ECONOMIES OF SCOPE, RESOURCE RELATEDNESS, AND THE DYNAMICS OF CORPORATE DIVERSIFICATION

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ABSTRACT

The dominant view has been that businesses that are more related to each other are more often combined within diversified firms. This study uses a dynamic model to demonstrate that, with inter-temporal economies of scope, diversified firms are more likely to combine moderately related businesses than the most related businesses. That effect occurs because strong relatedness reduces redeployment costs and makes firms redeploy all resources to better performing businesses. The strength of that effect depends on inducements for redeployment measured as the current return advantage of one business over another business, volatilities of business returns, and correlation of those returns. This study develops hypotheses for those relationships and suggests empirical operationalizations, encouraging empiricists to retest the implications of relatedness for the dynamics of corporate diversification.

Keywords: corporate diversification; resource-based view; resource relatedness; economies of scope; dynamic choice model.

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INTRODUCTION

A key rationale for corporate diversification is that firms aim for *economies of scope* (Panzar and Willig, 1981; Teece, 1980).[1] From the resource-based view (Penrose, 1959), such economies represent a reduction in costs for a diversified firm, which deploys resources in many businesses, relative to the costs those businesses would incur if managed as focused firms. Scope economies were linked to *resource relatedness*, the similarity of resource requirements between businesses (Rumelt, 1974). Relatedness supports economies by raising the applicability of resources across the combined businesses and enabling frugal use of the resources (*e.g.*, employees, plants, and technological and marketing knowledge) in those businesses (Hill, Hitt, and Hoskisson, 1992). In line with that logic, many empirical have studies confirmed that firms are more likely to become diversified by entering businesses that are more related to their existing businesses (Anand, 2004; Chang, 1996; Neffke and Henning, 2013; Silverman, 1999; Wu, 2013; Zhou, 2011).

Despite the compelling evidence that firms initiate diversification by entering related businesses, the impact of relatedness on the *dynamics* of diversification was unclear.[2] On one hand, the pattern that firms are also less likely to exit businesses more related to their other businesses (Chang, 1996; Lien and Klein, 2013; O'Brien and Folta, 2009) reinforced the view that relatedness keeps firms diversified. On the other hand, relatedness of combined businesses destabilizes the corporate scope. As Helfat and Eisenhardt (2004) argued, relatedness enables a firm to exit a business and enter a new business making the firm focused rather than diversified. Lieberman, Lee, and Folta (2016) verified empirically that relatedness of an entered business to a

[1] While focusing on economies of scope as a motive for diversification, this study only briefly discusses risk-reduction by firms (Amit and Livnat, 1988; Amit and Wernerfelt, 1990) and does not explicitly consider agency issues (Amihud and Lev, 1981).
[2] The term 'dynamics of diversification' accounts for the full evolution of a firm's scope (Helfat and Eisenhardt, 2004) involving both the expansion of the scope from focused to diversified and the contraction of the scope from diversified to focused.

firm's other businesses raises the likelihood that the firm will subsequently exit that business. Together, those findings introduced ambiguity regarding the ultimate effect of relatedness on the diversification propensity, the probability that a firm will be diversified across two businesses as opposed to being focused on one of them. In addition to the ambiguity of the effect of relatedness on the diversification propensity, two other issues were unresolved: whether relatedness alone suffices to predict the diversification propensity; and how that propensity evolves over time. The lack of clear answers to these three questions, listed in the first column of Table 1, resulted from the respective limitations in previous research outlined in the second column of the table.[3]

Insert Table 1 here

The first flaw was that, except for Lieberman *et al*. (2016), previous studies of the effect of relatedness on corporate scope choices did not distinguish between the types of economies of scope. According to Helfat and Eisenhardt (2004), 'intra-temporal' economies occur when a firm shares its resources between related businesses; whereas 'inter-temporal' economies are realized when a firm exits a business and enters another related business by redeploying its resources between them. The focus on the sharing of resources between related businesses led to the prevalent belief that relatedness between two businesses should enhance the propensity of a firm to be diversified across them (Breschi *et al*., 2003; Fan and Lang, 2000; Lemelin, 1982).

The second shortcoming was that the extant accounts implicitly assumed that the effect of relatedness on the diversification propensity is independent of other determinants of economies of scope. However, as Penrose (1959) argued, economies from corporate diversification depend on 'inducements,' return advantages of one business over another. Sakhartov and Folta (2015)

[3] Besides the limitations listed in Table 1, the argument that relatedness unambiguously enhances the diversification propensity confronts the effect of relatedness on coordination costs. Thus, Rawley (2010) speculated that relatedness raises coordination costs offsetting the realized economies of scope. Hence, firms may be less inclined to diversify relatedly to avoid coordination costs. That effect was also implied by Zhou (2011) showing that relatedness between existing and new businesses exacerbates the negative effect of the complexity of the existing business on the propensity of the firm to diversify into the new businesses. This paper offers a theory for the non-monotonic effect of relatedness on diversification that is independent of coordination costs.

formally demonstrated that inducements moderate the effect of relatedness on economies of scope. Inasmuch as scope economies determine corporate diversification decisions, inducements are also very likely to moderate the effect of relatedness on the diversification propensity.

The third limitation was that the theory on the effects of relatedness on the dynamics of diversification was informal. Nevertheless, verbal arguments can be 'very misleading' when there are inter-temporal links between choices (Ghemawat and Cassiman, 2007). With corporate diversification, such links exist because resource redeployment is costly to reverse. Hence, in deciding whether to enter (or exit) a business, a firm considers not only current redeployment costs but also costs of a future exit from (or re-entry into) the business, making scope decisions path-dependent (Sakhartov and Folta, 2014). The informal reasoning in that context led to the tenuous idea that relatedness linked to resource redeployment, unlike relatedness involved in resource sharing, has only short-run effect on corporate scope choices (Bryce and Winter, 2009).

Considering the three limitations, this study reviews the determinants of scope economies and builds a dynamic model of corporate diversification. Rooted in the general principle of dynamic optimality (Bellman, 1957), the model identifies the sequence of a firm's scope choices. The similarity between such choices and the allocation of wealth across securities by investors (Merton, 1969) enables the use of the simulation-based portfolio selection technique of Brandt *et al*. (2005), that resolves the challenges of the informal analysis and the analytical intractability of scope choices in path-dependent setting (Haugh and Kogan, 2007).

The model derives several novel results, listed in Table 1. First, the effect of relatedness on the diversification propensity depends on the type of scope economies. With intra-temporal economies, relatedness enhances the diversification propensity. In contrast, with inter-temporal economies, that propensity has an inverted U-shaped relationship with relatedness: firms are most likely to persist in sets of businesses that are moderately, rather than strongly, related to each other. The latter effect occurs because strong relatedness cuts redeployment costs and keeps a firm focused on an outperforming business, original or new. Moreover, the effects of relatedness on the diversification propensity are interdependent: the effect of relatedness involved in inter-temporal economies on the diversification propensity is most-concave when relatedness involved in intra-temporal economies is moderate. Second, with inter-temporal economies, inducements moderate the effect of relatedness on the diversification propensity. The interaction takes place because inducements reflect a possible future need for a reversal of resource redeployment, while relatedness facilitates the reversal by cutting redeployment costs. Finally, relatedness involved in inter-temporal economies has long-run implications for scope choices. With moderate relatedness present in inter-temporal economies, the diversification propensity grows over time and then remains very high throughout the resources' lifecycle.

The novel results make three contributions to corporate diversification research. First, the demonstrated difference between the two types of economies in the effect of relatedness on the diversification propensity motivates researchers to unmerge those economies in empirical models and retest the often-studied relationship between relatedness and corporate scope choices. The later section discusses how to separate empirically the two effects. Second, the study is the first to rigorously derive the complex relation between the diversification propensity and relatedness. The curvilinear relationship involved in inter-temporal economies reconciles the findings that relatedness induces both the entry into and the exit from a business. The result also replaces the informal argument that firms are more likely to persist with sets of more-related businesses. Third, the insight that inducements moderate the effect of relatedness on the diversification propensity necessitates the use of the interactions in empirical models predicting diversification choices. This paper develops hypotheses enabling the identification of the interactions between the previously known determinants of economies of scope reviewed in the following section.

DETERMINANTS OF ECONOMIES OF SCOPE

Two studies enable the identification of determinants of economies of scope. First, Helfat and Eisenhardt (2004) have classified economies of scope: ‘intra-temporal’ economies result from the *sharing* of a firm’s resources between businesses; whereas ‘inter-temporal’ economies occur when a firm *withdraws* resources from one business and redeploys them to another business. When a firm redeploys *part* of resources, the realized inter-temporal economies appear intra-temporal because the firm starts sharing the resources between the businesses. However, unless the sharing *per se* adds value, the resource withdrawal is the unique driver of such economies. Second, Levinthal and Wu (2010) have classified resources: ‘scale free’ resources are intangible resources, which have no physical substance (*e.g*., technological knowledge); while ‘non-scale free’ resources are tangible resources, which have limited physical capacity (*e.g*., manufacturing plants).[4] Their study has clarified that, because inter-temporal economies demand the withdrawal of a firm’s resources from one business, such economies involve only non-scale free resources. In contrast, intra-temporal economies occur when the sharing of scale free and/or non-scale free resources adds extra value. Relatedness, defined by Rumelt (1974) as the similarity between businesses, was identified as the key determinant of both types of economies (Hill *et al*., 1992).

Relatedness and intra-temporal economies of scope

With intra-temporal economies, relatedness enables the sharing of scale free and non-scale free resources. One source of such economies is knowledge. Because knowledge is scale free, a firm can apply knowledge created in one business to another business, avoiding costly duplication in

[4] As highlighted by Penrose (1959), firms deploy bundles of various resources to their businesses.

knowledge development (Porter, 1987; Teece, 1980). Although relatedness enhances the cross-applicability of knowledge, not any extent of relatedness creates economies. Knowledge transfer is costly (Maritan and Brush, 2003); so, in unrelated diversification, the transfer costs can exceed small cost savings. Conversely, in related diversification, substantial savings are likely to surpass the costs of the transfer. The sharing of scale free and non-scale resources can also add value through 'demand-side synergy' that occurs when a firm offers several products, adding the convenience of one-stop shopping and raising the consumers' willingness-to-pay (Ye, Priem, and Alshwer, 2012). Although relatedness enhances such synergy, only sufficiently strong relatedness makes that synergy positive because the resource sharing is intrinsically costly.

