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Capital Structure, Product Market Dynamics, and the Boundaries of the Firm

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We model a new product market opportunity as an option and ask whether it is best exploited by a large incumbent firm (integration) or by a small separate firm (nonintegration). Starting from a standard framework, in which value-maximizing investment and financing decisions are jointly determined, we show that integration protects assets in place value, whereas nonintegration protects option value and maximizes financial flexibility. We show that increases in standard measures of cash flow risk predict exploitation of new opportunities by specialized firms, whereas increases in product market competition (e.g., the risk of competitive preemption) predict exploitation by incumbents. We also show that alliances organized as licensing agreements or revenue-sharing contracts sometimes better balance the sources of value and thus may dominate more traditional forms of organization. These organizational equilibria arise from the dynamic interaction of the new opportunity's option-like features with realistic competitive forces.

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1. Introduction

Financial economists have long understood that the presence of preexisting debt financing can cause managers to make suboptimal investment decisions when they act in the interests of existing shareholders (Fama and Miller 1972, Myers 1977). At the same time, a vast literature in industrial organization and the economics of organizations has explored how firm boundaries are important for determining the success of new product market opportunities.[1] However, it remains an open question how debt financing and its associated investment distortions might affect the optimal placement of firm boundaries with respect to new opportunities.

Consider recent developments in the automotive industry. Most established auto companies use significant debt financing because of their sizeable assets in place, but they must also respond dynamically to changing product market opportunities. Over the past several years, automakers have had to determine whether and how they will respond to the rise in demand for electric vehicles. Should they produce new electric vehicles themselves, help fund start-up firms with separate control rights over electric vehicle production, or form alliances or joint ventures? Currently a wide range of organizational forms is observed, with, for example, major automakers GM and Nissan introducing their own mass-produced electric vehicles aimed at the lower end of the market, stand-alone firms Tesla and Fisker independently developing and marketing higher-end electric luxury and sports cars, and Toyota forming an alliance with Tesla to coproduce electric cars under the Toyota brand name. Furthermore, as is traditionally true with start-up companies, Tesla and Fisker relied almost exclusively on private equity financing in the early stages, in contrast to the significant traditional debt financing used by established firms even when undertaking new product market initiatives.

The main contribution of this paper is to help explain such patterns by analyzing how both capital structure decisions and new product investment decisions respond to different organizational designs in a dynamic product market, and how these responses in turn drive optimal ex ante choices of firm boundaries. We accomplish this by deriving closed-form valuation equations for different organizational designs in

[1] See, for example, Aghion and Tirole (1994), Anton and Yao (1995), Mathews and Robinson (2008), Robinson (2008), Inderst and Mueller (2009), and Fulghieri and Sevilir (2009). This line of research follows in the footsteps of earlier work on the boundaries of the firm in general, such as Coase (1937), Williamson (1973, 1979), Grossman and Hart (1986), and Hart and Moore (1990).

a dynamic model of investment and financing, and then computing optimal financing and investment policies so that we can compare the ex ante values of different designs. This enables us to provide a number of new, testable implications concerning how the optimal design varies with characteristics of both the new product and its market.

In the model, an existing firm operates a set of assets in place, and a related new product market opportunity modeled as an investment option must be optimally organized and financed. Both corporate activities are subject to cash flow risk, which we represent with a standard diffusion process. We compare two competing organizational forms, reflecting the fact that new opportunities can be implemented by an existing firm holding the assets in place (implementation by a large or "integrated" firm) or can be organized as a separate firm controlling the option but without assets in place (implementation by a small "nonintegrated" firm).

An integrated firm optimally takes on debt to finance assets in place due to tax benefits, but, as in past papers with investment distortions, it cannot commit to a firm-value maximizing exercise policy (i.e., as is standard, we assume that at the time debt is issued it is infeasible to contract on option exercise time as a function of the future state). The equity holders thus choose the exercise time ex post to maximize equity value, which results in inefficient delay in new product introduction due to "debt overhang." The existence of this distortion in an integrated firm naturally pushes the new opportunity out of the large firm to minimize the distortion and maximize capital structure flexibility.[2] In other words, choosing a nonintegrated design helps solve the firm's commitment problem by having the ex post exercise policy controlled by a separate firm with no debt overhang. However, several realistic features of dynamic product markets work against this tendency, and hence the optimal organization of new opportunities is determined by balancing the investment and financing benefits of nonintegration against factors that favor keeping the new project inside the large firm.

The first factor is cannibalization. This is a widely recognized potential cost of new product introduction: "Business leaders, academics and venture capitalists say the large companies [...] are ruthless about change. The most successful ones [...] cannibalize their big revenue generators to build new businesses" (Ante 2012). Because the new opportunity is related to the assets in place, exercising the option naturally involves cannibalizing some of the profits associated with the assets in place (cannibalization cost). The large, integrated firm internalizes the cannibalization cost in its decision to exercise the option, but the small, stand-alone firm does not. Thus, the product market externalities associated with having the small firm potentially implement the new opportunity too early in a nonintegrated design work against the investment and financing benefits of integration. As the cannibalization cost increases and the importance of timing exercise later to protect assets in place value grows, this naturally pushes the optimal organizational design toward integration. Indeed, we show that there will be, in general, a critical level of cannibalization above which integration is optimal.

The second factor working against the investment and financing benefits of nonintegration is product market competition. This embodies the idea that the new opportunity can potentially be preempted by competing firms. For example, the first mover in a new product space often enjoys large market share advantages, and a firm waiting to introduce a new product faces the risk that another firm will develop and introduce a competing product first. We assume such preemptive implementation by a competitor makes the option effectively worthless (obsolescence risk). Losing out to a competitor in the new market can also adversely affect the value of assets in place (preemption cost).

The effect of cannibalization is straightforward, but the effects of obsolescence risk and cash flow risk on optimal organizational design are not. An increase in cash flow risk tends to make integration less likely. This is in line with existing conventional wisdom that younger firms tend to be "nimbler" in riskier new markets. However, an increase in competition via obsolescence risk tends to make integration more likely.

Whereas both types of risk would simply reduce the value of a project in a static setting, they have differing effects in our model due to the interaction of the new opportunity's dynamic option-like features and product market forces. In particular, these results are driven by the fact that the two types of risk have opposite effects on both the value and the optimal exercise time for the option. Cash flow risk increases option value and makes it optimal to delay exercise, whereas obsolescence risk decreases option value and speeds up optimal exercise. The opposite value effects (which arise because of the optionality of the new opportunity) lead to opposing effects on optimal organizational design, and these effects are further reinforced by the different effects on optimal timing. Because the value of assets in place is increasing and concave in exercise time, choosing integration becomes increasingly important as exercise occurs earlier, i.e., when cash flow risk is low or obsolescence risk is high. Thus, factors that shift optimal exercise forward in time erode the value of

[2] Capital structure flexibility favors nonintegration because financing decisions reflect actual instead of expected debt capacity. In particular, the integrated firm cannot fully utilize the growth option's *actual* debt capacity, because it selects its capital structure at time zero based on the growth option's *expected* debt capacity, which is significantly lower, especially when obsolescence risk is high.

assets in place in the nonintegrated organizational form as the investment timing differences are magnified. This counterbalances the investment and financing benefits of separation. Because differences in both value effects and optimal exercise timing would be absent in a static setting, the contrasting results are visible only in a dynamic real options model such as ours.

These results imply that the optimal implementation of a new opportunity depends critically on the type of risk reflected in that opportunity. Greater cash flow risk, such as uncertainty about market size, predicts implementation by independent firms, whereas greater obsolescence (competitive) risk predicts implementation by larger, more established firms. Returning to the automotive example, our predictions are borne out in the patterns we observe in that industry. Higher-end electric cars aimed at luxury buyers, which likely have higher cash flow risk (their demand is more sensitive to external macroeconomic factors) but lower obsolescence risk (luxury cars are less "commoditized") are currently more likely to be produced by smaller, more specialized producers such as Tesla and Fisker. Lower-end cars, with relatively lower cash flow risk and higher obsolescence risk, and which are also more likely to cannibalize the companies' existing traditional offerings, are being produced by major integrated firms.

We also explore how optimal organizational design responds to traditional corporate finance variables, such as the corporate tax rate, the magnitude of bankruptcy costs, and the relative size of the growth option. Our analysis shows that nonintegration is more likely the greater is the corporate tax rate or the smaller is the level of bankruptcy costs. As tax rates rise or bankruptcy costs decline, the importance of debt overhang and financial flexibility are magnified. This leads to nonintegration since capital structure decisions can then be made independently. This implies an empirical prediction that new product market opportunities are more likely to be exploited by small, independent firms in physical-capital intensive industries where significant debt financing is optimal, and vice versa in more human-capital intensive industries. We also show that nonintegration is more likely the larger is the relative magnitude of the growth option. When the growth option is larger relative to assets in place, the negative effects of debt overhang and financial inflexibility are magnified, which leads to nonintegration to preserve option value. These results should prove useful for future empirical investigations of the organization of new product market opportunities.

Finally, we study how hybrid organizational forms, such as alliances, perform in our framework. In particular, starting from our nonintegrated case, we investigate the effect of a financial alliance that takes the form of a licensing or revenue-sharing contract, that is, a proportion of cash flows from the new product following exercise accrues to the large firm. Because the small firm still bears the full cost of exercise, this has the effect of causing the small firm to delay exercise closer to the time that is optimal to protect the large firm's value of assets in place. As with the risk comparative statics discussed above, this benefit of the alliance arises from our dynamic model and would not exist in a static setting. Intuitively, alliances can be optimal because separating the two firms removes debt overhang and increases financial flexibility, while the licensing contract ameliorates the resulting problem of suboptimal joint profit maximization in the exercise decision. We provide comparative statics for the optimal alliance structure, and compare values from this optimally structured hybrid form to those of traditional organizational forms to help predict when they will be observed in practice.

Most theories of the firm derive optimal firm boundaries based on trade-offs between advantages gained from internalizing externalities (or reducing redundancies) of market-based production across firms and disadvantages of increased communication, coordination, and incentive problems inside larger firms.[3] Our approach fits into the property/control rights paradigm in that we analyze how corporate investment incentives in different organizational forms determine the optimal location of control rights over a new product market opportunity. In this sense, debt and its associated agency problems act in our model as a source of misaligned investment incentives within the integrated firm, similar to the bureaucratic or hierarchical diseconomies that underlie traditional models. However, unlike traditional theories, which generally treat the firm's financial policy and operating environment as exogenous, we also consider how external competitive forces impact the relevant internal trade-offs. Moreover, we focus on incentives for the timing of investment rather than incentives for effort in idea generation or other innovative activities. Note that effort incentive effects are likely to be most important in the earliest stages of research and development, whereas in our setting we have chosen to assume the "idea" itself already exists at time zero, so that we do not need to provide incentives for generating (presumably randomly) new ideas.[4]

[3] See, for example, Coase (1937), Williamson (1973, 1979), Klein et al. (1978), Grossman and Hart (1986), and Hart and Moore (1990).

[4] Incentives might also be relevant in the later stages of research and development. We believe that although including an incentive problem that is better solved by one organizational design (such as an assumption that owning a small firm's stock gives better incentives) would potentially shift our equilibrium boundaries toward one design, it would likely leave the main comparative statics unaffected (barring subtle interactions between the incentive effects and our underlying capital structure forces, which to us seem unlikely).

Although we are the first to provide an analysis of how capital structure and organizational design jointly affect the dynamics of new market opportunities, our work is related to a number of papers, including Grenadier and Weiss (1997), Berk et al. (2004), Carlson et al. (2006), Philippon and Sannikov (2007), and others that model new product market opportunities as real options. Common features of such models are investment irreversibility, stochastic cash flows related to underlying market/economic uncertainty, and more recently, competitive implications. However, these models generally consider the operation of such projects in isolation (i.e., without consideration for optimal organization) and without debt financing, whereas we focus on the joint value effect of an integration decision for a new project together with value relevant capital structure decisions.

Our paper is also related to a small but growing literature of dynamic models that explore the interactions of real options and capital structure, such as Brennan and Schwartz (1984), Leland (1998), Hennessy and Whited (2005), Titman and Tsyplakov (2007), Tserlukevich (2008), and Morellec and Schuerhoff (2011). The analysis in our paper complements and extends these studies by focusing on organizational design issues.

Perhaps more closely related in spirit are several studies of capital structure and project finance in static settings without dynamic market opportunities or product market interactions. John (1986, 1993) and Flannery et al. (1993) consider how to optimally organize and finance two projects with varying payoff correlations or risk structures in the presence of agency-induced and tax-based incentives. More recently, Leland (2007) analyzes the role of net tax benefits for spin-offs and mergers in a static model with correlated cash flows but without agency problems. Finally, Shah and Thakor (1987) study the optimality of project finance when there is asymmetric information about project quality, whereas Chemmanur and John (1996) show that separate incorporation or project finance can be used to optimally allocate control rights.[5]

2. The Model

We consider two corporate activities: assets in place operated by an existing firm, and a new product market opportunity or growth option. At time zero, an organizational design choice concerning ownership and control of the growth option is made. We initially compare two polar cases, an integrated design and a nonintegrated design (§5 studies intermediate designs in the form of financial alliances). In the integrated design, the existing firm owns both the assets in place and the growth option (hereafter, "I" or the "integrated" firm). Thus, it chooses the time at which to exercise the option taking into account its effect on assets in place. In the nonintegrated design, the existing firm (hereafter, "L" or the "large" firm in the nonintegrated case) continues to own the assets in place, but ownership and control of the growth option is placed with a new, completely separate firm. The new firm (hereafter, "S" or the "small" firm) thus chooses the time of exercise independently. Note that we do not specify who initially owns the property right to the growth option. We assume that efficient bargaining at time zero (i.e., with no informational asymmetry and with costless transfers) will determine the equilibrium organizational design, and thus the initial placement of the property right is irrelevant.[6]

At every point in time t, assets in place generate uncertain cash flows, X_t, which follow a geometric Brownian motion with drift μ, volatility σ, and initial value $X > 0$. Agents are risk-neutral and discount cash flows at a risk-free rate r with $\mu < r$. To irreversibly exercise the growth option, its owner (either the existing firm or the new firm established to operate the option) has to spend an investment cost $\kappa > 0$, for which it receives assets with an incremental stream of cash flows equal to πX_t, where $\pi > 0$.[7] However, once the option is exercised, the existing firm's cash flows from assets in place are decreased by a fraction $\gamma > 0$, which represents a cannibalization effect of the new product on the existing business. This cannibalization cost γ leaves the assets in place generating $(1-\gamma)X_t < X_t$ in cash flows thereafter.

