Vertical Integration to Mitigate Internal Capital Market Inefficiencies: Theory and Evidence

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November, 2018

[#] Corresponding author. We thank Robert Bloom, Alex Butler, Lindsey Calkins, Kam Chan, David Farber, Bill Elliott, Alex Holcomb, Michael Keefe (FMA Europe discussant), Srini Krishnamurthy, Pascal Letourneau, Olivier Maisondieu Laforge, Qing Liu (FMA discussant), Andrew Lynch (SFA discussant), Frank Navratil, Dan Pastor, Andy Prevost, James Refalo, Tim Roth, Roberto Joaquín Santillán Salgado (FMA Latin America discussant), Brian Saxton, Garrett Smith, Aaron Sun, Joshua Spizman, Desmond Tsang, Jim Upson, Faith Xie, Emma Xu, Richard Warr, Yinglu Wu, Feng Zhan, Thomas Zlatopler and seminar participants at the 2017 FMA Annual Meeting, 2017 FMA European Meeting, 2017 FMA Latin America Meeting, 2016 SFA Annual Meeting, California State University – Los Angeles, John Carroll University, University of Texas at El Paso, University of Wisconsin - Whitewater, and Western Kentucky University for comments. The authors retain the responsibility for any remaining errors.

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Abstract

We argue that the spillover effect created by vertical integration mitigates internal capital market (ICM) inefficiencies in multi-divisional firms. We model how the spillover effect helps align the objectives of the division managers and the objective of the CEO/firm, and thus facilitates efficient capital allocation at equilibrium. Empirically, we measure the size of the spillover effect by the degree of vertical integration of the firm and present evidence that higher levels of vertical integration are associated with more efficient internal capital markets.

Vertical Integration to Mitigate Internal Capital Market Inefficiencies: Theory and Evidence

1. Introduction

This paper studies how diversification strategy impacts the efficiency of the internal capital market (ICM). Since Coase's (1937) treatise on the boundary of firms, there has been a large amount of literature and debate on the role of ICM in corporate resource allocation. ICM is created when investment projects of different divisions are financed through a single corporate headquarters (Stein, 1997), which, in turn, redistributes the capital obtained from the external capital market (ECM) between the divisions. The literature offers two schools of thought on the efficiency of ICM in resource allocation. The efficient ICM view argues that ICM allows for more efficient resource allocation, because, comparing to ECM, it possesses superior information on investment quality and stronger monitoring ability (e.g., Alchian, 1969; Hovakimian, 2011; Hubbard and Palia, 1999; Khanna and Tice, 2001; Matsusaka and Nanda, 2002; Peyer, 2002; Weston, 1970; Williamson, 1970, 1975, 1986; Yan, 2006). The control rights of the headquarters over all divisions also allow ICM to perform the "winner picking" function when allocating capital (Gertner, Scharfstein, and Stein 1994; Stein 1997, 2003). In contrast, the inefficient ICM view argues that ICM destroys allocation efficiency due to "internal competition" (Williamson, 1975; Donaldson, 1984). To illustrate, in a credit-constrained multi-divisional firm, the extent to which a division gets funded depends not only on the absolute value of its own projects, but also on the value of these projects relative to the investment opportunities of other divisions in the firm. While the CEO can maximize her private benefit by allocating capital to the most promising project, division managers tend to compete for corporate resources through various activities that hinder the CEO's "winner picking" process, which leads to allocation distortion (Meyer, Milgrom, and Roberts, 1992; Scharfstein and Stein, 2000; Rajan, Servaes, and Zingales, 2000). The inefficient ICM view has also received considerable empirical support (e.g., Lamont, 1997; Palia, 1999; Rajan, Servaes and Zingales, 2000; Scharfstein and Stein; 1998; Seru, 2014; Shin and Stulz, 1998).

ICM inefficiency is fundamentally an agency problem. Corporations have adopted a variety of monitoring- and incentive-based governance techniques to target agency problems. Unfortunately, evidence of ICM misallocation remains prominent. The reason for the persistence of ICM inefficiency in multi-divisional firms can be attributed to their unique two-tiered agency problem, which is first depicted in the model of Scharfstein and Stein (2000). At the first tier, investors face agency costs imposed by upper management, such as the CEO. In addition, the CEO faces agency costs imposed by the division managers. Corporations commonly adopt investor monitoring and incentive compensation to restrict moral hazard of top managers. However, both types of governance can be less efficient at the division level. Specifically, all division managers possess proprietary information and specialty knowledge regarding their own investments. The more diversified a firm is, the greater the information asymmetry the CEO faces, which hinders monitoring efficiency. With regard to incentive compensation, when division managers' compensation is partially based on division performance, they may be motivated to compete for corporate resources to maximize their own investments, which bring incremental cash flows to their own divisions, but may not be value maximizing for the firm. In other words, instead of facilitating efficient allocation, incentive-based compensation may, in fact, encourage internal competition and destroy efficiency.

Although the problems illustrated above generally apply to all diversified firms, not all types of diversification are equally prone to ICM inefficiencies. In this paper, we argue that the severity of ICM inefficiencies varies with diversification strategy. Galbraith and Nathanson (1978) lay out three major diversification strategies: unrelated diversification, related diversification, and vertical integration. ICM inefficiencies are likely to be the most severe in unrelated diversification. First, due to the dispersion in business scope, unrelated diversification is the most difficult to monitor from the standpoint of the CEO. In addition, because divisions share few similarities, inter-divisional relations are the most competitive, which makes performance-based incentive compensation ineffective at the division level. Related diversification occurs when multiple divisions belong to the same industry. The similarities between divisions and potential of synergies make both monitoring and performance-based incentives at the division level easier to implement under this structure, and the sharing of resources between divisions minimizes the role of ICM.

However, to the extent that divisions cannot be merged into a stand-alone firm, internal competition stays inevitable in related diversification, thus ICM inefficiency remains.

We argue that the ICM inefficiency is mitigated under vertical integration, where divisions are integrated along the supply chain. The economic benefits of vertical integration are created through the elimination of transaction costs and the control over raw materials or outlets (Pfeffer and Salancik, 1978). In vertically integrated firms, divisions engage in frequent inter-divisional transactions, and develop customer-supplier relations, which creates positive correlations between the revenues and/or costs of the divisions. As a result, a successful investment made by one division is likely to benefit another division along the supply chain, which we label the "spillover effect". The idea that the spillover effect exists between suppliers and customers is supported by Cohen and Frazzini (2008), who use the supplier-customer economic links to predict future stock returns. By creating such mutual benefits, the spillover effect can reduce "internal competition", and mitigate ICM inefficiencies. From the governance perspective, the inter-divisional spillover in vertical integration is a self-governing mechanism that aligns the interests of division managers with that of the firm, thus helps achieve the efficacy of incentive compensation at the division level. In addition, with aligned incentives, division managers are less likely to obscure proprietary information regarding their investment potential, which eases the CEO's monitoring efforts. We develop a model to illustrate this argument. Our model shows that, without the spillover effect, the optimums of the division managers are independent of the optimum of the CEO and the firm, and division managers' attempts to influence capital allocation can result in inefficiencies at equilibrium. With the spillover effect, production of different divisions become interrelated, and the optimums of the agents converge with the optimum of the firm, which reduces the managers' needs to influence the allocation process, thus facilitates an efficient equilibrium outcome. The larger the spillover effect, the closer the allocation is to the optimal.

To empirically test our model, we construct a vertical integration coefficient (*VIC*), using the IO accounts of dollar flows between all industries in the U.S. economy provided by the Bureau of Economic Analysis (BEA). *VIC* measures the level of vertical integration, and thus the size of the spillover effect. We then investigate the relation between *VIC* and indicators of ICM efficiency. We measure the efficiency of

ICM in three ways. The first measure is R&D investment outcomes. Seru (2014) argues that R&D investments are characterized by significant information asymmetry between the researchers (or divisions) and outside evaluators (i.e., corporate headquarters), and the division researchers have an incentive to overstate their investment prospects to corporate headquarters, which causes corporate headquarters to either allocate scarce capital to mediocre projects, or to refrain from embarking on novel research in the first place. Seru (2014) finds lower innovative efficiency in conglomerates, suggesting inefficient resource allocation by the ICM. Following the same intuition, we examine whether innovative efficiency in multi-divisional firms varies with the level of vertical integration. Consistent with the model, we find that, adjusted patent production increases with the level of vertical integration. Holding R&D intensity at the mean, a one standard deviation increase in *VIC* increases adjusted patent production by 46.69%.

As a second test of the model, we follow Shin and Stulz (1998), and examine the extent to which investments of small divisions in diversified firms depend on the divisions' own cash flows and investment prospects, and whether this dependence varies with the level of vertical integration. Without an efficient ICM, small divisions' investments usually receive the least support from headquarters, and thus strongly depend on the divisions' own cash flows, regardless of the investment quality. However, an efficient ICM can direct cash flows within the firm to support the investment with the greatest potential. Therefore, when small divisions face superior investment opportunities, their investment-cash flow sensitivity will decrease if ICM is efficient. Note that we cannot argue the same effect in large divisions, the investment of which naturally depend on their own cash flows. Consistent with this expectation, the results show that, while having the best investment opportunity in the firm lowers the investment-cash flow sensitivity of the small divisions, this effect becomes even stronger as the level of vertical integration increases. Specifically, when holding the smallest divisions' cash flows at the mean of the small division subsample, a one standard deviation increase in *VIC* will magnify the effect of the best investment opportunity by 1.48 times.

As a third test, we follow Cho (2015) and measure ICM efficiency by how actively firms redistribute capital from low- to high-opportunity divisions. Specifically, this approach measures capital allocation by division-level CAPX. It first constructs a measure of hypothetical passive allocation, under which corporate headquarters allocates capital in proportion to the size of the divisions, so that division level CAPX is in proportion to divisional sales. Second, deviations of actual division level CAPX from the passive allocation are computed. Finally, we compute the weighted average of division level CAPX deviations to obtain firm level CAPX deviation. Positive firm level CAPX deviation indicates that capital flows from low- to high-opportunity divisions and vice versa, suggesting efficient ICM. We then examine the relation between *VIC* and CAPX deviation. Consistent with the model's prediction, our results show that CAPX deviation increases with the level of vertical integration. To illustrate, a one standard deviation increase in *VIC* leads to a 0.36% increase in CAPX deviation. Given a mean CAPX deviation of -7.53%, this indicates approximately 4.77% improvement in allocation efficiency.

We acknowledge that endogeneity concerns may arise. Specifically, the decision to vertically integrate could be attributed to the unobserved nature of the firm or the industry. To mitigate this concern, we control for segment-firm, and industry fixed effects, along with year dummy variables in our analyses. In an alternative examination of how omitted variable bias can affect our results, we employ the Altonji, Elder, and Tabler (2005) test, which, in a nutshell, computes how large the effects of omitted variables have to be in order to invalidate the regression results. All of our tests pass the widely accepted robustness threshold. Furthermore, to eliminate the effects of time-invariant variables, we conduct change regressions and obtain consistent results. Lastly, our results remain unchanged in subsample tests and tests using an alternative measure of vertical integration.

Our paper contributes to the literature by being the first to examine the impact of diversification strategy on ICM efficiency. Although there exists a vast literature on ICM, all types of diversification are treated as equally prone to the misallocation problem. Based on theoretical foundations and empirical evidence, our paper enriches the extant literature by shedding light on the unexplored effects of diversification strategy on corporate resource allocation. Our model offers implications on the self-governing properties of vertical integration, which, by aligning the interests of internal agents, achieves the efficacy of incentive compensation at the division level and eases the monitoring efforts from corporate headquarters. It is important to note that we do not posit vertical integration is a superior diversification strategy and we acknowledge that the decision to vertically integrate also largely depends on a firm's competitive environment and the nature of its industry. Instead, we focus merely on the impact of vertical integration on ICM efficiency, one of the many factors that contributes to firm value. Lastly, although there is research on the effects of diversification strategy on firms' operations (Kumar, 2013), the financial implications of them remain largely unexplored. Our paper is a first attempt to investigate how diversification strategy affects ICM efficiency and, therefore opens up new avenues for future research.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 describes the data and the samples. Sections 4, 5, and 6 present the empirical tests of the model, and in Section 7 we report the results of the robustness analyses. Finally, Section 8 concludes.

2. The Model

2.1 Structural and Financial Settings

We start by describing the structural and financial settings of the model. The model futures a two-division firm with three types of agents: two division managers, the CEO, and outside investors. The CEO has no financial resources of her own, but is endowed control rights by outside investors, and thus has full authority in allocating capital across the two divisions. Both division managers and the CEO derive their private benefits from the assets they oversee. Specifically, the division managers' private benefits equal a fraction, ρ, of the production outputs of their own divisions; and the CEO's private benefits are a fraction, δ, of the total production outputs of the firm. Both ρ and δ are between zero and one. The objectives of division managers and the CEO are to maximize their own private benefits. As the CEO maximizes her private benefits through maximizing the firm's total production outputs, her interests align with the interests of the firm and outside investors. In contrast, the division managers maximize their private benefits through maximizing the production outputs of their own divisions, which as we show later, may not be optimal for the firm and outside investors. While the production outputs are costlessly verifiable *ex post*, the agents' private benefits are non-contractible. In every production cycle *t*, the firm has a capital endowment of $C_{f,t}$, which is fully allocated to divisions *i* and *j*, and thus $C_{i,t} + C_{j,t} = C_{f,t}$.

2.2 Investment and Production

The firm has a production function $k\ (C_t)$, where C_t is the capital invested in period *t*, and $k(.)$ is an increasing and concave function, with $k'(.) > 0, k'(0) = \infty$, and $k''(.) < 0$. Within each production cycle *t*, the production outputs equal $\theta_t k(C_t)$, where θ_t measures the productivity of the assets in place in period *t*. θ_t can also be considered as the investment state of period *t*. We assume that $\theta_1, \theta_2, \theta_3, \ldots$ are independently and identically distributed and drawn from a finite interval, $[\theta_L, \theta_H]$, which is common knowledge to all three types of agents. Furthermore, the productivities of the two divisions, $\theta_{i,t}$ and $\theta_{j,t}$ are independent, and only directly observable to their own division managers before any production occurs.