Relatedness and inter-temporal economies of scope

With inter-temporal economies, relatedness cuts the costs of redeployment of a firm's non-scale free resources from one business to another business (Montgomery and Wernerfelt, 1988) and the costs of a possible future reversal of the redeployment (or non-redeployment) (Sakhartov and Folta, 2015). Also, such economies depend on 'inducements,' return advantages of one business over another (Penrose, 1959). Inducements represent the opportunity cost of the continued use of resources in an underperforming business. [5] Sakhartov and Folta (2015) reviewed three dimensions of inducements. The first dimension, enhancing economies, is the current return advantages in the new business (Anand, 2004; Silverman, 1999; Wu, 2013). The second dimension, raising economies, is return volatilities in the current and the new businesses (Kogut and Kulatilaka, 1994; Triantis and Hodder, 1990). Finally, economies are reduced by return correlation between the businesses (Triantis and Hodder, 1990). Sakhartov and Folta (2015) demonstrated that inducements moderate the effect of relatedness on inter-temporal economies.

[5] Inducements were operationalized as the advantage in employment (MacDonald, 1985) or sales (Wu, 2013) of the new business over the original business and the change in sales in the new (Silverman, 1999) or the original business (Anand and Singh, 1997).

Implications of relatedness for corporate scope

Based on the impacts of relatedness on economies of scope, many exploratory studies have assessed the relationship between relatedness of two businesses and the probability that a firm is diversified across them. For instance, Lemelin (1982) examined diversification patterns of more than 2,000 Canadian firms in 1970s. That study found that the propensity of a firm to combine businesses is enhanced by their relatedness, measured as the similarity of distribution systems between those businesses based on input-output tables. Fan and Lang (2000) studied the propensity of a firm to combine businesses, based on the data from nearly 500 U.S. industries in the years 1982, 1987, and 1992. They reported that diversified firms are more likely to own more related segments, with relatedness captured as the affiliation with the same two-digit U.S. Standard Industry Classification (SIC) code. That result was confirmed in the same study when relatedness was measured as the similarity in both inputs and outputs between the segment industries, based on input-output tables. Finally, Breschi *et al*. (2003) explored the patterns of technological diversification in a large sample of firms in Europe and the U.S. in the years between 1982 and 1993. That study demonstrated that a firm active in one technological field is more likely to participate in another field when the two fields are more-related, with relatedness measured as co-occurrence of the two technological fields in patents.

Despite some empirical evidence regarding the impact of relatedness on diversification patterns, the tests that produced that evidence have been based on the underdeveloped theory. In particular, the theory has implied that the positive effect of relatedness on economies of scope translates into an unconditional positive effect of relatedness on the corporate scope. Notably, Teece *et al*. (1994: 5) 'assume that activities which are more related will be more frequently combined within the same corporation.' Subsequent work reiterated that assumption:

> We assume that each industry a diversified firm includes in its portfolio will affect firm performance. We refer to the performance effects of these combinations as the relatedness… related industries are more frequently combined in firms than unrelated industries. (Lien and Klein, 2013: 1480)

Bryce and Winter (2009: 1573) explained that the benefits of sharing scale free knowledge between related businesses (*i.e.*, intra-temporal economies) preserve the combinations of those businesses for a long time, while the benefits of redeploying non-scale free resources between related businesses (*i.e.*, inter-temporal economies) may have only short-run effects.

In summary, the theory regarding the impact of relatedness on the dynamics of corporate diversification and the empirical tests relying on that theory had three limitations listed in the third column of Table 1. First, the theory assumed, rather than derived, that the diversification propensity is enhanced by relatedness. Second, the effect of relatedness between businesses on the diversification propensity was implicitly assumed to be independent of other determinants of economies of scope (*i.e.*, inducements). Finally, the implications of relatedness occurring with inter-temporal economies of scope were deemed unimportant in the long run. The next section builds a model that enables the development of a theory free of those tenuous assumptions.

DYNAMIC MODEL OF CORPORATE DIVERSIFICATION

To study the impact of relatedness on corporate diversification, this section builds a model based on the principle of dynamic optimality (Bellman, 1957). That principle is well-established for representing sequential choices in various settings and has been applied to the specific context of corporate diversification (Bernardo and Chowdhry, 2002; Kogut and Kulatilaka, 1994; Matsusaka, 2001; Sakhartov and Folta, 2014; 2015; and Triantis and Hodder, 1990). The firm in the model is originally focused, deploying all its resources in product market (*i.e.*, business) i.

The firm can also use its resources in another market j.[6] Scale free and non-scale free resources can be shared between i and j. Besides, non-scale free resources may be fully or partially withdrawn from i and redeployed to j, or *vice versa*, at any time t before the end of the resource's lifecycle $t = T$. Proportions m_{it} and $m_{jt} = 1 - m_{it}$ of non-scale free resources used in markets i and j at time t reflect corporate scope choices, with m_{it} serving as a single *control variable*.[7] The sequence $\{m_{it}\}_{t=0}^{T-1}$ of corporate scope choices represents *the policy function*.

The specified corporate context involves the determinants of economies of scope. Namely, the model includes inducements: the current return advantage, return volatilities, and return correlation. Relatedness is modeled with the ease of sharing resources (pertinent to intra-temporal economies of scope) and the costs of redeploying non-scale free resources (pertinent to inter-temporal economies of scope). Redeployment costs make diversification choices path-dependent (*i.e*., the payoff to future choices depend on current choices) and intractable analytically (Haugh and Kogan, 2007). The structural similarity between the dynamic allocation of corporate resources and the dynamic portfolio choice model (Merton, 1969), as well as the generality of the principle of dynamic optimality (Bellman, 1957), enables the use of a numerical method created to optimize dynamic portfolio choices. Namely, the model uses the simulation-based technique of Brandt *et al*. (2005) illustrated in van Binsbergen and Brandt (2007).

To capture the dynamics of diversification, the model represents returns C_{it} and C_{jt} in product markets i and j at time t as two random *state variables* evolving in discrete time. The

[6] Diversification can unfold *via* sequential entries into multiple businesses, and a firm may end up combining two unrelated businesses even if each entry in the chain was related. That scenario is not considered in the model. Adding more businesses to the model would substantially extend the computation time and distract the focus from the specific gaps outlined in Table 1. The model follows prior research (Kogut and Kulatilaka, 1994; Triantis and Hodder, 1990) and focuses on one alternative business.
[7] There is no need to specify proportions of scale free resources since such resources are levered infinitely between the markets and cannot be used in isolation from non-scale free resources.

model simulates a large number of paths for C_{it} and C_{jt}, with realizations C_{kit} and C_{kjt} on path k at time t. Accordingly, m_{kit} and $m_{kjt} = 1 - m_{kit}$ capture a corporate choice on path k at time t. The sequence $\{m_{kit}\}_{t=0}^{T-1}$ of choices on path k is identified by using dynamic programming (Bellman, 1957). Namely, starting with time $t = T - 1$ when the last scope choice can be made before resources fully depreciate, the model finds on each path proportion m_{kit}^{*} that maximizes a Taylor approximation of *the value function*, the utility of the value the firm accumulates over the lifecycle of its resources by allocating them between the markets. Based on van Binsbergen and Brandt (2007), the coefficients for the Taylor series are estimated by running the ordinary least square regression of the value function realized at $t = T$ on a polynomial of the state variables at time $t = T - 1$. The algorithm then proceeds recursively from $t = T - 1$ to $t = 0$. To apply the method of Brandt *et al*. (2005), two extensions are introduced. First, because unlike Brandt *et al*. (2005) the present study is not interested in explicating the policy function, the scope choices are summarized across all paths as the probability that the firm is diversified at time t. Second, the algorithm is replicated for multiple sets of the determinants of economies of scope to derive how those determinants affect the resulting probability of diversification. Two key elements of the model, the corporate context and the identification of diversification choices, are outlined below.

Corporate context

In the model, at every time t the firm seeks to maximize the value function U_t of the terminal value V_T accumulated through resource deployment choices $\{m_{is}\}_{s=t}^{T-1}$ undertaken over the remaining lifecycle of the firm's resources. Formally, the problem the firm faces is:

$$U_t = \max_{\{m_{is}\}_{s=t}^{T-1}} E_t[u(V_T)], \qquad (1)$$

In Equation 1, $E_t[\cdot]$ is the expectation based on the information available at time t. The function $u(\cdot)$ captures the utility for the risk-averse firm of having value V_T given the attached risk.[8] The model uses the prevalent utility with constant absolute risk aversion (Arrow, 1971):

$$u(V_T) = 1 - e^{-\gamma V_T}, \qquad (2)$$

where γ is the coefficient capturing risk aversion.[9] That parameter has an intuitive interpretation that its higher value implies that the firm puts a greater discount for the risk associated with V_T.

To capture the dynamics of diversification, the model specifies the evolution of the state variables (*i.e.*, the market returns) C_{it} and C_{jt} as a vector autoregression with one lag VAR(1):

$$\begin{bmatrix} C_{it} \\ C_{jt} \end{bmatrix} = \begin{bmatrix} A_i \\ A_j \end{bmatrix} + \begin{bmatrix} \mu_{ii} & 0 \\ 0 & \mu_{jj} \end{bmatrix} \begin{bmatrix} C_{it-1} \\ C_{jt-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{it} \\ \varepsilon_{jt} \end{bmatrix}. \qquad (3)$$

That discrete-time stochastic process captures linear interdependence between univariate autoregressions AR(1) often used to empirically capture the evolution of a random variable. Equation 3 involves the dimensions of inducements used in the literature. Thus, intercepts A_i and

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[8] As repeatedly mentioned in the current section, the model operationalizes the determinants of economies of scope similar to Kogut and Kulatilaka (1994), Sakhartov and Folta (2014; 2015), and Triantis and Hodder (1990). Those studies used risk-neutral valuation models to identify the fair price for economies of scope in the equilibrium market. Such models provide an aggregate view of the market but are not capable of characterizing specific choices of heterogeneous firms. The present model considers a firm's preference for balancing risk and return to be the key source of heterogeneity in diversification choices and parameterizes that preference with the coefficient of risk aversion γ. Accordingly, the heterogeneous diversification choices are identified with different values of γ. The assumption of risk aversion is common in modeling individuals optimizing the allocation of wealth across risky securities. There are several reasons for extending that assumption to firms. First, firms' choices were shown to be driven by the risk preferences of their key stakeholders: chief executive officers (Cronqvist, Makhija, and Yonker, 2012), key managers (Koller, Lovallo, and Williams, 2012), or large shareholders (Faccio, Marchica, and Mura, 2011). Second, the idea replaces the restrictive assumption that firms make uniform choices based on risk-neutrality. Such uniformity would contrast with the actual heterogeneity of resolutions for the same corporate challenges. For example, facing the decline in the newspaper business, Belo Corporation completely withdrew from that business in 2002 to switch to broadcasting; while The Washington Post Co. persisted with that business. Also, facing the collapse in the snowmobile business in early 1970s, dozens of snowmobile businesses exited that business forever; whereas Bombardier Inc. withdrew only part of its resources from snowmobiles and persisted with that business until 2003. Finally, concave utility functions have been repeatedly used in the literature (*e.g.*, Asplund, 2002; Carceles Poveda, 2003; Choudhary and Levine, 2010; Loehman and Nelson, 1992; Meunier 2014) to specify the tradeoff between risk and returns faced by firms.