Furthermore, there is obsolescence risk, e.g., because preemptive product introduction by another firm or firms can make the product underlying the option's cash flows obsolete. Specifically, the new opportunity

[5] Habib and Mella-Barral (2013) study organizational design in a dynamic setting but focus on information transmission through mergers and alliances without considering either capital structure effects or investment options.

[6] As such, an integrated form could arise either because the existing firm owns the property right to the growth option and retains it, or because it buys it from the initial owner (e.g., in a merger). Similarly, a nonintegrated form could arise either because the existing firm initially owns the option and then sells or spins it off, or because someone else initially owns it and retains and operates it.

[7] That is, cash flows from the new product market opportunity and those from the assets in place are perfectly correlated because, e.g., they are subject to the same industry demand or macroeconomic shocks. In our example from the introduction, the demand for electric cars will certainly be related to overall demand for automobiles, leading to a positive correlation between the two streams of cash flows. However, one would also expect that new opportunities will be subject to some unique sources of uncertainty relative to existing assets (i.e., consumer sentiment toward "green" technology, gas prices, etc.), so our assumption is a simplification of reality that focuses on the shared uncertainties rather than the divergent ones. This approach significantly improves tractability, while still allowing us to model many realistic features of the product market interaction between the two assets. See §6.3 for further details.

may randomly "die" during any time interval dt with a constant probability $\rho\,dt$. In reality, the value of a new product market opportunity will be affected by the actions of potentially many other firms in the same and related markets, who may have already developed competing products and have to choose the timing of their introduction (as here), or who may still be developing such products and face uncertain timing and probability of success. Our assumption of a constant obsolescence probability per unit of time is meant to capture in reduced form the net effect of such outside competition, while allowing for tractability and clarity of results. More specifically, though, our assumption is consistent with a model in which the market has a "winner-take-all" structure, a single other competitor seeks to develop a competing product, and that competitor faces a constant success probability of $\rho\,dt$ per unit of time dt.[8] In addition, we assume that when the option becomes obsolete, the existing firm's assets in place suffer an adverse effect δ, such that its cash flows thereafter are equal to $(1-\delta)X_t < X_t$. This preemption cost δ represents in reduced form the competitive effect of product introduction by rival firm(s) that triggered the option's obsolescence.

We assume corporate taxes are paid at a rate τ on operating cash flows less interest, and full offsets of corporate losses are allowed. Thus, capital structure can affect firm value. We further assume that bankruptcy (which is triggered by an endogenous default decision on behalf of equity holders) leads to a loss of the tax benefits of debt, a loss of the option (if it is held by the defaulting firm and has not been exercised), and future cash flows are reduced by a proportion α of the base cash flows of the defaulting firm, where the base cash flows do not include cannibalization or preemption costs.[9] Thus, if the existing firm defaults at any point, future cash flows from assets in place are reduced by αX_t (regardless of whether the option is exercised or obsolete). Similarly, if the firm holding the growth option defaults after exercise, future cash flows from the new assets are reduced by $\alpha\pi X_t$.

In both the integrated and nonintegrated cases, we assume that the existing firm makes a once and for all capital structure choice immediately after the organizational design has been chosen (see §6.1 for an extension that relaxes this assumption). We also assume that there is no preexisting debt financing in place at the beginning of the model (see §6.3 for further discussion of this assumption). Following the organizational design choice, the existing firm chooses a perpetual coupon payment C to maximize its total firm value (which is equivalent to assuming it is all-equity financed ex ante and chooses a debt issuance that maximizes equity value). In the nonintegrated case, the new firm chooses its capital structure at the time of option exercise; prior to exercise it has no cash flows and therefore is all-equity financed by assumption.[10]

Finally, we assume throughout that managers act in the interests of existing equity holders. Since debt is issued prior to exercise in the integrated case, this means that the firm's exercise policy maximizes equity rather than firm value. In other words, there is no ability to commit ex ante to a firm-value-maximizing exercise policy. Thus, debt and its associated agency problems act in our model as a source of misaligned investment incentives within the integrated firm. In the nonintegrated design, there is no debt prior to exercise for the firm owning the option, so the chosen exercise time maximizes both firm and equity value. As such, nonintegration can serve to ameliorate the commitment problem engendered by integration.

3. Solution

To compare the two different organizational designs, we first solve in this section for contingent claim values. In a second step, we derive optimal financing and investment decisions for nonintegration and integration.

3.1. Nonintegration: The Small Firm

In the nonintegrated case, the small firm generates no cash flows and makes no debt payments prior to investment. That is, the small firm is all-equity financed until exercise. Upon exercise, the small firm's assets in place start generating a perpetual stream of after-tax cash flows $(1-\tau)\pi X_t$ at each time t. If no debt is issued, the small firm's unlevered value after exercise is given by

$$\mathrm{E}\left[\int_t^\infty e^{-r(s-t)}(1-\tau)\pi X_s\,ds\right] = \pi\Lambda X_t, \tag{1}$$

where $\mathrm{E}[\cdot]$ is the expectation operator, and $\Lambda = (1-\tau)/(r-\mu)$ is the after-tax, growth-adjusted discount factor, which is similar to Gordon's growth formula with μ being the growth rate (Gordon and Shapiro 1956).

Since debt and equity are issued to finance the capital expenditure κ, the small firm's levered total value after

[8] Given the winner-take-all market structure, it is reasonable to assume that the competitor, knowing about the existence of the nascent product modeled here, would introduce its product immediately upon development. Alternate assumptions about the competitive structure of the market should make for interesting future work.

[9] Bankruptcy costs are lower if the firm optimally relevers upon bankruptcy. Similarly, the option might entirely or partly survive bankruptcy. These changes do not affect any of our results except for minor quantitative differences.

[10] It is possible to envision that the small firm finds it optimal to issue some debt at time zero, for example, if there are very generous loss carry-forward provisions. However, this would greatly complicate the analysis without significantly changing any results.

exercise reflects the present value of the cash flows accruing until the default time, i.e., the after-tax cash flows $(1-\tau)\pi X_t$ plus the tax savings τC_S^+ (where C_S^+ is the coupon chosen by the firm at the time of exercise), and the present value of the cash flows accruing after default, i.e., $(1-\alpha)(1-\tau)\pi X_t$. The small firm's equity value after exercise reflects the present value of the cash flows accruing until the default time, i.e., the after-tax cash flows $(1-\tau)(\pi X_t - C_S^+)$, and the present value of the cash flows accruing after default, i.e., 0 assuming strict adherence to absolute priority.

We denote equity and firm values when the small firm has exercised its option, issued debt with coupon payment C_S^+, and selected the default threshold $\underline{X}_S^+$, by E_S^+ and V_S^+ (we use the + superscript to denote values after option exercise). As shown in Online Appendix A,[11] we can solve for the small firm's optimal decisions and its contingent claim values in closed form, which are summarized in the following lemma.

Lemma 1. *Given the current value of cash flow X, the small firm's total firm value after investment equals for all $X \geq \underline{X}_S^+$:*

$$V_S^+(X) = \pi\Lambda X + \frac{\tau C_S^+}{r}\left(1-\left(\frac{X}{\underline{X}_S^+}\right)^{\vartheta'}\right) - \alpha\pi\Lambda\underline{X}_S^+\left(\frac{X}{\underline{X}_S^+}\right)^{\vartheta'}, \tag{2}$$

and its equity value after investment is for all $X \geq \underline{X}_S^+$ given by

$$E_S^+(X) = \left(\pi\Lambda X - \frac{(1-\tau)C_S^+}{r}\right) - \left(\pi\Lambda\underline{X}_S^+ - \frac{(1-\tau)C_S^+}{r}\right)\left(\frac{X}{\underline{X}_S^+}\right)^{\vartheta'}, \tag{3}$$

where ϑ' is the negative characteristic root of the quadratic equation: $\frac{1}{2}x(x-1)\sigma^2 + x\mu = r$,

$$\vartheta' = \left(\tfrac{1}{2} - \mu/\sigma^2\right) - \sqrt{\left(\tfrac{1}{2} - \mu/\sigma^2\right)^2 + 2r/\sigma^2}. \tag{4}$$

The default threshold that maximizes equity value is

$$\underline{X}_S^+ = \frac{\vartheta'}{\vartheta'-1}\frac{r-\mu}{r}\frac{C_S^+}{\pi}, \tag{5}$$

and the coupon payment that maximizes firm value is

$$C_S^+ = \pi X \frac{\vartheta'-1}{\vartheta'}\frac{r}{r-\mu}\left[1-\vartheta'\left(1-\alpha+\frac{\alpha}{\tau}\right)\right]^{1/\vartheta'}. \tag{6}$$

[11] All online appendices are available at http://ssrn.com/abstract =2443868 or by request from any of the authors.

The first term in $V_S^+(X)$ is the value of assets in place in (1), the second term is the expected value of tax shield benefits from debt (which disappear if the firm defaults at $\underline{X}_S^+$), and the third term is the expected value of bankruptcy costs, which are triggered when the firm defaults at $\underline{X}_S^+$. To identify the sources of firm value, we will often refer jointly to the second and the third term as the firm's net tax benefits. For $E_S^+(X)$, the first term is the expected value of after-tax cash flows to equity holders, while the second term subtracts the expected value of those cash flows conditional on default at $\underline{X}_S^+$, so that equity holders' claim value equals zero upon default.

Next, we define the stopping time $\mathcal{T}_Y > 0$ that determines the time at which obsolescence occurs. Let Y_t be the associated indicator function, which is equal to zero if $t < \mathcal{T}_Y$ and one otherwise. If $Y_t = 0$, an unexercised option may be exercised, but if $Y_t = 1$ the option is worthless. Working backward, the value of the small firm prior to exercise, V_S, crucially depends on obsolescence risk or, more precisely, the distribution of $\mathcal{T}_Y$. As long as $Y_t = 0$, V_S equals the expected present value of the optimally levered firm value minus capital expenditure at the time of investment. We denote the investment threshold selected by shareholders by $\bar{X}_S$ and the first time for X to touch this threshold from below by $\mathcal{T}_G$. Thus, the small firm invests to maximize the value of its option:

$$V_S(X) = \sup_{\mathcal{T}_G} \mathrm{E}\left[1_{\mathcal{T}_G<\mathcal{T}_Y} e^{-r\mathcal{T}_G}(V_S^+(X_{\mathcal{T}_G}) - \kappa)\right], \tag{7}$$

where 1_ω represents the indicator function of the event ω. Because the firm does not produce any cash flows before investment, initial shareholders only receive capital gains of $\mathrm{E}[dV_S(X)]$ over each time interval dt prior to investment. The required rate of return for investing in the small firm is the risk-free rate r. Thus, the Bellman equation in the continuation region with $t < \mathcal{T}_Y$ is

$$rV_S(X)\,dt = \mathrm{E}[dV_S(X)]. \tag{8}$$

Applying Ito's lemma to expand the right-hand side of the Bellman equation, it is easy to show that the value of the small firm before investment or obsolescence satisfies

$$rV_S(X) = \mu X\frac{\partial V_S(X)}{\partial X} + \frac{1}{2}\sigma^2 X^2\frac{\partial^2 V_S(X)}{\partial X^2} + \rho[0 - V_S(X)]. \tag{9}$$

The left-hand side of this equation reflects the required rate of return for holding the claim per unit of time. The right-hand side is the expected change in the claim value (i.e., the realized rate of return). These expressions are similar to those derived in standard contingent claims models. However, they contain the additional term, $\rho[0 - V_S(X)]$, which reflects the impact of losing the growth option if a competitor moves first. This term is the product of the instantaneous probability of obsolescence and the change in the value function occurring due to obsolescence.

The ordinary differential Equation (9) is solved subject to the following boundary conditions. First, the value of equity at the time of investment is equal to the payoff from investment: $V_S(\bar{X}_S) = V_S^+(\bar{X}_S) - \kappa$. Second, as the level of the cash flow shocks tends to zero, the option to invest becomes worthless so that V_S satisfies $\lim_{X\downarrow 0} V_S(X) = 0$. In addition, to ensure that investment occurs along the optimal path, the value of equity satisfies the optimality condition (smooth-pasting): $(\partial V_S(X)/\partial X)|_{X=\bar{X}_S} = (\partial V_S^+(X)/\partial X)|_{X=\bar{X}_S}$ at the endogenous investment threshold. Solving the small firm's problem yields the following results.

