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TOWARD A SYNTHESIS OF THE RESOURCE-BASED AND DYNAMIC-CAPABILITY VIEWS OF RENT CREATION

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Two distinct causal mechanisms—resource-picking and capability-building—have been proposed in the strategic management literature about how firms create economic rents. Under the resource-picking mechanism, managers gather information and analysis to outsmart the resource market in picking resources, similar to the way that a mutual fund manager tries to outsmart the stock market in picking stocks. Under the capability-building mechanism, managers design and construct organizational systems to enhance the productivity of whatever resources the firm acquires. These two rent-creation mechanisms are certainly not mutually exclusive, and it is likely that firms generally use both of them. It is therefore important to consider the interaction between these two rent-creation mechanisms: Do they complement each other? Or are they substitutes for each other? In other words, do they enhance each other's value, or detract from each other's value? Answering these questions is a necessary precondition to understanding how firms should allocate their time and effort between these two rent-creation mechanisms. The present paper develops a basic theoretical model to address these questions, and derives testable hypotheses from the model. The model predicts that the two rent-creation mechanisms are complementary in some circumstances but substitutes in others. Copyright © 2001 John Wiley & Sons, Ltd.

> "The leading efficiency approaches to business strategy are the resource-based and the dynamic capabilities approach … It is not obvious to me how these two literatures will play out—either individually or in combination. Plainly, they deal with core issues. Possibly they will be joined." (Oliver Williamson, 1991: 76)

INTRODUCTION

In the strategic management literature, two distinct mechanisms—resource-picking and capability-building—have been proposed for understanding how managers create economic rents for their firms. The former mechanism asserts that firms create economic rent by being more effective than their rivals at *selecting* resources. The latter mechanism asserts that firms create economic rent by being more effective than their rivals at *deploying* resources. Let us consider the logic underlying each of these mechanisms in turn.

Under the resource-picking mechanism, managers gather information and analysis to outsmart the resource market in picking resources, similar to the way that a mutual fund manager tries to outsmart the stock market in picking stocks (e.g., Barney, 1986). The resource-picking mechanism creates economic rents when the firm purchases resources for less than their marginal productivity when used in combination with its stock of other

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resources. Barney (1986) argues that if the resource market is reasonably competitive and efficient, then systematically increasing a firm's *ex ante* expected profit through resource-picking is only possible when the firm has superior information about how valuable the resource is when used in combination with its stock of other resources. A concrete example of the resource-picking mechanism would be Microsoft's 1980 purchase of the QDOS operating system (the precursor to MS-DOS) from Seattle Computer Products for only $50,000. Given Microsoft's private information at the time about IBM's impending demand for a personal computer operating system, Microsoft was able to purchase the QDOS asset for far less than its productive value when used as part of the nascent IBM PC standard. So, over the decades that followed, Microsoft has generated billions of dollars of economic rent from its acquisition of the QDOS resource.

For those who take the Ricardian perspective (Ricardo, 1817) that has been codified into a 'resource-based view' (e.g., Barney, 1986, 1997: 138–141; Conner, 1991; Montgomery and Wernerfelt, 1988; Peteraf, 1993; Wernerfelt, 1984), resource-picking is the main mechanism for the creation of economic rent. According to the Ricardian logic, heterogeneity in performance is due to ownership of resources that have differential productivity. So, the logical question from this Ricardian perspective is: How do firms come into possession of resources with heterogeneous productivity in the first place? This question has been addressed by Barney's (1986) 'strategic factor market' theory. The conclusion of that theory is that there is only one systematic (i.e., nonluck-based) way for a firm to come into possession of resources capable of generating economic rent: It must outsmart the resource market by applying superior resource-picking skill—that is, by developing systematically more accurate expectations about the future value of resources than other resource market participants have.

One important implication of this Ricardian resource-based view is that this mechanism for creating economic rent actually takes place *before* the acquisition of a resource: Firms with superior resource-picking skill apply that skill to discern which resources are winners and which ones are losers, so that they can bid on the former while avoiding the latter. Under the resource-picking mechanism, all of this takes place *before* the firm actually comes into possession of the resource. A corollary of this observation is that resource-picking skills can affect a firm's economic profit even if the firm does not acquire any resources. This is true because resource-picking skills not only help a firm to acquire good resources, but they also help a firm to avoid acquiring bad resources. Indeed, this avoidance of bad resources may have an even greater impact on a firm's economic profit than the selection of good resources.

However, as Mahoney and Pandian (1992) point out, this Ricardian perspective has been challenged by the Schumpeterian perspective (Schumpeter, 1950) that has been codified into a 'dynamic-capability view' (e.g., Amit and Schoemaker, 1993; Dierickx and Cool, 1989; Mahoney, 1995; Nelson and Winter, 1982; Teece, Pisano, and Shuen, 1997). This Schumpeterian dynamic-capability view highlights the importance of an alternative rent-creation mechanism—namely, capability-building—which is rather different from resource-picking.

In order to articulate the capability-building mechanism, it is first necessary to define the distinction between the terms 'resource' and 'capability.' The present paper relies on the distinction drawn by Amit and Schoemaker (1993: 35):

> *Capabilities*, in contrast, refer to a firm's capacity to deploy *Resources*, usually in combination, using organizational processes, to effect a desired end. They are information-based, tangible or intangible processes that are firm-specific and are developed over time through complex interactions among the firm's *Resources*. They can abstractly be thought of as 'intermediate goods' generated by the firm to provide enhanced productivity of its *Resources*, as well as strategic flexibility and protection for its final product or service. [italics in the original]

In this definition, there are two key features that distinguish a capability from other types of resources: First, a capability is firm-specific since it is embedded in the organization and its processes, while an ordinary resource is not. Because of this embeddedness, ownership of a capability can not easily be transferred from one organization to another without also transferring ownership of the organization itself, or some reasonably self-contained subunit of the organization. As

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Teece *et al.* (1997: 518) argue, 'That which is distinctive cannot be bought and sold short of buying the firm itself, or one or more of its subunits.' If the organization were completely dissolved, its capabilities would also disappear, but its resources could survive in the hands of a new owner. For example, if the Intel Corporation were completely dissolved, then its microprocessor patents (a resource) could continue to exist in the hands of a new owner, but its skill at designing new generations of microprocessors (a capability) would vanish. Intel could easily transfer ownership of its microprocessor patents to another company, but it could not easily transfer ownership of its skill at designing new generations of microprocessors—at least not without losing an essential part of itself. The second feature that distinguishes a capability from other resources is that the primary purpose of a capability is to enhance the productivity of the other resources that the firm possesses—as articulated in Amit and Schoemaker's (1993: 35) 'intermediate goods' analogy. This distinction between a resource and a capability is roughly analogous to Miller and Shamsie's (1996) distinction between 'systemic' and 'discrete' resources, Brumagin's (1994) distinction between 'elementary' and 'higher-level' resources, and Black and Boal's (1994) distinction between 'traits' and 'configurations.'