[9] The chosen utility is common in portfolio selection (Çanakoğlu and Özekici, 2009; Henderson, 2005; Muthuraman and Kumar, 2006). That utility has a property that $u(V_T + \nu) = f(\nu)u(V_T) + g(\nu)$, where ν is a constant; and $f(\cdot)$ and $g(\cdot)$ are functions independent of V_T. That property enables modelers to ignore ν, making complex optimization feasible.

A_j capture the current return advantage $(A_j - A_i)/A_i$. Errors ε_{it} and ε_{jt} have variances σ_i^2 and σ_j^2 and correlation ρ capturing return volatilities and correlation, respectively. With Equation 3, C_{it} and C_{jt} are realized in $T+1$ points in time $t \in [0,T]$. In the context void of economies of scope, an arbitrary realization k of returns C_{kit} and C_{kjt} and deployment of proportions m_{kit} and $(1-m_{kit})$ of resources in markets i and j, respectively, would generate the net return at time t:

$$F_{kt} = [m_{kit}C_{kit} + (1-m_{kit})C_{kjt}]. \qquad (4)$$

Relatedness is modeled with its effects on economies of scope. With inter-temporal economies, relatedness cuts redeployment costs. Such costs represent a loss of efficiency in taking non-scale free resources from another business and switching them to a focal business below returns earned when the resources had been used in the focal business (Montgomery and Wernerfelt, 1988). That loss of efficiency is captured by expressing the full costs of redeploying resources to j (i) at time t as a product of (a) the marginal redeployment cost S of a unit of resources; (b) the amount $\max[0, m_{kit-1} - m_{kit}]$ $(\max[0, m_{kit} - m_{kit-1}])$ of resources moved to j (i) between $t-1$ and t; and (c) mean returns $\hat{C}_{jt}$ ($\hat{C}_{it}$) at time t in j (i). The used specification of redeployment costs has precedents: Sakhartov and Folta (2014; 2015) modeled redeployment costs as a proportion of returns in the receiving unit. Kogut and Kulatilaka (1994) modeled switching costs as a proportion of value outcomes; in their model such outcomes were captured with mean production costs. Thus, with inter-temporal economies, the net return at time t is

$$F_{kt} = [m_{kit}C_{kit} + (1-m_{kit})C_{kjt}] - S\{\max[0, m_{kit} - m_{kit-1}]\hat{C}_{it} + \max[0, m_{kit-1} - m_{kit}]\hat{C}_{jt}\}. \quad (5)$$

With intra-temporal economies, relatedness enables the sharing of resources. Therefore, the firm can save on knowledge development (Porter, 1987; Teece, 1980) and/or attain demand-side synergy (Ye *et al*., 2012), increasing net returns. The small economies realized in unrelated diversification can be below the costs of sharing resources (Maritan and Brush, 2003), turning economies into diseconomies. That possibility is represented by amending Equation 5 as follows

$$F_{kt} = [m_{kit}C_{kit} + (1-m_{kit})C_{kjt}] - S\{\max[0, m_{kit} - m_{kit-1}]\hat{C}_{it} + \max[0, m_{kit-1} - m_{kit}]\hat{C}_{jt}\} + I(\beta-1)](m_{kit}\hat{C}_{it} + (1-m_{kit})\hat{C}_{jt}) \quad (6)$$

In Equation 6, I is an indicator of resource sharing: $I=1$ if $0 < m_{kit} < 1$, and $I=0$ otherwise. Coefficient β is the sharing factor directly capturing the effect of relatedness on intra-temporal economies. When $\beta < 1$ ($\beta > 1$), i and j are weakly (strongly) related and diversification creates diseconomies (economies). When $\beta = 1$, i and j are moderately related and the firm generates neither economies nor diseconomies. That specification of relatedness involved in intra-temporal economies with the sharing factor has precedents (Sakhartov and Folta, 2014).[10]

The representation of relatedness imposes no dependence between S and β. Although a strong negative relationship may occur when relatedness is defined as the *general* similarity of resource requirements between businesses (Rumelt, 1974), the model avoids assuming a strong negative relationship for two reasons. First, the extant theory does not argue that two businesses using similar resources involved in intra-temporal economies should necessarily rely on equally similar resources involved in inter-temporal economies. Second, by not imposing a specific relationship between S and β, the model is agnostic about the nature of that relationship. That approach enables flexibility in examining the dynamic impact of relatedness on diversification for any dependence structure between S and β, instead of making the restrictive assumption.

[10] There are two reasons for specifying intra-temporal economies of scope as a proportion of average rather than actual market returns. First, that specification precludes intra-temporal economies from being negative for reasons other than low relatedness. That measure is needed because, with VAR(1), C_{it} or C_{jt} (in contrast to $\hat{C}_{it}$ or $\hat{C}_{jt}$) may have a negative realization. A negative realization may occur when the demand for the product in market i or j drops. That drop, however, will not eliminate cost savings from the resource sharing. Second, the specification is aligned with the specification of inter-temporal economies.

Identification of corporate diversification choices

Non-trivial redeployment costs ($S > 0$) make diversification path-dependent, precluding the analytical identification of the policy function (Haugh and Kogan, 2007). That issue is resolved with the simulation-based technique of Brandt *et al*. (2005) illustrated in van Binsbergen and Brandt (2007). Five steps in van Binsbergen and Brandt (2007) are amended with two last steps that assess the diversification propensity. Also, the algorithm is replicated for numerous sets of the determinants of economies of scope to identify how those determinants affect that propensity.

- **Step 1.** Simulate n of paths for C_{it} and C_{jt} based on Equation 3. Discretize proportion $m_{kit} \in [0, 1]$ of resources deployed in i with a grid $m_{kit} \in \{0, 1/L, 2/L, ..., (L-1)/L, 1\}$, where L is a discretization number. Estimate mean returns $\hat{C}_{it}$ and $\hat{C}_{jt}$ for Equation 6.
- **Step 2.** Take path k and consider time $t = T-1$ when returns are earned the last time. For a current diversification choice m_{kiT-1} and a most recent choice m_{kiT-2} taken from their discretized values, use Equation 6 and Online Appendix A to estimate value $\tilde{V}_{kT}$ relevant for the optimization of the choice m_{kiT-1}. Repeat the estimation of $\tilde{V}_{kT}$ for each of n paths. Use Equation 2 to compute utility $u(\tilde{V}_{kT})$. Assemble the dataset consisting of n combinations of $u(\tilde{V}_{kT})$, $C_{kiT\text{-}1}$, and $C_{kjT\text{-}1}$. Run an ordinary least square regression model such that $u(\tilde{V}_{kT}) = \alpha_0 + \alpha_1 C_{kiT\text{-}1} + \alpha_2 C_{kjT\text{-}1} + \alpha_3 C^2_{kiT-1} + \alpha_4 C^2_{kjT-1} + \alpha_5 C_{kiT\text{-}1} * C_{kjT\text{-}1} + \psi$.[11]
- **Step 3.** Using the coefficients (α's) estimated in Step 2, compute, on each path, the expected utility $\hat{u}(\cdot) = E[u(\tilde{V}_{kT}) \,|\, (C_{kiT\text{-}1}, C_{kjT\text{-}1}, m_{kiT\text{-}1}, m_{kiT\text{-}2})]$ conditioned on the firm being on path k, having previously committed choice m_{kiT-2}, and committing choice m_{kiT-1}.

[11] The model involves the second-order Taylor expansion of the utility function. Error ψ is normally distributed with zero mean.

- **Step 4.** Repeat Steps 2 and 3 for all values of m_{kiT-1} and m_{kiT-2}. Take values of $\hat{u}(\cdot)$ calculated for a particular value of m_{kiT-2} and, with those values, select an optimal current choice $(m^{*}_{kiT\text{-}1} \mid m_{kiT\text{-}2}) = \arg\max_{m_{kiT\text{-}1}} \hat{u}(\cdot)$ conditioned on the considered most recent choice $m_{kiT\text{-}2}$. Repeat Step 4 for all values of the most recent choice $m_{kiT\text{-}2}$.
- **Step 5.** Using the dynamic programming principle, proceed recursively backward from $t = T-2$ to $t = 0$ with Steps 2, 3, and 4 and retrieve the matrix of diversification choices $(m^{*}_{kit} \mid m_{kit\text{-}1})$ on all n paths conditioned on the most recent choices. In calculating value $\tilde{V}_{kT}$ relevant for the optimization of diversification choices, use Equation 6 and Online Appendix A.
- **Step 6.** Given that the firm is initially focused on market i, proceed recursively forward from $t = 0$ to $t = T-1$ through the conditional diversification choices $(m^{*}_{kit} \mid m_{kit\text{-}1})$ derived in Steps 5 and calculate the matrix of unconditional choices $\{m^{*}_{kit}\}_{t=0}^{T-1}$. Each of n columns of that matrix represents the policy function on path k. All columns together represent the policy function for all n states of the state variables C_{it} and C_{jt} over time.
- **Step 7.** Use the matrix of unconditional choices from Step 6 and estimate the probability $p_t = \Pr[\{m^{*}_{kit} \neq 0 \cap m^{*}_{kit} \neq 1\}]$ of diversification at time t by dividing the number of cases where the firm is not fully focused on either i or j at time t by the total number of possible scenarios n. On each path k, the longevity of diversification l_k is counted as the number of periods when the firm diversifies. The mean longevity is $\hat{l} = \sum_{k=1}^{n} l_k / n.$ [12]

[12] The value dynamics in the context with intra-temporal and inter-temporal economies are shown in Online Appendix A.

RESULTS

The analysis of the impact of relatedness on the dynamics of diversification addresses the three issues raised in Table 1. First, the diversification propensity is derived for various combinations of the sharing factor and the redeployment cost, while keeping other parameters constant. That design identifies the two roles of relatedness on the diversification propensity. Second, the diversification propensity is assessed for multiple sets of the determinants of inter-temporal economies, when intra-temporal economies are disallowed. In that step, the interactions between inducements and redeployment costs in determining the diversification propensity are explicated. Finally, the evolution of the diversification propensity is traced over time, and the sensitivity of that propensity to redeployment costs is checked at the end of the resources' lifecycle. That analysis uncovers the long-run impact of relatedness involved in inter-temporal economies.

Implications of relatedness for diversification propensity

A key aim of the study is to test the idea that relatedness enhances the diversification propensity. Figure 1 illustrates that propensity with the probability that the firm is diversified in the middle of the resource lifecycle (Panel A) and the average longevity of diversification (Panel B). Inter-temporal economies are represented with the marginal redeployment cost varying continuously. Intra-temporal economies are captured with the sharing factor, taking five values. The following three patterns in Figure 1 summarize the effects of relatedness on the diversification propensity.