2.3 Information Process and Capital Allocation

To understand the information and capital allocation process within the firm, consider a production cycle *t*. Without losing generality, we describe the timeline of the events using division *i*. Since the CEO cannot directly observe $\theta_{i,t}$, she forms an estimation of division *i*'s productivity, $\widehat{\theta_{i,t}}$, based on a signal received from manager *i*. This gives manager *i* the opportunity to exert her influence on the CEO's capital allocation decision. Specifically, at the beginning of period *t*, manager *i* first observes $\theta_{i,t}$ and decides the level of influence to exert, $I_{i,t}$. She then reports to the CEO information regarding her division's productivity in the form of a signal, $S_{i,t} = \theta_{i,t} + I_{i,t}$, where $I_{i,t}$ ε [*0*, *I*]. $I_{i,t}$ cannot be directly observed by the CEO or outside investors before production. However, once production occurs and outputs are verified, the CEO will be able to detect the level of influence that has been exerted. The concept of division managers' influence is captured in the influence cost model of Meyer et al. (1992), in which managers of the divisions facing potential layoffs exaggerate their units' investment prospects, in order to obtain corporate resources for investments and prevent downsizing. Similarly, Stein and Scharfstein (2000) develops a model in which division managers engage in rent-seeking activities to increase the bargaining power of the division managers during salary negotiations with the CEO.

With the signal, the CEO forms her own estimation of division *i*'s actual productivity. Being aware of manager *i*'s tendency to exert influence, the CEO estimates a conjectured level of influence $\widehat{I_{i,t}}$, based on the influence detected from the previous period. Specifically, $\widehat{I_{i,t}} = f(I_{i,t-1})$, where $f(.)$ is a non-decreasing function known only to the CEO. Subsequently, the CEO downgrades the signal received from manager *i*, by her own estimation of manager *i*'s influence efforts, thus her estimation of division *i*'s productivity is given by $\widehat{\theta_{i,t}} = S_{i,t} - \widehat{I_{i,t}} = \theta_{i,t} + I_{i,t} - \widehat{I_{i,t}}$. Similarly, $\widehat{\theta_{j,t}} = S_{j,t} - \widehat{I_{j,t}} = \theta_{j,t} + I_{j,t} - \widehat{I_{j,t}}$. The CEO's capital allocation decision is a function of her estimated relative productivities of the two divisions: in period *t*, the capital allocated to division *i*, $C_{i,t}$, is given by the function, $C_{i,t} = g(\frac{\widehat{\theta_{i,1}}}{\widehat{\theta_{j,1}}})$, where $g'(.) > 0$. The CEO's decision function implies that the CEO always allocates more capital to the division with relatively higher estimated productivity. The timeline of the events is shown in Figure 1.

2.3.1 The Case without the Spillover Effect

2.3.1.1 The CEO and the Firm's Optimum

In the case of no spillover effect between divisions *i* and *j*, we first examine the CEO's optimization problem. Since the CEO's private benefits align with the firm's interests, the optimum shown here also reflects the most efficient capital allocation for the firm. Specifically, the CEO and firm's optimum is given by the following proposition.

***Proposition 1*:** *Optimal capital allocation for the CEO and the firm requires* $\frac{\widehat{\theta_{j,t}}}{\widehat{\theta_{i,t}}} = \frac{\theta_{j,t}}{\theta_{i,t}}$.

Proof: In period *t*, the CEO's objective is to maximize her private benefits, given by:

$$U_{CEO,t} = \delta\left[\theta_{i,t}k(C_{i,t}) + \theta_{j,t}k(C_{j,t})\right] \quad (1)$$

subject to the fixed capital constraint:

$$C_{i,t} + C_{j,t} = C_{f,t} \tag{2}$$

The associated Lagrangian of this constrained maximization is:

$$L_{CEO,t} = \delta\left[\theta_{i,t}k\left(C_{i,t}\right) + \theta_{j,t}k\left(C_{j,t}\right)\right] - \lambda_{CEO,t}\left(C_{i,t} + C_{j,t} - C_{f,t}\right) \tag{3}$$

And the first-order conditions of this Lagrangian are:

$$\frac{\partial L_{CEO,t}}{\partial C_{i,t}} = \delta\theta_{i,t}k'\left(C_{i,t}\right) - \lambda_{CEO,t} = 0 \tag{4}$$

$$\frac{\partial L_{CEO,t}}{\partial C_{j,t}} = \delta\theta_{j,t}k'\left(C_{j,t}\right) - \lambda_{CEO,t} = 0 \tag{5}$$

$$\frac{\partial L_{CEO,t}}{\partial \lambda_{CEO,t}} = C_{f,t} - C_{i,t} - C_{j,t} = 0 \tag{6}$$

Define $C_{i,t}^{*}$ and $C_{j,t}^{*}$ as the optimal capital allocation for the CEO and the firm in period t. At the optimum:

$$\frac{k'(C_{i,t}^{*})}{k'(C_{j,t}^{*})} = \frac{\theta_{j,t}}{\theta_{i,t}} \tag{7}$$

In words, (7) implies that, at the CEO and the firm's optimum, the ratio of the marginal productivities of capital in the two divisions equals the reverse ratio of the two divisions' productivities. Given that $k'(.) > 0$ and $k''(.) < 0$, the optimum requires that the division with the higher productivity receives the bigger share of the capital, which is consistent with the CEO's capital allocation decision function described above.

Given that the CEO does not directly observe $\theta_{i,t}$ and $\theta_{j,t}$, her capital allocation decision will be based on her estimations of the productivities, $\widehat{\theta_{i,t}}$ and $\widehat{\theta_{j,t}}$, thus the CEO will allocate capital between the divisions according to:

$$\frac{k'(C_{i,t})}{k'(C_{j,t})} = \frac{\widehat{\theta_{j,t}}}{\widehat{\theta_{i,t}}} \tag{8}$$

Therefore, the sufficient and necessary condition for capital allocation, $C_{i,t}$ and $C_{j,t}$, to be optimal is:

$$\frac{\widehat{\theta_{j,t}}}{\widehat{\theta_{i,t}}} = \frac{\theta_{j,t}}{\theta_{i,t}} \tag{9}$$

Proposition 1 implies that, for the CEO to allocate capital efficiently, her estimated relative productivity must be equal to the actual relative productivity. Equation (9) conveys a similar idea as "winner picking" in Stein (1997). Corporate headquarters rank orders all investment opportunities to make the capital allocation decision, and the absolute errors in the CEO's estimations of the investments' prospects do not necessarily lead to inefficient capital allocation. As long as the estimation errors are correlated across all projects, the estimated relative ranking is the same as the actual relative ranking, and capital allocation is efficient. For example, suppose the CEO overestimates the productivities of both divisions by 10%, which means $\widehat{\theta_{i,t}} = 110\%\theta_{i,t}$, and $\widehat{\theta_{j,t}} = 110\%\theta_{j,t}$. It is easy to see that equation (9) is still satisfied.

2.3.1.2 Optimal Capital Allocation at Equilibrium

In this section, we incorporate the division managers' influence activities, and show how their influence affects the capital allocation at equilibrium. If the CEO can perfectly estimate relative productivity, condition (9) is always satisfied. However, the CEO's estimation is partially determined by the managers' influence. Therefore, at equilibrium, capital allocation is jointly determined by both the managers and the CEO.

Proposition 2**:** *Define $I_{i,t}^*$ and $I_{j,t}^*$ as the levels of managers' influence that lead to the CEO and the firm's optimum, optimal capital allocation at equilibrium requires* $\frac{I_{j,t}^* - \widehat{I_{j,t}}}{I_{i,t}^* - \widehat{I_{i,t}}} = \frac{\theta_{j,t}}{\theta_{i,t}}$.

Proof: At equilibrium, the CEO allocates capital according to (8). Substituting $\widehat{\theta_{i,t}} = S_{i,t} - \widehat{I_{i,t}} = \theta_{i,t} + I_{i,t} - \widehat{I_{i,t}}$ and $\widehat{\theta_{j,t}} = S_{j,t} - \widehat{I_{j,t}} = \theta_{j,t} + I_{j,t} - \widehat{I_{j,t}}$ into (8) yields:

$$\frac{k'(C_{i,t})}{k'(C_{j,t})} = \frac{\theta_{j,t} + I_{j,t} - \widehat{I_{j,t}}}{\theta_{i,t} + I_{i,t} - \widehat{I_{i,t}}} \tag{10}$$

Combining with (9), for capital allocation to be optimal at equilibrium, we must have:

$$\frac{\theta_{j,t} + I_{j,t}^{*} - \widehat{I_{j,t}}}{\theta_{i,t} + I_{i,t}^{*} - \widehat{I_{i,t}}} = \frac{\theta_{j,t}}{\theta_{i,t}} \tag{11}$$

Simplifying (11) yields:

$$\frac{I_{j,t}^{*} - \widehat{I_{j,t}}}{I_{i,t}^{*} - \widehat{I_{i,t}}} = \frac{\theta_{j,t}}{\theta_{i,t}} \tag{12}$$

Equation (12) is the sufficient and necessary condition for efficient capital allocation at equilibrium, after the managers' influence efforts are taken into consideration. In words, for equilibrium capital allocation to be optimal, the ratio of the actual influence exerted by the two managers, in excess to the CEO's estimations of their influences, must equal to the relative productivity of the two divisions. Suppose, if manager *j* exercises more influence than implied by (12), division *j* will be allocated more capital at equilibrium than the optimal amount. The excess influence exerted by both managers can be interpreted as the CEO's judgement errors of the managers' influence. In a sense, condition (12) conveys the same idea as condition (9) in that the absolute estimation errors may not necessarily destroy efficiency. If the estimation errors of the influence activities are in proportion to productivities, equilibrium capital allocation stays optimal. Importantly, equation (12) also shows that, at equilibrium, capital allocation is jointly determined by the behaviors of both division managers and the CEO. With none of the parameters in (12) directly observable to all the internal agents, this condition can only be satisfied with coordination among the managers and the CEO.

2.3.1.3 Division Managers' Optimum

Now, we examine the division managers' optimum and equilibrium behaviors, and how they impact capital allocation at equilibrium. As before, we use manager *i* to illustrate.

Proposition 3*: *Without the spillover effect, at equilibrium, manager i's influence is given by $I_{i,t} = min[\theta_H - \theta_{i,t}, I]$.

Proof: In period *t*, manager *i*'s objective is to maximize her private benefits:

$$U_{i,t} = \rho\theta_{i,t}k\left(C_{i,t}\right) \tag{13}$$

subject to the capital constraint:

$$C_{i,t} \leq C_{f,t} \tag{14}$$

The Lagrangian associated with this maximization is:

$$L_{i,t} = \rho\theta_{i,t}k\left(C_{i,t}\right) + \lambda_{i,t}\left(C_{f,t} - C_{i,t}\right) \tag{15}$$

The first order conditions of this Lagragian are:

$$\frac{\partial L_{i,t}}{\partial C_{i,t}} = \rho\theta_{i,t}k'\left(C_{i,t}\right) - \lambda_{i,t} = 0 \tag{16}$$

$$\frac{\partial L_{i,t}}{\partial \lambda_{i,t}} = C_{f,t} - C_{i,t} = 0 \tag{17}$$

$$\lambda_{i,t} \geq 0 \tag{18}$$

$$C_{i,t} \leq C_{f,t} \tag{19}$$

Define $C_{i,t}^{**}$ as the optimal capital allocation for manager *i*. At the optimum:

$$C_{i,t}^{**} = C_{f,t} \tag{20}$$

Comparing manager *i*'s optimum in (20) with the CEO and the firm's optimum in (7), we note that the CEO and the firm's optimum concerns the relative productivities of the two divisions, whereas manager *i*'s optimum is independent of this factor. In other words, it is not in the interests of the managers to rank order productivities of the divisions. This difference in the agents' objectives, as we show later, can lead to inefficient capital allocation.

Note that it is ideal for manager *i* to get the entirety of the corporate capital for her own division. Therefore, regardless of $\theta_{j,t}$, manager *i* will, to her best ability, maximize the signal reported to the CEO regarding the productivity of division *i*. Specifically,

$$S_{i,t} = \max[\theta_H, \theta_{i,t} + I] \tag{21}$$

Therefore, at equilibrium, manager *i*'s influence in period *t* is given by:

$$I_{i,t} = \min\left[\theta_H - \theta_{i,t}, I\right] \tag{22}$$

Equation (22) describes the equilibrium behavior of manager i. In words, manager i will, if within her ability, exert enough influence to signal to the CEO that her division's productivity is the highest productivity realizable. When that is beyond her influence ability, she will exert the maximum influence possible. Interestingly, (22) also implies that the lower the actual productivity of division *i* is, the more influence manager *i* is likely to exert. This is consistent with the conclusion of Meyer et al. (1992) that the influence costs arise from the divisions with the prospects of decline or layoffs. More importantly, consistent with equation (20), at equilibrium, manager *i*'s influence effort is independent of the relative productivities of the two divisions. Moreover, the behaviors of the other internal agents are also irrelevant to manager *i*'s equilibrium influence behavior. Given that (22) also applies to manager j, the condition for optimal capital allocation in (12) can only occur by random chance. To sum up, it is in the best interest of the firm for the agents to coordinate and base capital allocation decisions on the relative productivities but the managers have no incentives to be concerned about the other agents' behaviors or the productivity ranking orders. Therefore, to mitigate the inefficiency problem, an incentive is needed to align the interests of the managers with the interests of the CEO and the firm.

2.3.2 The Case with the Spillover Effect

In this section, we introduce the spillover effect between divisions *i* and j, and show how this effect helps align the interests of the agents, and facilitates capital allocation. In the presence of the spillover effect, the production of division j generates incremental outputs for division i, in the amount of a fraction, α, of division j's production outputs, with $\alpha \ \varepsilon \ [0,1]$ and observable to all the agents. Thus in period t, the spillover gain in division *i*'s outputs, from division j's production, is given by $\alpha\theta_{j,t}k(C_{j,t})$. This spillover gain is essentially a positive externality. To illustrate, consider a steel company, with one division controlling the mills that make the steel, and another division extracting iron from the mines. Suppose the mining division invests in an advanced iron extraction technology that significantly reduces the extraction costs and increases the outputs. As a result, the mining division supplies a greater quantity of iron to the mills at a lower price, and thus increases the production outputs of the mills without raising its costs. On the one hand, the mills do not incur any investment expenditure for the incremental outputs; on the other hand, the mining division does not need to share the return of this investment with the mills in order to create the spillover gain. This second point also distinguishes the spillover effect from the sharing of investment surplus modeled in Rajan et al. (2000), in which the gain of one division comes at the expense of the loss of another division.

This spillover effect essentially changes the production function of the firm. Specifically, with both divisions generating outputs for themselves and for each other, the firm's production function becomes $(1+\alpha)k(C_t)$. And the outputs of division *i* are now given by $\theta_{i,t}k(C_{i,t})+\alpha\theta_{j,t}k(C_{j,t})$. It can be easily proven that the spillover effect does not alter the CEO and the firm's optimization problem. In other words, with the spillover effect, Propositions 1 and 2 still hold. However, the spillover effect significantly changes the optimums and equilibrium behaviors of the managers. Specifically, we have the following proposition.