So, for the purposes of the present paper, a 'capability' is defined as a special type of resource—specifically, an organizationally embedded nontransferable firm-specific resource whose purpose is to improve the productivity of the *other* resources possessed by the firm. Based on this definition, Teece *et al.* (1997) have argued that 'Capabilities cannot easily be bought; they must be built.' Likewise, Amit and Schoemaker (1993: 35) contend, 'Some of the firm's *Resources*, but especially its *Capabilities*, may be subject to market failure' [italics in the original]. If capabilities must be built, not bought, then the manager's role may be more nearly analogous to an architect than to a stock-picker trying to beat the market. A concrete example of the capability-building mechanism would be Wal-Mart's internal development of a unique 'cross-docking' logistical system (Stalk, Evans, and Shulman, 1992), which greatly enhanced the productivity of the company's other resources, such as its commercial real estate, its trucking fleet, its workforce, and its information technology.

An important distinction between the resource-picking and capability-building mechanisms has to do with their timing. As mentioned earlier, under the resource-picking mechanism, economic profit is actually created *before* the acquisition of a resource. By contrast, the purpose of a capability—by definition—is to enhance the productive value of the other resources that are in the firm's possession. Therefore, by definition, a firm's capabilities can only generate economic profit *after* these other resources are acquired. By extension, this observation implies that capability-building only creates economic profit if a firm is successful at acquiring other resources on which the capability in question can exert its productivity-enhancing influence. No matter how great a firm's capabilities might be, they do not generate economic profit if the firm fails to acquire the resources whose productivity would be enhanced by its capabilities. This conclusion stands in stark contrast with the resource-picking mechanism, which (as mentioned earlier) can affect a firm's economic profit even if no resources are actually acquired (by helping the firm to avoid acquiring bad resources). So, in sum, the two mechanisms differ as follows: The resource-picking mechanism affects economic profit *before* the acquisition of resources and can do so *even if* such resource acquisitions do not actually take place. By contrast, the capability-building mechanism affects economic profit *only after* the acquisition of resources and can *not* do so if such resource acquisitions fail to materialize. This is because the resource-picking mechanism has its impact at the decision phase, while the capability-building mechanism has its impact at the implementation or deployment phase.

The distinction between the two mechanisms—resource-picking and capability-building—also has other important theoretical, empirical, and normative implications because it cuts directly to the core of the rent-creation process, and the role of managers in that process. If resource-picking is the primary mechanism for creating rents, then managers make their contribution largely through forming expectations about the value to their company of acquiring particular resources. In that case, strategy research should focus mainly on information and cognition—i.e., the information collected to inform strategy formulation, and the cognitive processes used for filtering that infor-

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mation when choosing which resources to acquire, and when forming expectations about the value of those resources to the firm. It would also follow that research should focus on measuring these expectations, identifying the techniques used to form them, assessing the skill of managers at applying these techniques, and tracing the impact of that skill on subsequent performance. On the other hand, if capability-building is the primary mechanism for creating rents, then managers make their contribution largely through architecting and constructing capabilities internally. Extending this architectural metaphor, it would follow that the theoretical, empirical, and normative focus should be on structural principles for appropriate design of capabilities, on the 'raw materials' from which capabilities are made, and on the 'construction techniques' by which they are built. In sum, these two mechanisms have very different implications for how strategy is done and how it should be researched, with the resource-picking mechanism implying greater emphasis on cognitive and informational factors and the capability-building mechanism implying greater emphasis on structural factors.

A third factor that should also be considered here is the possibility of 'idiosyncratic bilateral synergy' (Mahoney and Pandian, 1992: 368), where cospecialized assets between the resource buyer and seller generate a bilateral monopoly situation. In such a situation, it is possible for the resource buyer to share some portion of the economic surplus generated by the resource. Should such 'idiosyncratic bilateral synergy' situations be treated as part of the resource-picking mechanism, as part of the capability-building mechanism, or as something else entirely? First, it is fairly clear that any idiosyncratic bilateral synergy is independent of resource-picking skill. This fact is reflected most clearly in the timing of when the idiosyncratic bilateral synergy has its effect on economic profit. Resource-picking skill has its impact on economic profit *before* any resource is acquired, and it exerts this impact on economic profit even if no resource is acquired. By contrast, any idiosyncratic bilateral synergy can only affect economic profit *after* the resource in question is acquired. If some newly created resource has a higher productivity when used in combination with one particular firm's idiosyncratic pre-existing stock of other resources than with those of other firms, then that synergy will never actually be achieved unless the particular firm in question actually succeeds in acquiring the new resource. In this regard, idiosyncratic bilateral synergy has more in common with the capability-building mechanism than it has with the resource-picking mechanism.

Conceptually, we can think of idiosyncratic bilateral synergy as a phenomenon that is distinct from capability. However, mathematically, idiosyncratic bilateral synergy and capability have identical effects on economic profit. In the present paper, idiosyncratic bilateral synergy and capability are both labeled and treated as separate phenomena represented by separate parameters, even though it is mathematically redundant to do so because they have identical effects on economic profit.[1] The present paper develops some hypotheses about the impact of a firm's capability advantage, but it should be remembered that these particular hypotheses could also simply be relabeled as hypotheses about the impact of idiosyncratic bilateral synergy, because the effect would be identical. Indeed, even from a conceptual perspective, there could be a considerable 'gray area' between what one would consider a capability and what one would consider an idiosyncratic bilateral synergy, so that the distinction between them might, in many cases, be a matter of taste and judgment. Nevertheless, in order to minimize redundancy, the present paper focuses only on the two mechanisms of resource-picking and capability-building, with the caveat that all conclusions that are drawn about the latter mechanism would also apply equally well to idiosyncratic bilateral synergy. Whether idiosyncratic bilateral synergy is—or should be—treated as a third separate rent-creation mechanism in other different types of models is an open question, but it is definitely redundant in the context of the model developed here.

