownership and corporate innovation as measured by innovation inputs (scaled R&D expenditures) and innovation outputs (citation-weighted number of patents and total stock market value of patents). Moreover, throughout all of our specifications innovation is more positively related to common ownership when technological spillovers are higher, whereas more common ownership is associated with less innovation when product market spillovers are greater. In other words, common ownership and corporate innovation are positively related when technology spillovers are large relative to product market business stealing incentives and are negatively related otherwise.

Given that incentives to compete are tightly linked to incentives to innovate (D'Aspremont and Jacquemin, 1988; Hoskisson et al., 2002; Aghion et al., 2005; Bloom et al., 2013) our paper lies at the intersection of corporate innovation, corporate strategy, and corporate governance. The extant literature, most of which focuses on the potential benefits of cooperative R&D or on how innovation is affected by mergers or institutional ownership, has largely ignored the topic of how innovation is affected by whether these institutions also hold minority stakes in competitors, or in technologically related firms.[6] One of this literature's primary objectives is to examine the underinvestment of R&D and the welfare effects of moving from a noncooperative to a cooperative regime in R&D. For example, Kamien et al. (1992) identify conditions under which a cartelized Research Joint Venture (RJV) is optimal and Leahy and Neary (1997) show that R&D cooperation leads to more

[5] Both effects can lead to improvements in firm value. We therefore do not examine how stock market reactions relate to changes in common ownership as in Boller and Scott Morton (2020) with their effect of innovation.

[6] For the interplay between competition and innovation see, for example, Brander and Spencer (1983), Spence (1984), Katz (1986), D'Aspremont and Jacquemin (1988), Grossman and Helpman (1991), Kamien et al. (1992), Suzumura (1992), Aghion and Howitt (1992), and Leahy and Neary (1997). For comprehensive reviews of the literature see Jones (2005) and Gilbert (2006).

output, innovation, and welfare when spillovers are positive. We adopt these canonical models of innovation and product market competition and re-examine their conclusions in light of the fact that firms with different names do not necessarily have disjoint sets of investors.

The most closely related paper to our own analysis is by Bloom et al. (2013) who theoretically study the effect of product market and technology spillovers on innovation and provide economy-wide empirical evidence for the importance of both effects, but without considering the role of common ownership. They estimate the extent of spillovers in a panel of US firms from 1981 to 2001 and find that gross social returns to R&D are at least twice as high as the private returns. Their results imply that the internalization of those technological spillovers is a matter of first-order welfare importance.[7] We investigate how the relationships documented by Bloom et al. (2013) vary with the degree of common ownership between the firms. Our paper is also related to López and Vives (2019) who theoretically study the effect of (symmetric and identical) common ownership on innovation of industry competitors. In their model, all firms compete in the same industry and produce undifferentiated products. Technology spillovers and common ownership shares are identical between them. In contrast, our model also allows for common ownership of firms in the entire economy, including potentially in separate industries. To reflect that greater scope, we allow for product differentiation, technology spillovers, and common ownership to vary across firms. These generalizations are crucial to predict and understand the variation of the effect of common ownership on innovation found in the data.

Two recent empirical contributions also investigate the relationship between common ownership and innovation. Li et al. (2021) study common venture capital ownership of pharmaceutical startups and find evidence suggesting that common ownership improves innovation efficiency. In contrast to their work, we focus on a broad sample of public firms. Finally, He and Huang (2017) examine the question whether common *blockholders* have an effect on corporate innovation on average. In contrast, we study the entire institutional ownership structure of the firm, and examine whether the degree of technology spillovers and product market spillovers differentially affect the relationship between common ownership and innovation.

[7] Their approach builds on prior work by Jaffe (1988) who assigns firms to technology and product market space, but does not examine the distance between firms in both these spaces. Similarly, Branstetter and Sakakibara (2002) empirically examine the effects of technology closeness and product market overlap on patenting in Japanese research consortia. Lucking et al. (2018) extend the results of Bloom et al. (2013) to later time periods.

The remainder of this paper is organized as follows. Section 2 presents the theoretical framework that guides the empirical analysis. Section 3 describes the data. The empirical results are presented and discussed in Section 4. Section 5 concludes.

2 Theoretical Framework

2.1 Setup

We analyze the role of common ownership and its interplay with product market and technological spillovers in the canonical model of innovation and product market competition pioneered by D'Aspremont and Jacquemin (1988). By doing so, we also extend the model of Bloom et al. (2013) which studies the effect of product market and technology spillovers on innovation, to allow for overlapping ownership between firms. Our theoretical setup is also related to the model of López and Vives (2019) which studies the interplay between innovation and common ownership, but we allow for both product market and technology spillovers as well as common ownership weights to differ across firms.

Firms' innovation choices, product quantities, prices, and profits are endogenously co-determined by the degree of common ownership as well as product market and technological spillovers. In line with the existing literature on common ownership, we assume that ownership is exogenous.

2.1.1 Product Market Competition

Consider an economy with n firms which each produce a single differentiated product. As in our empirical implementation there are no industries per se, but all firms compete with each other depending on how closely related their products are. In our model the welfare-enhancing effects of common ownership are due to economy-wide horizontal and vertical externalities that arise from technology spillovers. Although strictly speaking we present a partial equilibrium model, all of our insights regarding the impact of common ownership under different technology and product market spillovers also hold in a general equilibrium model. For example, Pellegrino (2019) and Ederer and Pellegrino (2021) model and estimate a general equilibrium hedonic linear demand system in which all the n firms in the economy compete with each other and the investors (or managers) controlling the firms' operations consume an outside good (e.g., leisure).

Each firm is owned by a majority owner and a set of minority owners. Aside from a literal interpretation, this assumption can also be understood as a metaphor for an explicit or implicit coalition of shareholders that jointly hold an effective majority of the voting stocks.[8]

Following Singh and Vives (1984) and Häckner (2000), we derive demand from the behavior of a representative consumer with the following quadratic utility function:

$$U(\mathbf{q}) = A\sum_{i=1}^{n} q_i - \frac{1}{2}\left(a_{ii}\sum_{i=1}^{n} q_i^2 + 2\sum_{i\neq j} a_{ij}q_iq_j\right) \tag{1}$$

where q_i is the quantity of product i, $\mathbf{q} = (q_1, ..., q_n)$ is the vector of all quantities, $A > 0$ represents overall product quality, $a_{ii} > 0$ measures the concavity of the utility function, and a_{ij} represents the degree of substitutability between two differentiated products i and j. $a_{ii} > a_{ij} \geq 0$ ensures that the products are (imperfect) substitutes. Without loss of generality and to simplify notation, we set $a_{ii} = 1$. The higher the value of a_{ij}, the more alike the products are. The resulting consumer maximization problem yields linear demand for each product i, such that the firms face symmetric inverse demand functions given by

$$p_i(\mathbf{q}) = A - q_i - \sum_{j\neq i}^{n} a_{ij}q_j, \tag{2}$$

where $i = 1, 2, ..., n$. Because $1 > a_{ij} \geq 0$, a firm's quantity q_i has a greater impact on the price p_i for its own product than the quantity of any other firm q_j.[9] The parameter a_{ij} measures product homogeneity or product market spillovers. Given the symmetry of the empirical measure of product market spillovers (Bloom et al., 2013) which we describe in Section 3, we assume that this parameter is symmetric between firm i and j, $a_{ij} = a_{ji}$. If a_{ij} is small, the products of firm i

[8] Olson and Cook (2017) and Shekita (2020) discuss examples of explicit coalitions. Moskalev (2020) shows conditions under which shareholders with similar portfolios will optimally vote the same way, and therefore will be regarded as an implicit coalition or a single block by managers.

[9] In the main part of the paper we focus on the Cournot competition case where quantity choices are strategic substitutes. However, our results for Bertrand competition (see Appendix) where prices are strategic complements are essentially identical. Although we assume linear demands, the main results of our model generalize to nonlinear demand functions.

and j are quite distinct and thus expanding output q_i (or lowering price p_i) does not steal much market share from the competing firm j. On the other hand, if a_{ij} is large the product varieties produced by the firms are quite similar and thus business stealing is more pronounced.

2.1.2 Innovation

Following the extant theoretical literature on innovation (D'Aspremont and Jacquemin, 1988; Kamien et al., 1992; Leahy and Neary, 1997; López and Vives, 2019) we model corporate innovation as decreasing marginal cost. However, this is just a particular modeling choice that ensures tractability. One could also model innovation as increasing product quality which would yield qualitatively similar results.