Proposition 4: *With the spillover effect, at equilibrium, manager i's influence is given by* $I\_sp_{i,t}=\frac{\theta_{i,t}(\theta_{j,t}+I_{j,t}-\widehat{I_{j,t}})}{\alpha\theta_{j,t}}-\theta_{i,t}+\widehat{I_{i,t}}$.

Proof: With the spillover effect, in period *t*, manager *i*'s objective is still to maximize her private benefits:

$$U\_sp_{i,t}=\rho[\theta_{i,t}k(C_{i,t})+\alpha\theta_{j,t}k(C_{j,t})] \tag{23}$$

subject to the same capital constraint of (2). The Lagrangian associated with this maximization is:

$$L\_sp_{i,t}=\rho\left[\theta_{i,t}k(C_{i,t})+\alpha\theta_{j,t}k(C_{j,t})\right]-\lambda\_sp_{i,t}(C_{i,t}+C_{j,t}-C_{f,t}) \tag{24}$$

The first order conditions of this Lagragian are:

$$\frac{\partial L\_sp_{i,t}}{\partial C_{i,t}}=\rho\theta_{i,t}k'(C_{i,t})-\lambda\_sp_{i,t}=0 \tag{25}$$

$$\frac{\partial L\_sp_{i,t}}{\partial C_{j,t}}=\rho\alpha\theta_{j,t}k'(C_{j,t})-\lambda\_sp_{i,t}=0 \tag{26}$$

$$\frac{\partial L\_sp_{i,t}}{\partial \lambda\_sp_{i,t}}=C_{f,t}-C_{i,t}-C_{j,t}=0 \tag{27}$$

Define $C\_sp_{i,t}^{**}$ and $C\_sp_{j,t}^{**}$ as the optimal capital allocation for manager *i*, in the presence of the spillover effect. At optimum:

$$\frac{k'(C\_sp_{i,t}^{**})}{k'(C\_sp_{j,t}^{**})} = \alpha \frac{\theta_{j,t}}{\theta_{i,t}} \tag{28}$$

Comparing with the optimum in (20), manager *i*'s optimum in (28) is no longer independent of the two divisions' relative productivities. Essentially, the spillover effect makes division *j*'s productivity relevant in manager *i*'s optimum, and this relevance increases with α. Comparing manager *i*'s optimum in (28) with the CEO and firm's optimum in (7), we observe that, as α increases, manager *i*'s optimum approaches the CEO and the firm's optimum. In other words, the larger the spillover effect is, the less the objectives of the agents differ. In the extreme case where the spillover effect is 100%, the optimum of manager *i* in (28) converges to the optimum of the CEO and the firm given by (7).

Now we examine how the spillover effect facilitates efficient capital allocation through changing manager *i*'s equilibrium influence level. Once again, the CEO's capital allocation decision is given by (8). In order to maximize her private benefits, at equilibrium, manager *i* will exert influence, $I\_sp_{i,t}$, so that

$$\frac{\widehat{\theta_{j,t}}}{\widehat{\theta_{i,t}}} = \alpha \frac{\theta_{j,t}}{\theta_{i,t}} \tag{29}$$

Substituting $\widehat{\theta_{i,t}} = S_{i,t} - \widehat{I_{i,t}} = \theta_{i,t} + I_{i,t} - \widehat{I_{i,t}}$ and $\widehat{\theta_{j,t}} = S_{j,t} - \widehat{I_{j,t}} = \theta_{j,t} + I_{j,t} - \widehat{I_{j,t}}$ into (29) yields:

$$I\_sp_{i,t} = \frac{\theta_{i,t}(\theta_{j,t} + I_{j,t} - \widehat{I_{j,t}})}{\alpha\theta_{j,t}} - \theta_{i,t} + \widehat{I_{i,t}} \tag{30}$$

Equation (30) describes the equilibrium behavior of manager *i* in the presence of the spillover effect, and differs from (22) in that, the productivities of both divisions and the actions of all internal agents come into play in manager *i*'s decision making. Moreover, for given levels of productivity, manager *j*'s influence, and the CEO's estimations of the influence activities, the larger the spillover effect is, the less influence manager *i* will exert at equilibrium. Most importantly, as $\alpha \to 1$, $I\_sp_{i,t}$ in (30) approaches the sufficient and necessary condition required for efficient capital allocation in (12), and when $\alpha = 1$, both managers' optimums converge with the firm's optimum, and equation (30) converges with the optimal allocation condition (12). Essentially, Proposition 4 implies that the spillover effect helps align the objectives of different agents and the firm, and thus improves the efficiency of the ICM through changing the agents' equilibrium behaviors. The larger the spillover effect is, the closer the equilibrium capital allocation is to the optimal capital allocation. Eventually, when the spillover effect is 100%, there is no longer any discrepancy between the objectives of the agents. In this case, the inefficiencies of the ICM are eliminated, and capital allocation within a multi-divisional firm converges to the case of a stand-alone entity. In the Appendix, we provide arguments that link our model to existing theories in the ICM literature.

Our model predicts that ICM efficiency increases with the size of the spillover effect, which arises when firms vertically integrate. In the following sections, we measure the spillover effect by the degree of vertical integration, and empirically test the prediction of the model using three different proxies of ICM efficiency.

3. Data and Samples

3.1 Samples

We use three samples to run our tests: the innovation sample, cash flow sample, and CAPX sample. We test ICM efficiency using innovative efficiency on the innovation sample, investment-cash flow sensitivity on the cash flow sample, and CAPX deviation on the CAPX sample. As we will discuss later, we first construct a firm-level vertical integration coefficient (*VIC*) using segment industry information from Compustat, and the detailed Use Table of Benchmark Input-Output Accounts provided by the Bureau of Economic Analysis (BEA) from 1982 to 2007. To build the samples, we start with all multi-segment firms listed on the Compustat industry segment files between 1980 and 2007.

To construct the innovation sample, we obtain innovation related data from the National Bureau of Economic Research (NBER). The NBER patent dataset covers patent grants information from 1967 to 2006. Using this data, we construct a measure of innovative efficiency, and merge firm-level financial data of all multi-segment firms listed on the Compustat industry segment file with the innovation data and *VIC*.

Furthermore, we exclude financial firms (SIC code 6000 to 6999), and delete observations with missing information. This procedure generates 21,043 firm-year observations in the innovation sample.

We follow the procedures described in Shin and Stulz (1998) to form the cash flow sample. For each segment, we collect the following information: sales, operating profit (loss), depreciation, capital expenditures, identifiable total assets, and SIC code. The segment-years that do not contain complete information are excluded. Further, we eliminate the segment-years in which any of the following ratios exceed one: current value of net capital expenditure (gross capital expenditure minus depreciation) over the previous year's segment assets, sales growth from the previous year's sales, cash flows to segment assets, and other segments' cash flows to the total assets of those segments. Cash flows are calculated as operating profit (loss) plus depreciation and amortization. In addition, we delete cases in which the smallest segment has the same 2-digit SIC code as the largest segment. Lastly, we exclude financial firms (SIC code 6000 to 6999), and merge this data set with *VIC*. This procedure yields 17,583 firms-years and 46,760 segment-years in the cash flow sample.

To construct the CAPX sample, we start with all multi-segment firms listed on the Compustat industry segment file with complete information required to compute all variables needed in our later CAPX analyses. We first merge this dataset with Compustat to obtain firm level information, then merge it with *VIC*. Lastly, we exclude financial firms (SIC code 6000 to 6999). The final CAPX sample consists of 26,240 firm-year observations.

3.2 Variable Construction

3.2.1 Vertical Integration Coefficient (VIC)

We measure the degree of vertical integration based on commodity flows between industries in the U.S. economy. The BEA has published the Benchmark Input-Output tables (IO tables) between all producers and purchasers in the economy since 1947. The IO tables are primarily based on the Economic

Census and are published every five years with a five-year delay[1]. The BEA defines industries at the summary level and the detailed level. Our measure of vertical integration is based on the detailed Use Tables for the years 1982, 1987, 1992, 1997, 2002, and 2007. The Use Table reports, for each industry pair *m* and *n*, the dollar value of *m*'s output required to produce *n*'s total output, at the producer's price. Industries are defined by SIC code before 1997 and by NAICS code since 1997. The SIC codes reported range from 2-digit to 4-digit, whereas the NACIS codes reported range from 2-digit to 6-digit.

To construct *VIC*, we begin by dividing the segment data into six time periods, 1980-1982, 1983-1987, 1988-1992, 1993-1997, 1998-2002, and 2003-2007, and apply the Use Tables of years 1982, 1987, 1992, 1997, 2002, and 2007 to each time period, respectively. Within each firm, we pair each division with each of the other divisions in the same firm. For example, a firm, *A* with three divisions, *x*, *y*, and *z* will have six division pairs, *xy*, *xz*, *yx*, *yz*, *zx*, and *zy*. Then we match the division pairs to the Use Table by the divisions' industry codes to obtain the dollar value of commodities transferred between each division-pair's industries. To illustrate, a_{xy} denotes the dollar value of output produced by division *y*'s industry required to produce the total output of division *x*'s industry. We divide a_{xy} by the dollar value of total output produced by division *x*'s industry to get v_{xy}. v_{xy} represents the dollar value of output produced by division *y*'s industry that is required to produce one dollar's worth of output in division *x*'s industry. Similarly, we calculate v_{xz}, v_{yx}, v_{yz}, v_{zx}, and v_{zy}. In the next step, we take the weighted average of v_{xy} and v_{xz} to obtain V_x, using the sales of division *y* and division *z* as the weights. V_x represents the weighted average dollar value of output produced by the industries of all the other divisions in firm *A* that is required to produce one dollar's worth of output in division *x*'s industry. Accordingly, we calculate V_y and V_z. We define the vertical integration coefficient of firm *A* as the maximum of V_x, V_y and V_z, thus $VIC_A = \max \{V_x, V_y, V_z\}$. Ahern and Harford (2014), Fan and Lang (2000), and Kumar (2013) use a similar approach to measure vertical industry links. To obtain the most accurate and comprehensive match between the segment file and the Use Tables, for each division pair, we match with the divisions' primary SIC or NAICS codes first, and if no matches are

[1] For example, the IO table of 2007 is published in 2012.

found, we switch to the divisions' secondary SIC or NAICS codes. Furthermore, we start the match with the narrowest industry codes (4-digit SIC codes or 6-digit NAICS codes) and gradually loosen the matching criteria to the broadest industry codes (2-digit SIC codes or 2-digit NAICS codes).

By construction, *VIC* reflects the strongest supplier-customer relation that exists between the divisions within the same firm. One would expect *VIC* to be between 0 and 1, as it is not likely for a division to acquire more than one dollar's worth of inputs from other divisions in order to produce one dollar's worth of outputs. However, the Use Tables report only inter-industrial commodity flows, and it can significantly understate the actual total output of industries that mostly produce consumer products or services, which are directly supplied to end consumers, such as the retailing or health care industries. As a result, for divisions that belong to such industries, the calculated *VIC* can be greater than 1. Less than 1% of the *VIC*s we calculate are greater than 1. Nevertheless, to avoid extreme outliers, we set *VIC* to 3 for values greater than 3.

3.2.2 Innovative Efficiency

We use patent-based metrics to measure innovative efficiency. Trajtenberg (1990) and Griliches (1990) both suggest that whereas R&D intensity focuses on the expense incurred during the research and development process, patent-based metrics provide a better measure of the efficiency of R&D activities. We construct this measure the same way as in Seru (2014). Specifically, for each firm-year, we count the number of patents filed that were later granted. This simple measure of patent counts is biased for two reasons. First, as Hall, Jaffe, and Trajtenberg (2001) identify, a truncation bias exists toward the end of the sample period, because it takes an average of two years from the time when a patent is filed to the time when it is granted. Second, patent intensities vary across industries. To address these concerns, we follow Hall et al. (2001) and, in each year, dividing the number of patents by the mean number of patents in the industry to which a firm belongs. We use this adjusted number of patents for each firm-year, *Patent*, as the measure of innovative efficiency. For firm-years in which no patent filed has been granted, *Patent* equals zero.

3.2.3 CAPX Deviation

Following Cho (2015), we compute firm level CAPX deviation in three steps. First, we compute CAPX deviation from the passive allocation at the division level. Specifically, for division *j* of firm *i* in year *t*, CAPX deviation is calculated as follows:

$$CAPX\ Deviation_{i,j,t} = \frac{CAPX_{i,j,t}}{\sum_{j=1}^{n} CAPX_{i,j,t}} - \frac{Sale_{i,j,t}}{\sum_{j=1}^{n} Sale_{i,j,t}},$$

where $CAPX_{i,j,t}$ and $Sale_{i,j,t}$ are the capital expenditures and sales of division *j* of firm *i* in year *t*, respectively, and *n* is the number of divisions in firm *i*.

In the second step, we define signed CAPX deviation for each division as follows:

$$Signed\ CAPX\ Deviation_{i,j,t} = (+1) \times CAPX\ Deviation_{i,j,t}, if\ Tobin'sQ_{i,j,t}\ > \overline{Tobin'sQ_{i,t}}$$

$$Signed\ CAPX\ Deviation_{i,j,t} = (-1) \times CAPX\ Deviation_{i,j,t}, if\ Tobin'sQ_{i,j,t}\ \leq \overline{Tobin'sQ_{i,t}}$$

where *Tobin's* $Q_{i,j,t}$ is the Tobin's Q (defined below) of division *j* of firm *i* in year *t*, and $\overline{Tobin'sQ_{i,t}}$ is the asset-weighted average Tobin's Q of all the remaining divisions of firm *i* in year *t*. The signed CAPX deviation takes a positive value if a segment with higher opportunities receives more capital than it would under passive allocation, vice versa. Therefore, a positive signed CAPX deviation indicates higher ICM efficiency.

In the last step, we compute the firm level signed CAPX deviation, $CAPX\_Dev_{i,t}$, as the asset-weighted average of divisional signed CAPX deviation, as follows:

$$CAPX\_Dev_{i,t} = \sum_{i=1}^{n} w_{i,j,t}\, Signed\ CAPX\ Deviation_{ijt},$$

with $w_{i,j,t} = \frac{IAS_{i,j,t}}{\sum_{j=1}^{n} IAS_{i,j,t}}$,

where $IAS_{i,j,t}$ is the identifiable total assets of division *j* of firm *i* in year *t*. We use $CAPX\_Dev_{i,t}$ as our third measure of ICM efficiency.