The next logical question is how strategy researchers should treat the relationship between

[1] Specifically, in the model developed here, any idiosyncratic bilateral synergy would be reflected in the parameter difference $(\mu_1 - \mu_2)$, while capability advantages are reflected in the parameter γ. However, all of the hypotheses that are derived with respect to capability advantages could just as easily have been derived with respect to idiosyncratic bilateral synergy. This is true because any derivatives of the expected net profit function that are taken with respect to the capability advantage parameter γ are identical to the corresponding derivatives taken with respect to the difference $(\mu_1 - \mu_2)$.

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the resource-picking and capability-building mechanisms in their thinking about the rent-creation process. One could frame the distinction between these two mechanisms in 'either/or' terms and devise empirical tests of the two mechanisms, as if they represented competing hypotheses. As a first step, such an 'either/or' framing might yield some useful empirical insights. However, it seems more likely that firms would generally use some combination of both mechanisms, that the two mechanisms do not act independently of each other, and that their relative importance in generating economic rents would be a function of the firm's internal and external circumstances. In that case, interactions between the two mechanisms will make their joint effect differ from the sum of the two parts, and the two parts will themselves vary according to the firm's situation. A complete picture of the rent-creation process is therefore dependent upon developing a general theory that synthesizes the two rent-creation mechanisms and takes into account the contingencies that may influence their separate and joint effectiveness. Such a theory would have to incorporate differences between firms in their effectiveness at both resource selection and resource deployment (i.e., capability). The purpose of the present paper is to articulate the rough outlines of such a theory and to derive some basic testable hypotheses from it.

One of the most important issues that can be addressed by such a theory is the nature of the interaction between these two rent-creation mechanisms. Are resource-picking and capability-building complements for each other, or are they substitutes for each other? In other words, how does increasing one of these advantages affect the value of increasing the other advantage? Do they enhance each other's value, or detract from each other's value? For example, is the value of improving one's resource-picking advantage an increasing function of one's capability advantage (i.e., complementary advantages)? Or is the value of improving one's resource-picking advantage a decreasing function of one's capability advantage (i.e., substitute advantages)? Answering these questions is a necessary precondition to understanding how firms should allocate their time and effort between these two rent-creation mechanisms. Addressing these questions from a theoretical perspective is the main goal of the present paper. The model developed here predicts that the two mechanisms are complementary in some circumstances but substitutes in others.

There is some initial empirical evidence regarding the relationship between one particular type of resource-picking—namely, acquisitions—and one particular type of capability-building—namely, research and development (R&D). A series of Compustat-based studies (Hitt, Hoskisson, and Ireland, 1990; Hitt *et al.*, 1991a, 1991b) has found a negative association between acquisitions and R&D. The authors of these studies interpret their findings in terms of constraints on resources and managerial attention (as in Penrose, 1959), which reduce a firm's *ability* to engage in one activity whenever it engages in more of the other activity. However, the theory developed in the present paper suggests an alternative explanation for these empirical findings that has nothing to do with constraints on a firm's ability to engage in more than one activity simultaneously. Rather, under some circumstances, a firm's *incentive* to engage in one of these activities may be reduced whenever it engages in more of the other activity. So the empirically observed 'substitution' of acquisitions for R&D may have more to do with firms' *incentives* to engage in these two activities than with constraints on their *ability* to engage in them.

ASSUMPTIONS OF THE MODEL

Consider the sale of a unique, nonimitable, and nonsubstitutable resource. A concrete example might be a technology patented by an independent inventor who then offers the patent for sale to companies interested in commercializing the technology. Another concrete example might be a tract of land adjoining a planned new highway exit, where the site previously had no commercial value but, because of the new highway exit, could now be profitably acquired and developed by hotel chains, restaurant chains, service station chains, etc. The resource owner, in order to appropriate as much rent as possible from the resource, offers it for sale via an English auction,[2]

[2] This paper follows the particular definition of an English auction used by (Milgrom and Weber, 1982: 1104): '… the price is raised continuously, and a bidder who wishes to be active at the current price depresses a button. When he releases the button, he has withdrawn from the auction …. We assume that both the price level and the number of active

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which is the optimum method for selling a unique resource for the highest possible price (Lopomo, 1998; Milgrom, 1989; Milgrom and Weber, 1982). For mathematical tractability, assume that only two firms could potentially use this new resource, and thus only two bidders are in the auction. This two-firm limit might seem to be a serious restriction, but it actually is not. In any English auction with N bidders, the only impact that the $N - 2$ lowest bidders have on the outcome is that their bidding behavior reveals their private information to the top two bidders. Thus, any N-bidder English auction can be reduced to an equivalent two-bidder English auction where all of the private information of the $N - 2$ lowest bidders in the N-bidder auction is incorporated into the top two bidders' prior probability distribution for their valuations of the resource (Milgrom and Weber, 1982: 1104–1106). In the case of the model presented here, only one bidder has private information, so if this feature of the model were preserved then the addition of more bidders without private information would have no impact on the results.

Denote the two firms participating in the auction as firm 1 and firm 2. Both firms are treated as expected-profit maximizers. That is, risk is not a factor in their choice of optimum strategy to pursue. Because these two firms differ in their preexisting stocks of other resources, and because of complementarities between resources, the two firms differ in the value that they can obtain by using the auctioned resource in combination with their other resources. Let $\tilde{V}_1$ and $\tilde{V}_2$ represent the private values of the resource being auctioned when used in combination with the preexisting stocks of resources of firms 1 and 2, respectively. (For notational clarity, all random variables in this model are denoted with the tilde symbol, and all parameters are denoted as Greek letters.) Assume that their private values for the resource, $\tilde{V}_1$ and $\tilde{V}_2$, are distributed according to a bivariate normal prior probability distribution with mean vector and covariance matrix as follows:

$$\mathrm{M} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \text{ and } \Sigma = \sigma^2 \begin{bmatrix} 1 & \phi\rho \\ \phi\rho & \phi^2 \end{bmatrix}$$

for $\sigma > 0$, $\phi > 0$, and $-1 \leq \rho \leq 1$. Although both firms are assumed to be aware of this joint probability distribution for $\tilde{V}_1$ and $\tilde{V}_2$, they can not directly observe the actual values of $\tilde{V}_1$ or $\tilde{V}_2$ until after the auction is completed.