Firm i has a marginal cost of c_i given by

$$c_i = \bar{c} - x_i - \sum_{j \neq i}^{n} \beta_{ij} x_j. \tag{3}$$

Firm i can lower its marginal cost from $\bar{c}$ by investing in innovation x_i at a cost $\frac{\gamma}{2}x_i^2$. A firm's marginal costs are also reduced by the innovative investments of other firms x_j, to the extent that these investments benefit firm i because of technological spillovers captured by $0 \leq \beta_{ij} < 1$. This means that a firm i's investment in innovation reduces its own marginal cost c_i and to a lesser extent may also reduce the marginal cost c_j of firm j. Given the construction of the empirical measure of technological spillovers (Bloom et al., 2013) we assume that this parameter is symmetric, $\beta_{ij} = \beta_{ji}$. These technological spillovers are not confined within the same industry or even just to firms that produce relatively similar substitute products. Innovation benefits can spill over to technologically related firms (i.e., $\beta_{ij} > 0$) which produce goods that are entirely unrelated in terms of product market competition (i.e., $a_{ij} = 0$). The example mentioned in the introduction of IBM and its relationship to Intel and Motorola, which are close in technology space, but not in product market space, fits this case quite well.

The profits of firm i are given by

$$\pi_i = q_i \left[A - q_i - \sum_{j \neq i}^{n} a_{ij} q_j - \left(\bar{c} - x_i - \sum_{j \neq i}^{n} \beta_{ij} x_j \right) \right] - \frac{\gamma}{2} x_i^2. \tag{4}$$

Firms choose quantities q_i and innovation levels x_i simultaneously. We obtain qualitatively similar results when firms invest in innovation before choosing quantities (or prices).

2.1.3 Owners

There are n owners. Each owner i owns a (majority) stake in firm i as well as shares in other firms denoted by $j \neq i$. Azar (2012) and Backus et al. (2020) show that owner i's maximization problem can be restated in the following way:

$$\phi_i = \pi_i + \sum_{j \neq i} \kappa_{ij} \pi_j \tag{5}$$

where κ_{ij} is the weight that owner i places on the profits π_j of firm j. Its exact value depends on the type of ownership and corresponds to what Edgeworth (1881) termed the "coefficient of effective sympathy among firms." In fact, there is a long tradition in economics of weighting shareholder interests in the objective function of the firm, including Drèze (1974), Grossman and Hart (1979), and Rotemberg (1984). We assume that the profit weight κ_{ij} is between 0 (separate ownership) and 1 (perfectly common ownership). In contrast to a_{ij} and β_{ij}, we do not assume that κ_{ij} is symmetric between any firm pair i and j, that is $\kappa_{ij} \neq \kappa_{ji}$ in general.

We use the κ notation of Backus et al. (2020) which is equivalent to λ in Azar (2012), López and Vives (2019), and Azar and Vives (2020). Values of κ exceeding 1 are possible, but they lead to owners placing more weight on their competitors' profits than on their own profits. This would make it possible for common ownership to create incentives for the "tunneling" of profits from one firm to another (Johnson et al., 2000). By maximizing equation (5), the owner essentially maximizes a weighted average of her own firm as well as other firms' profits that she owns. The particular objective function given in equation (5) is a normalization. Firms do not maximize a sum that is larger than the entire economy.

2.2 Analysis and Comparative Statics

We now analyze the differential impact that common ownership has on corporate innovation which depends on both product market and technological spillovers. Firm i's first-order conditions with respect to quantity q_i and innovation x_i can be rearranged to yield the following best-response functions

$$q_i = \frac{1}{2}\left[A - \left(\bar{c} - x_i - \sum_{j\neq i}^{n} \beta_{ij} x_j\right) - \sum_{j\neq i}^{n} a_{ij} q_j - \underbrace{\sum_{j\neq i}^{n} \kappa_{ij} a_{ji} q_j}_{\text{CO} \times \text{product market spillovers}}\right] \tag{6}$$

$$x_i = \frac{1}{\gamma}\left(q_i + \underbrace{\sum_{j\neq i}^{n} \kappa_{ij} \beta_{ji} q_j}_{\text{CO} \times \text{technology spillovers}}\right) \tag{7}$$

where given our symmetry assumptions $a_{ij} = a_{ji}$ and $\beta_{ij} = \beta_{ji}$.

Note that firm innovation x_i is directly proportional to firm quantity q_i such that any increase in quantity q_i will also increase innovation x_i. These first-order conditions illustrate the driving forces of our model. When common ownership κ_{ij} increases, this has two distinct effects on firm i's first-order conditions.

First, in equation (6) an increase in κ_{ij} reduces q_i through the interaction of common ownership and product market spillovers (i.e., the term labeled "CO $\times$ product market spillovers") and thereby reduces innovation x_i in equation (7). This is the anticompetitive effect of common ownership arising from product market spillovers. Effectively, increasing innovation x_i causes firm i to steal business from any firm j that is selling a substitute product. This well-known business stealing effect of innovation will be larger the greater the product homogeneity (also known as the degree of product market spillovers) a_{ij}. The more closely related the products are, the larger will be the negative profit impact on other firms of any increase in quantity. Common ownership exacerbates this negative effect of product market similarity a_{ij} on output and innovation, because common ownership weakens the firm's business-stealing incentive. The reason is that when a firm's objective function puts positive weight κ_{ij} on other firms' profits π_j, firm i will partly internalize any negative profit repercussions on these other firms by reducing innovation x_i and quantity produced q_i.

Second, in equation (7) an increase in κ_{ij} directly increases innovation. When firm i innovates, it benefits other firms j by lowering their marginal cost c_j. This is the procompetitive effect of common ownership arising from technological spillovers (i.e., the term labeled "CO $\times$ technology spillovers"). The greater the technological proximity β_{ij} between the two firms, the larger is this technology spillover effect. This is because firm j which is more closely located in technology space to firm i, will benefit more from the firm i's innovation. Common ownership strengthens this technology spillover effect because with a positive weight κ_{ij} in its objective function, firm i partly internalizes the positive externality of innovation on other firms j that it would otherwise ignore. This output-increasing technology spillover effect is still present when the firms have no product market connection ($a_{ij} = 0$). In graphical terms, an increase in κ_{ij} tilts the innovation reaction function of firm i inwards due to the product market spillovers operating through a_{ji}, but shifts it outwards due to the technology spillovers operating through β_{ji}.

Thus, it is immediately obvious that the effect of common ownership on innovation has an ambiguous sign: it can be either positive or negative depending on the relative strength of product market and technology spillovers. If $a_{ij} = 0$ (i.e., product market spillovers are absent) any increase in common ownership κ_{ij} will raise firm innovation x_i due to technological spillovers $\beta_{ij} \geq 0$. Conversely, if $\beta_{ij} = 0$ (i.e., technological spillovers do not exist), any increase in κ_{ij} will decrease firm innovation x_i due to product market spillovers $a_{ij} \geq 0$.

We can rewrite the system of first order conditions given in equations (6) and (7) in the following way

$$
\begin{aligned}
\left(\mathbf{a} + \mathbf{K} \circ \mathbf{a}'\right) \mathbf{q} &= (A - \bar{c}) \cdot \mathbf{1} + \mathbf{B}\mathbf{x} \\
\left(\mathbf{K} \circ \mathbf{B}'\right) \mathbf{q} &= \gamma \mathbf{x}
\end{aligned}
$$

where $\circ$ is the Hadamard (element-by-element) product, $\mathbf{1}$ is an $n \times 1$ vector of ones, $\mathbf{a}$ is the product similarity matrix, $\mathbf{B}$ is the technology spillover matrix, and $\mathbf{K}$ is the common ownership matrix. The matrices $\mathbf{a}$, $\mathbf{B}$, and $\mathbf{K}$ are defined as follows:

$$\mathbf{a} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} 1 & \beta_{12} & \cdots & \beta_{1n} \\ \beta_{21} & 1 & \cdots & \beta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{n1} & \beta_{n2} & \cdots & 1 \end{bmatrix}, \quad \mathbf{K} = \begin{bmatrix} 1 & \kappa_{12} & \cdots & \kappa_{1n} \\ \kappa_{21} & 1 & \cdots & \kappa_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \kappa_{n1} & \kappa_{n2} & \cdots & 1 \end{bmatrix}$$

Defining $\mathbf{K_a} = \mathbf{a} + \mathbf{K} \circ \mathbf{a}'$ and $\mathbf{K}_\beta = \mathbf{K} \circ \mathbf{B}'$ and substituting the second system of first-order conditions into the first system yields the vector of equilibrium innovation choices $\mathbf{x}^*$ given by

$$\mathbf{x}^* = \begin{bmatrix} x_1^* \\ x_2^* \\ \vdots \\ x_n^* \end{bmatrix} = (A - \bar{c}) \left[\gamma \mathbf{K_a} {\mathbf{K}_\beta}^{-1} - \mathbf{B}\right]^{-1} \cdot \mathbf{1} \tag{8}$$

where $\mathbf{1}$ is an $n \times 1$ vector of ones.