Proposition 1. *Given the current value of cash flow X, the value of the nonintegrated, small firm's optimal equity/firm value equals for all $X \le \bar{X}_S$ and $t < \mathcal{T}_Y$:*

$$V_S(X) = \frac{\kappa}{\xi - 1}\left[\frac{X(\xi-1)}{\xi}\frac{1-\tau}{r-\mu}\frac{\pi}{\kappa} \cdot \left(1 + \frac{\tau}{1-\tau}\left(1 - \vartheta'(1-\alpha+\alpha/\tau)\right)^{1/\vartheta'}\right)\right]^{\xi}, \quad (10)$$

which can be rewritten as

$$V_S(X) = G_S(X) + NTB_S(X), \quad (11)$$

where $G_S(X)$ denotes value of the growth option for the small firm:

$$G_S(X) = (\pi\Lambda\bar{X}_S - \kappa)\left(\frac{X}{\bar{X}_S}\right)^{\xi}; \quad (12)$$

$NTB_S(X)$ denotes the value of net tax benefits for the small firm:

$$NTB_S(X) = \pi\Lambda\bar{X}_S\frac{\tau}{1-\tau}\left(1 - \vartheta'(1-\alpha+\alpha/\tau)\right)^{1/\vartheta'}\left(\frac{X}{\bar{X}_S}\right)^{\xi}; \quad (13)$$

and $\bar{X}_S$ denotes the value-maximizing exercise threshold for the small firm:

$$\bar{X}_S = \frac{\xi}{\xi-1}\frac{r-\mu}{1-\tau}\frac{\kappa}{\pi} \cdot \left(1 + \frac{\tau}{1-\tau}\left(1 - \vartheta'(1-\alpha+\alpha/\tau)\right)^{1/\vartheta'}\right)^{-1}; \quad (14)$$

and where ξ is the positive characteristic root of the quadratic equation $\frac{1}{2}x(x-1)\sigma^2 + x\mu = r + \rho$,

$$\xi = \left(\tfrac{1}{2} - \mu/\sigma^2\right) + \sqrt{\left(\tfrac{1}{2} - \mu/\sigma^2\right)^2 + 2(r+\rho)/\sigma^2}. \quad (15)$$

Proposition 1 provides the value of the small firm prior to exercise or obsolescence as the expected present value of the after-tax cash flows net of capital expenditures, G_S, and the net tax benefits, NTB_S, that are initiated at the time of investment $\mathcal{T}_G$. Several standard comparative statics results from the real options literature apply to V_S and $\bar{X}_S$. For example, the small firm's value is higher (lower), when the investment payoff π (investment cost κ) rises and hence its exercise threshold is lower (higher). Consistent with economic intuition, the proposition shows that V_S decreases with ρ, because when obsolescence becomes more likely, all else equal, it is less likely that the option's cash flows will ultimately be realized. That is, a higher risk of obsolescence erodes the value of the small firm's option. As a result of the reduced option value, the small firm optimally exercises this option, in expectation, earlier when obsolescence risk is higher, i.e., $\partial\bar{X}_S/\partial\rho < 0$. By exercising earlier, the small firm forestalls the possibility of obsolescence due to earlier product introduction by a rival in the states of the world in which it would otherwise continue to wait to invest. However, the small firm delays exercise when cash flow risk is higher, i.e., $\partial\bar{X}_S/\partial\sigma > 0$. Moreover, we see that $\partial\bar{X}_S/\partial\tau > 0$, even though higher corporate taxes provide more net tax benefits, because the first-order effect of higher taxes is substantially lower after-tax cash flows.[12]

3.2. Nonintegration: The Large Firm

Even though the large firm does not invest in the nonintegrated case, its values and hence its value-maximizing decisions are more complex than those of the small firm. This is because the large firm is initially capitalized by both debt and equity and, more importantly, because it is not known at time zero whether the small firm's option will be exercised (i.e., $\mathcal{T}_G < \mathcal{T}_Y$) or will become obsolete (i.e., $\mathcal{T}_G \ge \mathcal{T}_Y$). We denote the separated, large firm's equity and firm values when the small firm has exercised its option by E_L^+ and V_L^+ (again use of + superscript denotes values after option exercise). Correspondingly, let $\underline{X}_L^+$ denote the default threshold selected by shareholders. As in the previous section, we begin by deriving contingent claim values after exercise, which are gathered in the next lemma (see Online Appendix B for details).

Lemma 2. *Given the large firm's initial coupon choice C_L and the current value of cash flow X, total firm value equals for all $t \ge \mathcal{T}_G$ and $X \ge \underline{X}_L^+$,*

$$V_L^+(X) = (1-\gamma)\Lambda X + \frac{\tau C_L}{r}\left(1 - \left(\frac{X}{\underline{X}_L^+}\right)^{\vartheta'}\right) - \alpha\Lambda\underline{X}_L^+\left(\frac{X}{\underline{X}_L^+}\right)^{\vartheta'}, \quad (16)$$

[12] Note also that $\partial\bar{X}_S/\partial\alpha > 0$ because with higher bankruptcy costs less debt will optimally be issued for a given cash flow level X. Intuitively, more of the capital expenditures will be equity-financed and hence exercise optimally takes place, in expectation, later.

and its equity value after investment is for all $X \geq \underline{X}_L^+$ *given by*

$$E_L^+(X) = \left((1-\gamma)\Lambda X - \frac{(1-\tau)C_L}{r}\right) - \left((1-\gamma)\Lambda \underline{X}_L^+ - \frac{(1-\tau)C_L}{r}\right)\left(\frac{X}{\underline{X}_L^+}\right)^{\vartheta'}, \quad (17)$$

where ϑ' *is the negative characteristic root of the quadratic equation:* $\frac{1}{2}x(x-1)\sigma^2 + x\mu = r$,

$$\vartheta' = \left(\tfrac{1}{2} - \mu/\sigma^2\right) - \sqrt{\left(\tfrac{1}{2} - \mu/\sigma^2\right)^2 + 2r/\sigma^2}. \quad (18)$$

The default threshold that maximizes equity value is

$$\underline{X}_L^+ = \frac{\vartheta'}{\vartheta' - 1}\frac{r-\mu}{r}\frac{C_L}{1-\gamma}. \quad (19)$$

We denote the large firm's equity and firm values when the small firm's option has become obsolete by E_L° and V_L° (note that from here forward, use of the $\circ$ superscript denotes values after the option has become obsolete due to product introduction by a rival firm). Correspondingly, let $\underline{X}_L^\circ$ denote the default threshold selected by shareholders. We can obtain the following analytic expressions.

Lemma 3. *Given the large firm's initial coupon choice* C_L *and the current value of cash flow* X, *total firm value equals for all* $t \geq \mathcal{T}_Y$ *and* $X \geq \underline{X}_L^\circ$:

$$V_L^\circ(X) = (1-\delta)\Lambda X + \frac{\tau C_L}{r}\left(1 - \left(\frac{X}{\underline{X}_L^\circ}\right)^{\vartheta'}\right) - \alpha\Lambda\underline{X}_L^\circ\left(\frac{X}{\underline{X}_L^\circ}\right)^{\vartheta'}, \quad (20)$$

and its equity value after investment is for all $X \geq \underline{X}_L^\circ$ *given by*

$$E_L^\circ(X) = \left((1-\delta)\Lambda X - \frac{(1-\tau)C_L}{r}\right) - \left((1-\delta)\Lambda \underline{X}_L^\circ - \frac{(1-\tau)C_L}{r}\right)\left(\frac{X}{\underline{X}_L^\circ}\right)^{\vartheta'}, \quad (21)$$

where ϑ' *is the negative characteristic root of the quadratic equation* $\frac{1}{2}x(x-1)\sigma^2 + x\mu = r$,

$$\vartheta' = \left(\tfrac{1}{2} - \mu/\sigma^2\right) - \sqrt{\left(\tfrac{1}{2} - \mu/\sigma^2\right)^2 + 2r/\sigma^2}. \quad (22)$$

The default threshold that maximizes equity value is

$$\underline{X}_L^\circ = \frac{\vartheta'}{\vartheta' - 1}\frac{r-\mu}{r}\frac{C_L}{1-\delta}. \quad (23)$$

The results in Lemmas 2 and 3 afford a similar interpretation as the ones in Lemma 1. For example, the main sources of firm value are again the value of assets in place and the value of net tax benefits. Differences in the equations here include competitive effects such as the cannibalization cost ($\gamma > 0$) in (16) and the preemption cost ($\delta > 0$) in (20), which undermine the large firm's asset in place values and hence firm values.

Since equity value is the difference between firm and debt value, the preemption cost reduces equity value in (21) in lock step with (20). Furthermore, larger effects of cannibalization and preemption on equity value lead to larger increases in equity value-maximizing default thresholds. Like (19) in Lemma 2, the expression in (23) has a key term which scales up equity's optimal default boundary by a multiplicative factor related to the relevant cost to assets in place, i.e., $1/(1-\delta) > 1$ in (23) instead of $1/(1-\gamma) > 1$ in (19).

Working backward, the value of the large firm prior to exercise or obsolescence equals the expected present value of the levered firm values in three regions: (i) before investment or obsolescence, (ii) after investment, and (iii) after obsolescence. We denote the large firm's equity and firm values at time zero by E_L and V_L. Moreover, we denote the default threshold selected by shareholders in region (i) by $\underline{X}_L$ and the first time for X to touch this threshold from above by $\mathcal{T}_D$.

Because the large firm operates assets in place before the small firm's investment decision, its owners receive capital gains of $\mathrm{E}[dV_L(X)]$ and cash flows $(1-\tau)X + \tau C_L$ over each time interval dt. The required rate of return for investing in the large firm is the risk-free rate r. Thus, the Bellman equation in the continuation region with $t < \mathcal{T}_Y$ is

$$rV_L(X)\,dt = \mathrm{E}[dV_L(X)] + [(1-\tau)X + \tau C_L]\,dt. \quad (24)$$

Applying Ito's lemma to expand the right-hand side of the Bellman equation, it is immediate to derive that the value of the large firm before investment or obsolescence satisfies

$$rV_L(X) = (1-\tau)X + \tau C_L + \mu X\frac{\partial V_L(X)}{\partial X} + \frac{1}{2}\sigma^2 X^2 \frac{\partial^2 V_L(X)}{\partial X^2} + \rho[V_L^\circ(X) - V_L(X)]. \quad (25)$$

The left-hand side of this equation reflects the required rate of return for holding the claim per unit of time. The right-hand side is the after-tax cash flow cum tax savings, $(1-\tau)X + \tau C_L$, plus the expected change in the claim value (i.e., the realized rate of return). These expressions are similar to those derived in standard contingent claims models. However, they contain the additional term, $\rho[V_L^\circ(X) - V_L(X)]$, which reflects the impact of obsolescence risk and the resulting preemption cost on the large firm's value. This term equals the product of the instantaneous probability of obsolescence and the change in the large firm's value function at the time of obsolescence $\mathcal{T}_Y$.

The ordinary differential Equation (25) is solved subject to the following boundary conditions. First, the value of the large firm at the time of the small firm's investment $\mathcal{T}_G$ is equal to the value of the large firm in Lemma 2 evaluated at the small firm's investment threshold (value-matching): $V_L(\bar{X}_S) = V_L^+(\bar{X}_S)$. Second, the value of the large firm at the time its shareholders default $\mathcal{T}_D$ is equal to its value of assets in place net of bankruptcy costs plus the expected effect on assets in place due to the cannibalization cost or the preemption cost (value-matching): $V_L(\underline{X}_L) = (1-\alpha)\Lambda \underline{X}_L - \rho\delta\Lambda[\underline{X}_L - \bar{X}_S(\underline{X}_L/\bar{X}_S)^{\xi}]/(r+\rho-\mu) - \gamma\Lambda\bar{X}_S(\underline{X}_L/\bar{X}_S)^{\xi}$.

Similar arguments lead to the large firm's equity value, $E_L(X)$. As we show in Online Appendix B, equity satisfies a similar differential equation as (25),[13] which also has a solution with unknown constants that are determined by the following boundary conditions. First, the value of the large firm's equity at the time of the small firm's investment $\mathcal{T}_G$ is equal to the value of the large firm's equity in Lemma 2 evaluated at the small firm's investment threshold (value-matching): $E_L(\bar{X}_S) = E_L^+(\bar{X}_S)$. Second, equity value at the time of default $\mathcal{T}_D$ is equal to zero under the absolute priority rule (value-matching): $E_L(\underline{X}_L) = 0$. In addition, to ensure that default occurs along the optimal path, the value of equity satisfies the optimality (smooth-pasting) condition at the endogenous default threshold (see, e.g., Leland 1998). Solving yields the following results.

Proposition 2. *Given the current value of cash flow X, the nonintegrated, large firm's total value equals for all $X \in (\underline{X}_I, \bar{X}_S)$ and $t < \mathcal{T}_Y$:*

$$V_L(X) = AIP_L(X) + NTB_L(X), \tag{26}$$

where the value of assets in place, AIP_L, is given by

$$AIP_L(X) = \Lambda X - \frac{\rho}{r+\rho-\mu}\delta\Lambda\left[X - \left(\frac{X}{\bar{X}_S}\right)^{\xi}\bar{X}_S\right] - \gamma\Lambda\bar{X}_S\left(\frac{X}{\bar{X}_S}\right)^{\xi}, \tag{27}$$

and the value of net tax benefits, NTB_L, is given by

$$\begin{aligned} NTB_L(X) &= \frac{\tau C_L}{r}\left(1 - \Delta(X) - \Sigma(X)\left(\frac{\bar{X}_S}{\underline{X}_L^+}\right)^{\vartheta'} - \frac{\rho}{r-\mu'}\Psi(X)\right) \\ &\quad - \alpha\left(\Delta(X)\Lambda\underline{X}_L + \Sigma(X)\Lambda\underline{X}_L^+\left(\frac{\bar{X}_S}{\underline{X}_L^+}\right)^{\vartheta'} + \frac{\rho}{r-\mu'}\Lambda\underline{X}_L^{\circ}\Psi(X)\right). \end{aligned} \tag{28}$$