Firm 1 is arbitrarily chosen as the 'focal firm' in this model, and its properties and advantages are defined relative to firm 2. The first type of advantage to be considered is a capability advantage. In addition to their differences in preexisting stocks of other resources, assume that firm 1 also possesses a capability that firm 2 lacks. As defined earlier, a capability is an organizationally embedded firm-specific nontransferable resource that enhances the productivity of the firm's *other* resources. As per this definition, the capability possessed by firm 1 increases the value to firm 1 of the resource being auctioned by an amount γ. Let $\tilde{Y}_1$ and $\tilde{Y}_2$ represent the values of the auctioned resource to the two firms *after* the application of their capabilities, so that $\tilde{Y}_1 = \tilde{V}_1 + \gamma$ and $\tilde{Y}_2 = \tilde{V}_2$. If $\gamma > 0$, then firm 1 has a capability advantage over firm 2. If $\gamma < 0$, then firm 2 has a capability advantage over firm 1. If $\gamma = 0$, then neither firm has a capability advantage over the other.

The second type of advantage to be considered is a resource-picking advantage. Both firms are assumed to know the joint probability distribution of $\tilde{Y}_1$ and $\tilde{Y}_2$. In addition, firm 1 also receives a noisy private signal, denoted $\tilde{Z}$, about the actual value to itself of the resource being auctioned. Firm 2 receives no additional information about the value of the resource to either firm beyond its basic knowledge of the joint probability distribution of $\tilde{Y}_1$ and $\tilde{Y}_2$. For mathematical convenience, firm 1's private signal is defined with a mean of zero, as follows:

$$\tilde{Z} = \tilde{Y}_1 - (\mu_1 + \gamma) + \theta^{-1}\tilde{X} = \tilde{V}_1 - \mu_1 + \theta^{-1}\tilde{X} \tag{1}$$

where $\theta > 0$ is the reliability of the signal $\tilde{Z}$, and where $\tilde{X}$ is normally distributed noise with mean of 0, variance of 1, and independent of both $\tilde{Y}_1$ and $\tilde{Y}_2$. The higher the value of the reliability θ, the greater firm 1's resource-picking advantage over firm 2. As the reliability θ

bidders are continuously displayed. We use the term 'English auction' to designate this variant.' By contrast, 'in a Dutch auction, the auctioneer begins by naming a very high price and then lowers it continuously until some bidder stops the auction and claims the object for that price' (Milgrom and Weber, 1982: 1091).

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approaches zero, firm 1's resource-picking advantage over firm 2 diminishes and the two firms approach parity in resource-picking. Because of the independence of $\tilde{X}$ and $\tilde{Y}_1$, $\tilde{Z}$ has a normal distribution with mean 0 and variance $\sigma^2 + \theta^{-2}$.

MARGINAL BENEFITS OF RESOURCE-PICKING AND CAPABILITY ADVANTAGES

From the preceding assumptions, it follows that firm 2 will exit the English auction when the price reaches $E(\tilde{Y}_2) = \mu_2$. Applying the conditional distribution theorem from Tong (1990: ch. 2), firm 1 will exit the auction when the price reaches:[3]

$$E(\tilde{Y}_1 \,|\tilde{Z}) = \mu_1 + \gamma + \left(\frac{\sigma^2}{\sigma^2 + \theta^{-2}}\right)\tilde{Z} \qquad (2)$$

For notational convenience, define the following two functions:

$$\begin{aligned}\delta(\gamma) &= [(\mu_1 + \gamma) - \mu_2] \\ &= [(\mu_1 - \mu_2) + \gamma] = E(\tilde{Y}_1 - \tilde{Y}_2) \qquad (3)\end{aligned}$$

$$\beta(\theta) = \frac{\sigma^2}{\sqrt{\sigma^2 + \theta^{-2}}} \qquad (4)$$

Thus, if $E(\tilde{Y}_1|\tilde{Z}) = \mu_1 + \gamma + (\beta(\theta)/\sigma)^2\ \tilde{Z} > \mu_2$, then firm 1 wins the auction and the profit to firm 1 is $\tilde{Y}_1 - \mu_2$. Otherwise, firm 2 wins the auction and the profit to firm 1 is zero. It therefore follows (see Appendix for proof) that the expected profit to firm 1 is given by:

$$E(\tilde{\Pi}_1) = \delta(\gamma)\ F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) + \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \qquad (5)$$

where $F(\bullet)$ and $f(\bullet)$ are, respectively, the cumulative distribution function and the probability density function of the standard normal random variable (with mean 0 and variance 1). For all of the following derivations, it is helpful to remember that, by the definition of $F(\bullet)$ and $f(\bullet)$, and by applying the chain rule, $\partial F(U(w))/\partial w = f(U(w))U'(w)$ and $\partial f(U(w))/\partial w = f(U(w))\ [-U(w)]U'(w)$ for any differentiable function $U(w)$ and any variable w.

It therefore follows (see Appendix for proof) that the marginal benefit to firm 1 of a unit increase in its resource-picking advantage is:

$$\begin{aligned}B_\theta &= \frac{\partial E(\tilde{\Pi}_1)}{\partial \theta} \\ &= \beta'(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \qquad (6)\end{aligned}$$

By definition of $\beta(\theta)$, the derivative $\beta'(\theta)$ is positive for all $\sigma > 0$ and $\theta > 0$, so it follows that $B_\theta > 0$ under the assumptions of the model. Likewise, it also follows (see Appendix for proof) that the marginal benefit to firm 1 of a unit increase in its capability advantage is:

$$\begin{aligned}B_\gamma &= \frac{\partial E(\tilde{\Pi}_1)}{\partial \gamma} = F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) = \\ &\text{Prob}[E(Y_1|Z) > E(Y_2)] > 0 \qquad (7)\end{aligned}$$

As one would expect, the benefits from increasing both capability advantages and resource-picking advantages are always positive, since the 'main effects' of γ and θ on $E(\tilde{\Pi}_1)$ are both positive. These results underlie the first two (admittedly unsurprising) hypotheses:

> *Hypothesis 1: The greater a firm's resource-picking advantage, the higher its expected profit.*

> *Hypothesis 2: The greater a firm's capability advantage, the higher its expected profit.*

In these and all following hypotheses, a *ceteris paribus* condition is assumed to apply.