Proposition 1. *Common ownership κ_{ij} increases equilibrium firm innovation x_i^* if and only if technological spillovers β_{ij} are sufficiently large relative to product market spillovers a_{ij}. The effect of κ_{ij} on x_i^* is decreasing in a_{ij}, $\frac{\partial^2 x_i^*}{\partial \kappa_{ij} \partial a_{ij}} < 0$, and increasing in β_{ij}, $\frac{\partial^2 x_i^*}{\partial \kappa_{ij} \partial \beta_{ij}} > 0$.*

Proposition 1 shows that without knowledge of product differentiation and technological characteristics common ownership has an ambiguous effect on innovation. This insight helps explain the variation in empirical findings to date on the relation between common ownership and corporate innovation (Kostovetsky and Manconi, 2020; Geng et al., 2016; Borochin et al., 2020; Chiao et al., 2020). These empirical designs do not make the distinctions that our theoretical framework predicts to be crucial for determining the sign of the effect of common ownership on innovation. Depending on the relative strengths of (i) the business stealing and (ii) the technology spillover effect, common ownership can either decrease or increase corporate innovation. However, our framework also makes predictions under what conditions common ownership has a negative or a positive effect on innovation. Common ownership should decrease innovation if a_{ij} is sufficiently large relative to β_{ij}, whereas common ownership should increase innovation if the opposite is the case. In other words, we expect common ownership to decrease (increase) innovation when product market spillovers are sufficiently large (small) and technology spillovers are sufficiently small (large).

In our empirical implementation we follow Bloom et al. (2013) and construct measures of firm-specific product market spillovers for $\sum_{j\neq i}^{n} a_{ji}q_j$ and of firm-specific technological spillovers for $\sum_{j\neq i}^{n} \beta_{ji}q_j$ which we interact with the firm-specific common ownership measure of κ_{ij} to estimate the pro- and anticompetitive effects of common ownership due to product market and technology spillovers highlighted in the first-order conditions (6) and (7).

Importantly, once we control for the relative strength of product market and technology spillovers, the sign of the effect of common ownership on innovation is unambiguous and does not depend on whether firms compete in strategic substitutes or strategic complements. This is in contrast to the analysis in Bloom et al. (2013) where many of the predictions depend on the form of strategic competition. The reason for this difference is that common ownership has a "direct effect" (i.e., directly affecting the objective function) rather than a "strategic effect" (i.e., indirectly affecting it through the effect on decisions of other firms) as defined by Fudenberg and Tirole (1984). Hence, the sign of the common ownership effect on innovation does not depend on the sign of the strategic response of other firms.

Our predictions provide theoretical guidance for our empirical analysis. Specifically, they allow us to quantify whether and under what conditions common ownership should increase or decrease innovation and how product market and technology spillovers should affect this relationship.

3 Data

In this section we investigate the empirical relationship between common ownership, product market competition, and innovation. Specifically, we are interested in how innovation inputs (e.g., R&D expenditures) and outputs (e.g., citation-weighted value of patents and stock market value of patents) depend on the extent to which a firm is controlled by shareholders that have significant stakes in related firms, and on the extent to which the innovation spills over to neighboring firms in the product market and technology space. As in our theoretical framework we study the economy-wide implications of common ownership and do not restrict ourselves to the study of any particular single industry. Unless otherwise stated all of the data used for our estimations are from 1985 to 2015. Table 2 provides an overview of our summary statistics for the key variables.

3.1 Measures of Innovation

To proxy for a firm's innovation x_i in our theoretical model we construct empirical innovation measures, denoted by $INNOVATION_{it}$, based on firm-level patent grants and citations from the database built by Kogan et al. (2017). This database has additions and corrections to the NBER patent data built by Hall et al. (2001) from the official records of the United States Patent and Trademark Office (USPTO).[10]

Variables	Obs	Mean	Std. Dev.	10%	50%	90%
Innovation Variables						
R&D Expenditures	28,596	245.14	953.00	0.36	14.06	359.38
ln(1+R&D/Sales)	28,596	0.11	0.20	0.00	0.05	0.22
TCW (Citation-weighted patents)	28,631	87.45	418.96	0.00	4.01	131.43
TSM (Total stock market value of patents)	28,631	930.73	5,867.81	0.00	3.31	933.43
Proximity Measures (Bloom et al., 2013)						
ln(SPILLTECH)	28,631	15.42	1.01	14.12	15.53	16.60
ln(SPILLSIC)	28,631	4.49	1.78	2.32	4.67	6.65
Firm Characteristics						
K/L (Capital labor ratio)	28,200	55.22	77.16	11.05	31.45	116.95
ln(K/L)	28,200	3.52	0.94	2.41	3.44	4.75
Sales	28,631	4,080	14,265	18	288	8,652
Institutional Ownership	27,761	0.463	0.295	0.080	0.464	0.833
Common Ownership						
Kappa	27,755	0.208	0.167	0.050	0.161	0.426

Table 2. Summary Statistics for Key Variables

To measure innovation inputs, we use $\ln(1 + R_{it}/SALES_{it})$ where R_{it} is the level of inflation-adjusted R&D expenditures and $SALES_{it}$ are the total sales of firm i in year t as reported in Compustat. Since many firms report zero values for R&D expenditures in most years we follow

[10]The database is available on Noah Stoffman's website (http://kelley.iu.edu/nstoffma). More details on how to match patents and citations to the CRSP database can be found in the online appendix of Kogan et al. (2017).

Branstetter et al. (2006) by adding 1 to all observations of R&D scaled by sales and taking the natural logarithm of the resulting values.

To measure innovation outputs, we rely on two different measures that capture the scientific and economic value of innovation respectively. First, we use the number of citation-weighted patents TCW_{it} given by

$$TCW_{it} = \sum_{j \in P_{it}} \left(1 + \frac{C_j}{\bar{C}_j}\right) \tag{9}$$

where P_{it} denotes the set of patents issued to firm i in year t, C_j is the number of forward citations to patent j and $\bar{C}_j$ is the mean number of citations to patents granted in the same year as patent j. The innovation literature has argued that forward patent citations are a good indicator of the quality of the innovation and its scientific value (Hall et al., 2001).

Second, we measure the private economic value of innovation (Hall et al., 2005; Kogan et al., 2017) as proxied by stock market reactions following a patent issuance. Specifically, we use the measure of Kogan et al. (2017) which estimates a firm i's stock market reaction ξ_j during the three-day announcement window following the issuance of the firm's patent j. Kogan et al. (2017) then sum up all the estimated values ξ_j of patents j that were granted to firm i in year t to construct the total stock market value of innovation TSM_{it} generated by firm i in year t:

$$TSM_{it} = \sum_{j \in P_{it}} \xi_j. \tag{10}$$

These two innovation outputs (forward patent citations and stock market value of patents) likely measure different aspects of quality. Whereas patent citations are more reflective of the scientific value of the innovation, the total stock market value measures the private economic value that is fully appropriated by the firm. For example, a patent may constitute only a minor scientific progress (and therefore generate few patent citations) but may be particularly successful at limiting competition thereby generating significant profits for the issuing firm.

3.2 Measures of Technological and Product Market Proximity

For our analysis we require two distinct measures of technological proximity and product market proximity between firms. We follow Bloom et al. (2013) and Lucking et al. (2018) by using *SPILLTECH* and *SPILLSIC* as measures of technological and product market spillovers. *SPILLTECH* empirically measures the degree of technological spillovers $\sum_{j \neq i} \beta_{ij}$ and *SPILLSIC* measures the degree of product market spillovers $\sum_{j \neq i} a_{ij}$ in our model. We briefly explain the specific construction of these measures below. For a thorough discussion including microeconomic foundations see Bloom et al. (2013).

Following Bloom et al. (2013) we use both Jaffe and Mahalanobis distances for the construction of the *SPILLTECH* and *SPILLSIC* measures.