The value of the nonintegrated, large firm's equity equals for all $X \in (\underline{X}_L, \bar{X}_S)$ and $t < \mathcal{T}_Y$:

$$\begin{aligned} E_L(X) &= \left(\Lambda X - \frac{(1-\tau)C_L}{r}\right) \\ &\quad - \frac{\rho}{r+\rho-\mu}\delta\Lambda[X - \Delta(X)\underline{X}_L - \Sigma(X)\bar{X}_S] \\ &\quad - \gamma\Lambda\bar{X}_S\left(\frac{X}{\bar{X}_S}\right)^{\xi} \\ &\quad - \frac{\rho}{r-\mu'}\left((1-\delta)\Lambda\underline{X}_L^{\circ} - \frac{(1-\tau)C_L}{r}\right)\Psi(X) \\ &\quad - \Delta(X)\left(\Lambda\underline{X}_L - \gamma\Lambda\bar{X}_S\left(\frac{\underline{X}_L}{\bar{X}_S}\right)^{\xi} - \frac{(1-\tau)C_L}{r}\right) \\ &\quad - \Sigma(X)\left((1-\gamma)\Lambda X - \frac{(1-\tau)C_L}{r}\right)\left(\frac{\bar{X}_S}{\underline{X}_L^+}\right)^{\vartheta'}, \end{aligned} \tag{29}$$

where $\bar{X}_S$ is the small firm's investment threshold in (14), *the stochastic discount factors for default by the large firm and for investment by the small firm are given by*

$$\Delta(X) = \frac{X^{\xi}\bar{X}_S^{\vartheta} - X^{\vartheta}\bar{X}_S^{\xi}}{\underline{X}_L^{\xi}\bar{X}_S^{\vartheta} - \underline{X}_L^{\vartheta}\bar{X}_S^{\xi}}, \quad \text{and} \qquad \Sigma(X) = \frac{\underline{X}_L^{\xi}X^{\vartheta} - \underline{X}_L^{\vartheta}X^{\xi}}{\underline{X}_L^{\xi}\bar{X}_S^{\vartheta} - \underline{X}_L^{\vartheta}\bar{X}_S^{\xi}}, \tag{30}$$

the adjusted growth rate is $\mu' = \vartheta'\mu + \frac{1}{2}\vartheta'(\vartheta'-1)\sigma^2$, and the terms related to obsolescence risk are

$$\Psi(X) = \left(\frac{X}{\underline{X}_L^{\circ}}\right)^{\vartheta'} - \Delta(X)\left(\frac{\underline{X}_L}{\underline{X}_L^{\circ}}\right)^{\vartheta'} - \Sigma(X)\left(\frac{\bar{X}_S}{\underline{X}_L^{\circ}}\right)^{\vartheta'}, \tag{31}$$

and where ϑ' and ξ are given in (4) *and* (15), *and ϑ is the negative characteristic root of the quadratic equation $\frac{1}{2}x(x-1)\sigma^2 + x\mu = r+\rho$,*

$$\vartheta = \left(\tfrac{1}{2} - \mu/\sigma^2\right) - \sqrt{\left(\tfrac{1}{2} - \mu/\sigma^2\right)^2 + 2(r+\rho)/\sigma^2}. \tag{32}$$

Finally, the optimal (*firm value-maximizing*) *coupon choice solves $\max_{C_L} V_L(X)$, and the optimal* (*equity value-maximizing*) *default threshold solves $\partial E_L(X)/\partial X|_{X=\underline{X}_L} = 0$.*

Proposition 2 reports closed-form solutions for firm and equity values when the large, nonintegrated firm is affected by both diffusion risk (i.e., cash flow uncertainty) and jump risk (i.e., obsolescence uncertainty). The value of the large firm can again be broken down into two main parts, the value of assets in place, $AIP_L(X)$, and the value of net tax benefits, $NTB_L(X)$, which explains (26). Equations (27) and (28) provide the details for those two parts. The first term in (27) is the base cash flow value of assets in place, the second term represents the expected value of the preemption cost in case of obsolescence (which is offset by the possibility that the option will be exercised first, in

[13] More specifically, *equity* cash flows $(1-\tau)(X - C_L)$ replace *firm* cash flows $(1-\tau)X + \tau C_L$ in Equation (25).

which case obsolescence risk disappears as reflected in the term involving $\Sigma(X)$), and the third term represents the expected value of the cannibalization cost.

In (28), the first line gives the expected value of tax shields, and the second line gives the expected value of bankruptcy costs. The term in parentheses on the first line gathers terms involving the state prices for the various circumstances in which default can occur, which are (a) when the firm reaches the boundary $\underline{X}_L$ before either obsolescence or option exercise occurs (state price $\Delta(X)$, defined in (30)); (b) when the firm first exercises the option, then later defaults at $\underline{X}_L^+$ (state price involving $\Sigma(X)$, defined in (30), multiplied by the state price $(\bar{X}_S/\underline{X}_L^+)^{\vartheta'}$); and (c) when the option becomes obsolete prior to both exercise and default due to the instantaneous probability of obsolescence ρ, and the firm then later defaults at $\underline{X}_L^\circ$ (state price involving $\Psi(X)$ and $1/(r-\mu')$ is the appropriate discount factor for claim values that are contingent on $X^{\vartheta'}$ instead of X). Note that the term $\Psi(X)$, detailed in (31), corrects for the probability that the firm will default (the $\Delta(X)$ term) or that the option will be exercised (the $\Sigma(X)$ term) prior to obsolescence, at which point obsolescence risk disappears. The second line in (28) analogously accounts for the present value of bankruptcy costs for the various states in which default can occur (recall that bankruptcy costs are proportional to cash flows at the time of default, whereas tax shield cash flows are fixed from time zero).

Equity value in (29) accounts for the value of base cash flows to equity (the first term), the value of cannibalization cost and preemption cost (the next two terms, involving γ and δ), and the possibility that cash flows will cease under the various circumstances in which default can occur (the three terms involving $\Psi(X)$, $\Delta(X)$, and $\Sigma(X)$ in conjunction with $(\bar{X}_S/\underline{X}_L^+)^{\vartheta'}$). Finally, the large firm's coupon choice C_L and its preinvestment/preobsolescence default threshold $\underline{X}_L$ do not have explicit analytical solutions. However, they can easily be computed by maximizing firm value at time zero with respect to the coupon, and by imposing the smooth-pasting condition for equity value at $\underline{X}_L$, which can be expressed analytically as a nonlinear equation.

3.3. Integration: Large Firm's Value with Growth Option

In the integrated case, we solve for a single firm value that combines the different projects of the two separated firms under one umbrella. Thus, the firm's value-maximizing decisions attempt to strike a balance of their effect on assets in place value, growth option value, and net tax benefits. As in the previous section, it is not known at time zero whether the integrated firm's option will be exercised (i.e., $\mathcal{T}_G < \mathcal{T}_Y$) or will become obsolete (i.e., $\mathcal{T}_G \geq \mathcal{T}_Y$). We denote the integrated firm's equity and firm values after option exercise by E_I^+ and V_I^+. Correspondingly, let $\underline{X}_I^+$ denote default threshold selected by shareholders. The next lemma presents contingent claim values after exercise (see Online Appendix C for details).

Lemma 4. *Given the integrated firm's initial coupon choice C_I and the current value of cash flow X, total firm value equals for all $t \geq \mathcal{T}_G$ and $X \geq \underline{X}_I^+$:*

$$V_I^+(X) = (1+\pi-\gamma)\Lambda X + \frac{\tau C_I}{r}\left(1-\left(\frac{X}{\underline{X}_I^+}\right)^{\vartheta'}\right) - \alpha(1+\pi)\Lambda \underline{X}_I^+\left(\frac{X}{\underline{X}_I^+}\right)^{\vartheta'}, \tag{33}$$

and its equity value after investment is for all $X \geq \underline{X}_I^+$ given by

$$E_I^+(X) = \left((1+\pi-\gamma)\Lambda X - \frac{(1-\tau)C_I}{r}\right) - \left((1+\pi-\gamma)\Lambda \underline{X}_I^+ - \frac{(1-\tau)C_I}{r}\right)\left(\frac{X}{\underline{X}_I^+}\right)^{\vartheta'}, \tag{34}$$

where ϑ' is given in (4) *and the default threshold that maximizes equity value is*

$$\underline{X}_I^+ = \frac{\vartheta'}{\vartheta'-1}\,\frac{r-\mu}{r}\,\frac{C_I}{1+\pi-\gamma}. \tag{35}$$

Note that if a rival firm introduces its new product first, the integrated firm loses its option, and hence its unlevered value after obsolescence is the same as for the separated large firm, i.e., $(1-\delta)\Lambda X$ for $t \geq \mathcal{T}_Y$. We denote the integrated firm's equity and firm values when the growth option has become obsolete by E_I° and V_I°, with $\underline{X}_I^\circ$ again being the corresponding default threshold selected by shareholders. Observe next that for a given coupon payment there is no difference between integration and nonintegration after the option has become obsolete. Therefore, the analytic expressions from Lemma 3 directly apply to this organizational design, which yields the next result.

Lemma 5. *Given the integrated firm's initial coupon choice C_I and the current value of cash flow X, total firm and equity values are for all $t \geq \mathcal{T}_Y$ and $X \geq \underline{X}_L^\circ$ given by* (20) *and* (21), *and the default threshold that maximizes equity value is given by* (23) *where subscripts L are replaced by subscripts I.*

Working backward, the value of the integrated firm prior to exercise or obsolescence equals the expected present value of the levered firm values in three regions: (i) before investment or obsolescence, (ii) after investment, and (iii) after obsolescence. We denote the integrated firm's equity and firm values at time zero by E_I and V_I. Moreover, let $\underline{X}_I$ denote the default threshold in region (i) and the first time for X to touch this threshold from below by $\mathcal{T}_D$, while $\bar{X}_I$ is the investment threshold for moving from region (i) to region (ii) at time $\mathcal{T}_G$.

For brevity, we defer the derivations of firm value and equity value to Online Appendix C. For example, the derivation of firm value involves the same steps as outlined by (24) and (25). The contingent claim values and value-maximizing decisions under integration are collected in the next proposition.

Proposition 3. *Given the current value of cash flow X, the integrated firm's total value equals for all $X \in (\underline{X}_I, \bar{X}_I)$ and $t < \mathcal{T}_Y$:*

$$V_I(X) = AIP_I(X) + G_I(X) + NTB_I(X), \tag{36}$$

where the value of assets in place, AIP_I, is given by

$$AIP_I(X) = \Lambda X - \frac{\rho}{r+\rho-\mu}\delta\Lambda[X - \hat{\Sigma}(X)\bar{X}_I] - \gamma\Lambda\bar{X}_I\hat{\Sigma}(X), \tag{37}$$

the value of the growth option for the large firm is given by

$$G_I(X) = [\pi\Lambda\bar{X}_I - \kappa]\hat{\Sigma}(X), \tag{38}$$

and the value of net tax benefits, NTB_I, is given by

$$\begin{aligned} NTB_I(X) &= \frac{\tau C_I}{r}\left(1 - \hat{\Delta}(X) - \hat{\Sigma}(X)\left(\frac{\bar{X}_I}{\underline{X}_I^+}\right)^{\vartheta'} - \frac{\rho}{r-\mu'}\hat{\Psi}(X)\right) \\ &\quad - \alpha\left(\hat{\Delta}(X)\Lambda\underline{X}_I + \hat{\Sigma}(X)(1+\pi)\Lambda\underline{X}_I^+\left(\frac{\bar{X}_I}{\underline{X}_I^+}\right)^{\vartheta'} + \frac{\rho}{r-\mu'}\Lambda\underline{X}_I^\circ\hat{\Psi}(X)\right). \end{aligned} \tag{39}$$

The value of the integrated firm's equity equals for all $X \in (\underline{X}_L, \bar{X}_I)$ and $t < \mathcal{T}_Y$:

$$\begin{aligned} E_I(X) &= \left(\Lambda X - \frac{(1-\tau)C_I}{r}\right) \\ &\quad - \frac{\rho}{r+\rho-\mu}\delta\Lambda\big[X - \hat{\Delta}(X)\underline{X}_I - \hat{\Sigma}(X)\bar{X}_I\big] \\ &\quad + \big[(\pi-\gamma)\Lambda\bar{X}_I - \kappa\big]\hat{\Sigma}(X) \\ &\quad - \frac{\rho}{r-\mu'}\left((1-\delta)\Lambda\underline{X}_I^\circ - \frac{(1-\tau)C_I}{r}\right)\hat{\Psi}(X) \\ &\quad - \hat{\Delta}(X)\left(\Lambda\underline{X}_I - \frac{(1-\tau)C_I}{r}\right) \\ &\quad - \hat{\Sigma}(X)\left((1+\pi-\gamma)\Lambda X - \frac{(1-\tau)C_I}{r}\right)\left(\frac{\bar{X}_I}{\underline{X}_I^+}\right)^{\vartheta'}, \end{aligned} \tag{40}$$

where the stochastic discount factors for default and investment by the large firm are given by

$$\hat{\Delta}(X) = \frac{X^\xi\bar{X}_I^\vartheta - X^\vartheta\bar{X}_I^\xi}{\underline{X}_I^\xi\bar{X}_I^\vartheta - \underline{X}_I^\vartheta\bar{X}_I^\xi}, \quad \text{and} \qquad \hat{\Sigma}(X) = \frac{\underline{X}_I^\xi X^\vartheta - \underline{X}_I^\vartheta X^\xi}{\underline{X}_I^\xi\bar{X}_I^\vartheta - \underline{X}_I^\vartheta\bar{X}_I^\xi}, \tag{41}$$

the adjusted growth rate is $\mu' = \vartheta'\mu + \frac{1}{2}\vartheta'(\vartheta'-1)\sigma^2$, and the terms related to obsolescence risk are

$$\hat{\Psi}(X) = \left(\frac{X}{\underline{X}_I^\circ}\right)^{\vartheta'} - \hat{\Delta}(X)\left(\frac{\underline{X}_I}{\underline{X}_I^\circ}\right)^{\vartheta'} - \hat{\Sigma}(X)\left(\frac{\bar{X}_I}{\underline{X}_I^\circ}\right)^{\vartheta'}, \tag{42}$$

and where ϑ', ξ, and ϑ are given in (4), (15), *and* (32), *respectively. Finally, the optimal* (*firm value-maximizing*) *coupon choice solves* $\max_{C_I} V_I(X)$, *the optimal* (*equity value-maximizing*) *investment threshold solves* $(\partial E_I(X)/\partial X)|_{X=\underline{X}_I} = (\partial E_I^+(X)/\partial X)|_{X=\underline{X}_I}$, *and the optimal* (*equity value-maximizing*) *default threshold solves* $(\partial E_I(X)/\partial X)|_{X=\underline{X}_I} = 0$.

Proposition 3 presents closed-form solutions when cash flows from assets in place are affected by both diffusion risk (i.e., cash flow uncertainty) and jump risk (i.e., obsolescence uncertainty). In the integrated case, the value of the firm can be decomposed into three main parts, the value of assets in place, $AIP_I(X)$, the value of the growth option, $G_I(X)$, and the value of net tax benefits, $NTB_I(X)$, which explains (36). Clearly, a major difference from Proposition 2 is that in the integrated case the firm's value includes also the value of the growth option, $G_I(X)$, implying that capital structure decisions will affect the value of the growth option in this case.