The preceding formulas for B_θ and B_γ, the values of the two rent-creation mechanisms, can best be interpreted in terms of the different stages of the rent-creation process at which these mechanisms play their respective roles:

1. *Impact of resource-picking advantage on expected profit:* The reliability θ of a firm's resource-picking has its effect prior to the

[3] Because $\tilde{Z}$ is mean-centered to have a mean of zero, this expression for $E(\tilde{Y}_1|\tilde{Z})$ may appear unfamiliar to readers who are accustomed to the standard version of the Normal learning model without such mean-centering.

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acquisition of the resource by better enabling the firm to obtain those resources that would be profitable to acquire while avoiding those resources that would be unprofitable. Therefore, this effect boosts the firm's expected profit regardless of the actual outcome of the auction. Indeed, the greatest value of the resource-picking reliability θ may be in helping the firm decide which auctions it should lose. B_θ represents the value to firm 1 of improving the accuracy of its private information about the value of the resource. The greater the *ex ante* uncertainty about which firm will get more value from the resource, the greater the value of this private information. If one firm has a vastly higher *ex ante* expected value for the resource than the other, then there is little value to private information, because it is unlikely to influence firm 1's bidding very much, since the auction's outcome is largely a foregone conclusion anyway. However, if the two firms are close to each other in their *ex ante* expected values for the resource, then private information can be very valuable to firm 1 in helping to improve its bidding behavior so that it wins the auction only if it is profitable to do so. Hence, as the formula for B_θ shows, the value of improving the accuracy of firm 1's private information is highest when the two firms' *ex ante* expected values for the resource is at or near parity—i.e., when $\delta(\gamma)$ is close to zero. B_θ declines when either firm increases its expected value advantage over the other—i.e., when the absolute value of $\delta(\gamma)$ increases.

2. *Impact of capability advantage on expected profit:* Based on Amit and Schoemaker's (1993: 35) definition, the advantage provided by a capability is that it enhances the productivity of the *other* resources that the firm possesses. Therefore, the value of a capability grows in proportion to the quantity of the firm's *other* resources, upon which the capability exerts its productivity-enhancing influence. If a resource is not acquired, then its productivity certainly can not be enhanced by the firm's capabilities. So, in contrast to resource-picking (which can improve *ex ante* expected profit even when resources are not acquired), capability-building can only improve profitability when other resources are actually acquired. It is therefore not surprising that B_γ is exactly equal to the probability that firm 1 wins the auction.

These interpretations of the formulas for B_θ and B_γ underlie the next two hypotheses:

Hypothesis 3: The value of a resource-picking advantage is greatest when the firms competing to buy the resource in question are close to each other in their ex ante expected valuation of it.

Hypothesis 4: The value of a firm's capability advantage is increased by anything that increases its likelihood of acquiring resources.

These interpretations will prove useful in providing the intuition underlying the remaining hypotheses derived from the model. Indeed, all of the remaining hypotheses can be viewed as special cases of Hypotheses 3 and 4.

DERIVATION OF OTHER TESTABLE HYPOTHESES

Interaction of resource-picking and capability-building

Given that the main effects of both resource-picking and capability-building on expected profits are positive, it is natural to ask about the nature of the interaction between these two rent-creation mechanisms: Are they complements or substitutes? Differentiating their marginal benefits (Equation 6 or 7) by applying the chain rule reveals the following interaction effect:

$$\frac{\partial^2 E(\tilde{\Pi}_1)}{\partial\theta\partial\gamma} = \frac{\partial B_\theta}{\partial\gamma} = \frac{\partial B_\gamma}{\partial\theta} = f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[\frac{-\delta(\gamma)}{[\beta(\theta)]^2}\right]\beta'(\theta) \tag{8}$$

This expression always has the opposite sign as $\delta(\gamma) = E(\tilde{Y}_1 - \tilde{Y}_2)$, the *ex ante* expected resource valuation advantage of firm 1 over firm 2. Thus, if firm 1 has a lower *ex ante* expected value for the resource than another competing firm, then the interaction effect of resource-picking and capability-building is positive for firm 1, so that the two rent-creation mechanisms are complements. On the other hand, if firm 1 has a higher *ex ante* expected value for the resource

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than other competing firms, then the interaction effect of resource-picking and capability-building is negative for firm 1, so that the two rent-creation mechanisms are substitutes.

What is the intuition underlying this result? There are two ways to explain the intuition behind this result—one explanation in terms of $\partial B_\theta/\partial\gamma$, and one in terms of $\partial B_\gamma/\partial\theta$:

1. Recall from the preceding discussion that B_θ represents the value to firm 1 of improving the accuracy of its private information about the resource, and that this value is highest when the two firms are close to each other in their *ex ante* expected valuations for the resource. So, with regard to $\partial B_\theta/\partial\gamma$, the impact of γ on B_θ, the relevant question is: Does increasing γ push the two firms closer to parity in their *ex ante* expected valuation for the resource, or does it push them further apart? It depends upon which firm holds the *ex ante* expected-valuation advantage. If firm 1 already holds the expected-value advantage over firm 2, so that $\delta(\gamma)$ is positive, then increasing γ extends that advantage by increasing $\delta(\gamma)$, which means that the firms' *ex ante* expected valuations are pushed further apart, so that the outcome of the auction is even more of a foregone conclusion. In that case, increasing γ decreases B_θ, the marginal benefit of incrementally improving the accuracy of firm 1's private information. On the other hand, if firm 2 holds the expected-value advantage over firm 1, so that $\delta(\gamma)$ is negative, then marginally increasing γ pushes $\delta(\gamma)$ closer to zero, so that the firms are closer to parity in their expected valuations for the resource, and the auction is a closer contest. In that case, increasing γ increases B_θ, the marginal benefit of incrementally improving the accuracy of firm 1's private information.