3.2.1 Jaffe Distance

Denote the vector of the share of patents of firm i in any given technology class by T_i. We construct the pool of technology spillover R&D for firm i in year t, $SPILLTECH_{it}$, as

$$SPILLTECH_{it} = \sum_{j \neq i} TECH_{ij} G_{jt} \tag{11}$$

where G_{jt} is the stock of R&D and $TECH_{ij}$ is the uncentered correlation between all firm i, j pairings and closely corresponds to the β_{ij} parameter in our model. Following Jaffe (1988), this measure is defined as

$$TECH_{ij} = \frac{T_i T_j'}{(T_i T_i')^{1/2} (T_j T_j')^{1/2}}. \tag{12}$$

We follow Bloom et al. (2013) and Lucking et al. (2018) by using all available years of data for the construction of the $TECH_{ij}$ measure.

Analogously, let S_i denote the vector of the sales share of firm i in any given four-digit industry. We construct the pool of product market spillover R&D for firm i in year t, $SPILLSIC_{it}$, as

$$SPILLSIC_{it} = \sum_{j \neq i} SIC_{ij} G_{jt}. \tag{13}$$

This consists of the sum of the SIC_{ij} uncentered correlations between all firm pairings i and j in an exactly analoguous way to the technology closeness measure. This SIC_{ij} measure closely corresponds to the a_{ij} parameter in our model and is given by

$$SIC_{ij} = \frac{S_i S_j'}{(S_i S_i')^{1/2}(S_j S_j')^{1/2}}. \tag{14}$$

Following Lucking et al. (2018) rather than pool across all years to construct a firm's industry sales share, we pool the previous five years of data. Pooling the industry segments data across all 30 years of our sample is problematic in this setting. Future industry sales shares are clearly endogenous as firm innovation and R&D affect subsequent product market success. Past sales shares do not suffer from endogeneity but will be mismeasured if firms move in product space over time. We therefore use the five previous years of firm sales in order to (a) minimize reverse causality between firm outcomes and product market competition and (b) accurately measure the firm's location in product market space at time t.

3.2.2 Mahalanobis Distance

Following Bloom et al. (2013) and Lucking et al. (2018) we also construct alternative versions of *SPILLTECH* and *SPILLSIC* using the Mahalanobis distance metric which we denote by $SPILLTECH^M$ and $SPILLSIC^M$. These measures allow for spillovers between different technology classes and between different industries. In contrast, such spillovers across technology classes and four-digit industries are ruled out by the Jaffe metric which assumes full spillovers within the same class or industry and no spillovers otherwise. Complete detail on the definition and construction of the Mahalanobis measures is included in the online appendices of Bloom et al. (2013) and Lucking et al. (2018).

The Mahalanobis $SPILLTECH^M$ measure quantifies spillovers across technology class by using revealed preference. If two technologies are often located together in the same firm (for example, 'computer input/output' and 'computer processing'), then the distance between the technologies is smaller, so spillovers will be greater. The share of times the two technology classes are patented within the same firm proxies for this distance. The Mahalanobis $SPILLSIC^M$ measure is defined analogously for product market spillovers. When products within two industries are frequently sold within the same firm, the Mahalanobis $SPILLSIC^M$ measure infers that the distance between these two industries is small.

3.3 Measures of Common Ownership

To construct the ownership variables, we use Thomson Reuters 13Fs, which are taken from SEC regulatory filings by institutions with at least $100m total assets under management. We augment this data by scraping SEC 13F filings following Ben-David et al. (2020), which resolves the issues of stale and omitted institutional reports, excluded securities, and missing holdings from 2000 onward.[11] We describe the precise construction of the common ownership variables from these data in the following section.

A limitation implied by this data source is that we do not observe the holdings of individual owners, except if they are employed as officers of the company or serve on its board, in which case we complement these data with Execucomp. We assume that the remaining individual stakes of outsiders are relatively small and that in most cases they do not directly exert a significant influence on firm management. The arising inaccuracies introduce measurement error and an attenuation bias toward zero in our regressions.

To identify how common ownership influences the relationship between product market competition, technology spillovers, and innovation, we require a measure of common ownership. The existing literature provides several candidate measures of common ownership, the first of which is closely linked to the theoretical literature on common ownership, including our own model.

From equation (5), recall that the objective function of firm i is given by

$$\phi_i = \pi_i + \sum_{j \neq i} \kappa_{ij} \pi_j$$

where κ_{ij} is the weight that firm i places on firm j's profits, π_j. The weighted sum of these profit weights κ_{ij} across all the potential product market competitors of firm i is the principal object of

[11]This correction provides a full set of filings by institutional holders for the large universe of Compustat firms. For a detailed description of the problems with the original 13F database and the solutions provided see https://wrds-www.wharton.upenn.edu/documents/752/Research_Note_-Thomson_S34_Data_Issues_mldAsdi.pdf.

interest in the common ownership hypothesis (Backus et al., 2020). Our main measure of common ownership is κ_{ij} between any firm pair i and j across the entire economy. We refer to the equal- or value-weighted average of the weights that the owners of firm i place in year t on the profits of the $n-1$ other firms in the economy as $\overline{\kappa}_{it}$ or simply "kappa." More formally,

$$\overline{\kappa}_{it} = \frac{1}{n-1}\sum_{j \neq i} \kappa_{ij,t} \quad \text{or} \quad \overline{\kappa}_{it} = \frac{1}{\sum_{j\neq i}\omega_{jt}}\sum_{j \neq i} \kappa_{ij,t}\omega_{jt} \tag{15}$$

where the weighting ω_{jt} is the stock market value of firm j in year t. As in our theoretical model we exclude from our empirical analysis the small fraction of observations where $\overline{\kappa}_{it}$ exceeds 1 because these observations are indicative of incorrect or missing ownership data (Backus et al., 2020). Our results are virtually unchanged if we included these observations.

3.4 Other Variables

Throughout our analysis we also use an additional set of control variables. First, $\ln(SALES_{it})$ is the natural logarithm of sales of the company where we adjust for inflation as in Brav et al. (2018). Second, $\ln(K_{it}/L_{it})$ is the capital-labor ratio, computed as the natural logarithm of the ratio of plant property equipment K_{it} and the number of employees L_{it} as in Aghion et al. (2013), Hall et al. (2001), and Gompers and Metrick (2001). Finally, we control for a firm's share of all of its institutional ownership as in Aghion et al. (2013) as this could also influence corporate innovation independent of the overlapping shareholdings of institutional investors.

4 Empirical Analysis

We empirically study how corporate innovation depends on the degree to which the firms are commonly owned and how that relationship is affected by the spillovers on other firms in the technology and product market space. The theoretical model presented in Section 2 illustrates that common ownership can have a positive or a negative effect on innovation, depending on parameters. Specifically, the model predicts that the correlation between common ownership and innovation increases with the level of technological spillovers, but decreases the closer the firms are in product space.

4.1 Empirical Methodology

In our empirical analysis, we estimate for each of the three outcome variables (scaled R&D, citation-weighted patents, stock market value of patents) how innovation depends on common ownership as well as the interactions of common ownership with product market spillovers and technology spillovers, controlling for known or suspected co-determinants of innovation such the size of the firm, capital intensity, and institutional ownership (Aghion et al., 2013). Our baseline regression is

$$\begin{aligned} INNOVATION_{it} = \alpha_1 \cdot CO_{it} + \alpha_2 \cdot SPILLSIC_{it} + \alpha_3 \cdot SPILLTECH_{it} \\ + \alpha_4 \cdot CO_{it} \cdot SPILLSIC_{it} + \alpha_5 \cdot CO_{it} \cdot SPILLTECH_{it} \\ + \alpha_6 \cdot X_{it} + \sum_x \gamma_x \cdot \eta_x + \varepsilon_{ijt} \end{aligned} \tag{16}$$

where firms are indexed by i, and years by t. X_{it} is the vector of control variables $\ln(SALES_{it})$, $\ln(K_{it}/L_{it})$, and institutional ownership. η_x with $x \in \{i, t\}$ are firm i, and year t fixed effects. $CO_{it} = \overline{\kappa}_{it}$ measures to which extent the largest and most powerful shareholders of firm i are also beneficial owners of other firms that are connected to firm i. Standard errors are clustered at the firm level.

Following Bloom et al. (2013) and Lucking et al. (2018), we estimate OLS regressions for inputs (scaled R&D expenditures), and negative binominal count data models for outputs (citation-weighted patents and stock market value of patents). The negative binomial regressions include a firm pre-sample fixed effect which controls for the firm's average citation-weighted patents in the pre-sample period, as in Blundell et al. (1999), where the pre-sample period is defined as the five years before the firm enters the regression sample.