Insert Figure 1 here

First, the lines with a higher sharing factor are located at least as high as the lines with a lower factor. That result confirms the existing view that relatedness involved in intra-temporal economies of scope monotonically enhances the diversification propensity.

Second, most lines in Figure 1 have inverted U-shapes. That curvature suggests that, with inter-temporal economies, moderate rather than the strongest relatedness leads to the highest probability that the firm will be diversified, and to the greatest longevity of diversification. That result challenges the assumed monotonic positive relationship between relatedness and the diversification propensity. The novel result can be explained intuitively based on the role of relatedness with inter-temporal economies.

- With strong relatedness, the costs of redeploying resources to another business, and of reversing that redeployment or non-redeployment, are dispensable. Even a tiny advantage in another business makes the firm redeploy *all* resources to that business. As a result, the firm becomes focused on the new business. Conversely, a tiny disadvantage in another business makes the firm wait for a better redeployment opportunity. In both cases, the firm is more likely to remain focused rather than to become diversified.
- With weak relatedness, the costs of redeploying resources to another business, and of reversing that redeployment, are high. The firm waits for a very rare opportunity to redeploy *all* resources to the much better performing business, remaining focused on the original business in most realizations of uncertain returns.
- With intermediate relatedness, the costs of redeploying resources to another business, and of reversing that redeployment or non-redeployment, are moderate. The firm envisions interchanging advantages and disadvantages of the new business. The optimal choice for the firm is to economize on the current redeployment costs and the possible future cost of reversal. Hence, the firm rations the amount of redeployed resources, and redeploys only *part* of them to another business, the part that will remain in that business until the end of the resources' lifecycle. As a result, the firm becomes persistently diversified.

Third, lines in Figure 1 vary in concavity. Notably, the lines depicting a moderate sharing factor are concave. Conversely, the lines with a very low or very high factor are flat. With a very high sharing factor on the lines with plus signs, the firm instantly redeploys part of its resources to a new business to receive very strong intra-temporal economies. The firm then remains diversified regardless of redeployment costs. With a very low sharing factor, represented with the broken lines, the firm is reluctant to incur very strong diseconomies and never redeploys resources to the new business regardless of redeployment costs. With a moderate sharing factor, the firm is indifferent to the trivial intra-temporal economies but is sensitive to the redeployment costs determining inter-temporal economies of scope. That third pattern means that the effects of relatedness on corporate diversification, involved in the two types of economies of scope, are interdependent, necessitating the operationalization of that interdependence in empirical models.

Implications of inducements for diversification propensity

Although corporate diversification research has focused on relatedness, the effects of other determinants of economies of scope should also be explicated. That clarification would be particularly necessary if the effect of relatedness on the diversification propensity depended on inducements. That possible interdependence is tested below for each dimension of inducements.

Current return advantage

Figure 2 presents the effects of the current return advantage on the probability that the firm is diversified (Panel A) and the longevity of diversification (Panel B). The broken lines and the lines with downward-pointing triangles are close to the zero level indicating that, with negative current advantages, the diversification propensity is low and weakly affected by redeployment costs. The result is intuitive: the firm is reluctant to switch resources to an underperforming business regardless of redeployment costs. Although the lowest diversification propensity corresponds to the strong current disadvantage, the figure fails to demonstrate a robust direct effect of the current advantage on corporate diversification. For example, with low redeployment costs, the strongest diversification propensity results from zero current advantage. In turn, with high costs of redeployment, the positive current advantage leads to the strongest propensity.

Insert Figure 2 here

Despite the unclear direct effect, the current return advantage systematically alters the effect of redeployment costs on the diversification propensity: with greater current advantages, a peak in that propensity shifts to higher redeployment costs. That shift is interpreted as follows.

- Strong current advantages combined with low redeployment costs make the firm instantly switch *all* resources to another market. The effect is seen in the flat parts of the lines with plus signs where the firm is focused. With higher redeployment costs, the firm rations the amount of redeployed resources to cut current redeployment costs and possible future costs of reversing it. As a result, the firm switches only *part* of its resources, becoming diversified. That tendency is seen in the upward-sloping parts of the lines with plus signs.
- If current return advantages are weaker, the firm is less motivated to redeploy all resources to another business, and the rationing of the amount of redeployed resources (*i.e.*, partial redeployment leading to diversification) occurs with lower redeployment costs, as in the lines with upward-pointed triangles and the solid lines in Figure 2.

Return volatility

Figure 3 shows two effects of volatility on the diversification propensity. First, the lines with higher volatility are above the lines with lower volatility, verifying the portfolio theory that has predicted that volatility enhances the proclivity of investors to diversify (Markowitz, 1959).

Insert Figure 3 here

Second, the higher the volatility on a line, the farther the declining part of that line shifts to the right. As a result, the range of redeployment costs making the probability of diversification greater than 75 percent is six times broader with very high volatility than with low volatility. The fact that volatility extends the range of relatedness making the probability of diversification high was not part of the portfolio theory. The effect, confirmed in the longevity of diversification, is explained as follows: the firm faces the oscillation of relative returns in another business between advantages and disadvantages, with the extent of the realized differences depending on volatility.

- With low volatility, the confidence bands for returns are narrow and return advantages in another business are weak. Even medium redeployment costs exceed a weak advantage in another business and suffice to discourage the firm from resource redeployment. Hence, the sharp decline in the diversification propensity starts at medium redeployment costs.
- With very high volatility, the bands for returns are broad, and both strong advantages and strong disadvantages are abundant. The firm can switch resources to the business with a strong advantage, but it may have to costly undo that switch in the future. Alternatively, the firm can wait for even stronger advantages in another business, but it may miss the strongest advantage. With those tradeoffs, the firm accepts higher redeployment costs to cautiously switch part of its resources to the new business and become diversified.

Return correlation

Figure 4 demonstrates two effects of correlation on the diversification propensity. First, the lines with more-negative correlation are above the lines with more-positive correlation, revealing a direct negative effect. That effect supports the portfolio theory (Markowitz, 1959): correlation raises the variance of returns in a portfolio of assets, reducing the utility of diversification.

Insert Figure 4 here

Second, the more-negative the correlation on a line, the farther the downward-sloping part of that line shifts to the right. As a consequence, the range of redeployment costs making the probability of diversification greater than 75 percent is three times broader with strong negative correlation than with zero correlation. The pattern that correlation contains values of relatedness making the probability of diversification high was not explored in the portfolio theory. The extension, also revealed in the longevity of diversification, has the following interpretation.

- With positive correlation, returns in the two businesses are close to each other, and cases with strong advantages or disadvantages are rare. Even moderate costs exceed a weak advantage in another business and discourage the firm from resource redeployment. Hence, the decline in the diversification propensity starts at moderate redeployment costs.
- With negative correlation, both strong advantages and strong disadvantages are present. The firm faces the same dilemmas as with high volatility and accepts higher costs to cautiously switch part of its resources to the new business and become diversified.

Overall, inducements do alter how relatedness involved in inter-temporal economies affects the diversification propensity. Accordingly, the effect of relatedness on the patterns of diversification cannot be reliably identified without capturing its interactions with inducements.

Evolution of diversification propensity with different types of economies of scope

The last candidate for scrutiny is the claim that inter-temporal economies realized in switching resources between related businesses have only short-run implications. The model tests that idea by tuning the two effects of relatedness and tracing the probability of diversification over time.

To uncover the long-run implications of relatedness, Panel A of Figure 5 presents the effect of redeployment costs on the probability that the firm will be diversified at the end of the resources' lifecycle. When intra-temporal economies are absent, relatedness involved in inter-temporal economies strongly affects the probability of diversification even at the end of the resources' lifecycle. The inverted U-shaped relationship reported in Figures 1–4 persists in the long run. Moreover, the magnitude of the relation continues to be very strong: the probability of diversification varies between zero and 99 percent depending on the value of redeployment costs.

Insert Figure 5 here

Panel B shows the evolution of the probability of diversification with medium relatedness present in inter-temporal economies. The positions of the line with plus signs and the broken line confirm that relatedness present in intra-temporal economies has a durable effect on the scope of the firm. However, the solid line capturing the context void of intra-temporal economies rejects the claim that inter-temporal economies of scope have only a short-run effect on diversification. Specifically, when relatedness present with inter-temporal economies is moderate, the probability of diversification grows over time and remains very high (96%) in the long run.

Validation of results

A substantial effort has been made to verify that the model is applicable to corporate settings. First, the model uses concepts often applied in corporate diversification research. Second, in capturing those concepts, the model builds off the modelling precedents. Third, the model reconfirms the main idea of the extant theory and only qualifies it by considering the previously ignored issues. Fourth, every new result is given an intuitive interpretation. Fifth, robustness tests were run to check whether the results are due to the particular specification. As is common in sensitivity analyses, the results in each figure were re-estimated for alternative values of parameters held constant in the baseline estimation (Online Appendix B). All of the results have been reconfirmed. Finally, the later section compares the most intriguing result of the inverted U-shaped relationship with the patterns of corporate diversification observed in U.S. industries.

Summary of new theoretical results

The following hypotheses summarize the new theoretical results amending the existing theory.

H1: The propensity to diversify in two businesses has an inverted U-shaped relationship with relatedness involved in inter-temporal economies of scope between those businesses.

H2: The inverted U-shaped relationship between the propensity to diversify in two businesses and relatedness involved in inter-temporal economies of scope is strongest when relatedness involved in intra-temporal economies of scope is moderate.

H3: The inverted U-shaped relationship between the propensity to diversify in two businesses and relatedness involved in inter-temporal economies of scope sifts to lower levels of such relatedness with stronger current return advantages.

H4: The inverted U-shaped relationship between the propensity to diversify in two businesses and relatedness involved in inter-temporal economies of scope expands onto a broader range for such relatedness with higher return volatilities.

H5: The inverted U-shaped relationship between the propensity to diversify in two businesses and relatedness involved in inter-temporal economies of scope expands onto a broader range for such relatedness with more-negative return correlation.