2. Recall from the preceding discussion that capability-building is only effective at boosting profits when the auction is actually won, so that the resource is acquired and its productivity is enhanced by the capability. Therefore B_γ, the marginal value of capability-building, is exactly equal to the probability that firm 1 wins the auction. So, with regard to $\partial B_\gamma/\partial\theta$, the impact of θ on B_γ, the relevant question is: Does increasing resource-picking reliability θ increase or decrease the probability of firm 1 winning the auction? It depends upon which firm holds the *ex ante* expected-value advantage, as shown in Equation 7. If firm 1 already holds the expected-value advantage over firm 2, so that $\delta(\gamma)$ is positive, then increasing the reliability θ decreases the probability that firm 1 will win the auction. On the other hand, if firm 2 holds the expected-value advantage over firm 1, so that $\delta(\gamma)$ is negative, then increasing the reliability θ increases the probability that firm 1 will win the auction.

The expression for the interaction effect shown earlier confirms both of these intuitive explanations for the next two testable hypotheses:

Hypothesis 5a: If a firm does not have the highest ex ante expected valuation for a resource, then its resource-picking ability and its capabilities for deploying the resource are complements.

Hypothesis 5b: If a firm has the highest ex ante expected value for a resource, then its resource-picking ability and its capabilities for deploying the resource are substitutes.

Other determinants of the value of the rent-creation mechanisms

What other factors can influence B_θ and B_γ, the marginal benefits of the two rent-creation mechanisms? In addition to the interaction effects discussed in the previous section, the model also allows us to explore how B_γ changes as a function of γ and σ. Unfortunately, the signs of the effects of θ and σ on B_θ are indeterminate, so no hypotheses are formulated here regarding these two effects.

It is, however, possible to demonstrate that B_γ is an increasing function of γ:

$$\frac{\partial B_\gamma}{\partial\gamma} = \frac{\partial^2 E(\tilde{\Pi}_1)}{\partial\gamma^2} = [\beta(\theta)]^{-1} f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) > 0 \quad (9)$$

In effect, this result implies that there are 'increasing returns to capability': The stronger a firm's capability advantage is, the greater the marginal benefit of further improving that capability advantage. Again, this result makes sense in light of the fact that capability-building is only

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effective at boosting profits when the auction is won and that B_γ is therefore equal to the probability that firm 1 wins the auction. Certainly, increasing γ is one sure way to increase the probability that firm 1 wins the auction. This result yields the next hypothesis:

> *Hypothesis 6: The value of increasing a firm's capability advantage is an increasing function of its current capability advantage.*

Interestingly, this 'increasing returns to capability' result would seem to imply exactly the sort of positive-feedback path dependence (Arthur, 1989, 1990, 1994) that has been a central feature of a number of variants on the dynamic-capability view (Nelson and Winter, 1982: ch. 12; Teece *et al.*, 1997). It is also consistent with the important role of absorptive capacity in the dynamic-capabilities literature (e.g., Cohen and Levinthal, 1990), where absorptive capacity is viewed as a central generative capability that, in a positive-feedback fashion, enables the firm to develop other capabilities.

Finally, it is also possible to articulate how B_γ is affected by the amount of variability in the underlying value of the resource, σ:

$$\frac{\partial B_\gamma}{\partial \sigma} = \frac{\partial^2 E(\gamma_1)}{\partial \sigma \partial \gamma} = \left(\frac{-\delta(\gamma)(\sigma^2 + 2\theta^{-2})}{\sigma^3 \sqrt{\sigma^2 + \theta^{-2}}} \right) f\left(\frac{\delta(\gamma)}{\beta(\theta)} \right) \tag{10}$$

This expression has the opposite sign as $\delta(\gamma) = E(\tilde{Y}_1 - \tilde{Y}_2)$, the *ex ante* expected resource valuation advantage of firm 1 over firm 2. Thus, if firm 1 has a lower *ex ante* expected valuation for the resource than another competing firm, then increases in the amount of variability in the underlying value of the resource will increase the value of capability-building for firm 1. On the other hand, if firm 1 has a higher *ex ante* expected valuation for the resource than other competing firms, then increases in the amount of variability in the underlying value of the resource will decrease the value of capability-building for firm 1. Again, these results make sense in light of the fact that capability-building is only effective at boosting profits when the auction is won and that B_γ is therefore equal to the probability that firm 1 wins the auction. Increased variability in the underlying value of the resource will, *ceteris paribus*, increase the value of the private information held by firm 1. In this regard, an increase in variability σ has a similar effect on firm 1's probability of winning the auction as an increase in reliability θ would have. This insight provides the final two hypotheses:

> *Hypothesis 7a: If a firm does not have the highest ex ante expected value for a resource, increases in variability of the resource's value will raise the value of improving the firm's capability.*

> *Hypothesis 7b: If a firm has the highest ex ante expected value for a resource, increases in variability of the resource's value will reduce the value of improving the firm's capability.*

DISCUSSION

The primary goal of this paper has been to examine the nature of the interaction between the two main forms of managerial rent-creation activities that have been identified in the strategy literature, namely resource-picking and capability-building. However, all theories—regardless of whether or not they are expressed mathematically—make assumptions that generate boundary constraints, outside of which the theory's conclusions may or may not be valid.[4] The present paper is certainly no exception, since it makes a number of fairly stringent and stark assumptions for the sake of mathematical tractability. Indeed, one can view the present paper as perhaps the simplest 'bare minimum' model necessary to accomplish the goal of assessing the interaction between the two rent-creation mechanisms. Consequently, some degree of realism and generality has been sacrificed here in the service of maintaining tractability, thereby limiting the potential range of applicability of the present paper. Accordingly, a useful avenue for future research would be to assess how the conclusions that are drawn in the present paper would be affected by relaxing some of the model's stringent and unrealistic assumptions.

[4] One advantage of expressing a theory mathematically is that it forces the theorist to state his/her assumptions explicitly, so that these assumptions can be examined, questioned, and altered as needed.

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For example, perfect inelasticity in the supply of the resource is assumed in the model. This assumption is an extreme version of the resource-based theme that only resources that are rare, difficult to imitate, and difficult to substitute are capable of generating rents for their owners (Barney, 1991, 1997: 138–141; Peteraf, 1993). However, in reality, many rent-generating resources have at least some elasticity in their supply—e.g., they are at least partially imitable or substitutable. One useful extension of the present model would therefore be to relax the assumption of perfect inelasticity, and to examine how varying the elasticity of supply of the resource affects the separate and joint values of the two rent-creation mechanisms. A second limitation of the present model is its focus on a single resource. Firms usually must deal with a variety of different resources in generating rents. Therefore, another useful extension of the present model might be to relax its assumptions in a way that would admit multiple resources. Third, the particular market structure assumed in this paper—a two-bidder English auction—may not be a realistic description of many resource markets. So, a useful extension of the present model might be to examine the robustness of its conclusions under alternative resource–market structures such as oligopsony.