3.2.4 Other Variables

We also employ a set of other segment- and firm-level control variables. Following Shin and Stulz (1998), we construct the following segment-level variables include: $Investment_{i,j,t}$, calculated as the capital expenditure of division j of firm i in year t, divided by the total assets of firm i in year t-1; $Sales\ Growth_{i,j,t}$, calculated as the sales growth of division j of firm i from year t-2 to year t-1; $Cash\ Flow_{i,j,t}$, calculated as the sum of operating profit and depreciation and amortization of division j of firm i in year t, divided by the total assets of firm i in year t-1; and $Tobin's\ Q_{i,j,t}$, Tobin's Q of division j of firm i in year t, calculated as the median Q of single-division firms in division j's 2-digit SIC industry in year t, where Q is calculated as the ratio of the book value of assets minus the book value of equity plus the market value of equity to the book value of assets.

Firm-level variables include: $LogAT_{i,t}$, calculated as the natural log of firm i's total assets in year t; $R\&D_{i,t}$, a measure of R&D intensity, calculated as R&D expenditure divided by the total assets of firm i in year t (we set missing R&D expenditure to zero); $Profitability_{i,t}$, calculated as the ratio of *EBITDA* to the total assets of firm i in year t; $Leverage_{i,t}$, calculated as the sum of long-term debt and debt in current liabilities, divided by the total assets of firm i in year t; $Market\text{-}to\text{-}Book_{i,t}$, calculated as the ratio of the market value of equity to the book value of equity of firm i in year t; $Cash_{i,t}$, calculated as cash divided by the total assets of firm i in year t; and $Capx_{i,t}$, calculated as the capital expenditure divided by the total assets of firm i in year t; $HHI_{i,t}$, 2-digit SIC industry level Herfindahl index; $LogMV_{i,t}$, calculated as the natural log of the market value of equity; $CF_{i,t}$, firm-level cash flow, calculated as operating cash flows divided by beginning-of-period total assets, $Tangibility_{i,t}$, calculated as net PPT scaled by total assets; $Extfin_{i,t}$, external financing, calculated as net external financing scaled by capital expenditures, where net external financing is calculated as (sale of common stock and preferred stocks + long-term debt issuance)-(purchase of common stocks and preferred stocks + long-term debt reduction) + changes in current debt – dividend; $Dividend_{i,t}$, a dummy variable that takes the value of one if firm i pays positive dividend on common stocks in year t, zero otherwise; $NumSeg_{i,t}$, the number of segments in firm i in year t; and $NumInd_{i,t}$, the number of unique 2-digit SIC industries that all the segments of firm *i* belong to in year *t*. All accounting ratios are winsorized at 1% and 99% to eliminate extreme outliers.

3.3 Summary Statistics

Table 1 reports the summary statistics of the three samples. For the innovation sample (Panel A), $VIC_{i,t}$ has a mean of 0.14, a median of 0.02, and a standard deviation of 0.36. The mean and median of $R\&D_{i,t}$ are 0.02 and 0.00, respectively, with a standard deviation of 0.05. The mean, median, and standard deviation of $Patent_{i,t}$ are 0.43, 0.00, and 1.19. $LogAT_{i,t}$ has a mean of 6.10, a median of 6.16, and a standard deviation of 2.40. The mean of $Profitability_{i,t}$ is 0.10, with the median and standard deviation of 0.12 and 0.13, respectively. $Leverage_{i,t}$ has a mean of 0.26, a median of 0.26, and a standard deviation of 0.17. The mean, median, and standard deviation of $Market\text{-}to\text{-}Book_{i,t}$ are 2.65, 1.67, and 3.92. The mean of $Cash_{i,t}$ is 0.07, and its median and standard deviation are 0.03 and 0.10, respectively. $Capx_{i,t}$ has a mean of 0.07, a median of 0.05, and a standard deviation of 0.06. Lastly, the mean, median, and standard deviation of $HHI_{i,t}$ are 0.08, 0.05, and 0.08, respectively.

Panel B presents the summary statistics for the cash flow sample.[2] The mean and median of $VIC_{i,t}$ are 0.14 and 0.02, respectively, with a standard deviation of 0.39. $LogAT_{i,t}$ has a mean of 5.73, a median of 5.80, and a standard deviation of 2.45. For the segment-level variables, the mean (median) of $Investment_{i,j,t}$ is 0.02 (0.01) and the standard deviation is 0.03; $Sales\ Growth_{i\ j,t}$ has a mean of 0.07, a median of 0.06, and a standard deviation of 0.24; the mean, median, and standard deviation of $Cash\ Flow_{i,j,t}$ are 0.05, 0.03, and 0.06, respectively; $Tobin's\ Q_{i,j,t}$ has a mean of 1.50, a median of 1.37, and a standard deviation of 0.49.

Panel C reports the summary statistics for the CAPX sample. The mean, median and standard deviation of $VIC_{i,t}$ are 0.14, 0.02 and 0.36, respectively. $CAPX\_Dev_{i,t}$ has a mean of -0.08, a median of -0.02 and a standard deviation of 0.25. Note that the negative mean indicates average firm in the CAPX

[2]We report the summary statistics of *all* the segment-year observations in the cash flow sample to provide a representative description of the levels of the variables. In the regression analyses, we follow Shin and Stulz (1998) and run the regressions on the smallest and largest segments only.

sample exhibits certain degree of allocation inefficiency. The mean (median) of $LogMV_{i,t}$ is 1.25 (1.65), with a standard deviation of 1.08. $Market\text{-}to\text{-}Book_{i,t}$ has a mean of 2.13, a median of 1.44 and a standard deviation of 2.72. $CF_{i,t}$ has a mean of -0.11, a median of 0.02, and a standard deviation of 0.25. $Capx_{i,t}$ has a mean of 0.20, a median of 0.17 and a standard deviation of 0.15. The mean of $R\&D_{i,t}$ is 0.02, with a median and standard deviation of 0.00 and 0.04, respectively. The mean, median and standard deviation of $Tangibility_{i,t}$ are 0.35, 0.31, and 0.23, respectively. $Extfin_{i,t}$ has a mean of -0.01, a median of 0.00, and a standard deviation of 0.26. The mean of $Cash_{i,t}$ is 0.06, with a median of 0.02 and standard deviation of 0.09. $Leverage_{i,t}$ has a mean (median) of 0.27 (0.26), with a standard deviation of 0.17. On average, 57% of the sample pays dividends. The average firm has 3.63 divisions. And number of unique industries the average firm belongs to is 2.38. Lastly, the mean, median and standard deviation of $HHI_{i,t}$ is 0.08, 0.05, and 0.08.

3.4 Correlations

Table 2 presents the Pearson correlation coefficients among the key variables. For the innovation sample (Panel A) it appears that $VIC_{i,t}$ is positively related to$LogAT_{i,t}$, $Profitability_{i,t}$, $Leverage_{i,t}$, $Capx_{i,t}$, and $HHI_{i,t}$. Furthermore, higher $VIC_{i,t}$ leads to lower R&D investment, but not significantly fewer patents produced. This seems to suggest that when the level of vertical integration increases, R&D activities become more productive, indicating higher capital allocation efficiency by the ICM in more vertically integrated organizations. In the following sections, we perform additional tests to examine whether this relation is robust.

In Panel B, we report the correlations for the cash flow sample. At first glance, $VIC_{i,t}$ is negatively related to segment-level $Investment_{i,j,t}$, $Cash\ Flow_{i,j,t}$, and $Tobin's\ Q_{i,j,t}$. It is positively related to segment sales growth. In addition, segment-level investments are strongly positively correlated with the segment's own cash flows and sales growth, although the magnitude of the correlation between $Investment_{i,j,t}$ and $Sales\ Growth_{i,j,t}$ is only 0.1413. As we will discuss in a later section, we use the cash flow sample to test the role of vertical integration in ICM capital allocation by examining how *VIC* moderates the dependence of segment-level investments on the segment's own cash flows, when the segment has the best investment opportunity in the firm. This moderation effect cannot be observed in the univariate correlations.

Panel C presents the correlation matrix for the CAPX sample. It is worth noting that $VIC_{i,t}$ has a significant positive correlation $CAPX\_Dev_{i,t}$, which suggests that $CAPX\_Dev_{i,t}$ increases with the degree of vertical integration. Since higher $CAPX\_Dev_{i,t}$ indicates higher ICM efficiency, this evidence is consistent with the model's prediction that vertical integration makes allocation more efficient. Furthermore, $CAPX\text{-}\_Dev_{i,t}$ is negatively related to $NumSeg_{i,t}$, suggesting that ICM efficiency decreases with the number of divisions. This confirms the notion that firms with greater number of divisions are more likely to have higher diversity in their investment opportunities, which can lead to more severe misallocation (Rajan et al., 2000).

3.5 Univariate Analysis

In Table 3, we divide all three samples into quartiles by the level of *VIC* and conduct univariate t-tests on the main variables. As mentioned in the previous section, we use the cash flow sample to test the moderation effect of *VIC* on the dependence of segment-level investments on the segment's own cash flows, when the segment faces the best investment opportunities in the firm. Because this effect can only be observed in a multivariate setting, we will only focus on the univariate results of the innovation sample and CAPX sample in this section.[3] Panel A presents the univariate analysis of the innovation sample. Comparing to firms in the lowest *VIC* quartile, we observe that firms located in the highest *VIC* quartile do not have significantly different R&D intensity, but produce a significantly larger number of patents. This is consistent with what we observed in the correlations, and suggests that more vertically integrated firms conduct more efficient R&D. In other words, the limited R&D capital is allocated to the more promising projects among all the divisions under higher degrees of vertical integration, and thus yields a higher return.

[3] We report the univariate comparison of the base sample in Panel A for completeness sake only.

The results suggest that, as our model predicts, the spillover effect created by vertical integration increases ICM allocation efficiency.

We present the results of the CAPX sample in Panel C. In summary, the univariate analysis suggests that higher degree of vertical integration is associated with higher market value, cash flow, asset tangibility, greater number of segments, and higher industry diversity. More vertically integrated firms also appear to be more likely to pay dividend. However, external financing in the most vertically integrated firms is lower than that of the least vertically integrated firms. Although there is some evidence that $CAPX\_Dev_{i,t}$ tends to increase with *VIC*, the difference between the highest and lowest *VIC* quartiles is insignificant.

4. *VIC* and Innovative Efficiency

In this section, we present further evidence of the link between vertical integration and ICM efficiency through the efficiency of R&D investments. As Seru (2014) suggests, R&D activities are characterized by a high degree of information asymmetry between the divisions and corporate headquarters, which hinders efficient internal capital allocation. Therefore, higher innovative efficiency is an indication of a more efficient ICM. Incorporating vertical integration to this rationale, we investigate whether innovative efficiency changes with the level of vertical integration. Specifically, we test the following models:

$$R\&D_{i,t} = \eta_1 VIC_{i,t} + \eta_2 LogAT_{i,t} + \eta_3 Profitability_{i,t} + \eta_4 Leverage_{i,t} + \eta_5 Market\text{-}to\text{-}Book_{i,t} + \eta_6 Cash_{i,t} + \eta_7 Capx_{i,t} + \eta_8 HHI_{i,t} + \eta_9 HHI^2_{i,t} + \eta_{10} Industry\ Fixed\ Effects + \eta_{11} Year\ Dummies + \varepsilon_{i,t} \quad (31)$$

$$Patent_{i,t} = \lambda_1 VIC_{i,t} + \lambda_2 LogAT_{i,t} + \lambda_3 Profitability_{i,t} + \lambda_4 Leverage_{i,t} + \lambda_5 Market\text{-}to\text{-}Book_{i,t} + \lambda_6 Cash_{i,t} + \lambda_7 Capx_{i,t} + \lambda_8 HHI_{i,t} + \lambda_9 HHI^2_{i,t} + \lambda_{10} R\&D_{i,t} + \lambda_{11} Industry\ Fixed\ Effects + \lambda_{12} Year\ Dummies + \varepsilon_{i,t} \quad (32)$$

The regression results are presented in Table 4. First, *VIC* is negatively related to *R&D*, indicating that as the level of vertical integration increases, R&D intensity decreases, although the economic significance in the decrease in *R&D* seems trivial. However, when holding *R&D* constant, we find that *VIC* is positively related to *Patent*. Specifically, for a given level of R&D intensity, a 1% increase in *VIC* leads to 0.0462% more adjusted patents produced. In other words, R&D investments are more efficient when firms are more vertically integrated. This suggests that under higher degrees of vertical integration, R&D capital is allocated to the more productive projects.

To more directly examine how much vertical integration increases innovative efficiency, we add an interaction term between $VIC_{i,t}$ and $R\&D_{i,t}$ and run the following model:

$$Patent_{i,t} = \zeta_1 VIC_{i,t} + \zeta_2 R\&D_{i,t} + \zeta_3 VIC_{i,t} * R\&D_{i,t} + \zeta_4 LogAT_{i,t} + \zeta_5 Profitability_{i,t} + + \zeta_6 Leverage_{i,t} + \zeta_7 Market\text{-}to\text{-}Book_{i,t} + \zeta_8 Cash_{i,t} + \zeta_9 Capx_{i,t} + \zeta_{10} HHI_{i,t} + \zeta_{11} HHI^2_{i,t} + \zeta_{12} Industry\ Fixed\ Effects + \zeta_{13} Year\ Dummies + \varepsilon_{i,t} \quad (33)$$

We expect ζ_2 and ζ_3 to be positive and significant. A positive ζ_2 indicates that higher R&D intensity leads to more patents produced and a positive ζ_3 indicates that vertical integration enhances the positive effects of R&D intensity on the number of patents produced. The results are presented in Table 5. Consistent with our expectations, we observe that a 1% increase in *R&D* leads to 1.9606% more adjusted patents produced. More importantly, as the level of *VIC* increases by 1%, the positive effects of *R&D* on *Patent* increases further by 2.5157%. Holding *R&D* at the sample mean, a one standard deviation increase (0.3637) in *VIC* leads to a 46.69% increase in innovative efficiency[4]. This again suggests that as the level of vertical integration increases, limited R&D capital is distributed to the more promising opportunities, yielding better innovation outcomes. Overall, the evidence presented in Tables 4 and 5 provides additional evidence that, as the level of vertical integration increases, the ICM becomes more efficient.

5. *VIC* and Investment-Cash Flow Sensitivity

To further examine the effect of vertical integration on ICM efficiency, we investigate investment-cash flow sensitivity based on Shin and Stulz (1998). Their paper argues that efficient internal capital allocation implies a lower investment-cash flow sensitivity for the segment with the best investment opportunity in a firm, because an efficient ICM should allow that segment to pursue good investment opportunities, regardless of the amount of cash flows that segment generates itself. However, one can only

[4] This is calculated as (2.5057*0.0220*0.3637)/(1.9606*0.0220).

expect to observe this effect for the small segments in a firm, because the large segments are the primary source of cash flows of the firm, thus naturally fund their own investments, regardless of the investment prospects. In contrast, the small segments are more likely to be constrained by the amount of cash flows they generate and not have sufficient resources to pursue good investment project(s) when they emerge. Under these circumstances, if the ICM is efficient, capital will be directed from other segments to the small segments with superior opportunities. Therefore, we should observe a significant decrease in the reliance of the small segments' investments on their own cash flows when good opportunities exist.