TOWARDS EMPIRICAL IDENTIFICATION OF THEORETICAL RESULTS

Empirical models seeking to test the implications of relatedness for the dynamics of corporate diversification, elaborated with Hypotheses 1–5, can take the following form:

$$\begin{aligned} Y = \varphi_0 + \varphi_1 K + \varphi_2 \beta_{ij} + \varphi_3 S_{ij} + \varphi_4 \beta_{ij}^2 S_{ij}^2 + \varphi_5 (C_{jt} - C_{it}) + \varphi_6 [S_{ij} + \varphi_7 (C_{jt} - C_{it})]^2 \\ + \varphi_8 \sigma_i + \varphi_9 \sigma_i S_{ij}^2 + \varphi_{10} \sigma_j + \varphi_{11} \sigma_j S_{ij}^2 + \varphi_{12} \rho_{ij} + \varphi_{13} \rho_{ij} S_{ij}^2 + \varepsilon \end{aligned} . \qquad (7)$$

The dependent variable Y may be captured as the probability of the co-occurrence of businesses i and j in the corporate scope or the duration of that combination. Businesses can be identified based on the U.S. SIC. All φ's are estimated coefficients. Determinants of the diversification propensity other than those used in this study are denoted by K. The sharing factor β_{ij} can be measured inversely with the Euclidean distance between SIC industries i and j in the patent categories based on industry patent profiles (Silverman, 1999). That distance would capture how the dissimilarity in requirements to the technological knowledge between i and j hampers the knowledge sharing. To capture the demand-side synergy, β_{ij} can also be measured inversely as the Euclidean distance between SIC industries in consumers based on the industry output tables (Brush, 1996). Redeployment costs S_{ij} can be measured directly as the Euclidian distance between industries i and j in non-scale free, tangible resources. Current returns C_{it} and C_{jt} can be taken from the Compustat Segments as mean industry return on asset (ROA) at time t. Volatilities σ_i and σ_j can be computed as standard deviations of industry ROA. Return correlation ρ_{ij} can be measured as correlation of mean ROA between industries. Finally, the distribution of the error term ε is chosen based on the used dependent variable, the probability of the co-occurrence or the duration of the co-occurrence.

Hypotheses H1–H5 are tested by checking the signs of the respective φ's. Based on the theoretical results derived in the present study, the expected signs of the coefficients are the following: $\varphi_4 > 0$ (H2), $\varphi_6 < 0$ (H1), $\varphi_7 < 0$ (H3), $\varphi_9 < 0$ and $\varphi_{11} < 0$ (H4), and $\varphi_{13} > 0$ (H5).

DISCUSSION

Does relatedness between businesses enhance the tendency for a diversifying firm to persistently combine them? Existing theory answered that question affirmatively (Bryce and Winter, 2009; Lien and Klein, 2013; Teece *et al*., 1994). The direct relationship, inferred from the positive impact of relatedness on intra-temporal economies of scope resulting from resource sharing, has been tested empirically (Breschi *et al*., 2003; Fan and Lang, 2000; Lemelin, 1982). However, there has also been recognition of inter-temporal economies of scope, with which relatedness can destabilize the corporate scope making firms exit some businesses to enter related businesses (Helfat and Eisenhardt, 2004; Lieberman *et al*. 2010; Sakhartov and Folta, 2014; 2015). With that insight, the ultimate effect of relatedness on the dynamics of diversification is less certain than previously believed. In addition, determinants of economies of scope other than relatedness were argued to interact with relatedness in creating economies (Penrose, 1959; Sakhartov and Folta, 2015) and, therefore, can alter the effect of relatedness on the diversification propensity. To improve the understanding of the effect of relatedness on the dynamics of diversification, this study builds the dynamic model of diversification choices that includes both types of economies of scope. The model delivers several stimulating insights for corporate diversification research.

First, the model identifies separate and joint effects of relatedness on the diversification propensity with the two types of economies of scope. As known previously, that propensity is enhanced by relatedness present in intra-temporal economies. In contrast, with inter-temporal economies, the diversification propensity has an inverted U-shaped relationship with relatedness: firms are most likely to combine businesses with moderate rather than the strongest relatedness. In addition, the two effects of relatedness are interdependent. In particular, the diversification propensity is most sensitive to relatedness present in inter-temporal economies when relatedness involved in intra-temporal economies is intermediate. The difference between the two effects of relatedness, along with the interdependence between them, necessitates the separate operationalizations of the two manifestations of relatedness and the re-examination of the often-tested relationship between diversification and relatedness.

Second, relatedness alone does not suffice to predict the proclivity of a firm to diversify. Inducements significantly moderate the effect of relatedness. The derived interactions suggest that the effect of relatedness on diversification cannot be identified empirically, unless its interactions with inducements are captured. The study summarizes the empirical relationships and provides the direction for their empirical operationalization, laying the groundwork for a better empirical identification of the determinants of the diversification propensity.

Finally, the paper reveals the dynamics of diversification resulting from inter-temporal economies. In contrast to the extant view, the diversification propensity is shown to remain very sensitive to relatedness involved in such economies in the long run. With moderate relatedness present in inter-temporal economies, the firm is diversified, even when intra-temporal economies are absent. Moreover, that propensity grows over time. The risk of assuming that relatedness involved in inter-temporal economies is unimportant in the long run is illustrated below.

Relationship between diversification propensity and relatedness in U.S. industries

This section provides tentative evidence of the relationship between the proclivity of U.S. firms to diversify and the two effects of relatedness. The diversification propensity is computed as the mean time of combining two U.S. SIC industries within a firm's scope based on the Compustat Segments in years 1976–2013. The sharing factor for intra-temporal economies is estimated with patent profiles of U.S. SIC industries. The measure (described in Online Appendix C) captures the similarity between industries in terms of scale free technological knowledge classified into categories (*e.g.*, *Explosives*; *Basic Electric Elements*; and *Optics*). Redeployment costs, capturing un-relatedness in inter-temporal economies, are computed using profiles of U.S. SIC industries in tangible resources. The measure (detailed in Online Appendix C) considers the dissimilarity between industries in terms of non-scale free resources classified into categories of tangible resources in Compustat (*e.g.*, *Inventories*; *Property, Plant, and Equipment*; *Cash and Short-term Investments*). The relationship between the two proxies for relatedness is illustrated in Figure 6.

Insert Figure 6 here

Figure 6 indicates that various combinations of the two effects of relatedness occur in U.S. industries. The declining regression line shows a negative relationship between the sharing factor and redeployment costs. That relationship is expected when relatedness is conceived of as an aggregate similarity of resource requirements between businesses. While that relationship is significant statistically, its magnitude is weak. The weakness of the relationship between the two effects of relatedness implies that two businesses using similar scale free knowledge do not necessarily rely on equally similar non-scale free resources.

Figure 7 plots the time of combining industries against the two effects of relatedness. If the assumed simple relationship, with which relatedness enhances the diversification propensity, were true, the graph would have one peak (Panel A). With actual data (Panel B), there is indeed a peak in the top left corner confirming the persistence of pairs of strongly related businesses. However, there is another peak where the two proxies are moderate. Hence, the long survival of pairs of businesses *moderately* related to each other may be erroneously classified as establishing *strong* relatedness between those businesses. The second peak, where both the sharing factor and redeployment costs are moderate, matches the peak in the solid line in Panel B of Figure 1.

Insert Figure 7 here

Limitations

This study builds the dynamic model to scrutinize the dynamics of diversification. However, the methodology used has some limitations. The generalizability of the numerically derived results may be compromised by arbitrary choices of the parameters used. This study attempts to mitigate that concern by undertaking extensive sensitivity checks and confirming that the directions of all the reported relationships are robust throughout a wide variety of parameter specifications.

In addition, the practical significance of the theoretically derived relationships depends on their strength relative to other predictors of the diversification propensity in real corporate contexts. Although the previous section shows the tentative evidence from the real industry setting to be consistent with the main derived result, the illustration falls short of controlling for multiple alternative predictors of the diversification propensity. Future empirical work should use more sophisticated empirical models to ascertain whether the reported effects of relatedness on the proclivity of firms to diversify are statistically significant in representative samples.

Some readers may find the model of diversification used in this study to be too simplistic because it ignores time lags in resource allocation, organizational inertia, bounded rationality of corporate managers, competitive advantages of incumbent or new firms in businesses entered, and possible acquisitions and divestitures of resources. While adding those features would enrich the enquiry, they would also considerably complicate the model making it intractable even numerically. Future studies may attempt to build more comprehensive models of diversification.

Finally, the focus on economies of scope confronts the tenet that corporate diversification is redundant because market investors can, by themselves, efficiently diversify their investments. While providing investors with the opportunity to reduce risk to a level adequate for returns on their investment, portfolio diversification does not guarantee that investors will attain the best possible value available to managers through the active use of economies of scope. In particular, managers, but not investors, have the prerogative to redeploy employees and physical assets.[13]

[13] Resource redeployment at Bombardier Inc. illustrates economies realized by managers but unavailable to investors. With the downturn of the snowmobile business in early 1970s, many snowmobile manufacturers exited the business by bankruptcy or divestment. Such solutions were costly to investors who had to sell the depreciating stock with a substantial discount. In contrast, managers of Bombardier Inc. redeployed resources to the public transportation, whose relatedness to snowmobiles remarkably reduced redeployment costs and whose current advantage over snowmobiles provided strong inducements for redeployment.

Conclusion

The present paper examines the implications of resource relatedness for the dynamics of corporate diversification. The benchmark for the scrutiny is the very prevalent belief that firms are more likely to diversify in combinations of more-related businesses, because relatedness enhances intra-temporal economies of scope by enabling the contemporaneous sharing of resources between combined businesses. This study uses the dynamic model of diversification choices to reconsider that proposition. The model follows recent research and involves the effects of relatedness on the diversification propensity with various types of economies of scope. The model demonstrates that, with inter-temporal economies resulting from the redeployment of non-scale free resources, the effect of relatedness on the diversification propensity differs markedly from what is commonly assumed. In particular, with inter-temporal economies, the strongest diversification propensity derives from moderate, rather than the strongest, relatedness. Moreover, with inter-temporal economies, the effect of relatedness on the diversification propensity is critically moderated by other determinants of such economies and by relatedness involved in intra-temporal economies. The study develops empirically testable hypotheses for those complex relationships, thereby qualifying the commonly tested, simple proposition that firms are more likely to diversify in more-related businesses. The paper also suggests empirical operationalizations for the hypotheses developed. Those developments may encourage empiricists to retest the dynamic implications of relatedness for corporate diversification.