Understanding the expressions for each value component in Proposition 3 is best accomplished by comparison to Propositions 1 and 2. First, the expression for assets in place value, $AIP_I(X)$, is analogous to $AIP_L(X)$ from Proposition 2, with the only difference being that the state price for the cannibalization cost must now take into account the probability that the integrated firm will default and the option will be destroyed prior to exercise. This is reflected in the replacement of $(X/\bar{X}_S)^\xi$ in (27) with $\hat{\Sigma}(X)$ in (37). The probability of default by the large firm was not relevant for the value of the small firm in the nonintegrated case since default had no effect on the option, and therefore the implications of the cannibalization cost were the same for the new owners of the assets in place after default as for the original owners prior to default. Second, the treatment of the cannibalization cost and the reflection of the option's payoff are the key differences between equity values in (29) and (40). Third, $NTB_I(X)$ is analogous to $NTB_L(X)$ from Proposition 2, with the state prices simply adjusted for the different exercise and default decisions taken by the integrated firm.

Finally, the expression for $G_I(X)$ is analogous to $G_S(X)$ in Proposition 1, except that the two-sided state price $\hat{\Sigma}(X)$ accounts for the possibility that if the integrated firm defaults prior to exercise, the growth option will be lost. As a result, the integrated firm's option in (38) will always be worth less than it is for the separated, small firm in (12), so long as $C_I > 0$. To understand this, first consider a comparison of the two while holding the exercise threshold constant. Note first that the two-sided investment claim converges to the one-sided investment claim as $\underline{X}_L$ goes to zero; that is,

$$\lim_{\underline{X}_L \downarrow 0} \frac{\underline{X}_I^{\xi} X^{\vartheta} - \underline{X}_I^{\vartheta} X^{\xi}}{\underline{X}_I^{\xi} \bar{X}_I^{\vartheta} - \underline{X}_I^{\vartheta} \bar{X}_I^{\xi}} = \left(\frac{X}{\bar{X}_I}\right)^{\xi}, \qquad (43)$$

where the term on the right-hand side corresponds to the state price in (12) if we replace $\bar{X}_I$ by $\bar{X}_S$. Second, the first derivative of the two-sided investment claim with respect to $\underline{X}_I$ is given by

$$\frac{\partial}{\partial \underline{X}_L}\left(\frac{\underline{X}_I^{\xi} X^{\vartheta} - \underline{X}_I^{\vartheta} X^{\xi}}{\underline{X}_I^{\xi} \bar{X}_I^{\vartheta} - \underline{X}_I^{\vartheta} \bar{X}_I^{\xi}}\right) = (\xi - \vartheta)\frac{(X^{\xi} \bar{X}_I^{\vartheta} - X^{\vartheta} \bar{X}_I^{\xi})}{(\underline{X}_I^{\xi} \bar{X}_I^{\vartheta} - \underline{X}_I^{\vartheta} \bar{X}_I^{\xi})^2}, \qquad (44)$$

which is negative as the numerator on the right-hand side is negative if $X^{\xi-\vartheta} < \bar{X}_I^{\xi-\vartheta}$, which is clearly the case since $X < \bar{X}_I$ at time zero. Optimization, of course, implies that exercise will take place at different threshold levels under the two different organizational forms (i.e., $\bar{X}_I \neq \bar{X}_S$), which, as we will see, increases the wedge in option values between the two organizational forms.

The differences in option values for the two organizational forms are driven by interactions among the firms' strategic decisions, i.e., mainly their coupon choices and their selected investment thresholds. Coupon choices will be different across the two cases because the integrated firm will issue debt immediately following the organizational design choice at time zero, which reflects both the debt capacity of assets in place and the expected debt capacity of the assets created upon exercise of the growth option; while the large firm in the nonintegrated case will consider only the debt capacity of assets in place. In both cases, however, the firms consider possible future reductions in the debt capacity of assets in place due to cannibalization or obsolescence. In addition, the firms' capital structure choices influence option value strongly by affecting the optimal exercise trigger (with a delay due to the debt overhang resulting from the inability to commit to an exercise time up front in the integrated case, but not in the nonintegrated case), and also weakly by differences in how default by the owner of the assets in place affects the value of the option (default by the existing firm destroys the option in the integrated case, but has no effect in the nonintegrated case).[14] Notably, exercise timing affects option value directly, but also affects assets in place value through cannibalization, which is taken into account by the integrated firm in choosing its exercise threshold, but not by the small firm in the nonintegrated case.

4. Results and Implications

To illustrate some of the model's results and implications in more detail, we now provide a number of numerical solutions in which we determine which organizational form maximizes the joint time zero value of the two corporate activities. In particular, we compare the time zero value of the firm in the integrated case with the sum of the time zero values of the two firms in the nonintegrated case, and assume that the form with the higher value is chosen in equilibrium. Since there is no asymmetric information, and as long as ex ante transfers are possible, this exercise will predict actual organizational form choices in the model (though how the equilibrium form is arrived at, i.e., through spin-off, sale, or merger, will depend on where the property right to the growth option resides ex ante). Also note that since we assume no debt financing prior to time zero, there is no need to consider whether equity value should instead be maximized at time zero. Our main focus in this section is on the role played by competitive forces, risk types, and capital structure determinants.

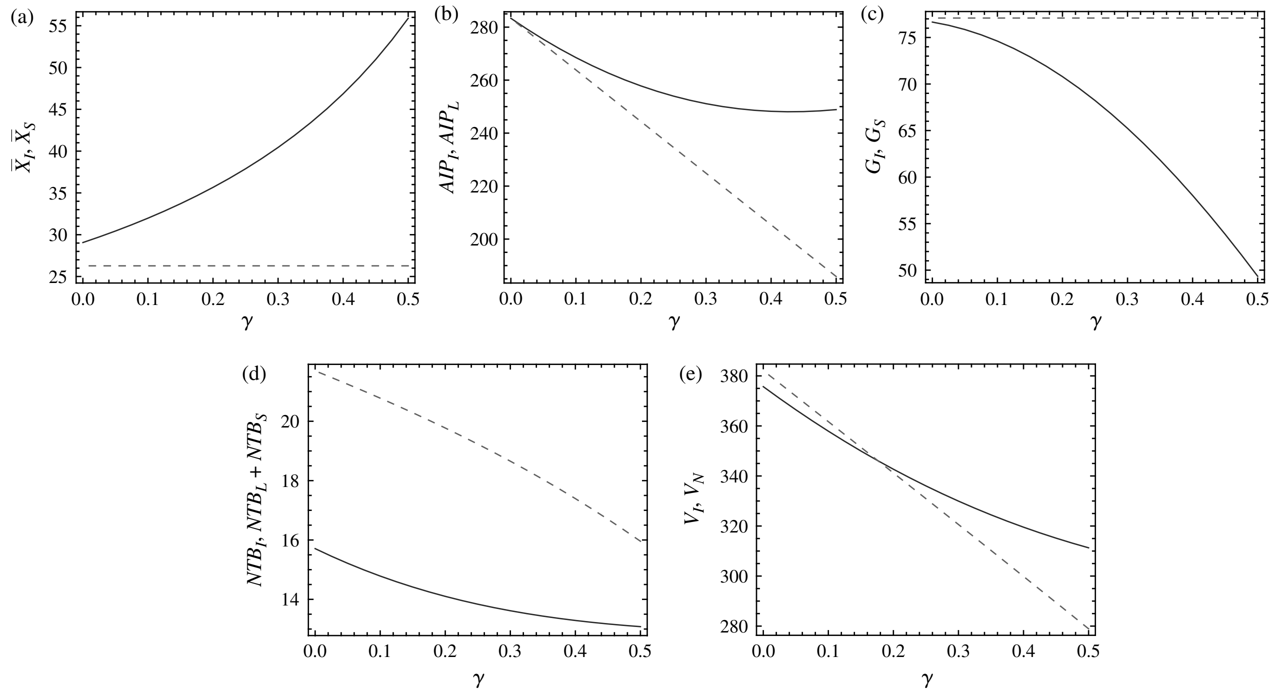
4.1. Cannibalization Implications

We start by considering the effect of the cannibalization cost parameter, γ, in a baseline environment in which cash flows start at $X = \$20$, the risk-free interest rate is $r = 7\%$, the growth rate of cash flows is $\mu = 1\%$, the volatility of cash flows is $\sigma = 30\%$, the risk of obsolescence is $\rho = 10\%$, the corporate tax rate is $\tau = 15\%$, the proportional cost of bankruptcy is $\alpha = 30\%$, the investment factor is $\pi = 100\%$, the investment cost is $\kappa = \$225$, and the preemption cost is $\delta = 0\%$. These base case parameter choices are similar to other recent studies, such as Morellec and Schuerhoff (2011) or Hackbarth and Mauer (2012). Although they can be motivated in more detail, we omit this for the sake of brevity. Moreover, similar to Schaefer and Strebulaev (2008), we examine entire ranges of reasonable parameter values, which reveals that the model's results and implications vary only quantitatively but not qualitatively with parameter values.

In each equilibrium configuration, the total joint value of corporate activities can be broken down into three main categories: the cash flow value of assets

[14] The loss of the option in default introduces an element of default risk in the option value for the integrated case. However, this is not a significant driver of any of our results. Intuitively, while relaxing this assumption would, all else equal, increase option value for the integrated firm, in equilibrium the firm will also issue additional debt and incur greater overhang costs, mitigating the increase.

Figure 1 The Effect of Cannibalization Cost, γ, on Optimal Exercise Times and Values



Note. The solid lines correspond to the integrated form, and the dashed lines correspond to the nonintegrated form.

in place, the cash flow value of the growth option, and the value of net tax benefits (i.e., tax shields less expected costs of financial distress). The organizational form that best balances these three sources of value will be optimal.

First consider a case when the cannibalization cost, γ, is close to zero. In this case the exercise of the growth option has little effect on the value of assets in place. Since the existing firm has significant cash flows from assets in place, it will be optimal to carry a significant amount of debt. However, because of the well-known debt overhang effect, the existence of this debt in the integrated case will significantly alter the firm's chosen exercise policy. In particular, since equity holders cannot commit ex ante to a firm-value-maximizing exercise policy, they will tend to exercise "too late" as some of the value of option exercise will confer to debt holders. In turn, anticipating this effect, the firm will issue less debt, reducing the value of net tax benefits. On the other hand, in the nonintegrated form the option exercise time is chosen in an environment that is independent from the assets in place and resulting agency conflict with debt holders, and thus does not suffer from this commitment problem. It is therefore likely that the nonintegrated organizational form maximizes the value of the growth option. In addition, the large firm does not have to reduce its debt level to avoid the overhang effect, which increases the value of net tax benefits related to assets in place. Further enhancing this effect is the fact that the small firm in the nonintegrated case will be able to choose an optimal debt level for the new assets at the time of exercise. Thus, nonintegration is likely to best balance the three sources of value, namely the values of assets in place, growth option, and net tax benefits.

Now consider an increase in γ, which causes the timing of exercise to start having a significant effect on the value of assets in place. In this case an element of joint profit maximization becomes important in balancing the value of the growth option against the value of assets in place. Since the small firm in the nonintegrated case ignores this effect (i.e., there is no joint profit maximization by design), the small firm's exercise policy imposes increasingly larger costs on the large firm's assets in place value as γ rises. Thus, there exists in general a cutoff level of gamma, say γ^*, such that integration will be the optimal organizational form for $\gamma > \gamma^*$, and nonintegration will be optimal for $\gamma < \gamma^*$.[15]

To see the effect of γ quantitatively, consider Figure 1. Panel (a) of Figure 1 graphs the optimal exercise time for each organizational form (the solid line in all

[15] This conjecture is borne out in every numerical solution we have attempted. Note, however, there may be parameterizations where no $\gamma^* \le 1$ exists because the growth option is so valuable relative to the assets in place (e.g., when π is very high). Such cases represent "corner" cases where the growth option is so valuable that the existing business would be immediately sacrificed if necessary. We do not focus on such cases as the organizational design decision becomes trivial.

figures corresponds to the integrated form, whereas the dashed line corresponds to the nonintegrated form) as a function of γ given the base parameters provided above. Note that the optimal exercise time in the nonintegrated case is invariant to γ—the small firm ignores the effect of its exercise on the large firm's assets in place. Also, as expected, the integrated firm responds aggressively to changes in γ, exercising much later when the cannibalization effect is larger.

Panel (b) of Figure 1 graphs the time zero value of assets in place as a function of γ. Consistent with the results in panel (a), the value of assets in place is much more sensitive to γ in the nonintegrated case since the small firm's exercise policy does not react, and the assets in place are subjected directly to changes in cannibalization. In the integrated case the firm's optimal tradeoff between the value of the option and the value of assets in place dampens the relationship. Overall, the gap in assets in place value between the two forms grows quickly as γ rises.

Panel (c) of Figure 1 graphs the option value as a function of γ. Consistent with panel (a), in the nonintegrated case the option value is insensitive to γ (the time of exercise is the main variable that affects option value). However, in the integrated case option value is highly sensitive to γ as the exercise time also accounts for cannibalization. In particular, option value in the integrated case rises quickly as γ becomes smaller since concerns about cannibalization diminish and hence the exercise policy gets closer to the nonintegrated case.

Panel (d) of Figure 1 graphs the time zero value of tax shields less bankruptcy costs. Net tax benefits are higher in the nonintegrated case since capital structure for the new assets is set at the time of option exercise and the large firm can optimize its own capital structure without concern for debt overhang, which best maximizes the associated net tax benefits. The difference between the curves is not particularly sensitive to changes in γ (relative to the sensitivity of assets in place value and growth option value), and therefore does not contribute much to the comparative static.

Finally, panel (e) of Figure 1 compares total time zero value of the two projects across the different organizational forms (i.e., it is the sum of assets in place value, option value, and value of net tax benefits from the three prior graphs). As discussed above, the two curves cross at the critical cannibalization value $\gamma^* \approx 17.5\%$ with integration being optimal for all higher γ and nonintegration being optimal for all lower γ. In comparing the three prior graphs, it is clear that this is being driven mainly by relative changes in assets in place and option values since the two organizational forms place relatively more/less weight on jointly or separately optimizing assets in place and option values. For high γ integration best protects assets in place value, whereas for low γ this effect is less important, and the greater option value and net tax benefits of the nonintegrated form dominate.