In our next test, we examine whether vertical integration affects segment-level investment-cash flow sensitivity. Specifically, we run the following regression model:

$$Investment_{i,j,t} = \beta_1 \, Sales\ Growth_{i,j,t} + \beta_2 Cash\ Flow_{i,j,t} + \beta_3 Cash\ Flow_{i,other,t} + \beta_4 Tobin's\ Q_{i,j,t} + \beta_5 High\ Q_{i,j,t} * Cash\ Flow_{i,j,t} + \beta_6 High\ Q_{i,j,t} * Cash\ Flow_{i,other,t} + \beta_7 Tobin's\ Q_{i,other,t} + \beta_8 Segment\ Fixed\ Effects + \beta_9 Year\ Dummies + \varepsilon_{i,j,t} \quad (34)$$

where $Cash\ Flow_{i,other,t}$ is calculated as the sum of cash flows of all the segments in firm *i*, except for the cash flows of segment *j* in year *t*, divided by the total assets of firm *i* in year *t*-1; $High\ Q_{i,j,t}$ is a dummy variable that takes the value of 1 if segment *j* has the highest *Tobin's Q* among all the segments within firm *i* in year *t*, zero otherwise; $Tobin's\ Q_{i,other,t}$ is the highest *Tobin's Q* among all the segments within firm *i*, except for segment *j*, in year *t*; and other variables are calculated as described in section 3.2.

We run model (34) for the smallest and the largest segments located in the lowest and highest *VIC* quartiles of the cash flow sample. The expectation is that β_2 is positive and significant, as the investments of a segment depend, among other things, on its own cash flows. However, if an active internal capital market exists, we should expect β_5 to be negative and significant for the smallest segment, because as argued above, an efficient ICM should lower the investment-cash flow sensitivity of the smallest segment, when that segment has the best investment opportunity within the firm. Furthermore, if vertical integration increases ICM efficiency, we should expect the magnitude of β_5 to be greater in the highest *VIC* quartile compared to the lowest *VIC* quartile. Since the effects of ICM may not be profound in the largest segment, we do not have an expectation for the two largest segment subsamples.

The results are presented in Table 6. As expected, β_2 is positive and significant for all four subsamples, indicating that segments' own cash flows play an important role in determining segment-level investments. And consistent with our theoretical prediction, we observe β_5 to be negative and significant for the two smallest segment subsamples. For the smallest segments located in the lowest *VIC* quartile, a 1% increase in segment $Cash\ Flow_{i,j,t}$ leads to a 0.1035% increase in $Investment_{i,j,t}$. However, if the smallest segment has the highest *Tobin's Q* within the firm, the investment-cash flow sensitivity decreases by 0.0281%. This implies about a 27% decrease in investment-cash flow sensitivity. When we look at the results for the smallest segments located in the highest *VIC* quartile, the effect of the ICM appear to be much greater. First, a 1% increase in *Cash Flow* leads to approximately 0.0931% increase in *Investment*. However, if the smallest segment has the highest *Tobin's Q* within the firm, the investment-cash flow sensitivity decreases by 0.0419%, which is about a 45% decrease, comparing to the 27% decrease for the smallest segments in the lowest *VIC* quartile. These findings suggest that while there is an active ICM, the ICM is more efficient in more vertically integrated firms.

To show further evidence of the effects of *VIC* on ICM efficiency, we add *VIC* and a three-way interaction term between $VIC_{i,t}$, $High\ Q_{i,j,t}$, and $Cash\ Flow_{i,j,t}$ to model (34). To be specific, we run the following model separately for the smallest and largest segments:

$$Investment_{i,j,t} = \gamma_1\ Sales\ Growth_{i,j,t} + \gamma_2 Cash\ Flow_{i,j,t} + \gamma_3 Cash\ Flow_{i,other,t} + \gamma_4 Tobin's\ Q_{i,j,t} + \gamma_5 VIC_{i,t} + \gamma_6 High\ Q_{i,j,t} * Cash\ Flow_{i,j,t} + \gamma_7 VIC_{i,t} * High\ Q_{i,j,t} * Cash\ Flow_{i,j,t} + \gamma_8 High\ Q_{i,j,t} * Cash\ Flow_{i,other,t} + \gamma_9 VIC_{i,t} * High\ Q_{i,j,t} * Cash\ Flow_{i,other,t} + \gamma_{10} Tobin's\ Q_{i,other,t} + \gamma_{11} Segment\ Fixed\ Effects + \gamma_{12} Year\ Dummies + \varepsilon_{i,j,t} \quad (35)$$

We expect vertical integration to further lower the investment-cash flow sensitivity in the smallest segment of a firm, when that segment has the best investment opportunity, and thus expect γ_7 to be negative and significant for the smallest segment subsample.

The results of this analysis are presented in Table 7. Consistent with our expectations, γ_7 is negative and significant at the 5% level. To interpret the economic significance of the coefficient, we first obtain the mean cash flow of the smallest segment subsample, which is 0.0231. While having highest Tobin's Q reduces the smallest segment's investment-cash flow sensitivity, the coefficients indicate that holding the cash flows of the smallest subsample at the mean level, a one standard deviation increase (0.3942) in *VIC* magnifies the effect of having the best investment opportunity by 1.61 times[5]. Because the effect of an efficient ICM is to reduce the investment- cash flow sensitivity, especially for the small segments, this finding suggests that capital allocation is more efficient within more vertically integrated firms. Overall, the evidence presented in Tables 6 and 7 supports our model's prediction that the spillover effect associated with vertical integration improves ICM efficiency.

6. *VIC* and CAPX Deviation

In the third test on the relation between vertical integration and ICM efficiency, we follow Cho (2015) and measure ICM efficiency by $CAPX\_Dev_{i,t}$. The logic of this test is straightforward. Since higher CAPX deviation indicates better efficiency, $VIC_{i,t}$ should be positively related to $CAPX\_Dev_{i,t}$ based on the model's prediction. Specifically, we run the following model:

$$CAPX\_Dev_{i,t} = \kappa_1 VIC_{i,t} + \kappa_2 LogMV_{i,t} + \kappa_3 Market\text{-}to\text{-}Book_{i,t} + \kappa_4 CF_{i,t} + \kappa_5 CAPX_{i,t} + \kappa_6 R\&D_{i,t} + \kappa_7 Tangibility_{i,t} + \kappa_8 Extfin_{i,t} + \kappa_9 Cash_{i,t} + \kappa_{10} Leverage_{i,t} + \kappa_{11} Dividend_{i,t} + \kappa_{12} NumSeg_{i,t} + \kappa_{13} NumInd_{i,t} + \kappa_{14} HHI_{i,t} + \kappa_{15} Industry\ Fixed\ Effects + \kappa_{16} Year\ Dummies + \varepsilon_{i,j,t} \quad (36)$$

We construct the control variables following Cho (2015). We expect κ_1 to be positive and significant. The results are reported in Table 8. Consistent with this expectation, the coefficient of *VIC* is significantly positive. And the coefficient suggests, comparing with the mean *CAPX_Dev* of 7.53%, that a one standard deviation increase (0.3622) in *VIC* leads to a 4.77%[6] improvement in CAPX deviation. Since higher CAPX

[5] This is calculated as (0.0352*0.0231*0.3942)/(0.0086*0.0231).
[6] This is calculated as (0.0099*0.3622)/0.0753.

deviation suggests better allocation efficiency, this result, again, indicates that higher degree of vertical integration is associated with more efficient ICM.

7. Robustness

The decision for a firm to be vertically integrated may not be random. Firms systematically may decide their diversification strategies based on a set of fundamental and idiosyncratic characteristics that pertain to themselves or their industries. Therefore, unobserved variables can potentially bias our test results. To address this concern and validate our results, in this section, we conduct a set of robustness tests. In addition, we also provide test evidence using an alternative measure of vertical integration.

7.1 Omitted Variable Bias: Unobserved Selection and Coefficient Stability

Since vertical integration may result from a set of unobserved variables, which can ultimately lead to a more efficient ICM, it is important to quantify how strong the effects of the unobserved characteristics have to be in order to invalidate the results reported in Sections 4, 5 and 6.

Altonji et al. (2005) derive a consistent estimator of the ratio of the convariances between (1) the treatment (*VIC* in our case) and the unobserved control variables and (2) the treatment and the observed control variables that is needed in order to render the treatment effect zero. They suggest a threshhold ratio of 1 for effect of the treatment to be considered robust. In other words, if the treatment effect is robust, the selection on unobserved variables needs to be t least as important as the selection on observed variables in order for the treatment effect to be zero. Oster (2017) denotes the ratio δ, and formalizes the calucation of δ in the STATA module "psacalc". In addition, since δ =1 is used as the robustness cutoff, the "psacalc" procedure also allows the calculation of the treatment effect under the assumption of δ =1, which is the bias adjusted treatment effect.

To examine whether omitted variable bias is driving our results on the effects of *VIC* on ICM efficiency, we perform the Altonji et al. (2005) test using the the methodology specified in Oster (2017) on our regressions in Tables 5, 7 and 8. The results are reported in Table 9. We present the estimates of δ, the bias-adjusted treatment effect assuming δ =1, and the controlled treatment effect, which are the original regression coeffcients in Tables 5, 7 and 8, for comparison purposes. In Table 9, the first row reports the Altonji et al. (2005) test results on the effects of *VIC* on innovative efficiency (Table 5). Since the effects are only observed in the smallest segments, we perform the "psacalc" procedure on the regression in column 1 of Table 5 only. The second row of Table 9 reports the "psacalc" test results on the effects of *VIC* on investment-cash flow sensitivity (Table 7). And in the third row, the test is performed on the effects of *VIC* on CAPX deviation (Table 8).

In the case of innovative efficiency, δ is estimated to be 3.1594, which indicates unobserved variables need to be 3.1594 times as important as observed control variables in order to render the results in Table 5 invalid. Similarly, with regards to the investment-cash flow sensitivity test, the estimated δ is -4.1413, which suggests that unobserved variables need to be 4.1413 times as important as the control variables included in the regression in order to render the results in Table 7 invalid. Lastly, the estimated δ for the CAPX deviation test indicates the effects of unobserved variables need to be 2.2106 times as important as the effects of the controlled variables to invalidate the results in Table 8. The δ's in all cases are well above the robustness cutoff point of δ = 1. Therefore, the results of the Altonji et al. (2005) tests suggest that omitted variables are unlikely to be driving our results.

In addition, we also report the bias adjusted coefficients under the assumption that δ = 1 in Table 9. The bias-adjusted treatment effects in all three tests carry the same signs as the original regression coefficients. Moreover, the magnitude of the bias-adjusted treatment effects do not deviate from the controlled treatment effects by a great margin: 1.7930 vs. 2.5157 for the innovative efficiency test, -0.0475 vs. -0.0352 for the investment cash flow sensitivity test, and 0.0078 vs. 0.0099 for the CAPX deviation test. This provides further evidence that our findings are unlikely to be the results of omitted variable bias.

7.2 Change Regressions

To provide further validation that time-invariant unobserved factors are not causing bias in our results, we examine the effects of vertical integration on ICM efficiency using change regressions. Because the one-year change in *VIC* is very small, we run our regressions using two-year and three-year changes in the variables. In addition, because the changes in *R&D* are trivial even up to a five-year window, which does not provide enough variation in the variable for us to examine the effect of *VIC*, we perform the change regressions on the investment-cash flow sensitivity test and CAPX deviation test only. Specifically, we run the following models:

$$\Delta Investment_{i,j,t} = \tau_1 \Delta Sales\ Growth_{i,j,t} + \tau_2 \Delta Cash\ Flow_{i,j,t} + \tau_3 \Delta Cash\ Flow_{i,other,t} + \tau_4 \Delta Tobin's\ Q_{i,j,t} + \tau_5 \Delta VIC_{i,t} + \tau_6 \Delta High\ Q_{i,j,t} * \Delta Cash\ Flow_{i,j,t} + \tau_7 \Delta VIC_{i,t} * \Delta High\ Q_{i,j,t} * \Delta Cash\ Flow_{i,j,t} + \tau_8 \Delta High\ Q_{i,j,t} * \Delta Cash\ Flow_{i,other,t} + \tau_9 \Delta VIC_{i,t} * \Delta High\ Q_{i,j,t} * \Delta Cash\ Flow_{i,other,t} + \tau_{10} \Delta Tobin's\ Q_{i,other,t} + \tau_{11} Segment\ Fixed\ Effects + \tau_{12} Year\ Dummies + \varepsilon_{i,j,t} \quad (37)$$

$$\Delta CAPX\_Dev_{i,t} = \omega_1 \Delta VIC_{i,t} + \omega_2 \Delta LogMV_{i,t} + \omega_3 \Delta Market\text{-}to\text{-}Book_{i,t} + \omega_4 \Delta CF_{i,t} + \omega_5 \Delta CAPX_{i,t} + \omega_6 \Delta R\&D_{i,t} + \omega_7 \Delta Tangibility_{i,t} + \omega_8 \Delta Extfin_{i,t} + \omega_9 \Delta Cash_{i,t} + \omega_{10} \Delta Leverage_{i,t} + \omega_{11} \Delta Dividend_{i,t} + \omega_{12} \Delta NumSeg_{i,t} + \omega_{13} \Delta NumInd_{i,t} + \omega_{14} \Delta HHI_{i,t} + \omega_{15} Industry\ Fixed\ Effects + \omega_{16} Year\ Dummies + \varepsilon_{i,j,t} \quad (38)$$

If our previous results are valid, we expect to see similar evidence in the change regressions. In other words, in model (37), τ_7 should be negative and significant, and in model (38), ω_1 is expected to be positive and significant.

Table 10 reports the results of model (37). Specifically, using two-year changes, the coefficient on the triple interaction term τ_7 is negative and significant at 1%, for the smallest segments only, indicating that as firms increase their levels of vertical integration, the investment-cash flow sensitivities of the smallest segments drop further, when they face superior investment opportunities. Similar results are obtained using three-year changes, and the coefficient on the triple interaction term τ_7 is negative and significant at 5% for the smallest segments. This evidence is consistent with the results reported in Table 7. The results of model (38) are reported in Table 11. Using both two- and three-year changes, the coefficients ω_1 are positive and significant at least at 5% level. This suggests that bigger changes in the degree of vertical integration leads to bigger changes in CAPX deviation in the same direction. This is consistent with the positive relation between $VIC_{i,t}$ and $CAPX\_Dev_{i,t}$ reported in Table 8. Overall, the change regressions provide further evidence that ICM efficiency increases with *VIC*, and the results are unlikely to be driven by time-invariant unobserved variables.