Recall that firms influence each other because they benefit from any innovation activities of firm i (technology spillovers), and/or because they are natural product market competitors of firm i (product market spillovers). The principal coefficients of interest are therefore α_4 and α_5 which measure how the relationship between common ownership and innovation varies with product market and technology spillovers.

4.2 Empirical Results

We begin our analysis by examining the impact of common ownership and technology spillovers on innovation inputs (R&D expenses) as the outcome variable. Table 3 reports the results for estimation of equation (16) with the R&D to sales ratio as the dependent variable. Across the different specifications we include firm and year fixed effects. Column 1 starts by replicating the results of Lucking et al. (2018) as our baseline specification. Column 2 adds common ownership and shows that it is negatively correlated with innovation input. In columns 3 and 4, which include interaction terms between common ownership and our two proximity measures, and column 5, which uses the Mahalanobis proximity measures, common ownership is associated with lower innovation input, even after controlling for time and firm fixed effects. We therefore reject the null hypothesis that innovation is not related to a firm's common ownership. Columns 4 and 5 include controls for institutional ownership, as in Aghion et al. (2013). We find a positive coefficient as they do, but it is statistically insignificant in our specifications.

Our primary concern, however, is with how the relation between common ownership and innovation varies with technology and product market spillovers. Columns 3, 4, and 5 include interaction terms between common ownership and our two measures of spillovers. Consistently throughout all the specifications, the estimated coefficient on the interaction term with technological spillovers *SPILLTECH* is positive whereas it is negative with product market spillover *SPILLSIC*. In accordance with our theoretical analysis, the negative relation between common ownership and innovation inputs becomes more negative as the degree of product market spillovers increases. Conversely, the relationship between common ownership and innovation inputs becomes less negative and can even turn positive the larger technology spillovers are.

In aggregate, as can be seen in column 2, common ownership is negatively related to corporate innovation, but the estimated coefficient is very small: increasing the average kappa all the way from 0 (no common ownership) to 1 (equal profit weights on all other firms) is only associated with a 0.15% ($= e^{0.00151} - 1$) decrease in sales-adjusted R&D expenditure. Thus, in the aggregate the countervailing forces of technology and product market spillovers that pull the relationship

R&D expenditure $\ln(1 + R_{it}/S_{it})$	(1) Jaffe	(2) Jaffe	(3) Jaffe	(4) Jaffe	(5) Mahalanobis
CO		-0.00151**	-0.0347**	-0.0346**	-0.0699***
		(0.000736)	(0.0163)	(0.0164)	(0.0215)
$CO \times \ln(SPILLTECH)$			0.00247**	0.00245**	0.00487***
			(0.00108)	(0.00109)	(0.00143)
$CO \times \ln(SPILLSIC)$			-0.00111**	-0.00103**	-0.00225**
			(0.000507)	(0.000513)	(0.000881)
$\ln(SPILLTECH)$	-0.0204***	-0.0216***	-0.0223***	-0.0215***	-0.0176**
	(0.00642)	(0.00651)	(0.00653)	(0.00667)	(0.00840)
$\ln(SPILLSIC)$	0.00468***	0.00442***	0.00470***	0.00488***	0.00265
	(0.00134)	(0.00135)	(0.00135)	(0.00137)	(0.00220)
$\ln(K/L)$	0.0142***	0.0144***	0.0144***	0.0142***	0.0140***
	(0.00195)	(0.00199)	(0.00199)	(0.00199)	(0.00200)
Institutional Ownership				0.00429	0.00471
				(0.00347)	(0.00347)
Observations	25,985	25,276	25,276	25,009	25,009
R-squared	0.855	0.857	0.857	0.858	0.858
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

Table 3. Sales-adjusted R&D expenditure as a function of common ownership, technology spillovers, and product market spillovers

The table reports coefficient estimates of equation (16) with the dependent variable $\ln(1 + R_{it}/S_{it})$. Standard errors are clustered at the firm level. Variable definitions are described in Section 3. Industry sales in t and in $t-1$ are also included as controls, but are not shown in the table.

between common ownership and corporate innovation in different directions, essentially cancel each other out.

We now turn to the empirical relation between common ownership and innovation outputs. Table 4 reports the results for the citation-weighted value of patents held by a firm using a negative binomial count data model. On average, the citation-weighted value of patents is weakly positively correlated with common ownership as shown in column 2, but the estimated coefficient is both small and statistically insignificant. Even a very large increase in common ownership from 0 (no common ownership) to 1 (full common ownership) is only associated with a 3.8% ($= e^{0.0374} - 1$) increase in citation-weighted patents. In other words, on average across our entire sample common

Citation-weighted patents TCW_{it}	(1) Jaffe	(2) Jaffe	(3) Jaffe	(4) Jaffe	(5) Mahalanobis
CO		0.0374	-5.950***	-5.932***	-6.383**
		(0.139)	(2.164)	(2.191)	(2.675)
$CO \times \ln(SPILLTECH)$			0.457***	0.460***	0.512***
			(0.154)	(0.156)	(0.185)
$CO \times \ln(SPILLSIC)$			-0.240***	-0.237**	-0.351***
			(0.0920)	(0.0929)	(0.135)
$\ln(SPILLTECH)$	0.135***	0.135***	0.0442	0.0434	0.0708
	(0.0475)	(0.0475)	(0.0566)	(0.0567)	(0.0707)
$\ln(SPILLSIC)$	-0.0177	-0.0175	0.0324	0.0334	0.0460
	(0.0257)	(0.0257)	(0.0318)	(0.0319)	(0.0460)
$\ln(SALES)$	0.257***	0.257***	0.254***	0.245***	0.242***
	(0.0304)	(0.0304)	(0.0301)	(0.0312)	(0.0312)
$\ln(K/L)$	0.193***	0.193***	0.194***	0.189***	0.189***
	(0.0373)	(0.0374)	(0.0372)	(0.0375)	(0.0375)
Institutional Ownership				0.151	0.150
				(0.0953)	(0.0954)
Observations	24,688	24,688	24,688	24,492	24,492
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

Table 4. Citation-weighted measure of patents as a function of common ownership, technology spillovers, and product market spillovers

The table reports coefficient estimates of equation (16) with the dependent variable TCW_{it} using a negative binominal count data model. Standard errors are clustered at the firm level. Variable definitions are described in Section 3. Industry sales in t and in $t-1$ are also included as controls, but are not shown in the table.

ownership and corporate innovation are not particularly strongly related. However, this is because the interactions of common ownership with technology and product market spillovers cancel each other out in the aggregate.

In particular, once we include the interaction terms between common ownership and the two spillover measures in columns 3, 4, and 5, the coefficient on common ownership is consistently negative. As before and in accordance with our theoretical predictions, we find that this negative relationship is larger in magnitude when product market spillovers *SPILLSIC* are larger, but smaller in magnitude and even positive when technology spillovers *SPILLTECH* are larger. Because there is considerable heterogeneity of these spillovers across industries and firms this leads to vastly different effects of common ownership on corporate innovation. For example, for a firm at the 75th percentile of technology spillovers (16.13) and the 25th percentile of product market spillovers (3.53), an interquartile range increase of common ownership from the 25th percentile (0.092) to the 75th percentile (0.277) would be associated with a 12.8% increase in citation-weighted patents.[12] In contrast, the same increase in common ownership would imply a decrease of -8.4% in citation-weighted patents for a firm at the 25th percentile of technology spillovers and 75th percentile of product market spillovers.

Similar patterns emerge in Table 5 which reports the coefficient estimates for the relationship between the total stock market value of patents and common ownership. On average, the total stock market value of patents is now significantly positively correlated with common ownership as shown in column 2. However, once we include the interaction terms between common ownership and the two spillover measures in columns 3, 4, and 5, the coefficient on common ownership is consistently negative. As predicted by our theoretical framework, we find that this negative relationship is larger in magnitude when product market spillovers *SPILLSIC* are larger, but closer to zero and even positive when technology spillovers *SPILLTECH* are larger. The coefficient on institutional ownership is positive and significant in line with the results of Aghion et al. (2013).

Taken together, we find strong and consistent support for the model's theoretical predictions. First, there exists an empirically ambiguous relationship between common ownership and innovation which can be either positive or negative on average. Second, the innovation-reducing effect of common ownership increases with the degree of product market spillovers. Third, technology spillover increase the innovation-enhancing effect of common ownership. As predicted by the theoretical framework, the overall effect of common ownership on corporate innovation crucially depends on the relative strength of product market business stealing incentives and of technological spillovers between firms and differs markedly across firms.