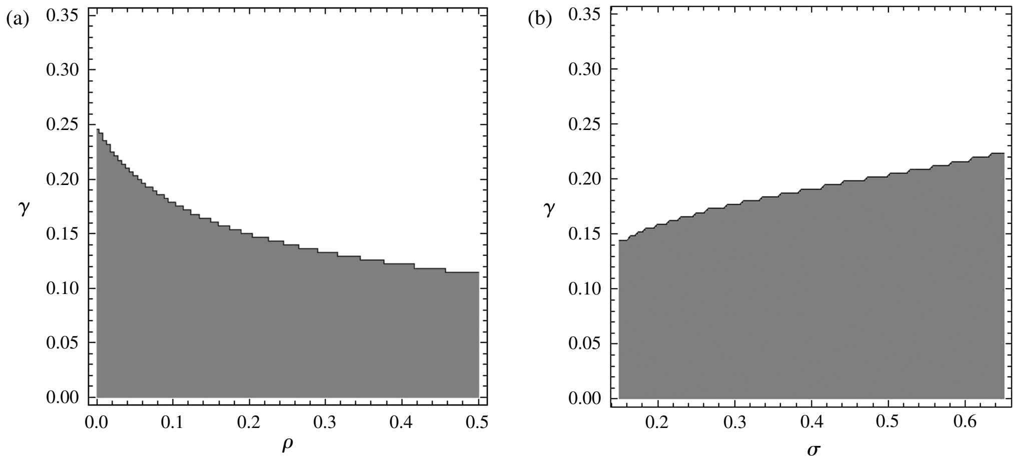
As noted in the introduction, the model is designed to deliver this central trade-off, so qualitatively these results are not surprising. From a quantitative perspective, though, it is worth noting from panel (e) that organizational form choice has a significant effect on overall firm value, in particular around 10% for large γ, and between 1% and 2% at $\gamma = 0$. Furthermore, since the organizational form choice concerns how to best operate the growth option in particular, it is perhaps more appropriate to compare these gains to the value of the new product market opportunity by itself. For example, at $\gamma = 0$ the increase in firm value from choosing nonintegration is around 8% of the value of the growth option, whereas at $\gamma = 0.5$ the gain from choosing integration is around 40% of the value of the growth option under nonintegration. In addition to these quantitative implications, the basic tradeoff developed here provides a useful foundation from which to explore the more subtle and unique comparative statics discussed below.

4.2. Risk Implications

To investigate the effects of other parameters on the organizational design choice, we use the clear-cut γ^* result as a baseline characterization of the solution, and study the comparative statics of γ^* with respect to the remaining parameters. First consider ρ, which measures the risk of obsolescence, and σ, which measures the underlying uncertainty of the cash flows. Figure 2 provides two equilibrium "maps" that plot the optimal organizational form as a function of γ and obsolescence risk ρ (panel (a)), or γ and cash flow risk σ (panel (b)), holding all other parameters constant at their base levels. In this and all proceeding figures, the shaded area of each map represents the part of the parameter space for which nonintegration is the optimal organizational form, and the white part of the map represents that part where integration is optimal.

First consider panel (a) of Figure 2. The existence of the cutoff γ^* is clearly verified for all ρ considered in the map, from zero to 50%. There is also a clear effect that γ^* is monotonically decreasing in ρ. In other words, integration is more likely to be optimal at high ρ than at low ρ. This is partially because an increase in ρ reduces the value of the growth option, and protecting its value becomes relatively less important. However, because of the model's dynamics, this is not a complete explanation. To understand more deeply, first consider the optimal exercise policy as ρ increases. As the probability of obsolescence becomes higher, the firm holding the growth option must speed up exercise significantly to maintain the value of the option. The small firm in the nonintegrated case always exercises sooner than the integrated firm, which waits to avoid excessive cannibalization and because of debt overhang.

Figure 2 Equilibrium Maps Showing the Optimal Organizational Form as a Function of Parameters ρ and σ Holding All Others Constant

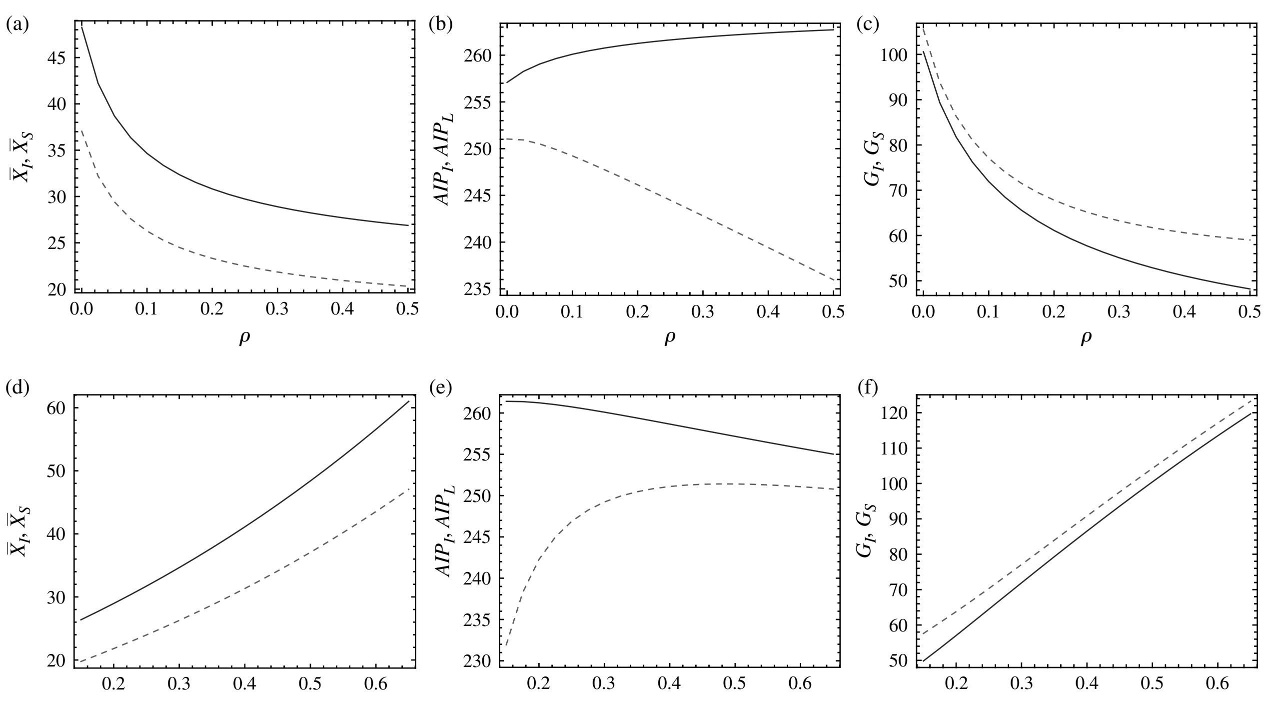


Note. Nonintegration is optimal in shaded regions.

See panel (a) of Figure 3 for an illustration of this effect when $\gamma = 0.175$. Note that the exercise times in the two cases decrease in ρ similarly, but the small firm in the nonintegrated case always exercises significantly earlier than the integrated firm.

Now consider panel (b) of Figure 3, which plots assets in place value as a function of ρ. Recall that assets in place value will be higher the longer the owner of the option waits to exercise because of a lower realized cannibalization effect, and thus the value of assets in place will always be higher in the integrated case (the solid line is always higher than the dashed line). More importantly, though, note that the gap in the value of assets in place grows significantly as ρ rises despite the fact that the difference in exercise times does not grow very quickly. This is because the value of assets in place is increasing and concave in the exercise time—i.e., the delay caused by moving from the nonintegrated to the integrated form has a much stronger impact on assets in place value when the exercise time is sooner (closer to the initial value of X). Panel (c) of Figure 3 shows the effect of ρ on option value. Clearly, as ρ rises, so does the spread in option values between nonintegration and integration, as the

Figure 3 The Effect of Obsolescence Risk, ρ, and Cash Flow Risk, σ, on Optimal Exercise Times, Growth Option Values, and Assets in Place Values



Note. The solid lines correspond to the integrated form, and the dashed lines correspond to the nonintegrated form.

importance of optimal exercise timing is magnified in present value terms when exercise occurs sooner.[16] Overall, though, the effect of ρ on assets in place value is more important than its effect on option values, and as a result the integrated form is more likely to dominate at high ρ values as its ability to better preserve assets in place value becomes more important. Put another way, although it would be better to choose nonintegration to speed up exercise in the face of increased competition when the value of the option is considered in isolation, it turns out that this strategy maximizes the negative impact of the small firm's disregard for assets in place value. Thus, the concern for assets in place value overturns the simple intuition that one should choose the organizational form that will be most responsive to the increase in competition.

The result that nonintegration is more likely when obsolescence risk is lower may seem somewhat counterintuitive, as many argue that small firms are better able to respond in highly dynamic markets. This may be true, but our results indicate that when the source of high uncertainty is the risk of obsolescence due to preemptive product introduction by third parties, a small firm's behavior may impose excessive costs on incumbent firms, so that it could be optimal for them to be absorbed by existing players in the market despite the negative impact on their own value. The resulting empirical implication is then that new product market opportunities are more likely to be exploited by specialized, small firms when the new products are so novel that obsolescence is unlikely, but new opportunities that are more aggressively contested by competitors might be more often implemented within existing firms. This is not because the existing firm is more able to invest aggressively to ward off competition (which may also be true; see, e.g., Mathews and Robinson 2008), but because the incumbent firm's own assets are better protected.

Second consider panel (b) of Figure 2. Again, the existence of the cutoff γ^* is verified for all values of σ, the volatility of cash flows. Also, γ^* again varies monotonically but this time is clearly increasing in σ. To understand this, consider the effect of increasing σ on the growth option. Since σ is a standard measure of cash flow volatility, real option theory tells us that as σ rises the option's value increases, and exercise should occur later (see panel (d) of Figure 3 for an illustration). In contrast to ρ an increase in σ increases the value of the growth option and makes it relatively more important to focus on optimizing its value. Again, though, because of the model's dynamics this is not a complete explanation. The fact that exercise now optimally occurs later means that higher σ states will be those where the small firm's earlier exercise choice (because of the lack of debt overhang and lack of concern for cannibalization) has less of a negative impact on the value of assets in place (since, as noted above, assets-in-place value is concave in exercise time). Thus, assets in place are worth more in the nonintegrated case in relative terms at higher σ, implying that nonintegration is more likely to be optimal in environments with greater underlying cash flow risk (see panel (e) of Figure 3 for an illustration—and note from panel (f) of Figure 3 that the effect on option value is again much smaller). This is consistent with the conventional wisdom that small firms are nimbler in uncertain environments.

These results imply an interesting dichotomy wherein the effect of risk on organizational design depends strongly on the type of risk being considered. Whereas greater cash flow risk, such as uncertainty about market size, favors the operation of new product market opportunities in independent firms, greater obsolescence risk instead favors the operation of such projects within existing larger firms. This dichotomy should prove useful for empirical investigations of why new opportunities tend to be exploited in different organizational structures across different markets and/or time periods. Also note that since these results arise from differences in exercise timing decisions across the different organizational forms, they could not be derived in a static model.

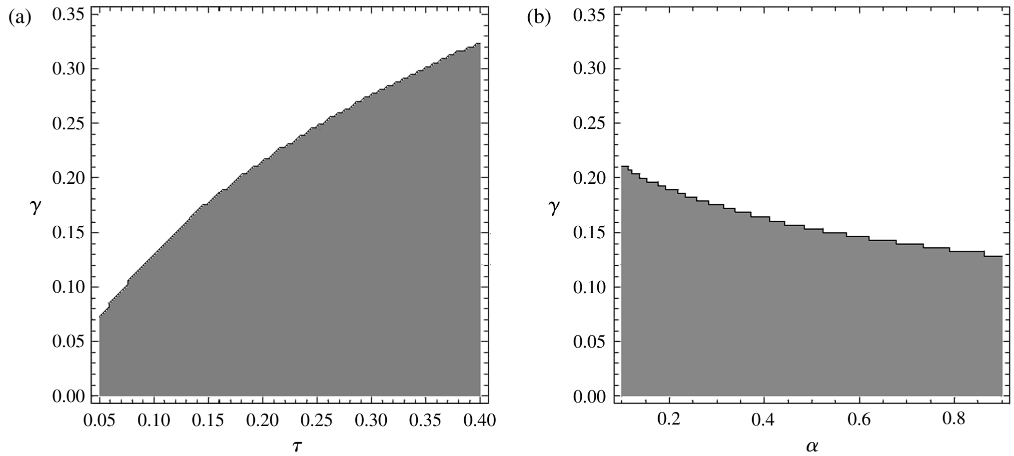
4.3. Capital Structure Implications

Next consider the two parameters that most directly measure the importance of capital structure effects, namely, τ, the corporate tax rate, and α, the magnitude of bankruptcy costs. Figure 4 provides equilibrium maps for these parameters. First consider panel (a) of Figure 4. Here there is a very clear pattern in that γ^* increases quickly in τ. An increase in τ clearly has multiple effects—it directly reduces after-tax cash flows, while it at the same time makes capital structure decisions and their associated value implications more important. The fact that the nonintegrated form becomes more dominant as τ rises comes mostly from the latter effect. Specifically, the net tax benefits of debt rise faster in τ for the nonintegrated form than for the integrated form, because the nonintegrated form is better able to utilize the debt capacity of the growth option (i.e., instead of having to make a decision based on expected cash flows, it can make the decision based on actual cash flows at the time of issuance).

Next consider panel (b) of Figure 4, which shows the effect of the bankruptcy cost parameter, α. Here, γ^* is decreasing in α. The effect of α is more straightforward

[16] Note that this goes in the opposite direction of what might be expected based on exposure to default risk. Since nonintegration removes default risk from option value, and default risk tends to be more important when exercise is delayed due to longer exposure, one might expect that nonintegration would be particularly helpful for preserving option value when obsolescence risk is low. However, this turns out to be a second-order effect.