7.3 Subsample Tests and Alternative Measure of Vertical Integration

Our measure of vertical integration, reflects the strongest inter-divisional vertical link within a firm and minimizes the noise caused by non-vertical inter-divisional links. This implies that this measure should best describe the level of vertical integration for firms with relatively fewer divisions, and thus lower potential noise from complex inter-divisional relations. We find that 50% of the sample consists of firms with three or fewer divisions. In untabulated tests, we repeat our analyses using firms with three or fewer divisions, and find similar results. For the innovative efficiency test, we find that, holding $R\&D_{i,t}$ at the mean, one standard deviation increase in $VIC_{i,t}$ increases patent production by 32.54%. The result is significant at 1% level. For the investment-cash flow sensitivity test, while having the best investment opportunity within the firm reduces the cash flow sensitivity of the smallest segment's investment, we find that, holding $Cash\ Flow_{i,t}$ at the sample mean, a one standard deviation increase in $VIC_{i,t}$ strengthens the effects of a good investment opportunity by 1.08 times. The result remains significant at 10% level. For the CAPX deviation test, comparing to a mean $CAPX\_Dev_{i,t}$ of -0.0667, one standard deviation increase in $VIC_{i,t}$ leads to an improvement in $CAPX\_Dev_{i,t}$ by approximately 4.75%, although the t-statistics of this result is 1.60. Overall, the results remain unchanged the subsample of firms with three or fewer divisions.

We also conduct our analyses using a weighted average vertical integration coefficient, $wVIC_{i,t}$, which is calculated as the weighted average of bilateral vertical links between all divisions in the firm, using division sales as the weights. In untabulated tests, we obtain qualitatively similar results. For the innovative efficiency test, holding $R\&D_{i,t}$ at the mean, a one standard deviation increase in $wVIC_{i,t}$ increases patent production by 50.86%. This result is significant at 5% level. For our investment-cash flow sensitivity test, while having the best investment opportunity within the firm reduces the investment-cash flow sensitivity of the smallest segment, we also find that, holding $Cash\ Flow_{i,t}$ at the sample mean, a one standard deviation increase in $wVIC_{i,t}$ enhances ICM efficiency by 82.60%. The result remains significant at 10% level. Lastly, for the CAPX deviation test, comparing to a mean $CPAX\_Dev_{i,t}$ of -0.0753, a one standard deviation increase in $wVIC_{i,t}$ increases $CAPX\_Dev_{i,t}$ by 5.48%. This result is significant at 1% level. Overall, the weighted average measure of vertical integration yields consistent results.

8. Conclusion

The role of internal capital markets in corporate resource allocation has ignited vigorous academic discussion. Due to "internal competition" at the division level, multi-division firms face a two-tiered agency problem which cannot be effectively targeted at using traditional monitoring and incentive governance techniques. As a result, ICM persistently causes misallocation of scarce corporate resources. In our study, however, we argue that not all types of diversification are equally prone to the ICM inefficiency problem. In particular, ICM inefficiency problem is mitigated in vertical integration, which generates a spillover effect through inter-divisional transactions. By allowing one division's production to benefit from other divisions' investments, the spillover effect reduces "internal competition", and aligns the interests of division managers with that of the firm, in which case, performance-based compensation can achieve the purpose of encouraging value-maximizing investment for the firm, as opposed to individual divisions. In addition, better alignment of interests reduces the tendency of information manipulation at the division level, which eases the monitoring efforts of CEO and headquarters. Essentially, the spillover effect in vertical integration serves as a self-governing mechanism that leads to more efficient resource allocation. We develop a model to prove our argument. Our model demonstrates that the inter-divisional spillover effect creates a positive interdependence in the divisions' production, and causes the optimums of the agents converge with the optimum of the firm, which reduces the managers' needs to influence the capital allocation process, and thus facilitates an efficient equilibrium outcome. The larger the spillover effect, the closer the allocation outcome is to the optimal.

Empirically, we test the prediction of our model through the relation between the degree of vertical integration and three measures of ICM efficiency. Our results show that a higher degree of vertical integration is associated with higher innovative efficiency, lower investment-cash flow sensitivity, and more efficient CAPX deviation, all of which suggest a more efficient ICM under vertical integration. While existing theories have identified various mechanisms that can cause the ICM inefficiencies, such as influence cost, rent-seeking and power-grabbing, in some aspect, all these mechanisms originate from the same fact, that the firm and its agents have different objectives. Therefore, by aligning the interests of different parties, the spillover effect addresses the various causes of ICM inefficiency identified by existing theories.. More importantly, our paper is the first to investigate the unexplored effects of diversification strategy on corporate resource allocation. In doing so, we offer insights on the self-governing properties of vertical integration that improves capital allocation in diversified firms.

Appendix: **Related Models**

A.1 Efficient ICM: Stein (1997)

In this section, we relate our model to existing theories in the literature. In support of the ICM, Stein (1997) models how the "winner picking" function of corporate headquarters provides a partial solution to the overinvestment problem that occurs when all investments are financed as stand-alone projects. "Winner picking" only requires that the CEO's judgement errors on the qualities of all investment projects are correlated, and it justifies a focused diversification strategy, because higher degrees of focus lead to more correlated projection errors, in which case, the CEO's ranking orders of the investment opportunities are likely to be correct. Stein (1997) provides an example of focused diversification where all the divisions in the firm belong to the same industry. Because divisions in the same industry are more likely to face similar investment opportunities and prospects, the CEO is more likely to mis-evaluate all investment opportunities to the same extent, and thus effectively perform "winner picking".

Diversifying within industry is not the only way to mitigate allocation inefficiencies in a multi-divisional firm. Without contradicting Stein (1997), our model proposes another solution that applies to a broader scope of firms. Essentially, the spillover effect partially links the productions of different divisions. As a result, managers adjust their equilibrium influence levels according to both the relative productivity, and the influence exerted by their counterparts. As the size of the spillover increases, the managers are more likely to exert excess influence in proportion to the two divisions' productivities, leading to a higher correlation in the CEO's estimation errors. Most importantly, the spillover effect can be created through internal transaction, and thus does not require the divisions to belong to the same industry.

A.2 Inefficient ICM: The Rent-seeking Models

The literature also offers theories in support of ICM inefficiencies. Among inefficient ICM theories, our model is first closely related to the two rent-seeking models of Meyer et al. (1992), and Scharfstein and Stein (2000), in that inefficient capital allocation starts with division managers' manipulation of the capital distribution process. Rent-seeking generates private benefits for the managers in different ways. In Meyer et al. (1992), managers exert influence effort to increase their job security, whereas in Scharfstein and Stein (2000), rent-seeking helps to increase the managers' bargaining power with the CEO, and thus increases their compensation. Relating to both theories, by aligning the objectives of the managers and the firm, the spillover effect reduces the managers' incentives of engaging in any form of rent-seeking.

Comparing to the influence cost model in Meyer et al. (1992), our model factors in an additional layer of conflict of interest. Specifically, Meyer et al. (1992) only focus on the conflict between the divisions and corporate headquarters, but does not model the competition between the divisions. In contrast, in our model, absent any spillover, all three internal agents have different objectives.

In Scharfstein and Stein (2000), one manager's rent-seeking may depend on the rent-seeking strategy of the other manager, and inefficiencies are most likely to occur when a weak division is paired with a strong division. It implies that the more diverse the prospects of the divisions are, the more likely it is for the ICM to be inefficient. In some respect, the spillover effect also addresses the problem of diverse investment states by creating a positive correlation between the productions of different divisions. Larger the spillover effect leads to the smaller the gap between the divisions' production outcomes, which essentially reduces the diversity of production prospects.

A.3 Inefficient ICM: The Power-grabbling Model

Rajan et al. (2000) offer a different explanation of the investment distortion within ICM. Instead of focusing on the inefficiencies in the *ex ante* distribution of investment capital, they examine the *ex post* sharing of investment surplus among the divisions. Specifically, both divisions make investments with their initial endowments of capital, and the investment surplus is redistributed between divisions through negotiation. In their setting, each division faces an efficient project and a defensive project. The efficient project offers higher return, but is more prone to poaching by the other division, whereas the defensive project yields a lower return, but provides better protection to the division itself. Rajan et al. (2000) show that as the difference in the products of productivity and initial capital increases, the divisions become more likely to choose the defensive project over the efficient one. This situation is labeled as the "power grabbing" problem. In this section, we incorporate the *ex post* sharing of investment surplus in our model, and show that the spillover effect also provides a solution to division managers' "power grabbing".

For simplicity, assume initial capital allocation is optimal, thus $C_{i,t} = C^*_{i,t}$ and $C_{j,t} = C^*_{j,t}$. Following the setting in Rajan et al. (2000), suppose the defensive project lowers the productivity by x, so, for example, by making the defensive investment, division *i*'s production outputs become $(\theta_{i,t} - x)k(C^*_{i,t})$. If both divisions choose the efficient projects, production outputs are split equally between them. If, suppose division i, chooses the efficient investment and division *j* does not, *j* will have the opportunity to grab division *i*'s surplus. Division *i* can defend itself, but at a greater cost than if a defensive project had been chosen. Specifically, if division *j* poaches, the production outputs of division *i* are given by $(\theta_{i,t} - y)k(C^*_{i,t})$, where $y > x$. On the other hand, the surplus that division *j* grabs from division *i* is almost fully matched by the cost of poaching, therefore, its production outputs are given by $(\theta_{j,t} - x)k(C^*_{j,t}) + v$, where v is a very small number. To sum up, the payoff of division *i* under different investment scenarios are shown in the following table.

Payoff of Division i- without spillover

		Division *j*'s investment	
		Efficient	Defensive
Division *i*'s investment	Efficient	$\frac{1}{2}[\theta_{i,t}k(C^*_{i,t}) + \theta_{j,t}k(C^*_{j,t})]$	$(\theta_{i,t} - y)k(C^*_{i,t})$
	Defensive	$(\theta_{i,t} - x)k(C^*_{i,t}) + v$	$(\theta_{i,t} - x)k(C^*_{i,t})$

Given the payoffs shown above, the conditions for manager *i* to choose the efficient investment are that manager *j* is expected to do the same, and

$$\frac{1}{2}[\theta_{i,t}k(C^*_{i,t}) + \theta_{j,t}k(C^*_{j,t})] \geq (\theta_{i,t} - x)k(C^*_{i,t}) \tag{39}$$

Manager *j* also requires similar conditions in order to choose the efficient project, therefore, the condition for both divisions to make the efficient investments is:

$$\frac{1}{2}[\theta_{i,t}k(C^*_{i,t}) + \theta_{j,t}k(C^*_{j,t})] \geq \max[(\theta_{i,t} - x)k(C^*_{i,t}), (\theta_{j,t} - x)k(C^*_{j,t})] \tag{40}$$

For simplicity, define $z_{i,t} = \theta_{i,t} - x$, and suppose, without loss of generality, that $z_{i,t}k(C^*_{i,t}) > z_{j,t}k(C^*_{j,t})$. Simplifying (40) gives:

$$x[k(C^*_{i,t}) + k(C^*_{j,t})] \geq z_{i,t}k(C^*_{i,t}) - z_{j,t}k(C^*_{j,t}) \tag{41}$$

For any period *t*, optimal capital allocation is fixed, resulting in a fixed level of the left-hand side of (41). Therefore, the inequality in (41) implies that, in order for the efficient investments to be made in both divisions, the difference between the products of division productivity and the initial investment capital cannot be too large. Rajan et al. (2000) interpret this as the inefficiencies caused by the diversity in resources and opportunities.

Now, we incorporate the spillover effect in the analysis. In presence of a spillover effect, suppose that, if division *j* pursues the efficient project, it generates a spillover gain for division *i* that equals a fraction, α, of division *j*'s outputs. At the same time, when the defensive project is chosen, no spillover will be generated. Thus, the payoff of division *i*, when both "power grabbing" and spillover are present, are given in the following table.

Payoff of Division i- with spillover

		Division j's investment	
		Efficient	Defensive
Division i's investment	Efficient	$\frac{1}{2}(1+\alpha)[\theta_{i,t}k(C_{i,t}^{*})+\theta_{j,t}k(C_{j,t}^{*})]$	$(\theta_{i,t}-y)k(C_{i,t}^{*})$
	Defensive	$(\theta_{i,t}-x)k(C_{i,t}^{*})+\alpha\theta_{j,t}k(C_{j,t}^{*})+v$	$(\theta_{i,t}-x)k(C_{i,t}^{*})$

Now, the conditions for manager i to make the efficient investment are that manager j makes the efficient investment, and

$$\frac{1}{2}(1+\alpha)\left[\theta_{i,t}k(C_{i,t}^{*})+\theta_{j,t}k(C_{j,t}^{*})\right] \geq (\theta_{i,t}-x)k(C_{i,t}^{*})+\alpha\theta_{j,t}k(C_{j,t}^{*}) \quad (42)$$

Simplifying (42) gives:

$$(1-\alpha)[\theta_{i,t}k(C_{i,t}^{*})-\theta_{j,t}k(C_{j,t}^{*})] \leq 2xk(C_{i,t}^{*}) \quad (43)$$

Similarly, the conditions that apply to manager j are manager i chooses the efficient investment, and

$$(1-\alpha)[\theta_{j,t}k(C_{j,t}^{*})-\theta_{i,t}k(C_{i,t}^{*})] \leq 2xk(C_{j,t}^{*}) \quad (44)$$

In words, for both managers to make the efficient investments, conditions (43) and (44) must be satisfied. Again, without losing generality, assume $\theta_{i,t}k(C_{i,t}^{*}) > \theta_{j,t}k(C_{j,t}^{*})$, so condition (44) is always satisfied. Given fixed levels of $\theta_{i,t}k(C_{i,t}^{*})-\theta_{j,t}k(C_{j,t}^{*}), x$ and $k(C_{i,t}^{*})$, the larger α is, the more likely it is for condition (43) to be satisfied. Therefore, even with the possibility of inter-divisional "power grabbing", the spillover effect can improve the efficiency of the ICM.

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Figure 1 Timeline of the Capital Allocation Process

Manager i observes productivity $\theta_{i,t}$, decides the level of influence $I_{i,t}$, and sends the CEO signal $S_{i,t}$.

↓

CEO receives signal $S_{i,t}$, forms estimations of influence $\widehat{I_{i,t}}$ and productivity$\widehat{\theta_{i,t}}$, and allocates capital $C_{i,t}$ to division i.

↓

Production occurs, $\theta_{i,t}$ realized, $\widehat{I_{i,t}}$ observed.

↓

CEO adjusts estimation of influence in period $t+1$, $\widehat{I_{i,t+1}}$.