Nevertheless, despite its limitations, the present model offers interesting insights into the inner workings of the rent-creation process: Resource-picking ability affects profitability prior to the acquisition of resources, so it can have value regardless of whether or not the resources are actually acquired. Resource-picking ability is most valuable with regard to resources for which firms are close to each other in their *ex ante* expected values. A capability affects profitability by enhancing the productivity of the *other* resources that the firm possesses, so it affects profitability only after resources are acquired. If a firm does not acquire a resource, then that resource's productivity can not be enhanced by the firm's capability. Therefore, anything that enhances a firm's ability to acquire additional resources also enhances the value of its capability-building efforts. As a consequence of these considerations, resource-picking and capability-building are substitutes for each other with regard to those resources for which no other firm has higher expected value, and complements with regard to all other resources.

In this regard, the empirical finding of a substitution relationship between R&D and acquisitions by Hitt *et al.* (1990, 1991a, 1991b) is exactly what the model presented here would predict, since the actual acquirer of any firm is likely to be the bidder that placed the highest *ex ante* expected value on it. These empirical findings of a substitution effect have been interpreted as a result of constraints on managerial attention and resources—i.e., devoting attention and resources to acquisitions reduces the firm's ability to pursue R&D. However, the model presented here offers an alternative explanation for these findings that has nothing to do with constraints on the firm's ability. Rather, the model presented here focuses on the firm's incentives. Assuming that the acquiring firm is the one that placed the highest *ex ante* expected value on the acquired firm, increased acquisitions (i.e., resource-picking) would, according to the model, simply reduce the incentive for and value of R&D (i.e., capability-building).

Finally, the theory and hypotheses presented here are rich with normative implications for managers in guiding their choices about how to allocate their time and effort between the two rent-creation mechanisms. One normative implication is that firms should not waste time and money to research the value of a resource in situations where any firm places a much larger *ex ante* expected value on the resource than other bidders, because the outcome is a foregone conclusion. Rather, it should focus its resource-picking research efforts mainly on those resources where it and another bidder are close to each other in their expected values for the resource (see Hypothesis 3). A second normative implication is that firms should not waste time and money building capabilities to enhance the productivity of resources in situations where it is likely to be outbid for the acquisition of those resources. Rather, it should focus its capability-building efforts mainly on capabilities to enhance the productivity of resources for which it is likely to be the winning bidder (see Hypothesis 4). Also, if a firm has a higher *ex ante* expected value for a resource than other bidders, it should allocate its time and resources to either improving its estimate of the resource value or improving its capabilities for exploiting the resource, *but not both*—because they are substitutes (see Hypothesis 5b). Alternatively, if a firm has a lower *ex ante*

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expected value for a resource than another bidder, then it should invest in some combination of both improving its estimate of the resource value and improving its capabilities for exploiting the resource (see Hypothesis 5a). This distinction (Hypothesis 5a vs. Hypothesis 5b) between the circumstances under which resource-picking and capability-building are complements and the circumstances under which they are substitutes is a nonobvious implication derived from the model, and it would be difficult to discern without such a model.

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APPENDIX

Derivation of expected profit function

If $E(\tilde{Y}_1|\tilde{Z}) = \mu_1 + \gamma + (\beta(\theta)/\sigma)^2\ \tilde{Z} > \mu_2$, then firm 1 wins the auction and the profit to firm 1 is $\tilde{Y}_1 - \mu_2$. Otherwise, firm 2 wins the auction and the profit to firm 1 is zero. Therefore:

$$\tilde{\Pi}_1 = (\tilde{Y}_1 - \mu_2)\left\{\mu_1 + \gamma + \left(\frac{\beta(\theta)}{\sigma}\right)^2 \tilde{Z} > \mu_2\right\}$$

$$= (\tilde{Y}_1 - \mu_2)\left\{\delta(\gamma) + \left(\frac{\beta(\theta)}{\sigma}\right)^2 \tilde{Z} > 0\right\} = (\tilde{Y}_1 - \mu_2)\left\{\tilde{Z} > \frac{-\sigma^2\delta(\gamma)}{(\beta(\theta))^2}\right\}$$

$$= (\tilde{Y}_1 - \mu_2)\left\{\tilde{Y}_1 > (\mu_1 + \gamma) - \frac{\sigma^2\ \delta(\gamma)}{(\beta(\theta))^2} - \frac{\tilde{X}}{\theta}\right\} \tag{11}$$

By independence, the joint density function $f_{\tilde{X},\tilde{Y}_1}(x,y_1) = f_{\tilde{X}}(x) f_{\tilde{Y}_1}(y_1) = f(x) f_{\tilde{Y}_1}(y_1)$, where $f_{\tilde{X}}(x)$ and $f_{\tilde{Y}_1}(y_1)$ are the marginal density functions of $\tilde{X}$ and $\tilde{Y}_1$ respectively, and $f(\bullet)$ is the standard normal density function. Then the expected value of firm 1's profit is therefore:

$$E(\tilde{\Pi}_1) = \iint_{y_1 > (\mu_1+\gamma) + \frac{-\sigma^2\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta}} (y_1 - \mu_2) f_{\tilde{X},\ddot{Y}_1}(x,y_1)\,dy_1 dx$$

$$= \iint_{\frac{y_1-(\mu_1+\gamma)}{\sigma} > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} (y_1 - \mu_2) f(x) f_{\tilde{Y}_1}(y_1)\,dy_1 dx \tag{12}$$