One limitation of this study is that, in the theoretical model, ownership is taken as an exogenously given parameter, whereas the data we rely on for our estimation of common ownership effects of innovation is the result of a process involving choices (and hence selection) of ownership. This could potentially lead to an endogeneity problem that challenges a causal interpretation of

[12] The exact calculation of this estimate comes from column 4 of Table 4 and is given by $0.128 = \exp[(-5.932 + 0.460 \times 16.13 - 0.237 \times 3.53) \times (0.277 - 0.092)] - 1$.

Patent stock market value TSM_{it}	(1) Jaffe	(2) Jaffe	(3) Jaffe	(4) Jaffe	(5) Mahalanobis
CO		0.663***	-8.650***	-9.027***	-11.74***
		(0.183)	(2.750)	(2.713)	(3.393)
$CO \times \ln(SPILLTECH)$			0.668***	0.736***	0.898***
			(0.189)	(0.187)	(0.225)
$CO \times \ln(SPILLSIC)$			-0.236**	-0.209**	-0.294**
			(0.102)	(0.101)	(0.149)
$\ln(SPILLTECH)$	0.275***	0.272***	0.138**	0.138**	0.202***
	(0.0535)	(0.0534)	(0.0634)	(0.0614)	(0.0762)
$\ln(SPILLSIC)$	-0.0843***	-0.0821***	-0.0353	-0.0414	-0.0894*
	(0.0308)	(0.0307)	(0.0366)	(0.0357)	(0.0524)
$\ln(SALES)$	0.724***	0.722***	0.717***	0.646***	0.639***
	(0.0315)	(0.0312)	(0.0310)	(0.0315)	(0.0315)
$\ln(K/L)$	0.364***	0.363***	0.367***	0.345***	0.341***
	(0.0449)	(0.0446)	(0.0446)	(0.0442)	(0.0440)
Institutional Ownership				1.371***	1.374***
				(0.128)	(0.128)
Observations	24,688	24,688	24,688	24,492	24,492
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

Table 5. Stock market value of patents as a function of common ownership, technology spillovers, and product market spillovers

The table reports coefficient estimates of equation (16) with the dependent variable TSM_{it} using a negative binominal count data model. Standard errors are clustered at the firm level. Variable definitions are described in Section 3. Industry sales in t and in $t-1$ are also included as controls, but are not shown in the table.

the panel correlations we estimate. That said, we find it difficult to formulate, even informally, a simple economic model that would give rise to the two opposing effects we measure, but not allow for a causal interpretation. Take, for example, a perfectly "passive" investor holding the market portfolio as a benchmark. Some types of active investors might pursue a strategy of underweighting industry competitors while overweighting technologically related firms, and at the same time have a preference for more innovation (for reasons unrelated to their portfolio choice). Other types of active investors might deliberately overweight industry competitors and sell other holdings, and push firms to reduce innovation—again for reasons unrelated to their portfolio choice. We are not aware of an economic rationale that links these portfolio choices with a preference for low or high innovation. Or perhaps firms with high innovation activity attract active shareholders that tend to underweight industry competitors in their investment strategy, whereas firms with low innovation activities attract active investors that specialize in holding industry competitors. Again, we are not aware of an economic rationale that could give rise to such a relationship.

In contrast, the economic model proposed in the present paper provides a significantly simpler and economically intuitive explanation for the empirical patterns we observe. In sum, we are not aware of any alternative theory that would give rise to an endogeneity problem and suggest a different interpretation of the empirical evidence. In sum, the causal interpretation of the empirical correlations we document in this paper comes from combining theory with a set of nuanced patterns in the data, rather than from empirical observations alone.

5 Conclusion

In this paper we show that common ownership can increase innovation when technological spillovers are sufficiently large and product market spillovers are sufficiently low. On the other hand, common ownership can also decrease innovation because common owners would like to discourage business stealing between commonly-owned companies that compete in product markets against each other. The ambiguity in theoretical predictions thus poses an interesting empirical question about the sign and magnitude of the effect of common ownership on innovation. We use our theoretical model's predictions to investigate how the relationship between common ownership and innovation depends on the relative strength of technological and product market spillovers. Consistent with the model's theoretical predictions, we find that common ownership has a positive effect on innovation inputs and outputs whenever innovation spillovers to other firms are relatively large compared to the firms' distance in the product market space and a negative effect if the product market spillovers dominate.

Our findings inform an active debate on whether welfare-enhancing effects of common ownership outweigh the previously empirically documented negative effects of common ownership on firms' incentives to compete. Given that a positive effect on innovation which we model as an efficiency increase in this paper, is a necessary condition for common ownership to positively affect welfare (López and Vives, 2019), our findings are a necessary ingredient in the argument against regulatory interventions in the common ownership debate. The more nuanced insight, however, is that antitrust and innovation policy should distinguish between common ownership of horizontal competitors and common ownership of technologically and perhaps vertically related firms. Previous literature indicates that the former weakens competition and, as we show, also reduces innovation. Our theoretical analysis and empirical results suggest that the latter promotes innovation and potentially even increases total welfare.

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A Proofs and Additional Theoretical Results

A.1 Strategic Substitutes

We can rewrite the system of first order conditions given in equations (6) and (7) in the following way

$$
\begin{aligned}
(\mathbf{a} + \mathbf{K} \circ \mathbf{a}')\,\mathbf{q} &= (A - \bar{c}) \cdot \mathbf{1} + \mathbf{B}\mathbf{x} \\
(\mathbf{K} \circ \mathbf{B}')\,\mathbf{q} &= \gamma \mathbf{x}
\end{aligned}
$$

where $\circ$ is the Hadamard (element-by-element) product, $\mathbf{1}$ is an $n \times 1$ vector of ones, $\mathbf{a}$ is the product similarity matrix, $\mathbf{B}$ is the technology spillover matrix, and $\mathbf{K}$ is the common ownership matrix. The matrices $\mathbf{a}$, $\mathbf{B}$, and $\mathbf{K}$ are defined as follows:

$$
\mathbf{a} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} 1 & \beta_{12} & \cdots & \beta_{1n} \\ \beta_{21} & 1 & \cdots & \beta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{n1} & \beta_{n2} & \cdots & 1 \end{bmatrix}, \quad \mathbf{K} = \begin{bmatrix} 1 & \kappa_{12} & \cdots & \kappa_{1n} \\ \kappa_{21} & 1 & \cdots & \kappa_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \kappa_{n1} & \kappa_{n2} & \cdots & 1 \end{bmatrix}
$$

Defining $\mathbf{K}_{\mathbf{a}} = \mathbf{a} + \mathbf{K} \circ \mathbf{a}'$ and $\mathbf{K}_{\beta} = \mathbf{K} \circ \mathbf{B}'$ and plugging the second system of first-order conditions into the first yields the vector of equilibrium innovation $\mathbf{x}^*$ given by

$$
\mathbf{x}^* = \begin{bmatrix} x_1^* \\ x_2^* \\ \vdots \\ x_n^* \end{bmatrix} = (A - \bar{c}) \left[\gamma \mathbf{K}_{\mathbf{a}} {\mathbf{K}_{\beta}}^{-1} - \mathbf{B} \right]^{-1} \cdot \mathbf{1}. \tag{17}
$$

Recall the best response functions for q_i and x_i given in equation (6) and (7)

$$q_i = \frac{1}{2}\left[A - \left(\bar{c} - x_i - \sum_{j\neq i}^{n} \beta_{ij} x_j\right) - \sum_{j\neq i}^{n} a_{ij} q_j - \sum_{j\neq i}^{n} \kappa_{ij} a_{ji} q_j\right]$$
$$x_i = \frac{1}{\gamma}\left(q_i + \sum_{j\neq i}^{n} \kappa_{ij} \beta_{ji} q_j\right)$$

We are interested in finding conditions under which $\frac{\partial x_i^*}{\partial \kappa_{ij}} > 0$

Rewriting (8) we have

$$(A - \bar{c}) \cdot \mathbf{1} = \left[\gamma \mathbf{K}_a \mathbf{K}_\beta^{-1} - \mathbf{B}\right] \mathbf{x} \tag{18}$$

First, assume that $\mathbf{B} = \mathbf{I}$ where I is the identity matrix. Thus, there are no technology spillovers as all off-diagonal elements β_{ij} of $\mathbf{B}$ are equal to zero. Therefore $\mathbf{K}_\beta = \mathbf{K} \circ \mathbf{B}' = I$. Hence (8) becomes

$$(A - \bar{c}) \cdot \mathbf{1} = [\gamma \mathbf{K}_a - I]\, x$$

This system is isomorphic to a Cournot Game and the following reaction function for each firm i:

$$x_i = \frac{1}{2\gamma - 1}\left[(A - \bar{c}) - \gamma \sum_{j\neq i} (a_{ij} + \kappa_{ij} a_{ji})\, x_j\right]$$

We are looking for a stable Nash equilibrium, so we have to impose some restrictions on the parameters. In particular, we need that

$$\left|\frac{\partial x_i}{\partial x_j}\right| < 1$$

which imposes the following restriction

$$\frac{\gamma}{2\gamma - 1}(a_{ij} + \kappa_{ij} a_{ji}) < 1.$$

With this condition it follows that $\frac{\partial x_i^*}{\partial \kappa_{ij}} < 0$. A graphic representation for the $n = 2$ duopoly case is given in Figure 1.