Table 1 Summary Statistics

This table reports the summary statistics of the key variables for innovation sample (Panel A), the cash flow sample (Panel B), and CAPX sample (Panel C). $VIC_{i,t}$ is calculated using the BEA Benchmark Use Tables of the years 1982, 1987, 1992, 1997, 2002 and 2007; $VIC_{i,t}$ greater than 3 is set 3 to avoid extreme outliers; $R\&D_{i,t}$, is calculated as R&D expenditure divided by the total assets of firm *i* in year *t* (We replace missing R&D expenditure with zero)*;* $Patent_{i,t}$ is calculated as the number of patents filed by firm *i* in year *t* that were later granted, divided by the mean number of patents in the industry to which firm *i* belongs in year *t;* $LogAT_{i,t}$, is calculated as the natural log of firm *i*'s total assets in year *t*; $Profitability_{i,t}$ is calculated as the ratio *EBITDA* to total assets of firm *i* in year *t*; $Leverage_{i,t}$ is calculated as the sum of long-term debt and debt in current liabilities divided by the total assets of firm *i* in year *t*; $Market\text{-}to\text{-}Book_{i,t}$ is calculated as the ratio of the market value of equity to the book value of equity of firm *i* in year *t*; $Cash_{i,t}$ is calculated as cash divided by the total assets of firm *i* in year *t*; $Capx_{i,t}$ is calculated as capital expenditure divided by the total assets of firm *i* in year *t*; and $HHI_{i,t}$ is the 2-digit SIC industry level Herfindahl index of firm *i* in year *t*; $Investment_{i,j,t}$, is calculated as the capital expenditure of division *j* of firm *i* in year *t* divided by the total assets of firm *i* in year *t*-1; $Sales\ Growth_{i,j,t}$ is calculated as the sales growth of division *j* of firm *i* from year *t*-2 to year *t*-1; $Cash\ Flow_{i,j,t}$, is calculated as the sum of operating profit and depreciation and amortization of division *j* of firm *i* in year *t* divided by the total assets of firm *i* in year *t*-1; *Tobin's* $Q_{i,j,t}$, Tobin's Q of division *j* of firm *i* in year *t*, is calculated as the median Q of single-division firms in segment *j*'s 2-digit SIC industry in year *t*, where Q is calculated as the ratio of the book value of assets minus the book value of equity plus the market value of equity to the book value of assets; $CAPX\_Dev_{i,t}$ is CAPX deviation, and is calculated as specified in Section 3.2.3; $LogMV_{i,t}$ is calculated as the natural log of the market value of equity of firm *i* in year *t*; $CF_{i,t}$ is firm-level cash flow, calculated as operating cash flows divided by beginning-of-period total assets of firm *i* in year *t*; $Tangibility_{i,t}$ is calculated as net PPT scaled by total assets of firm *i* in year *t*; $Extfin_{i,t}$ measures external financing, and is calculated as net external financing scaled by capital expenditures of firm *i* in year *t*., where net external financing is calculated as (sale of common stock and preferred stocks + long-term debt issuance)-(purchase of common stocks and preferred stocks + long-term debt reduction) + changes in current debt – dividend. $Dividend_{i,t}$ is a dummy variable that takes the value of one if a firm *i* pays positive dividend on common stocks in year *t*, zero otherwise. $NumSeg_{i,t}$ is the number of segment in firm *i* in year *t. NumInd*$_{i,t}$ is the number of unique 2-digit SIC industries that all the segments of firm *i* belong to in year *t*.

Panel A: Innovation Sample						
Variables	N	Mean	Median	25%	75%	Standard Deviation
$VIC_{i,t}$	21,043	0.1438	0.0245	0.0039	0.1052	0.3637
$R\&D_{i,t}$	21,043	0.0220	0.0000	0.0000	0.0243	0.0478
$Patent_{i,t}$	21,043	0.4268	0.0000	0.0000	0.0994	1.1900
$LogAT_{i,t}$	21,043	6.0997	6.1571	4.2802	7.9459	2.4040
$Profitability_{i,t}$	21,043	0.1024	0.1197	0.0708	0.1658	0.1348
$Leverage_{i,t}$	21,043	0.2642	0.2574	0.1357	0.3727	0.1693
$Market\text{-}to\text{-}Book_{i,t}$	21,043	2.6457	1.6652	1.0781	2.7181	3.9155
$Cash_{i,t}$	21,043	0.0659	0.0289	0.0111	0.0778	0.0972
$Capx_{i,t}$	21,043	0.0654	0.0512	0.0291	0.0835	0.0573
$HHI_{i,t}$	21,043	0.0760	0.0528	0.0351	0.0763	0.0797

Panel B: Cash Flow Sample						
	N	Mean	Median	25%	75%	Standard Deviation
Firm Level Variables						
$VIC_{i,t}$	17,583	0.1446	0.0189	0.0022	0.0856	0.3942
$LogAt_{i,t}$	17,583	5.7280	5.8014	4.0250	7.5580	2.4450
Segment Level Variables						
$Investment_{i,j,t}$	46,760	0.0228	0.0107	0.0036	0.0273	0.0329
$Sales\ Growth_{i,j,t}$	46,760	0.0708	0.0626	-0.0432	0.1792	0.2417
$Cash\ Flow_{i,j,t}$	46,760	0.0496	0.0317	0.0097	0.0748	0.0631
$Tobin's\ Q_{i,j,t}$	46,760	1.5018	1.3692	1.1678	1.6983	0.4919

Panel C: CAPX Sample						
	N	Mean	Median	25%	75%	Standard Deviation
$VIC_{i,t}$	26,240	0.1401	0.0226	0.0033	0.0998	0.3622
$CAPX\_Dev_{i,t}$	26,240	-0.0753	-0.0201	-0.1555	0.0546	0.2461
$LogMV_{i,t}$	26,240	1.2466	1.6509	1.0362	1.9858	1.0834
$Market\text{-}to\text{-}Book_{i,t}$	26,240	2.1289	1.4427	0.7893	2.3889	2.7188
$CF_{i,t}$	26,240	-0.1138	0.0203	-0.4306	0.0919	0.2513
$Capx_{i,t}$	26,240	0.2021	0.1735	0.1048	0.2580	0.1478
$R\&D_{i,t}$	26,240	0.0194	0.0000	0.0000	0.0222	0.0376
$Tangibility_{i,t}$	26,240	0.3528	0.3092	0.1770	0.5151	0.2267
$Extfin_{i,t}$	26,240	-0.0088	0.0000	0.0000	0.0000	0.2558
$Cash_{i,t}$	26,240	0.0564	0.0224	0.0064	0.0664	0.0866
$Leverage_{i,t}$	26,240	0.2709	0.2628	0.1426	0.3797	0.1714
$Dividend_{i,t}$	26,240	0.5700	1.0000	0.0000	1.0000	0.4951
$NumSeg_{i,t}$	26,240	3.6332	3.0000	2.0000	4.0000	1.7197
$NumInd_{i,t}$	26,240	2.3760	2.0000	2.0000	3.0000	1.1635
$HHI_{i,t}$	26,240	0.0768	0.0528	0.0349	0.0777	0.0811

Table 2 Pearson Correlation Matrix

This table reports the Pearson correlations between the key variables for the innovation sample (Panel A) and the cash flow sample (Panel B), and CAPX sample (Panel C). All variables are defined in Table 1. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Panel A: Innovation Sample

	$VIC_{i,t}$	$R\&D_{i,t}$	$Patent_{,t}$	$LogAT_{i,t}$	$Profitability_{I,t}$	$Leverage_{i,t}$	$Market\text{-}to\text{-}Book_{i,t}$	$Cash_{i,t}$	$Capx_{i,t}$	$HHI_{I,t}$
$VIC_{i,t}$	1									
$R\&D_{i,t}$	-0.0472***	1								
$Patent_{,t}$	-0.0041	0.1510***	1							
$LogAT_{i,t}$	0.0187***	-0.1080***	0.3966***	1						
$Profitability_{i,t}$	0.0184***	-0.3440***	0.1140***	0.3285***	1					
$Leverage_{i,t}$	0.0205***	-0.2427***	-0.0577***	0.1409***	0.0207***	1				
$Market\text{-}to\text{-}Book_{i,t}$	-0.0037	0.2056***	0.0333***	-0.0753***	-0.1611***	0.0238***	1			
$Cash_{i,t}$	-0.0120*	0.3209***	-0.0366***	-0.2031***	-0.2311***	-0.3156***	0.1504***	1		
$Capx_{i,t}$	0.0241***	-0.0655***	0.0099	0.0408***	0.1394***	0.0592***	0.0135**	-0.1128***	1	
$HHI_{i,t}$	0.0387***	-0.0969***	-0.0804***	-0.1227***	-0.0198***	-0.0052	-0.0292***	0.0203***	-0.0255***	1

Panel B: Cash Flow Sample

	$VIC_{i,t}$	$Investment_{i,j,t}$	$Sales\ Growth_{i,j,t}$	$Cash\ Flow_{i,j,t}$	$Tobin's\ Q_{i,j,t}$
$VIC_{i,t}$	1				
$Investment_{i,j,,t}$	-0.0224***	1			
$Sales\ Growth_{i,j,t}$	0.0149***	0.1413***	1		
$Cash\ Flow_{i,j,t}$	-0.0230***	0.5315***	0.1672***	1	
$Tobin's\ Q_{i,j,t}$	-0.0501***	-0.0135***	0.0239***	0.0211***	1

Table 2 Pearson Correlation Matrix (continued)

Panel C: CAPX Sample

	$VIC_{i,t}$	$CAPX\_Dev_{i,t}$	$LogMV_{i,t}$	$Market\text{-}to\text{-}Book_{i,t}$	$CF_{i,t}$	$Capx_{i,t}$	$R\&D_{i,t}$	$Tangibility_{i,t}$	$Extfin_{i,t}$	$Cash_{i,t}$	$Leverage_{i,t}$	$Dividend_{i,t}$	$NumSeg_{i,t}$	$NumInd_{i,t}$	$HHI_{i,t}$
$VIC_{i,t}$	1														
$CAPX\_Dev_{i,t}$	0.0283***	1													
$LogMV_{i,t}$	0.0134**	0.0558***	1												
$Market\text{-}to\text{-}Book_{i,t}$	-0.0009	-0.0427***	0.2984***	1											
$CF_{i,t}$	0.0064	-0.0764***	0.2868***	0.1373***	1										
$Capx_{i,t}$	0.0086	-0.0564***	0.0622***	0.1730***	-0.0118*	1									
$R\&D_{i,t}$	-0.0486***	-0.1228***	0.0109*	0.1927***	-0.0206***	0.2031***	1								
$Tangibility_{i,t}$	0.0126**	0.1059***	0.1482***	-0.0925***	0.0940***	-0.2178***	-0.2765***	1							
$Extfin_{i,t}$	-0.0059	-0.0035	0.0155**	0.0152**	-0.0165***	0.0418***	0.0178***	-0.0688***	1						
$Cash_{i,t}$	-0.0038	-0.1515***	-0.0601***	0.1534***	0.1746***	0.2008***	0.3070***	-0.2916***	0.0221***	1					
$Leverage_{i,t}$	0.0109*	0.0432***	-0.0521***	0.0000	0.0109*	-0.1672***	-0.2628***	0.2336***	0.0128**	-0.2996***	1				
$Dividend_{i,t}$	0.0132**	0.1001***	0.4404***	-0.0353***	0.0986***	-0.1051***	-0.1439***	0.2587***	-0.0296***	-0.2329***	-0.0366***	1			
$NumSeg_{i,t}$	0.0563***	-0.0537***	0.1577***	-0.0091	0.0769***	-0.0495***	-0.0263***	-0.0029	0.0377***	-0.0332***	0.0405***	0.1737***	1		
$NumInd_{i,t}$	0.0841***	0.0965***	0.0955***	-0.0737***	-0.1192***	-0.0754***	-0.1743***	0.0610***	0.0349***	-0.1372***	0.0832***	0.1829***	0.5375***	1	
$HHI_{i,t}$	0.0279***	0.0220***	-0.0728***	-0.0307***	-0.0650***	0.0353***	-0.1050***	-0.0882***	0.0301***	0.0135**	0.0019	-0.0858***	-0.0141**	0.1195***	1

Table 3 Univariate Analysis

This table reports the T-tests of the difference in the key variables between the highest *VIC* quartile and the lowest *VIC* quartile for innovation sample (Panel A) and the cash flow sample (Panel B), and CAPX sample (Panel C). All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Panel A: Innovation Sample						
Variables	*VIC Q1*	*VIC Q2*	*VIC Q3*	*VIC Q4*	*Difference (Q4-Q1)*	*T-Statistics*
$VIC_{i,t}$	0.0018	0.0143	0.0613	0.4974	0.4956***	(59.99)
$R\&D_{i,t}$	0.0205	0.0220	0.0238	0.0215	0.0010	(1.08)
$Patent_{i,t}$	0.3451	0.4124	0.5081	0.4405	0.0953***	(4.29)
$LogAT_{i,t}$	5.5874	6.0016	6.3396	6.4663	0.8789***	(18.69)
$Profitability_{i,t}$	0.0936	0.1036	0.1047	0.1077	0.0141***	(5.13)
$Leverage_{i,t}$	0.2662	0.2592	0.2666	0.2646	-0.0016	(-0.49)
$Market\text{-}to\text{-}Book_{i,t}$	2.6664	2.6849	2.5262	2.7065	0.0401	(0.51)
$Cash_{i,t}$	0.0668	0.0679	0.0635	0.0653	-0.0015	(-0.78)
$Capx_{i,t}$	0.0622	0.0631	0.0678	0.0685	0.0064***	(5.74)
$HHI_{i,t}$	0.0738	0.0771	0.0782	0.0748	0.0010	(0.65)
Panel B: Cash Flow Sample						
Variables	*VIC Q1*	*VIC Q2*	*VIC Q3*	*VIC Q4*	*Difference (Q4-Q1)*	*T-Statistics*
Firm Level Variables						
$VIC_{i,t}$	0.0016	0.0146	0.0608	0.5479	0.5464***	(51.50)
$LogAt_{i,t}$	5.4215	6.0042	6.1170	6.3818	0.9602***	(19.06)
Segment Level Variables						
$Investment_{i,j,t}$	0.0260	0.0225	0.0215	0.0212	-0.0047***	(-10.93)
$Sales\ Growth_{i,j,t}$	0.0660	0.0740	0.0680	0.0752	0.0092***	(2.90)
$Cash\ Flow_{i,j,t}$	0.0592	0.0485	0.0449	0.0459	-0.0133***	(-15.51)
$Tobin's\ Q_{i,j,t}$	1.5023	1.5014	1.4925	1.5108	0.0085	(1.31)
Panel C: CAPX Sample						
Variables	*VIC Q1*	*VIC Q2*	*VIC Q3*	*VIC Q4*	*Difference (Q4-Q1)*	*T-Statistics*
$VIC_{i,t}$	0.0016	0.0136	0.0585	0.4855	0.4840***	(65.28)
$CAPX\_Dev_{i,t}$	-0.0675	-0.0812	-0.0809	-0.0714	-0.0039	(-0.90)
$LogMV_{i,t}$	1.1324	1.2319	1.2881	1.3332	0.2008***	(10.66)
$Market\text{-}to\text{-}Book_{i,t}$	2.1121	2.1507	2.0723	2.1802	0.0676	(1.40)
$CF_{i,t}$	-0.1184	-0.1133	-0.1168	-0.1068	0.0115***	(2.63)
$Capx_{i,t}$	0.2005	0.2052	0.2007	0.2020	0.0015	(0.58)
$R\&D_{i,t}$	0.0185	0.0196	0.0205	0.0189	0.0004	(0.55)
$Tangibility_{i,t}$	0.3365	0.3450	0.3574	0.3721	0.0355***	(8.98)
$Extfin_{i,t}$	-0.0034	-0.0022	-0.0125	-0.0171	-0.0137***	(-3.11)
$Cash_{i,t}$	0.0573	0.0590	0.0534	0.0557	-0.0016	(-1.06)
$Leverage_{i,t}$	0.2738	0.2665	0.2733	0.2700	-0.0038	(-1.26)
$Dividend_{i,t}$	0.5239	0.5631	0.5929	0.5999	0.0760***	(8.80)
$NumSeg_{i,t}$	2.9847	3.6742	3.9342	3.9358	0.9511***	(34.85)
$NumInd_{i,t}$	2.1242	2.4590	2.4812	2.4389	0.3147***	(17.01)
$HHI_{i,t}$	0.0751	0.0792	0.0784	0.0759	-0.0005	(-0.35)