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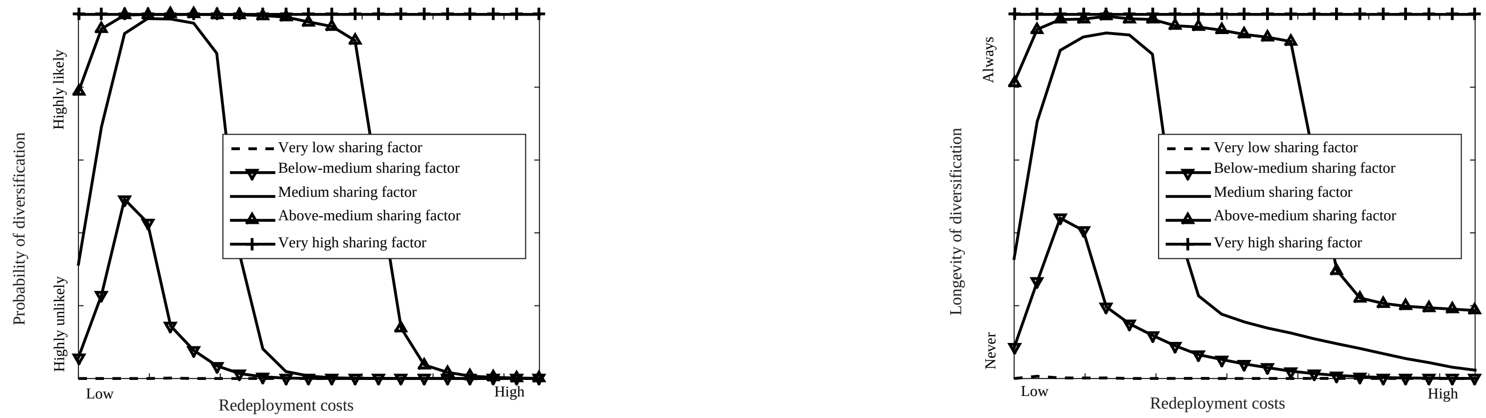
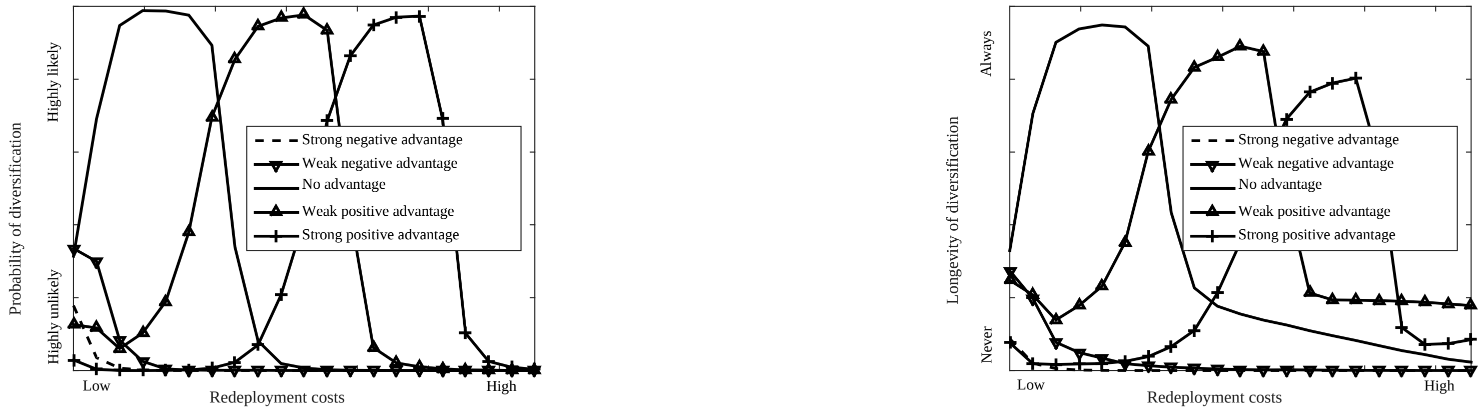


A. Effects of redeployment costs and the sharing factor on the probability of corporate diversification

B. Effects of redeployment costs and the sharing factor on the longevity of corporate diversification

Figure 1. Implications of relatedness for the dynamics of corporate diversification

Figure 1 shows the probability p_t of the firm being diversified in markets i and j in the middle of the resources' lifecycle (Panel A), and the average longevity $\hat{l}$ of such diversification (Panel B). The first (inverse) proxy for relatedness, the marginal redeployment cost S, represents inter-temporal economies of scope and varies within the interval $S \in [0.0, 1.3]$. In particular, $S = 0.0$ corresponds to the strongest possible relatedness involved in inter-temporal economies between i and j, whereas $S = 1.3$ corresponds to very weak relatedness with inter-temporal economies. The second (direct) proxy for relatedness, the sharing factor β, represents intra-temporal economies of scope and takes five values $\beta \in \{0.90, 0.99, 1.00, 1.01, 1.10\}$. To clarify, with $\beta = 0.90$ (depicted with the broken lines), i and j are very weakly related, resulting in strong intra-temporal diseconomies of scope. With $\beta = 0.99$ (depicted with the lines with downward-pointing triangles), relatedness is slightly below average, resulting in weak intra-temporal diseconomies. With $\beta = 1.00$ (depicted with the solid lines), relatedness is average, generating neither intra-temporal diseconomies nor intra-temporal economies. With $\beta = 1.01$ (depicted with the lines with upward-pointing triangles), relatedness is slightly above average, creating weak intra-temporal economies. With $\beta = 1.10$ (depicted with the lines with plus signs), i and j are very strongly related, resulting in strong intra-temporal economies. The following values of other parameters were used to generate the graphs: the length of the resources' lifecycle, $T = 10$; the coefficient of absolute risk aversion, $\gamma = 0.5$; the discreteness with which resource capacity may be redeployed, $L = 10$; the offsets capturing the current returns, $A_i = A_j = 0.50$; the trends for returns, $\mu_{ii} = \mu_{jj} = 0.1$; the variances of the innovation terms capturing the volatilities of returns, $\sigma_i^2 = \sigma_j^2 = 0.45$; the correlation of the innovation terms capturing the correlation of returns, $\rho = 0$; the number of simulated paths for the returns, $n = 10{,}000$; the risk-free interest rate, $r = 0.1$; and the value of the invested resources, $V_0 = 1$.

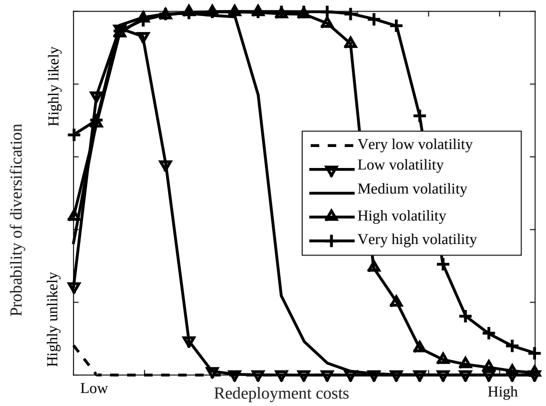


A. Effects of redeployment costs and the current return advantage on the probability of diversification

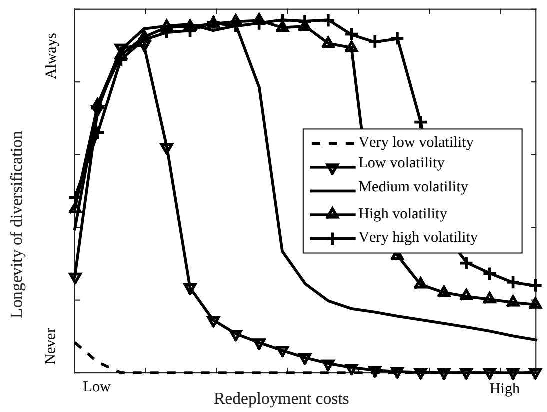
B. Effects of redeployment costs and the current return advantage on the longevity of diversification

Figure 2. Implications of redeployment costs and the current return advantage for the dynamics of corporate diversification

Figure 2 shows the probability p_t of the firm being diversified in markets i and j in the middle of the resources' lifecycle (Panel A), and the average longevity $\hat{l}$ of such diversification (Panel B). The first (inverse) proxy for relatedness, the marginal redeployment cost S, represents inter-temporal economies of scope and varies within the interval $S \in [0.0, 1.3]$. In particular, $S = 0.0$ corresponds to the strongest possible relatedness with inter-temporal economies between i and j, whereas $S = 1.3$ corresponds to very weak relatedness with inter-temporal economies. The second proxy for relatedness, the sharing factor β, is set to the medium value $\beta = 1.00$ with which relatedness is moderate and intra-temporal diseconomies or economies are absent. The current return advantage $(A_j - A_i)/A_i$ takes five values. In particular, in the broken lines, $A_i = 0.50$ and $A_j = 0.40$ showing a strong negative current advantage. In the lines with downward-pointing triangles, $A_i = 0.50$ and $A_j = 0.45$ revealing a weak negative current advantage. In the solid lines, $A_i = A_j = 0.50$ capturing zero current advantage. In the lines with upward-pointing triangles, $A_i = 0.50$ and $A_j = 0.55$ showing a weak positive current advantage. In the lines with plus signs, $A_i = 0.50$ and $A_j = 0.60$ revealing a strong positive current advantage. The following values of other parameters were used to create the graphs: the length of the resources' lifecycle, $T = 10$; the coefficient of absolute risk aversion, $\gamma = 0.5$; the discreteness with which resource capacity may be redeployed, $L = 10$; the trends for returns, $\mu_{ii} = \mu_{jj} = 0.1$; the variances of the innovation terms showing return volatilities, $\sigma_i^2 = \sigma_j^2 = 0.45$; the correlation of the innovation terms capturing return correlation, $\rho = 0$; the number of simulated paths for the returns, $n = 10{,}000$; the risk-free interest rate, $r = 0.1$; and the value of the invested resources, $V_0 = 1$.



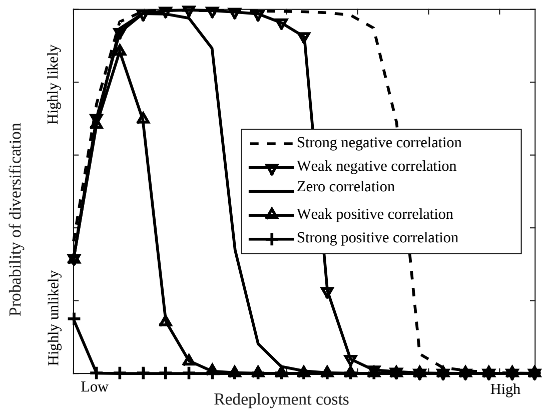
A. Effects of redeployment costs and return volatility on the probability of corporate diversification



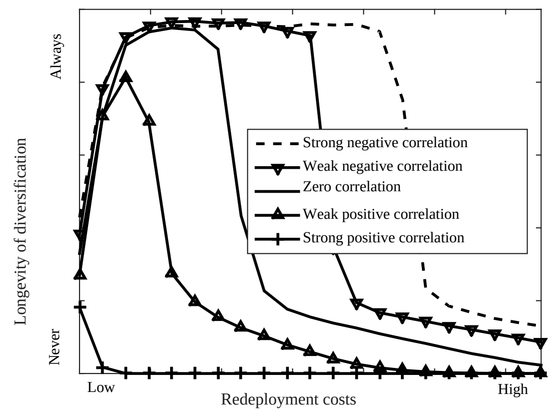
B. Effects of redeployment costs and return volatility on the longevity of corporate diversification

Figure 3. Implications of redeployment costs and return volatility for the dynamics of corporate diversification