Now instead assume that $\mathbf{a} = \mathbf{I}$ such that there are no product market spillovers. The best

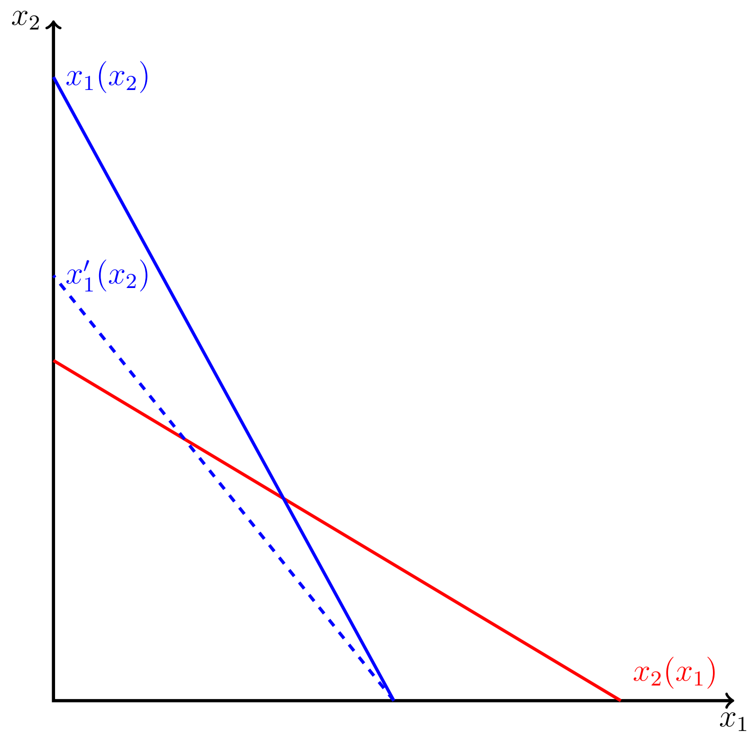

Figure 1. Innovation best response functions for $\mathbf{B} = I$ and $n = 2$

response function for quantity (6) becomes

$$q_i = \frac{1}{2}\left[(A - \bar{c}) + x_i + \sum_{j \neq i}^{n} \beta_{ij} x_j\right]$$

which we can substitute into the best response function for innovation (7) to obtain

$$x_i = \frac{1}{\gamma}\left(\frac{1}{2}\left[(A - \bar{c}) + x_i + \sum_{j \neq i} \beta_{ij} x_j\right] + \sum_{j \neq i}^{n} \kappa_{ij} \beta_{ji} \frac{1}{2}\left[(A - \bar{c}) + x_j + \sum_{l \neq j} \beta_{jl} x_l\right]\right).$$

By reordering terms we obtain

$$2\gamma x_i = \left(1 + \sum_{j \neq i}^{n} \kappa_{ij} \beta_{ji}\right)(A - \bar{c}) + \left(1 + \sum_{j \neq i}^{n} \kappa_{ij} \beta_{ji}^2\right) x_i + \sum_{j \neq i}^{n}\left(\beta_{ij} + \kappa_{ij}\beta_{ji} + \sum_{l \neq \{i,j\}}^{n} \kappa_{il} \beta_{li} \beta_{lj}\right) x_j.$$

Therefore this system is isomorphic to a Cournot game with positive spillovers (instead of negative ones) with the following reaction function for firm i

$$x_i = \frac{\left(1 + \sum_{j\neq i}^{n} \kappa_{ij}\beta_{ji}\right)}{2\gamma - 1 - \left(\sum_{j\neq i}^{n} \kappa_{ij}\beta_{ji}^2\right)} + \sum_{j\neq i}^{n} \frac{\beta_{ij} + \kappa_{ij}\beta_{ji} + \sum_{l\neq\{i,j\}}^{n} \kappa_{il}\beta_{li}\beta_{lj}}{2\gamma - 1 - \left(\sum_{j\neq i}^{n} \kappa_{ij}\beta_{ji}^2\right)} x_j$$

We are looking for a stable Nash equilibrium, so we have to impose some restrictions on the parameters. In particular, we need that

$$\left|\frac{\partial x_i}{\partial x_j}\right| < 1$$

which imposes the following restriction

$$\frac{\beta_{ij} + \kappa_{ij}\beta_{ji} + \sum_{l\neq\{i,j\}} \kappa_{il}\beta_{li}\beta_{lj}}{2\gamma - 1 - \left(\sum_{j\neq i}^{n} \kappa_{ij}\beta_{ji}^2\right)} < 1$$

It then follows that $\frac{\partial x_i^*}{\partial \kappa_{ij}} > 0$. A graphic representation for the $n = 2$ duopoly case is given in Figure 2.

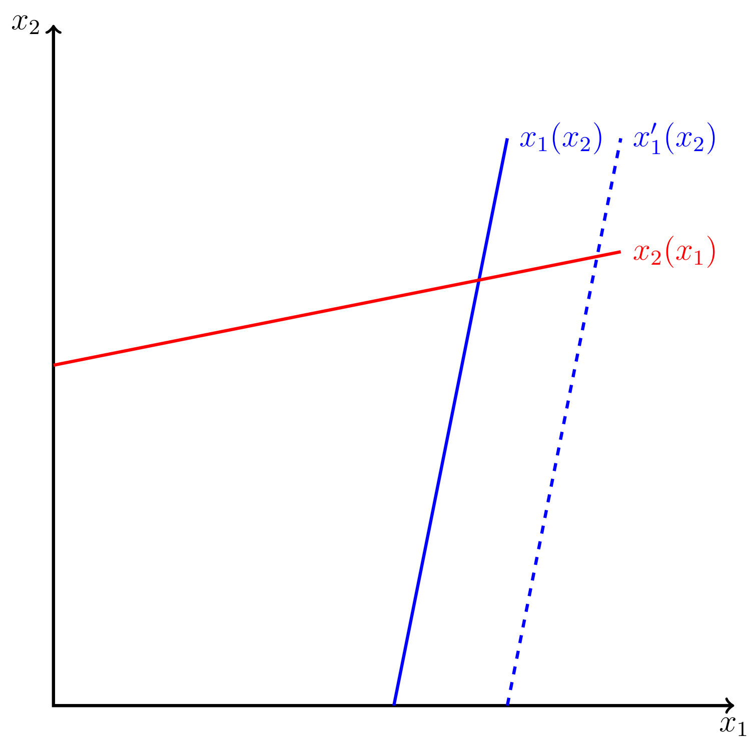

Figure 2. Innovation best response functions for $\mathbf{a} = I$ and $n = 2$

Now consider the general case for arbitrary $\mathbf{a}$ and $\mathbf{B}$. Define

$$\psi(\mathbf{a}, \mathbf{B}) = \frac{\partial x_i^*}{\partial \kappa_{ij}}(\mathbf{a}, \mathbf{B})$$

From our previous discussion we know that

$$\psi(\mathbf{J}, I) < 0 \qquad \psi(I, \mathbf{J}) > 0$$

where $\mathbf{J} = \mathbf{11}'$. Since ψ is continuous and bounded then there exist $\tilde{\mathbf{a}}$ and $\tilde{\mathbf{B}}$ such that

$$\psi\left(\tilde{\mathbf{a}}, \tilde{\mathbf{B}}\right) = 0$$

Let $\Delta = \{\mathbf{a}, \mathbf{B} : \psi(\mathbf{a}, \mathbf{B}) = 0\}$ denote the set of all such matrices. Then $\psi\left(\tilde{\mathbf{a}}, \tilde{\mathbf{B}} + d\mathbf{B}\right) > 0$ for $d\mathbf{B} > 0$: at our initial point the business stealing effect and the technology spillover effects offset each other, but now the technology spillover is bigger.