Table 4 *VIC* and ICM Efficiency: Innovative Efficiency I

This table reports the regression results of models (31) and (32) using the innovation sample. The dependent variables are $R\&D_{i,t}$, and $Patent_{i,t}$. All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

	Dependent Variable	
Independent Variables	$R\&D_{i,t}$	$Patent_{i,t}$
$VIC_{i,t}$	-0.0019***	0.0462**
	(-2.59)	(2.45)
$LogAT_{i,t}$	0.0022***	0.2467***
	(15.09)	(66.29)
$Profitability_{i,t}$	-0.1015***	-0.0845
	(-47.87)	(-1.46)
$Leverage_{i,t}$	-0.0316***	-0.5236***
	(-18.67)	(-11.84)
$Market\text{-}to\text{-}Book_{i,t}$	0.0012***	0.0172***
	(17.58)	(9.82)
$Cash_{i,t}$	0.0569***	-0.1118***
	(18.99)	(-1.43)
$Capx_{i,t}$	0.0553***	0.3943***
	(11.33)	(3.11)
$HHI_{i,t}$	-0.0151	0.3884
	(-0.78)	(0.78)
$HHI_{i,t}^2$	0.0476	-0.4046
	(1.18)	(-0.39)
$R\&D_{i,t}$		2.222***
		(12.32)
Industry Fixed Effects	Yes	Yes
Year Dummies	Yes	Yes
N	21,043	21,043
R-squared	0.4687	0.4240

Table 5 *VIC* and ICM Efficiency: Innovative Efficiency II

This table reports the regression results of model (33) using the innovation sample. The dependent variable is $Patent_{i,t}$. All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Independent Variables	*Patent*
$VIC_{i,t}$	0.0206
	(1.03)
$R\&D_{i,t}$	1.9606***
	(10.19)
$R\&D_{i,t} * VIC_{i,t}$	2.5157***
	(3.90)
$LogAT_{i,t}$	0.2465***
	(66.25)
$Profitability_{i,t}$	-0.0807
	(-1.39)
$Leverage_{i,t}$	-0.5226***
	(-11.82)
$Market\text{-}to\text{-}Book_{i,t}$	0.0171***
	(9.77)
$Cash_{i,t}$	-0.1097
	(-1.40)
$Capx_{i,t}$	0.3947***
	(3.11)
$HHI_{i,t}$	0.3482
	(0.70)
$HHI_{i,t}^2$	-0.3306
	(-0.32)
Industry Fixed Effects	Yes
Year Dummies	Yes
N	21,043
R-squared	0.4244

Table 6 *VIC* and ICM Efficiency: Investment-Cash Flow Sensitivity I

This table reports the regression results of model (34) for the smallest and largest segments in the cash flow sample. The dependent variable is $Investment_{i,j,t}$. All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

	Smallest Segment		*Largest Segment*	
Independent Variables	*VIC Q1*	*VIC Q4*	*VIC Q1*	*VIC Q4*
Sales Growth$_{i,j,t}$	0.0024**	-0.0001	0.0099***	0.0131***
	(2.26)	(-0.15)	(3.32)	(4.26)
Cash Flow$_{i,j,t}$	0.1035***	0.0931***	0.0970***	0.1540***
	(8.76)	(6.63)	(7.49)	(10.15)
Cash Flow_Other$_{i,j,t}$	0.0118**	0.0103**	0.0578***	0.0530***
	(2.52)	(2.55)	(3.27)	(2.82)
Tobin's Q$_{i,j,t}$	0.0004	-0.0008	0.0030	-0.0013
	(0.37)	(-0.91)	(1.24)	(-0.54)
High Q$_{i,j,t}$ * *Cash Flow*$_{i,j,t}$	-0.0281**	-0.0419**	-0.0013	-0.0191
	(-2.16)	(-2.54)	(-0.10)	(-1.24)
High Q$_{i,j,t}$ * *Cash Flow_Other*$_{i,j,t}$	0.0059	0.0039	0.0549**	0.0510**
	(1.18)	(0.94)	(2.51)	(2.30)
Highest Q_Other$_{i,j,t}$	0.0006	0.0007*	0.0001	0.0002*
	(0.79)	(1.95)	(0.56)	(1.69)
Segment Fixed Effects	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
N	3,860	2,797	4,439	3,321
R-Squared	0.7262	0.8569	0.7287	0.7862

Table 7 *VIC* and ICM Efficiency: Investment-Cash Flow Sensitivity II

This table reports the regression results of model (35) for the smallest and largest segments in the cash flow sample. The dependent variable is $Investment_{i,j,t}$. All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Independent Variables	*Smallest Segment*	*Largest Segment*
$Sales\ Growth_{i,j,t}$	0.0013**	0.0099***
	(2.41)	(6.99)
$Cash\ Flow_{i,j,t}$	0.1028***	0.1283***
	(15.85)	(19.60)
$Cash\ Flow\_Other_{i,j,t}$	0.0168***	0.0524***
	(7.17)	(6.31)
$Tobin's\ Q_{i,j,t}$	0.0005	0.0033***
	(0.97)	(3.03)
$VIC_{i,t}$	0.0001	0.0002
	(0.20)	(0.17)
$High\ Q_{i,j,t}$ * $Cash\ Flow_{i,j,t}$	-0.0086	0.0003
	(-1.13)	(0.05)
$VIC_{i,j,t}$ * $High\ Q_{i,j,t}$ * $Cash\ Flow_{i,j,t}$	-0.0352**	-0.0026
	(-2.38)	(-0.19)
$Hight\ Q_{i,j,t\_}$ * $Cash\ Flow\_{}_{i,other,t}$	0.0014	0.0192*
	(0.55)	(1.86)
$VIC_{i,j,t}$ * $Hight\ Q_{i,j,t\_}$ * $Cash\ Flow\_{}_{i,other,t}$	0.0006	-0.0272
	(0.15)	(-1.37)
$Tobin's\ Q_{i,other,t}$	0.0004	0.0001
	(1.58)	(1.08)
Segment Fixed Effects	Yes	Yes
Year Dummies	Yes	Yes
N	12,672	14,827
R-Squared	0.6793	0.7040

Table 8 *VIC* and ICM Efficiency: CAPX Deviation

This table reports the regression results of model (36) using the CAPX sample. The dependent variable is $CAPX\_Dev_{i,t}$. All variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Independent Variables	*Depend Variable:* $CAPX\_Dev_{i,t}$
$VIC_{i,t}$	0.0099**
	(2.35)
$LogMV_{i,t}$	0.0082***
	(4.76)
$Market\text{-}to\text{-}Book_{i,t}$	-0.0005
	(-0.76)
$CF_{i,t}$	0.0366***
	(3.47)
$Capx_{i,t}$	-0.0279***
	(-2.58)
$R\&D_{i,t}$	-0.3470***
	(-7.27)
$Tangibility_{i,t}$	0.0211**
	(2.33)
$Extfin_{i,t}$	0.0067
	(1.17)
$Cash_{i,t}$	-0.1492***
	(-7.47)
$Leverage_{i,t}$	0.0033
	(0.35)
$Dividend_{i,t}$	-0.0008
	(-0.23)
$NumSeg_{i,t}$	-0.0052***
	(-4.31)
$NumInd_{i,t}$	0.0103***
	(5.96)
$HHI_{i,t}$	0.1952***
	(4.49)
Industry Fixed Effects	Yes
Year Dummies	Yes
N	26,240
R-Squared	0.1015

Table 9 Unobserved Selection and Coefficient Stability

This table presents results of the Altonji et al. (2005) tests on unobserved selection and coefficient stability using the STATA module "psacalc" developed by Oster (2017). We present the estimates of δ, bias-adjusted treatment effect assuming δ =1, and the controlled treatment effect (the original regression coeffcients in Tables 5 and 7), for comparison purposes. The first row reports the test results on the effects of *VIC* on the investment-cash flow sensitivity in the smallest segments (Table 5). The second row reports the test results on the effects of *VIC* on innovative efficiency (Column 1 Table 7). The third row reports the test results on the effects of *VIC* on CAPX deviation (Table 8).

	δ for Treatment Effect = 0	*Controlled Treatment Effect*	*Bias-adjusted Treatment Effect for δ = 1*
$R\&D_{i,t} * VIC_{i,t}$	3.1594	2.5157	1.7930
$High\ Q_{i,j,t} * Cash\ Flow_{i,j,t}$	-4.1413	-0.0352	-0.0475
$VIC_{i,t}$	2.2106	0.0099	0.0078

Table 10 *VIC* and Investment –Cash Flow Sensitivity- Change Regression

This table reports the regression results of model (37) for the smallest and largest segments in the cash flow sample. The two-year and three-year changes of the variables are used in the regression. All the variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

	2-year Changes		*3-Year Changes*	
Independent Variables	*Smallest Segment*	*Largest Segment*	*Smallest Segment*	*Largest Segment*
$\Delta Sales\ Growth_{i,j,t}$	0.0014*	0.0065***	0.0012	0.0117***
	(1.93)	(3.61)	(1.34)	(5.39)
$\Delta Cash\ Flow_{i,j,t}$	0.0702***	0.1212***	0.1273***	0.1190***
	(7.69)	(13.55)	(13.03)	(11.90)
$\Delta Cash\ Flow\_Other_{i,j,t}$	0.0149***	0.0473***	0.0206***	0.0755***
	(4.37)	(4.18)	(5.35)	(6.01)
$\Delta Tobin's\ Q_{i,j,t}$	0.0004	0.0007	-0.0005	-0.0009
	(0.49)	(0.49)	(-0.62)	(-0.53)
$\Delta VIC_{i,j,t}$	0.0008	-0.00152	0.0004	-0.0012
	(1.04)	(-1.01)	(0.53)	(-0.76)
$\Delta High\ Q_{i,j,t}$ * $Cash\ Flow_{i,j,t}$	-0.0085	-0.0091	-0.0354***	0.0008
	(-0.81)	(-1.01)	(-3.11)	(0.08)
$\Delta VIC_{i,t}$ * $High\ Q_{i,j,t}$ * $Cash\ Flow_{i,j,t}$	-0.0560***	-0.0092	-0.0401**	0.0054
	(-2.82)	(-0.51)	(-2.01)	(0.25)
$\Delta High\ Q_{i,j,t}$ * $Cash\ Flow\_Other_{i,j,t}$	-0.0013	0.0263**	0.0036	0.0185
	(-0.38)	(1.96)	(0.88)	(1.20)
$\Delta VIC_{i,t}$ * $High\ Q_{i,t}$ * $Cash\ Flow\_Other_{i,j,t}$	-0.0010	-0.0027	0.0020	-0.0404
	(-0.19)	(-0.10)	(0.30)	(-1.20)
$\Delta Highest\ Q\_Other_{i,j,t}$	0.0006	0.0000	0.0005	0.0001
	(1.40)	(0.32)	(1.22)	(0.64)
Segment Fixed Effects	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
N	7,344	9,254	5,663	7,236
R-Squared	0.3526	0.2995	0.4666	0.3454

Table 11 *VIC* and Investment –CAPX deviation- Change Regression

This table reports the regression results of model (38) for the CAPX sample. The two-year and three-year changes of the variables are used in the regression. All the variables are defined in Table 1. T-statistics are reported in parentheses. ***, **, and * denote significance levels at 1%, 5% and 10%, respectively.

Independent Variables	*2-year Changes*	*3-year Changes*
$\Delta VIC_{i,t}$	0.0150***	0.0121**
	(2.92)	(2.36)
$\Delta LogMV_{i,t}$	0.0085***	0.0095***
	(3.16)	(3.42)
$\Delta Market\text{-}to\text{-}Book_{i,t}$	0.0014*	0.0005
	(1.73)	(0.62)
$\Delta CF_{i,t}$	-0.0139	-0.0186
	(-1.12)	(-1.45)
$\Delta Capx_{i,t}$	-0.0103	-0.0177
	(-0.79)	(-1.22)
$\Delta R\&D_{i,t}$	0.2023*	0.1744
	(1.90)	(1.52)
$\Delta Tangibility_{i,t}$	-0.0168	-0.0042
	(-0.88)	(-0.22)
$\Delta Extfin_{i,t}$	-0.0024	0.0003
	(-0.44)	(0.05)
$\Delta Cash_{i,t}$	-0.0626**	-0.0116
	(-2.39)	(-0.41)
$\Delta Leverage_{i,t}$	-0.0487***	-0.0350**
	(-3.10)	(-2.21)
$\Delta Dividend_{i,t}$	0.0007	0.0068
	(0.11)	(1.09)
$\Delta NumSeg_{i,t}$	0.0047***	0.0023
	(2.70)	(1.28)
$\Delta NumInd_{i,t}$	0.0025	0.0045
	(0.81)	(1.51)
$\Delta HHI_{i,t}$	0.1954***	0.1924***
	(3.30)	(3.17)
Industry Fixed Effects	Yes	Yes
Year Dummies	Yes	Yes
N	18,235	15,518
R-Squared	0.0111	0.013