Figure 4 Equilibrium Maps Showing the Optimal Organizational Form as a Function of Parameters τ and α Holding All Others Constant



Note. Nonintegration is optimal in shaded regions.

than the effect of τ since there is no confounding effect on overall profitability—i.e., α impacts only the firm's net tax benefits. The direction of the effect has essentially the same intuition as the effect of τ, in that greater bankruptcy costs decrease the importance of net tax benefits as a source of value, and since protecting that value was one reason for choosing nonintegration, that choice is less likely to be optimal when the available value shrinks. If one considers bankruptcy cost magnitude to be related to the physical versus human capital intensity of an industry, then this implies that in more physical-capital intensive industries new ideas are more likely to be exploited by small, specialized firms, while in more human-capital intensive industries they are more likely to exploited within large firms.

Unlike the tax rate, bankruptcy costs do not directly affect cash flows, and hence variations in α provide a better gauge for how debt overhang influences organizational design. All else equal, lower bankruptcy costs imply higher optimal coupon payments, and they produce on the margin more overhang costs that are a disadvantage of integration. Consistent with this intuition, the critical cutoff γ^* increases at an increasing rate when α declines (i.e., nonintegration is also more likely for lower bankruptcy costs because they are associated with higher debt overhang costs under integration).

4.4. Additional Implications

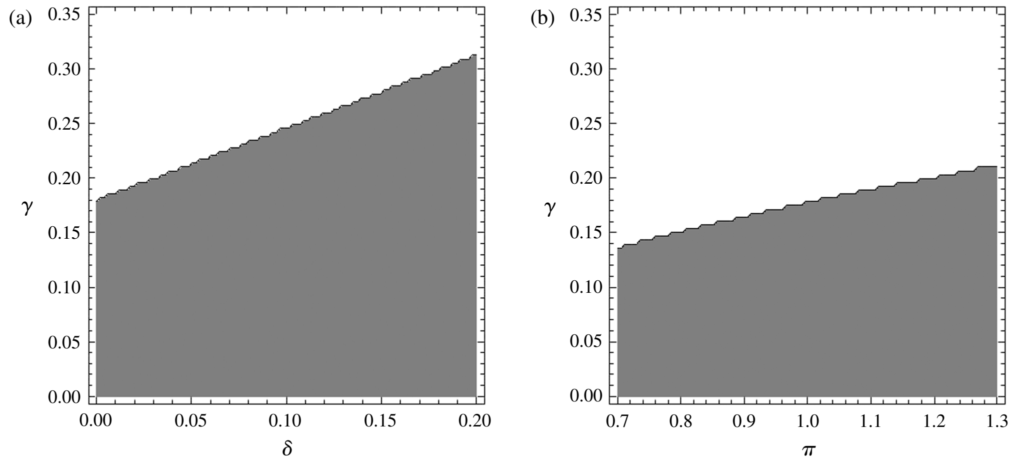
In the base case, for simplicity we assume that when the growth option becomes obsolete, there is no preemption cost for the assets in place (i.e., $\delta = 0$). Panel (a) of Figure 5 provides an equilibrium map showing the effect of including a preemption cost due to the operation of a competing asset by a third- party firm (or firms).

The map shows that the cutoff for the cannibalization cost parameter, γ^*, grows as the preemption cost parameter becomes significant (δ rises). In other words, nonintegration is more likely to be optimal when obsolescence imposes a large preemption cost on the assets in place. To understand this, first consider starting from the base case of $\delta = 0$. In this case, the integrated firm will clearly exercise later than the nonintegrated firm because of debt overhang and the desire to avoid the cannibalization cost (γ). Thus, in relative terms the nonintegrated form imposes a significant cost on the value of assets in place, while the integrated form imposes a significant cost on option value. However, as δ becomes larger, the integrated firm starts exercising the option earlier to avoid the preemption cost (it is better to get the benefits of investment, π, despite the cannibalization cost, γ, than to suffer the preemption cost, δ, with no offsetting payoff), whereas the small, nonintegrated firm's exercise time remains the same as it ignores the effect of δ on the assets in place. This brings the exercise times closer and shrinks the gap in assets in place and option values, with the former having a larger effect. Intuitively, as the exercise times converge, the desire to integrate to protect assets in place value disappears, and nonintegration is more likely to be chosen to exploit its greater financial flexibility.

The size of the growth option's payoff relative to assets in place, π, also influences optimal organizational form. Panel (b) of Figure 5 provides the relevant equilibrium map. As expected, the larger is π the more likely it is that nonintegration is optimal, as this form best protects the value of the option and its associated net tax benefits, which become more important as π grows.

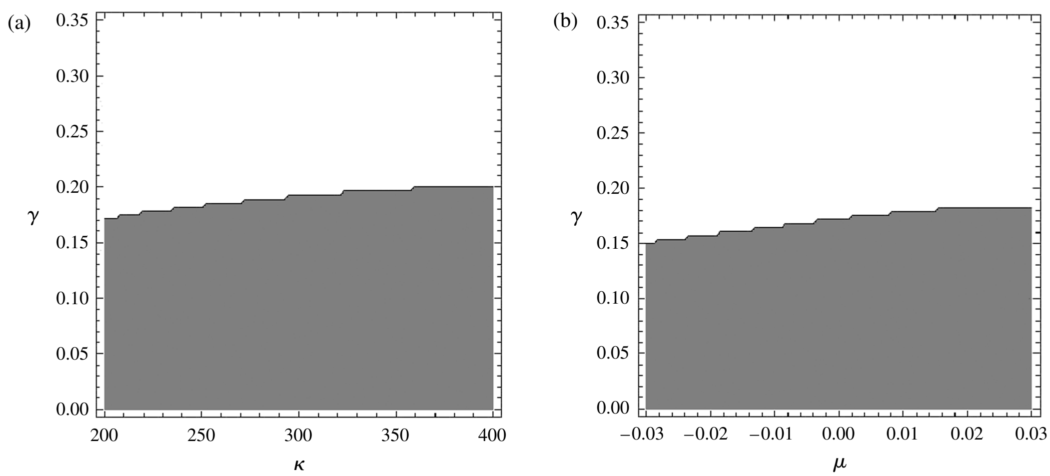
Finally, Figure 6 provides equilibrium maps for the investment cost, κ, and the growth rate, μ. Although the effects are not large, nonintegration is more likely to be optimal the higher are both κ and μ. A higher κ value makes the owner of the option wait longer

Figure 5 **Equilibrium Maps Showing the Optimal Organizational Form as a Function of Parameters δ and π Holding All Others Constant**



Note. Nonintegration is optimal in shaded regions.

Figure 6 **Equilibrium Maps Showing the Optimal Organizational Form as a Function of Parameters κ and μ Holding All Others Constant**



Note. Nonintegration is optimal in shaded regions.

to exercise in either organizational form, and because of the concavity of the value of assets in place with respect to the exercise date, the value of those assets rises faster with κ in the nonintegrated case. An increase in μ not only enhances the option payoff, which makes maximizing pure option value more important, but it also induces the owner of the option to exercise it sooner because the opportunity cost of waiting increases with the larger rate of forgone cash flows, which leads to higher costs of cannibalization. In addition, however, a higher μ raises the value of assets in place and hence induces the integrated form to optimally issue more debt at time zero, which increases the cost of debt overhang. Taken together, these effects produce a γ^* profile that increases with μ.

5. Financial Alliances

Thus far, we analyze two possible organizational designs, complete integration or complete nonintegration. In reality, there are a multitude of possible organizational design choices with these two arrangements at either end of a continuum, and hybrid forms such as joint ventures and alliances in between. It is therefore natural to ask whether such a hybrid form could dominate the two extreme forms considered above. In this section we consider one particular such hybrid form, defined by a contractual arrangement between two separate organizations, which we refer to as a financial alliance to distinguish it from other possible types of alliances.[17]

A defining characteristic of many joint ventures and alliances is a contract that specifies the rights of each involved party with respect to exploiting any new products arising from the relationship. For example, contracts may specify rights to market new products in specific geographical regions or in particular forms.

[17] For example, a strategic product market alliance could be an arrangement that has a direct controlling effect on the extent of cannibalization, γ, which it could be natural to assume might vary across different organizational forms.

These agreements often come in the form of licensing arrangements. In the context of our dynamic model, such arrangements are particularly interesting because they will likely affect the parties' incentives with respect to both option exercise and capital structure. We thus investigate whether a licensing-type contract between two separate organizational forms can help in providing a superior trade-off between the three sources of value in our setting: assets in place value, pure growth option value, and net tax benefits.

To model the alliance, it is easiest to start from our model's nonintegrated case. In this context, a financial alliance involves a licensing contract that stipulates a proportion, l, of the future cash flows of the growth option that are pledged to the large firm. We assume that the small firm retains full decision rights over option exercise timing and its own capital structure, as well as full responsibility for funding the exercise cost. Intuitively, siphoning off more of the benefit from exercising the option to the large firm will cause the small firm to exercise later, which helps protect the value of assets in place. Furthermore, since the small firm retains the right to choose the exercise time, this arrangement avoids imposing the cost of debt overhang that would arise with a switch to a fully integrated form. Thus, as with the nonintegrated form, the integrated firm's commitment problem is solved, but joint profit maximization can be maintained. On the other hand, the delay in exercise timing will decrease the pure value of the growth option. The licensing contract also affects net tax benefits since the small firm will optimally take on less debt at exercise, while the large firm will take on more debt at time zero in anticipation of receiving the extra cash flows in the future. This will tend to result in a lower overall value of net tax benefits since the contract moves the cash flow allocation more toward the integrated form, which inherently has less capital structure flexibility. Thus, the optimality of such a licensing contract depends on whether the two benefits (protecting assets in place value and avoiding overhang costs) can outweigh the two costs (reduced growth option value and net tax benefits).

Re-solving the model with the parameter l is straightforward. In the valuation equations for the small firm in §3.1, every instance where the parameter π appears would be changed to $(1-l)\pi$. For example, the small firm's postexercise value, previously given by (2), becomes

$$V_S^+(X;l) = (1-l)\pi\Lambda X + \frac{\tau C_S^+}{r}\left(1-\left(\frac{X}{\underline{X}_S^+}\right)^{\vartheta'}\right) - \alpha(1-l)\pi\Lambda \underline{X}_S^+\left(\frac{X}{\underline{X}_S^+}\right)^{\vartheta'}, \quad (45)$$

while its objective function remains the same since it funds the entire exercise cost, κ,

$$V_S(X;l) = \sup_{\mathcal{T}_G} \mathrm{E}[1_{\mathcal{T}_G<\mathcal{T}_Y} e^{-r\mathcal{T}_G}(V_S^+(X_{\mathcal{T}_G};l)-\kappa)]. \quad (46)$$

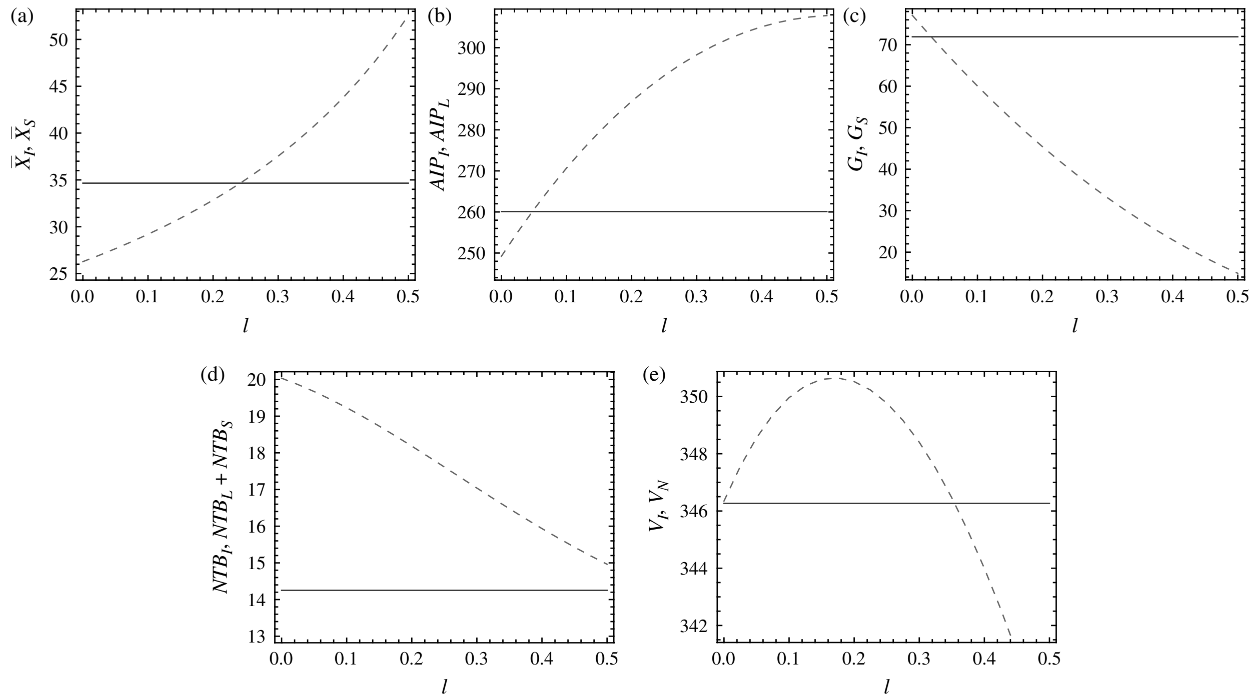
Similarly, in the large firm's valuation equations in §3.2, the cannibalization cost γ is changed to $\gamma - l\pi$ since the extra cash flows to the large firm following option exercise occur in exactly the same states as the reduction in cash flows due to cannibalization (and thus can equivalently be seen as an adjustment to the cannibalization parameter from the large firm's perspective).

5.1. Effect of Alliances

To illustrate the impact of the licensing parameter l, we first solve the model at the same base parameters used previously, and investigate the impact on decisions and values as l is adjusted (thinking of l as an exogenous parameter for now). Panel (a) of Figure 7 plots the small firm's optimal exercise timing as a function of l (represented by the dashed line). Note that this and all remaining panels of the figure also show the equivalent value for integration (represented by the solid line), under which decisions and values are not affected by l. As expected, and as seen analytically after replacing π by $(1-l)\pi$ in Equation (14), increasing the proportion of cash flows l given to the large firm delays the small firm's exercise. This will clearly increase the value of assets in place (see panel (b) of the Figure 7) which, as noted previously, is increasing and concave in exercise time. At the same time (panels (c) and (d) of Figure 7), the value of the growth option and of total net tax benefits falls. Panel (e) puts all these effects together and shows that overall joint firm value is initially increasing in l as the effect on assets in place dominates, but at some point the erosion of option value and net tax benefits becomes dominant. As a result, joint value is a concave function of l (a result that appears in every parameterization we have used). This implies that there will generally exist an optimal licensing proportion, l^*, that best balances the benefits and costs of the alliance. With our base parameters, choosing an optimal licensing proportion (as opposed to one of the pure organizational forms) raises firm value by 6%–10% of the value of the growth option (depending on which growth option value is used as the basis).