Illustration of the Symmetric Case Because the equilibrium expression of our asymmetric model are very unwieldy and do not offer any guidance beyond the comparative statics stated in Proposition 1, we provide the expressions of a simplified symmetric case for illustrative purposes. We assume that the owners are symmetric such that owner i owns a majority stake in firm i as well as a residual symmetric share in all other firms. Therefore, we have $\kappa_{ij} = \kappa$. Furthermore, we assume that both the degree of product differentiation a_{ij} and technological spillovers β_{ij} are identical across firm pairs such that $a_{ij} = a$ and $\beta_{ij} = \beta$.

Solving for the symmetric equilibrium we obtain

$$q^* = \frac{A - \bar{c}}{2b + a(n-1)(1+\kappa) - \frac{\tau B}{\gamma}} \tag{19}$$

$$x^* = \frac{\tau}{\gamma} q^* \tag{20}$$

where $\tau = 1 + \kappa\beta(n-1)$ and $B = 1 + \beta(n-1)$.

Common ownership κ affects equilibrium innovation x^* in equation (20) in two ways: (i) through the "business stealing effect" on the equilibrium quantity q^* and (ii) through the "technology spillover effect" captured by τ.

From equation (19) one can see that whether the net effect of common ownership κ on equilibrium output q^* is positive or negative depends on the relative importance of product market spillovers a and technological spillovers β. Moreover, it is immediate from equations (19) and (20) that common ownership can only have a positive effect on output if it has a positive effect on innovation. The following proposition formalizes this insight, and makes it quantitatively precise.

Corollary 1. *Denote β' as the (positive) solution to $1+\beta(n-1)-\frac{a\gamma}{\beta}=0$. The comparative statics of equilibrium quantity q^* and innovation x^* with respect to common ownership κ are characterized by 3 regions.*

(i) If $\beta \leq \frac{a}{2+a(n-1)}$, then $\frac{\partial q^*}{\partial \kappa} < 0$ and $\frac{\partial x^*}{\partial \kappa} \leq 0$.

(ii) If $\frac{a}{2+a(n-1)} < \beta \leq \beta'$, then $\frac{\partial q^*}{\partial \kappa} \leq 0$ and $\frac{\partial x^*}{\partial \kappa} > 0$.

(iii) If $\beta > \beta'$, then $\frac{\partial q^*}{\partial \kappa} > 0$ and $\frac{\partial x^*}{\partial \kappa} > 0$.

Equilibrium innovation x^* is proportional to equilibrium quantity q^* and is also increasing in τ which itself is increasing in κ. Thus, if quantity q^* is increasing in the degree of common ownership κ then innovation x^* will also be increasing in common ownership. Compared to equilibrium quantity q^*, equilibrium innovation x^* receives an additional kick through τ because of the technological spillovers which common ownership internalizes. As a result, common ownership will increase equilibrium innovation for some parameter values for which common ownership will decrease equilibrium quantity.

Although our model provides predictions about the equilibrium quantity, our primary empirical focus is on how the equilibrium level of innovation x^* varies with the level of common ownership κ. Therefore, the first two parts of Corollary 1 which determine the threshold above which common ownership increases innovation, are instructive. In particular, product market and technology spillovers jointly determine the sign of the common ownership effect on innovation as the following corollary illustrates.

Corollary 2. *Common ownership κ can decrease or increase innovation.*

(i) If and only if product market spillovers are sufficiently large, $a > \frac{2\beta}{1-\beta(n-1)}$, common ownership κ decreases equilibrium innovation x^*. Otherwise, common ownership κ increases equilibrium innovation x^*.

(ii) If and only if technology spillovers are sufficiently large, $\beta > \frac{a}{2+a(n-1)}$, common ownership κ increases equilibrium innovation x^*. Otherwise, common ownership κ decreases equilibrium innovation x^*.

Corollary 2 shows that without knowledge of product differentiation and technological characteristics common ownership has an ambiguous effect on innovation.[13] Depending on the relative strengths of (i) the business stealing and (ii) the technology spillover effect common ownership can either decrease or increase equilibrium innovation. However, the corollary also makes precise predictions under what conditions common ownership has a negative or a positive effect on innovation. Common ownership should decrease innovation if a is sufficiently large relative to β, whereas common ownership should increase innovation if the opposite is the case. In other words, we expect common ownership to decrease (increase) innovation when product market spillovers are sufficiently large (small) and technology spillovers are sufficiently small (large).

Corollary 3. *The effect of common ownership κ on innovation x^* is decreasing in product homogeneity a, $\frac{\partial^2 x^*}{\partial\kappa\partial a} < 0$, and increasing in technology proximity β, $\frac{\partial^2 x^*}{\partial\kappa\partial\beta} > 0$.*

Corollary 3 shows that product market and technology spillovers modify the relationship of common ownership on innovation in opposite ways. Whereas product market spillovers reinforce the negative effect of common ownership on innovation, technology spillovers strengthen its positive effects.

A.2 Strategic Complements

Consider the following change to our baseline model. Instead of competing in quantities q_i, firms compete in prices p_i. The proof for this case is essentially identical to the case of strategic

[13]This insight helps explain the variation in empirical findings to date on the relation between common ownership and corporate innovation. These designs have not made the distinctions our model predicts to be crucial.

substitutes. The innovation reaction function of any firm i is linear and downward-sloping with respect to innovation of any firm j.

Assume again, for illustrative purposes, that product market and technological spillovers are identical across the n firms in the economy. Given the representative consumer's preferences the demand function facing firm i is given by

$$q_i(\mathbf{p}) = \omega - \rho p_i + \delta \sum_{j \neq i} p_j \tag{21}$$

where $\mathbf{p} = (p_1, ..., p_n)$ is the vector of all product market prices, $\omega = \frac{A}{1+(n-1)a}$, $\rho = \frac{1+(n-2)a}{[1+(n-1)a](1-a)}$, and $\delta = \frac{a}{[1+(n-1)a](b-a)}$. By assuming $1 > a > 0$ we have $\rho > (n-1)\delta > 0$. Thus, a firm's price choice has a greater impact on the demand for its own product than its competitive rivals' actions in that particular market.

The profits of firm i are given by

$$\pi_i = (p_i - c_i)\left(\omega - \rho p_i + \delta \sum_{j \neq i} p_j\right) - \frac{\gamma}{2} x_i^2. \tag{22}$$

The objective function of the owner of firm i is as in equation (5) given by

$$\phi_i = \pi_i + \sum_{j \neq i} \kappa_{ij} \pi_j \tag{23}$$

where we again, for illustrative purposes, assume that $\kappa_{ij} = \kappa$ is identical across firms.

Firm i's first-order conditions with respect to quantity p_i and innovation x_i can be rearranged to yield the following best-response functions:

$$p_i = \frac{1}{2\rho}\left[\omega + \rho c_i + \delta \sum_{j \neq i}^{n} p_j + \kappa \delta \sum_{j \neq i}^{n} (p_j - c_j)\right] \tag{24}$$

$$x_i = \frac{1}{\gamma}\left(q_i + \kappa \beta \sum_{j \neq i}^{n} q_j\right) \tag{25}$$

where $q_i = \omega - \rho p_i + \delta \sum_{j \neq i} p_j$ and $c_i = \bar{c} - x_i - \beta \sum_{j \neq i}^{n} x_j$. We solve for the symmetric equilibrium price p^* and equilibrium innovation x^* of the n firms in the economy which are given by

$$p^* = \frac{\gamma[\omega + \bar{c}(\rho - \kappa\Delta)] + \omega B(\rho - \kappa\Delta)\tau}{\gamma[2\rho - (1+\kappa)\Delta] + B(\rho - \kappa\Delta)\tau(\rho - \Delta)} \tag{26}$$

$$x^* = \frac{\tau}{\gamma}[\omega - p^*(\rho - \Delta)] \tag{27}$$

where $\tau = 1 + \kappa\beta(n-1)$, $B = 1 + \beta(n-1)$, and $\Delta = \delta(n-1)$.

As in the case of strategic substitutes, equilibrium innovation x^* increases (decreases) with common ownership κ, if technology spillovers β are sufficiently large (small) relative to product market spillovers a. A sufficient condition for $\frac{\partial x^*}{\partial \kappa} > 0$ is $\beta > \frac{\delta(\rho-\Delta)}{\rho(2\rho-\Delta)}$.