Figure 3 shows the probability p_t of the firm being diversified in markets i and j in the middle of the resources' lifecycle (Panel A), and the average longevity $\hat{l}$ of such diversification (Panel B). The first (inverse) proxy for relatedness, the marginal redeployment cost S , represents inter-temporal economies of scope and varies within the interval $S \in [0.0, 1.3]$. In particular, $S = 0.0$ corresponds to the strongest possible relatedness involved in inter-temporal economies between i and j , whereas $S = 1.3$ corresponds to very weak relatedness with inter-temporal economies. The second proxy for relatedness, the sharing factor β, is set to the medium value $\beta = 1.00$ with which relatedness is moderate and intra-temporal diseconomies or economies are absent. The variances σ_i^2 and σ_j^2 of the innovation terms capturing the volatilities of returns take five values. In particular, in the broken lines, $\sigma_i^2 = \sigma_j^2 = 0.05$ capturing very low volatility. In the lines with downward-pointing triangles, $\sigma_i^2 = \sigma_j^2 = 0.30$ revealing low volatility. In the solid lines, $\sigma_i^2 = \sigma_j^2 = 0.45$ corresponding to moderate volatility. In the lines with upward-pointing triangles, $\sigma_i^2 = \sigma_j^2 = 0.80$ corresponding to high volatility. In the lines marked with plus signs, $\sigma_i^2 = \sigma_j^2 = 1.05$ corresponding to very high volatility. The following values of other parameters were used to generate the graphs: the length of the resources' lifecycle, $T = 10$; the coefficient of absolute risk aversion, $\gamma = 0.5$; the discreteness with which resource capacity may be redeployed, $L = 10$; the offsets capturing the initial returns, $A_i = A_j = 0.50$; the trends for returns, $\mu_{ii} = \mu_{jj} = 0.1$; the correlation of the innovation terms capturing return correlation, $\rho = 0$; the number of simulated paths for the returns, $n = 10{,}000$; the risk-free interest rate, $r = 0.1$; and the value of the invested resources, $V_0 = 1$.



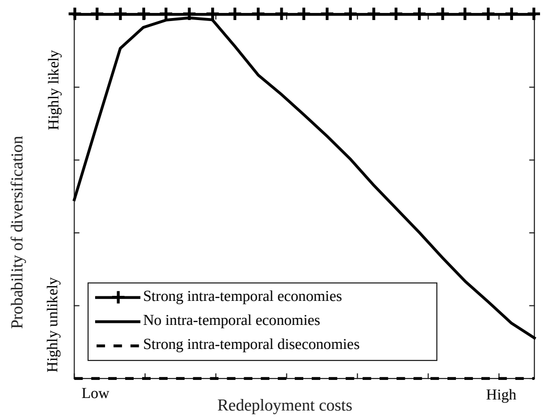
A. Effects of redeployment costs and return correlation on the probability of corporate diversification



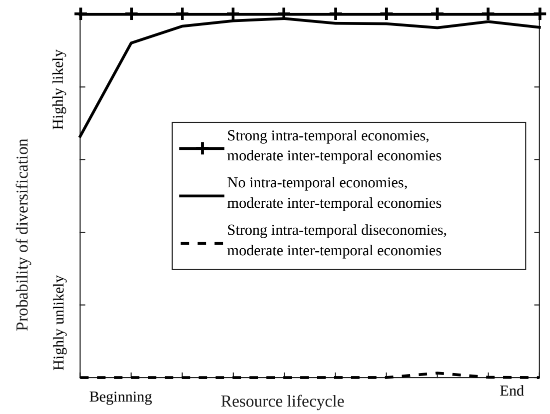
B. Effects of redeployment costs and return correlation on the longevity of corporate diversification

Figure 4. Implications of redeployment costs and return correlation for the dynamics of corporate diversification

Figure 4 shows the probability p_t of the firm being diversified in markets i and j in the middle of the resources' lifecycle (Panel A), and the average longevity $\hat{l}$ of such diversification (Panel B). The first (inverse) proxy for relatedness, the marginal redeployment cost S, represents inter-temporal economies of scope and varies within the interval $S \in [0.0, 1.3]$. In particular, $S = 0.0$ corresponds to the strongest possible relatedness involved in inter-temporal economies between i and j, whereas $S = 1.3$ corresponds to very weak relatedness with inter-temporal economies. The second proxy for relatedness, the sharing factor β, is set to the medium value $\beta = 1.00$ with which relatedness is moderate and intra-temporal diseconomies or economies are absent. The correlation ρ of the innovation terms capturing return correlation takes five values. In particular, in the broken lines, $\rho = -0.99$ representing strong negative correlation. In the lines with downward-pointing triangles, $\rho = -0.50$ revealing weak negative correlation. In the solid lines, $\rho = 0.00$ representing zero correlation. In the lines with upward-pointing triangles, $\rho = 0.50$ showing weak positive correlation. In the lines with plus signs, $\rho = 0.99$ capturing strong positive correlation. The following values of other parameters were used to generate the graphs: the length of the resources' lifecycle, $T = 10$; the coefficient of absolute risk aversion, $\gamma = 0.5$; the discreteness with which resource capacity may be redeployed, $L = 10$; the offsets capturing the initial returns, $A_i = A_j = 0.50$; the trends for returns, $\mu_{ii} = \mu_{jj} = 0.1$; the variances of the innovation terms capturing the volatilities of returns, $\sigma_i^2 = \sigma_j^2 = 0.45$; the number of simulated paths for the returns, $n = 10{,}000$; the risk-free interest rate, $r = 0.1$; and the value of the invested resources, $V_0 = 1$.



A. Long-run effect of redeployment costs on the probability of corporate diversification



B. Evolution of the probability of corporate diversification over time

Figure 5. Long-run implications of relatedness for the dynamics of corporate diversification

Panel A of Figure 5 shows the probability p_T of the firm being diversified in markets i and j in the end of the resources' lifecycle. In Panel A, the first (inverse) proxy for relatedness, the marginal redeployment cost S, represents inter-temporal economies of scope and varies within the interval $S \in [0.0, 1.3]$. In particular, $S = 0.0$ corresponds to the strongest possible relatedness involved in inter-temporal economies between i and j, whereas $S = 1.3$ corresponds to very weak relatedness with inter-temporal economies. In Panel A, the second proxy for relatedness, the sharing factor β, takes three values. In particular, with $\beta = 0.90$ (depicted by the broken line), i and j are very weakly related, resulting in strong intra-temporal diseconomies. With $\beta = 1.00$ (depicted by the solid line), relatedness is average, generating no intra-temporal diseconomies or economies. With $\beta = 1.10$ (depicted by the line with plus signs), i and j are very strongly related, resulting in strong intra-temporal economies. Panel B of Figure 5 shows the evolution of the probability p_t of the firm being diversified in markets i and j over the resources lifecycle. In Panel B, the marginal redeployment cost takes an intermediate value $S = 0.195$ representing moderate relatedness involved in inter-temporal economies. The sharing factor β in Panel B takes the same three values as in Panel A: $\beta = 0.90$ (depicted by the broken line), $\beta = 1.00$ (depicted by the solid line), and $\beta = 1.10$ (depicted by the line with plus signs). In both panels, the following values of other parameters were used: the length of the resources' lifecycle, $T = 10$; the coefficient of absolute risk aversion, $\gamma = 0.5$; the discreteness with which resource capacity may be redeployed, $L = 10$; the offsets capturing the initial returns, $A_i = A_j = 0.50$; the trends for returns, $\mu_{ii} = \mu_{jj} = 0.1$; the variances of the innovation terms capturing the volatilities of returns, $\sigma_i^2 = \sigma_j^2 = 0.45$; the correlation of the innovation terms capturing return correlation, $\rho = 0$; the number of simulated paths for the returns, $n = 10{,}000$; the risk-free interest rate, $r = 0.1$; and the value of invested resources, $V_0 = 1$.

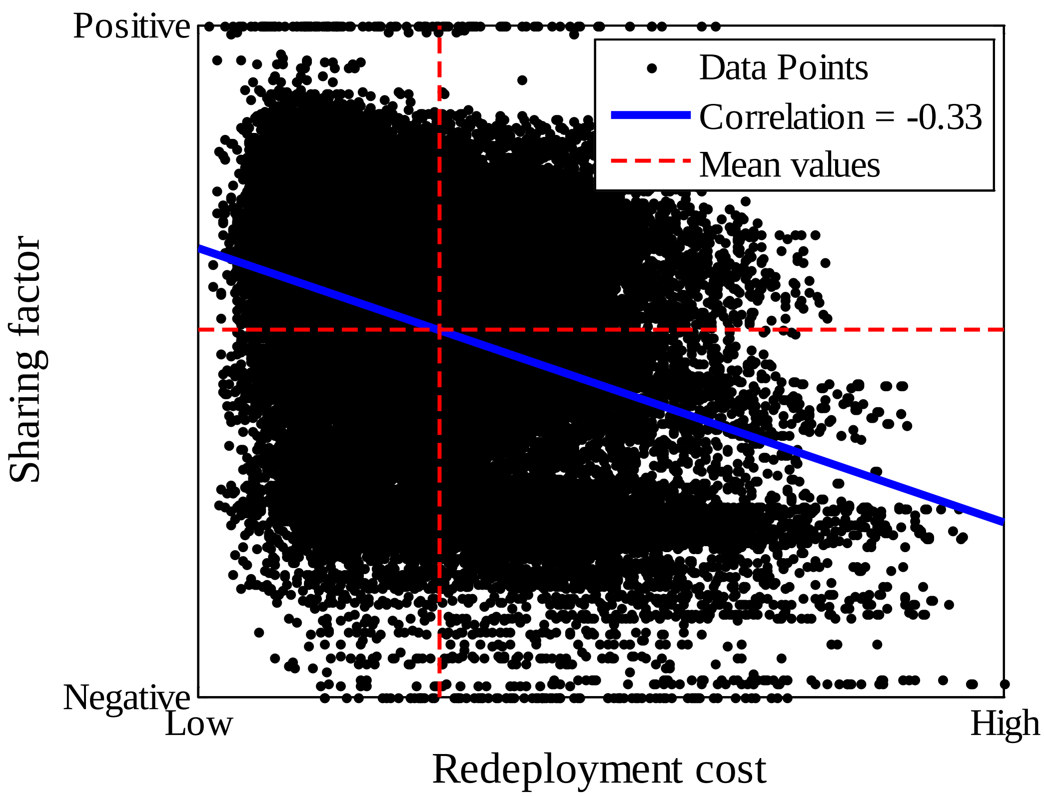
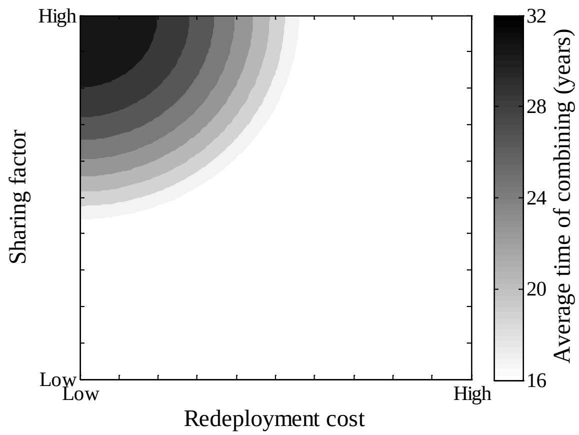
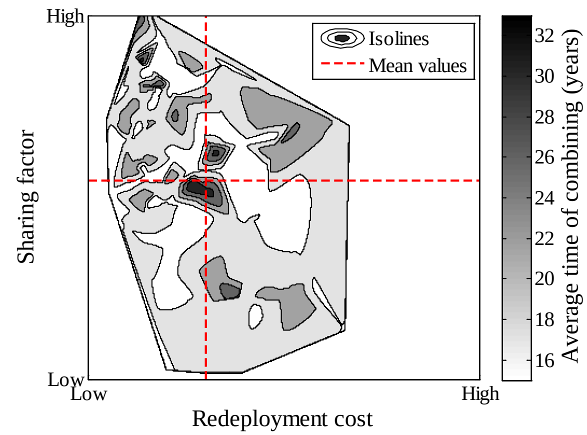