Since a licensing proportion of $l=0$ is the same as our nonintegrated case, the existence of an interior optimum licensing proportion implies that a financial alliance will generically be preferred to straight nonintegration. However, it might or might not induce better joint profit maximization than the integrated form. In particular, an optimally structured financial alliance will clearly dominate the integrated form in cases where nonintegration was already optimal (i.e., the shaded regions of the equilibrium maps above). In addition, our numerical solutions show that a financial

Figure 7 The Effect of the Licensing Proportion, *l*, on Optimal Exercise Times and Values



Note. The solid lines correspond to an integrated firm, and the dashed lines correspond to an alliance of two nonintegrated firms.

alliance with the optimal licensing proportion can often dominate integration even in the nonshaded portions of the equilibrium maps in the previous section.

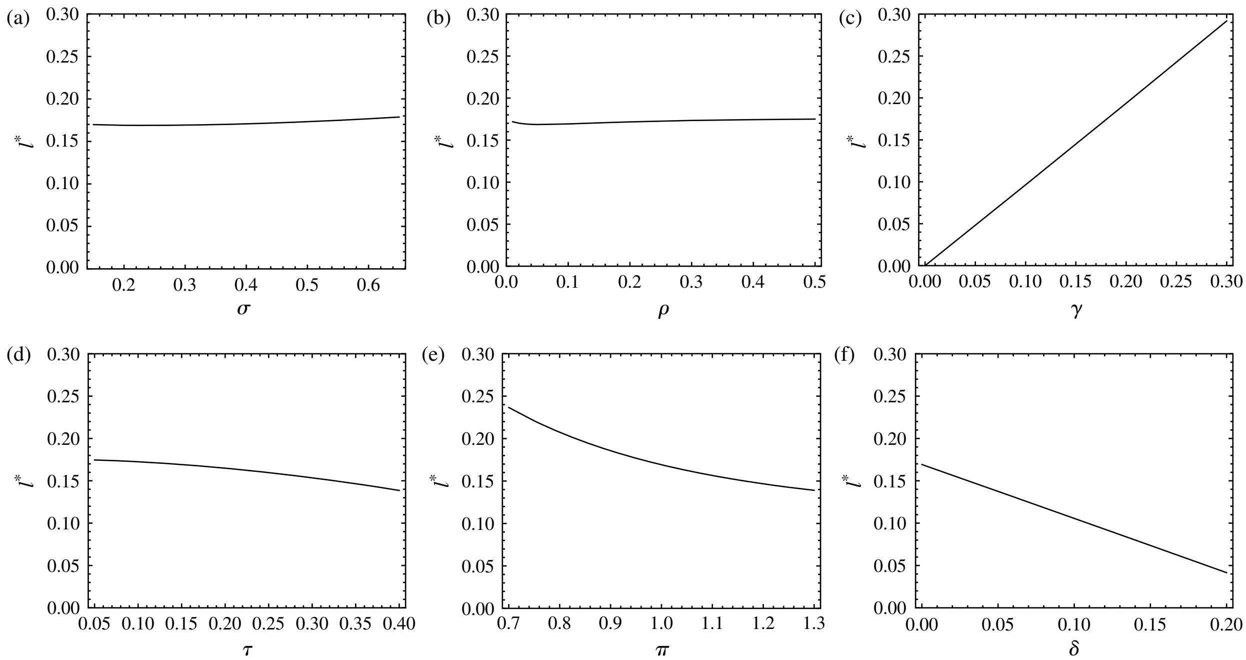
5.2. Optimal Alliances

We next investigate how the optimal licensing proportion, l^*, varies with other parameters, which provides empirical implications for studies of alliance structuring. Figure 8 plots the optimal licensing fraction against our key risk parameters as well as four other parameters that have been found to have the greatest influence. To understand these comparative statics, first recall that a financial alliance as modeled here is a hybrid organizational form between the extremes of nonintegration and integration. One of the key differences between these extremes arises from the differing allocation of control over the option exercise timing. When the small firm has control, it tends to exercise sooner to maximize option value; when the large firm has control, it tends to exercise later due to debt overhang and a desire to protect the value of assets in place. The licensing contract modeled here serves to "bridge the gap" between these two extremes by coordinating on an intermediate exercise time. Thus, optimal alliance structuring trades off the benefit of being able to "fine-tune" the exercise time to protect assets in place value versus the loss of option value and capital structure benefits (i.e., flexibility) if the licensing proportion gets too large. Based on this tradeoff, a higher (lower) l^* follows from a greater (lesser) desire to protect assets in place or a greater (lesser) desire to preserve option value and net tax benefits. Put differently, any parameter change that would push toward integration (nonintegration) in the base case analysis will generally imply a higher (lower) l^* for the financial alliance, since the underlying trade-off is the same.

Panels (a) and (b) of Figure 8 show the effect of cash flow risk, σ, and obsolescence risk, ρ. In contrast to the results above where these parameters had strong and opposite effects on the cutoff cannibalization level γ^*, they here have similar, and very minor, effects on the optimal alliance contract, l^*. To understand this, note that changes in both σ and ρ will have similar effects on growth option value and exercise policy no matter who controls the option. In particular, an increase in σ increases the value of the option and induces later exercise times whether the option is controlled by the small firm (as in the nonintegrated case), or by the large firm (as in the integrated case). Since these exercise times move together with changes in σ, and the gap between the optimal exercise times from the two firms' perspectives does not change much, the optimal licensing proportion (which, as noted above, is essentially set to ameliorate this gap) is not significantly changed. Similarly, an increase in ρ tends to reduce option value and induce earlier exercise times no matter who controls the option, without significantly changing the size of the gap in exercise times.

We next consider the four parameters that have the greatest impact on the optimal l. Panel (c) of Figure 8 shows the effect of the cannibalization cost, γ. Unsurprisingly, the larger is γ, the larger is the optimal

Figure 8 **The Effect of Cash Flow Risk, σ, Obsolescence Risk, ρ, Cannibalization Cost, γ, the Corporate Tax Rate, τ, the Size of the Growth Option, π, and Preemption Cost, δ, on the Optimal Licensing Proportion, l^***



licensing proportion. As the cannibalization effect of option exercise grows, it becomes more important to protect the value of assets in place, which is accomplished by pushing the exercise time more toward that resulting from joint profit maximization of the large firm in the integrated case. A larger licensing proportion accomplishes exactly that, i.e., it moves the hybrid organizational form closer to integration and therefore better protects the value of assets in place.

Panel (d) of Figure 8 shows the effect of τ, the corporate tax rate. The larger is τ, the smaller is the optimal licensing proportion. As τ grows, capital structure effects become more important, which tends to favor nonintegration over integration due to its greater capital structure flexibility. In addition, the exercise threshold increases with τ and hence protecting the large firm's assets in place is less important. Taken together, an increase in τ makes the negative effect of licensing on net tax shield value more important, and thus the alliance is optimally pushed more toward the nonintegrated form by choosing a lower licensing proportion.

Panel (e) of Figure 8 studies the size of the growth option, π. Clearly, an increase in π decreases the optimal licensing share. The logic here is based again on the relative importance of protecting assets in place versus preserving option value: as π increases it becomes relatively more important to preserve option value because the firm's assets in place are normalized to one, so again the alliance is optimally pushed more toward the nonintegrated form by choosing a lower licensing proportion. Put another way, since a move toward the integrated form with a larger l erodes option value by pushing the exercise time later, a lower proportion is chosen despite the cost to assets in place value.

Panel (f) of Figure 8 shows the effect of preemption cost, δ. In this case, the optimal licensing proportion falls as δ rises. As δ becomes large, the large firm prefers earlier exercise times to avoid experiencing the preemption cost with no offsetting cash flows, so the small firm's bias toward an early exercise time becomes more in line with joint profit optimization. In other words, the change in δ does not affect the optimal exercise time in the nonintegrated case, but it makes it significantly earlier in the integrated case, so a smaller l is sufficient to optimally bridge the gap between these preferred times.

6. Extensions

In this section, we discuss some of the assumptions we have made for clarity or tractability. In some cases, our motivation is to examine the robustness of model's results quantitatively or qualitatively. In others, extending the analysis implies additional results, which are left for future research.

6.1. Alternative Financing Arrangements

As has been noted, one might be tempted to conclude that the nonintegrated form often dominates the integrated form largely because it has inherently more capital structure flexibility in our base case analysis. It is therefore natural to examine the extent to which design choices and resulting comparative statics results depend on the assumption that the integrated form cannot issue debt at the exercise time of the growth option. To address this, we have analyzed the effect of an alternative financing arrangement in the integrated case, in which the integrated firm is able to follow a similar capital structure policy as the small, nonintegrated firm at the time of option exercise. Specifically, at the time of option exercise in the integrated case we grant the integrated firm the option to recapitalize with respect to the new collateral pool from the option (i.e., π), but not with respect to the existing collateral pool that we normalized to one (i.e., assets in place). In addition to the time zero debt with coupon C_I, we assume the integrated firm issues a second, time $\mathcal{T}_G$ debt tranche with coupon payments C_I^+ specified as in (6). Specifying this amount of debt (i.e., the amount that would be chosen by an all-equity stand-alone firm for this set of assets at the time of exercise) gives the integrated firm a limited measure of flexibility that most closely matches the flexibility advantage enjoyed by the small firm in the nonintegrated case. The details of this analysis, which shows that the main qualitative results of the paper are unchanged, are available in Online Appendix D.

6.2. Alternative Licensing Contracts

Note that an alternative alliance contract could specify a fee paid to the large firm by the small firm at the time of exercise.[18] To model this alternative licensing agreement, it is again easiest to start from our model's nonintegrated case. In this context, a financial alliance involves a fee contract that stipulates an exercise fee, l, that is paid to the large firm at the time of exercise. The small firm's postexercise value, $V_S^+(X)$, is given by (2), but its objective function changes, because it also incurs the fee payment in addition to the exercise cost:

$$V_S(X; l) = \sup_{\mathcal{T}_G} \mathrm{E}\big[1_{\mathcal{T}_G<\mathcal{T}_Y} e^{-r\mathcal{T}_G}(V_S^+(X_{\mathcal{T}_G}) - l - \kappa)\big]. \quad (47)$$

As a result, the large firm's valuation equations in §3.2 contain an additional term, l. Intuitively, it reflects compensation by the small firm for the large firm's cannibalization cost.

Like the specification considered in §5, a fee paid by the small firm upon exercise has the effect of fine-tuning the small firm's exercise decision. It may also distort capital structure decisions less than the licensing alliance analyzed in §5. The reason is that the small firm fully retains the cash flows from the new product following exercise and hence is able to optimize the amount of debt issued against those cash flows at the time of exercise, whereas the large firm does not have to issue debt against an uncertain collateral pool at time zero. However, such a contract or fee may be more difficult to write or enforce, and is not often observed in reality, which is why we focus in §5 on a more traditional licensing arrangement instead.

[18] We thank Paolo Fulghieri for suggesting to us this possibility.

6.3. Other Aspects

There are other aspects that have not been considered here. For tractability, we have not examined activities with imperfectly correlated cash flows. This could provide the integrated form with an additional source of value in that more negatively correlated cash flows create additional debt capacity. However, the net effect of this additional debt capacity could be ambiguous since the inclination to issue more debt should provoke more debt overhang, but the exercise threshold itself should decline relative to that of the small, stand-alone firm (because the option's payoff in the integrated firm increases when the correlation decreases). Moreover, Leland (2007) shows that imperfect correlation of corporate activities makes a single debt coupon choice under integration inefficient relative to separate coupon choices under nonintegration because of the effect of limited liability.

Also, we have assumed throughout that the firms are unlevered at the time the organizational form is chosen. In reality, an idea will often be developed inside a firm that is already levered, which could affect the organizational design decision. In particular, equity holders' decision of whether to retain the option or sell/spin it off will maximize their payoff rather than overall firm value. If the shareholders are able to keep the proceeds of such a transaction for themselves (as is likely if the firm is far from financial distress), the existence of a fixed amount of debt will make them more likely to sell/spin off the option (they enjoy all the benefits of the sale, but if the option is retained the creditors will enjoy part of the future cash flows in some states). However, if the firm were able to optimally re-lever when the idea appears, the effect could be more subtle because it would depend on whether existing debt is retired at face or market value.

7. Conclusion

This paper provides a first step toward analyzing how capital structure and organizational design jointly affect the value of new opportunities in dynamic product markets. We consider an integrated form, in which all activities are operated in a single firm, and a nonintegrated form, in which the new opportunity is instead operated by a small, stand-alone firm. For each organizational form, there are three sources of value: the value of assets in place, the value of the growth option, and the value of net tax benefits. Nonintegration removes overhang from the exercise decision, maximizing pure option value and creating more capital structure flexibility. On the other hand, integration best protects assets in place by taking joint profit considerations into account. These forces drive different organizational equilibria depending on firm and product market characteristics.

The analysis yields several testable implications. Notably, we find starkly different risk implications. Higher cash flow risk favors nonintegration, whereas higher obsolescence risk favors integration. In addition, since nonintegration best maximizes financial flexibility, an increase in net tax benefits (due to lower tax rates or higher bankruptcy costs) makes nonintegration more likely. Moreover, we establish that alliances organized as licensing agreements or revenue-sharing contracts can better balance the different sources of value and thus may dominate more traditional forms of organization. We also provide comparative statics for the optimal alliance structure. Our results should prove useful for future empirical investigations of whether successful implementation of new products occurs inside or outside existing incumbent firms across different types of markets, as well as investigations of the role and structuring of alliances.

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