Let $\tilde{R} = \sigma^{-1}[\tilde{Y}_1 - (\mu_1 + \gamma)]$ and $r = \sigma^{-1}[y_1 - (\mu_1 + \gamma)]$. Then a simple change of variables yields:

$$E(\tilde{\Pi}_1) = \iint_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} (\sigma r + \delta(\gamma)) f(x) f_{\tilde{Y}_1}(\sigma r + (\mu_1 + \gamma))\sigma\ dr\ dx$$

$$= \iint_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} (\sigma r + \delta(\gamma)) f(x)\, \frac{\exp\left[\frac{-(\sigma r + (\mu_1 + \gamma) - (\mu_1 + \gamma))^2}{2\sigma^2}\right]}{\sqrt{2\pi\sigma^2}}\ \sigma\ dr\ dx$$

$$= \iint_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} (\sigma r + \delta(\gamma)) f(x) \frac{e^{\frac{-r^2}{2}}}{\sqrt{2\pi}}\ dr\ dx = \iint_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} (\sigma r + \delta(\gamma)) f(x) f(r)\ dr\ dx$$

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$$= \left[\sigma \iint\limits_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} r\, f(x) f(r)\, dr\, dx\right] + \left[\delta(\gamma) \iint\limits_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} f(x) f(r)\, dr\, dx\right] \tag{13}$$

By its definition, $\tilde{R}$ is distributed normally with mean of 0 and variance of 1, and is also independent of $\tilde{X}$, so $f_{\tilde{X},\tilde{R}}(x,r) = f(x)f(r)$. Therefore, by substitution:

$$\iint\limits_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} f(x) f(r)\, dr\, dx = \iint\limits_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} f_{\tilde{X},\tilde{R}}(x,r)\, dr\, dx = \mathrm{Prob}\left(\tilde{R} > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-\tilde{X}}{\theta\sigma}\right)$$

$$= \mathrm{Prob}\left(\tilde{Y}_1 - (\mu_1 + \gamma) > \frac{-\sigma^2\delta(\gamma)}{(\beta(\theta))^2} + \frac{-\tilde{X}}{\theta}\right) = \mathrm{Prob}\left(\tilde{Z} > \frac{-\sigma^2\delta(\gamma)}{(\beta(\theta))^2}\right) \tag{14}$$

Let $\tilde{W} = -\tilde{Z}/\sqrt{\sigma^2 + \theta^{-2}}$, so that $\tilde{W}$ is distributed normally with mean of 0 and variance of 1, and $\tilde{Z} = -\tilde{W}\sqrt{\sigma^2 + \theta^{-2}}$. Therefore, by substitution:

$$\iint\limits_{r > \frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}} f(x) f(r)\, dr\, dx = \mathrm{Prob}\left(\tilde{Z} > \frac{-\sigma^2\delta(\gamma)}{(\beta(\theta))^2}\right) = \mathrm{Prob}\left(\tilde{W} < \frac{\delta(\gamma)}{\beta(\theta)}\right) = F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \tag{15}$$

where $F(\bullet)$ is the cumulative distribution function of the standard normal. The penultimate term in equation 13 can be rewritten as:

$$\sigma \int_{-\infty}^{\infty} f(x) \left(\int_{\frac{-\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{-x}{\theta\sigma}}^{\infty} r\, f(r)\, dr \right) dx = \sigma \int_{-\infty}^{\infty} f(x) \left(\frac{e^{\frac{-1}{2}\left(\frac{\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{x}{\theta\sigma}\right)^2}}{\sqrt{2\pi}} \right) dx$$

$$= \frac{\sigma}{2\pi} \int_{-\infty}^{\infty} e^{\left[\frac{-1}{2}\left(\frac{\sigma\delta(\gamma)}{(\beta(\theta))^2} + \frac{x}{\theta\sigma}\right)^2 + \frac{-x^2}{2}\right]} dx = \frac{\sigma}{2\pi} \int_{-\infty}^{\infty} e^{\frac{-1}{2}\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)^2} e^{\frac{-\left(x + \frac{\delta(\gamma)}{\sigma^2\theta}\right)^2}{2\left(\frac{\beta(\theta)}{\sigma}\right)^2}} dx$$

$$= \left(\frac{e^{\frac{-1}{2}\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)^2}}{\sqrt{2\pi}} \right) \beta(\theta) \int_{-\infty}^{\infty} \frac{e^{\frac{-\left(x + \frac{\delta(\gamma)}{\sigma^2\theta}\right)^2}{2\left(\frac{\beta(\theta)}{\sigma}\right)^2}}}{\sqrt{2\pi\left(\frac{\beta(\theta)}{\sigma}\right)^2}} dx = \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \mathrm{Prob}(\tilde{H} < \infty) = \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \tag{16}$$

where $\tilde{H}$ is normally distributed with mean of $\frac{-\delta(\gamma)}{\sigma^2\theta}$ and variance of $\left(\frac{\beta(\theta)}{\sigma}\right)^2$. Substituting Equations 15 and 16 into Equation 13 yields:

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$$E(\tilde{\Pi}_1) = \delta(\gamma)\, F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) + \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \tag{17}$$

Derivation of marginal benefits of increasing advantages

By application of the chain rule,

$$\begin{aligned}
B_\theta &= \frac{\partial E(\tilde{\Pi}_1)}{\partial \theta} \\
&= \delta(\gamma) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[\frac{-\delta(\gamma)}{[\beta(\theta)]^2}\right]\beta'(\theta) + \beta'(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) + \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[\frac{-\delta(\gamma)}{\beta(\theta)}\right]\left[\frac{-\delta(\gamma)}{[\beta(\theta)]^2}\right]\beta'(\theta) \\
&= \beta'(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[-\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)^2 + 1 + \left(\frac{\delta(\gamma)}{\beta(\theta)}\right)^2\right] \\
&= \beta'(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)
\end{aligned} \tag{18}$$

Likewise, by application of the chain rule and by substituting the derivative $\delta'(\gamma) = 1$,

$$\begin{aligned}
B_\gamma &= \frac{\partial E(\tilde{\Pi}_1)}{\partial \gamma} \\
&= F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\delta'(\gamma) + \delta(\gamma) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[\frac{1}{\beta(\theta)}\right]\delta'(\gamma) + \beta(\theta) f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)\left[\frac{-\delta(\gamma)}{\beta(\theta)}\right]\left[\frac{1}{\beta(\theta)}\right]\delta'(\gamma) \\
&= F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) + \left[\frac{\delta(\gamma)}{\beta(\theta)}\right] f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) - \left[\frac{\delta(\gamma)}{\beta(\theta)}\right] f\left(\frac{\delta(\gamma)}{\beta(\theta)}\right) \\
&= F\left(\frac{\delta(\gamma)}{\beta(\theta)}\right)
\end{aligned} \tag{19}$$

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