Figure 6. Relationship between two manifestations of relatedness in U.S. industries

Figure 6 presents the scatterplot for the joint distribution of the two ramifications of relatedness, the sharing factor and redeployment costs, across U.S. industries. The sharing factor, representing relatedness in intra-temporal economies, is estimated using patent profiles of three-digit U.S. SIC industries. That operationalization captures the similarity between any two industries, in scale free technological knowledge classified into patent categories. Redeployment costs, capturing un-relatedness in inter-temporal economies, are represented using profiles of three-digit U.S. SIC industries in terms of tangible resources. That operationalization measures the dissimilarity between any two industries, in non-scale free resources, classified into categories of tangible resources in Compustat balance sheet statements. In the reported correlation between the sharing factor and the redeployment cost, p-value<0.001.



A. Assumed diversification propensity *versus* sharing factor and redeployment cost



B. Actual diversification propensity *versus* sharing factor and redeployment cost

Figure 7. Diversification propensity in U.S. industries

Figure 7 presents filled contour maps showing the average time of combining different pairs of U.S. SIC industries against the two ramifications of relatedness. Panel A arbitrarily illustrates the previously assumed simple relationship, with which relatedness unambiguously enhances the diversification propensity. Panel B demonstrates the actual relationship occurring in the real U.S. industry data. The diversification propensity is computed as the average time of combining a pair of three-digit U.S. SIC industries within a firm's scope based on the Compustat Segments data in years from 1976 to 2013. The sharing factor, representing relatedness in intra-temporal economies, is estimated using patent profiles of three-digit U.S. SIC industries. That operationalization captures the similarity between any two industries, in scale free technological knowledge classified into patent categories. Redeployment costs, capturing un-relatedness in inter-temporal economies, are represented using profiles of three-digit U.S. SIC industries in terms of tangible resources. That operationalization measures the dissimilarity between any two industries, in non-scale free resources, classified into categories of tangible resources in Compustat balance sheet statements.

Table 1. Previous and novel insights into the implications of relatedness for the dynamics of corporate diversification

Questions on dynamics of corporate diversification	**Limiting approaches in extant research**	**Specific implication in previous research**	**Novel results**
How does relatedness between two businesses affect the propensity of a firm to be diversified across them?	Limited recognition of different types of economies of scope	Relatedness between two businesses monotonically enhances the propensity of a firm to be diversified across them.	The monotonic positive effect of relatedness on the diversification propensity does not hold with inter-temporal economies of scope, wherein the diversification propensity has an inverted U-shaped relationship with relatedness.
Does relatedness between two businesses suffice to predict the proclivity of a firm to be diversified across them?	Limited attention to determinants of economies of scope other than relatedness	The effect of relatedness between two businesses on the proclivity of a firm to be diversified across them is unconditional (*i.e.*, that effect does not depend on other determinants of economies of scope).	The effect of relatedness on the diversification propensity strongly interacts with inducements.
How does the propensity of a firm to diversify across two businesses evolve over time?	Verbal theorizing in the complex context with inter-temporal linkages between corporate diversification decisions	In the long run, the propensity of a firm to diversify across two businesses is affected by relatedness linked to intra-temporal economies of scope but unaffected by relatedness linked to inter-temporal economies of scope.	In the long run, the diversification propensity is very sensitive to relatedness present in inter-temporal economies. Moreover, with moderate levels of relatedness involved in inter-temporal economies of scope, the diversification propensity due to such economies remains very high throughout the resource's lifecycle.

ONLINE APPENDIX A: Value dynamics over resources lifecycle

Time *t*	$t=0$	$t=1$	$t=2$	$t=3$	$t=4$	$t=5$	$t=6$	$t=7$	$t=8$	$t=9$	$t=T=10$
Value V_{kt} accumulated by time t	V_{k0}	$V_{k0}+V_{k0}F_{k1}$	$V_{k0}+$ $[(1+r)^{1}-1]V_{k0}F_{k1}+$ $V_{k0}F_{k2}$	$V_{k0}+$ $[(1+r)^{2}-1]V_{k0}F_{k1}+$ $[(1+r)^{1}-1]V_{k0}F_{k2}+$ $V_{k0}F_{3}$	$V_{k0}+$ $[(1+r)^{3}-1]V_{k0}F_{k1}+$ $[(1+r)^{2}-1]V_{k0}F_{k2}+$ $[(1+r)^{1}-1]V_{k0}F_{k3}+$ $V_{k0}F_{k4}$	$V_{k0}+$ $[(1+r)^{4}-1]V_{k0}F_{k1}+$ $[(1+r)^{3}-1]V_{k0}F_{k2}+$ $[(1+r)^{2}-1]V_{k0}F_{k3}+$ $[(1+r)^{1}-1]V_{k0}F_{k4}+$ $V_{k0}F_{k5}$	$V_{k0}+$ $[(1+r)^{5}-1]V_{k0}F_{k1}+$ $[(1+r)^{4}-1]V_{k0}F_{k2}+$ $[(1+r)^{3}-1]V_{k0}F_{k3}+$ $[(1+r)^{2}-1]V_{k0}F_{k4}+$ $[(1+r)^{1}-1]V_{k0}F_{k5}+$ $V_{k0}F_{k6}$	$V_{k0}+$ $[(1+r)^{6}-1]V_{k0}F_{k1}+$ $[(1+r)^{5}-1]V_{k0}F_{k2}+$ $[(1+r)^{4}-1]V_{k0}F_{k3}+$ $[(1+r)^{3}-1]V_{k0}F_{k4}+$ $[(1+r)^{2}-1]V_{k0}F_{k5}+$ $[(1+r)^{1}-1]V_{k0}F_{k6}+$ $V_{k0}F_{k7}$	$V_{k0}+$ $[(1+r)^{7}-1]V_{k0}F_{k1}+$ $[(1+r)^{6}-1]V_{k0}F_{k2}+$ $[(1+r)^{5}-1]V_{k0}F_{k3}+$ $[(1+r)^{4}-1]V_{k0}F_{k4}+$ $[(1+r)^{3}-1]V_{k0}F_{k5}+$ $[(1+r)^{2}-1]V_{k0}F_{k6}+$ $[(1+r)^{1}-1]V_{k0}F_{k7}+$ $V_{k0}F_{k8}$	$V_{k0}+$ $[(1+r)^{8}-1]V_{k0}F_{k1}+$ $[(1+r)^{7}-1]V_{k0}F_{k2}+$ $[(1+r)^{6}-1]V_{k0}F_{k3}+$ $[(1+r)^{5}-1]V_{k0}F_{k4}+$ $[(1+r)^{4}-1]V_{k0}F_{k5}+$ $[(1+r)^{3}-1]V_{k0}F_{k6}+$ $[(1+r)^{2}-1]V_{k0}F_{k7}+$ $[(1+r)^{1}-1]V_{k0}F_{k8}+$ $V_{k0}F_{k9}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$
Value V_{kT} as seen from time t	$V_{k0}+$ $\mathbf{[(1+r)^{9}-1]V_{k0}F_{k1}+}$ $\mathbf{[(1+r)^{8}-1]V_{k0}F_{k2}+}$ $\mathbf{[(1+r)^{7}-1]V_{k0}F_{k3}+}$ $\mathbf{[(1+r)^{6}-1]V_{k0}F_{k4}+}$ $\mathbf{[(1+r)^{5}-1]V_{k0}F_{k5}+}$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $\mathbf{[(1+r)^{8}-1]V_{k0}F_{k2}+}$ $\mathbf{[(1+r)^{7}-1]V_{k0}F_{k3}+}$ $\mathbf{[(1+r)^{6}-1]V_{k0}F_{k4}+}$ $\mathbf{[(1+r)^{5}-1]V_{k0}F_{k5}+}$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $\mathbf{[(1+r)^{7}-1]V_{k0}F_{k3}+}$ $\mathbf{[(1+r)^{6}-1]V_{k0}F_{k4}+}$ $\mathbf{[(1+r)^{5}-1]V_{k0}F_{k5}+}$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $\mathbf{[(1+r)^{6}-1]V_{k0}F_{k4}+}$ $\mathbf{[(1+r)^{5}-1]V_{k0}F_{k5}+}$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $\mathbf{[(1+r)^{5}-1]V_{k0}F_{k5}+}$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $\mathbf{[(1+r)^{4}-1]V_{k0}F_{k6}+}$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $\mathbf{[(1+r)^{3}-1]V_{k0}F_{k7}+}$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $\mathbf{[(1+r)^{2}-1]V_{k0}F_{k8}+}$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $\mathbf{[(1+r)^{1}-1]V_{k0}F_{k9}+}$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $\mathbf{V_{k0}F_{k10}}$	$V_{k0}+$ $[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$
Value $\tilde{V}_{kT}$ relevant for maximization of V_{kT} at time t	$[(1+r)^{9}-1]V_{k0}F_{k1}+$ $[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{8}-1]V_{k0}F_{k2}+$ $[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{7}-1]V_{k0}F_{k3}+$ $[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{6}-1]V_{k0}F_{k4}+$ $[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{5}-1]V_{k0}F_{k5}+$ $[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{4}-1]V_{k0}F_{k6}+$ $[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{3}-1]V_{k0}F_{k7}+$ $[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{2}-1]V_{k0}F_{k8}+$ $[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$[(1+r)^{1}-1]V_{k0}F_{k9}+$ $V_{k0}F_{k10}$	$V_{k0}F_{k10}$	

The notation in the table is as described in the section "DYNAMIC MODEL OF CORPORATE DIVERSIFICATION." The illustration is for $T=10$. The first row in the table indicates how value V_t accumulated by time t evolves over time and how that value derives from the net return on investment F_t. To isolate economies of scope from the option to buy new resources, returns are not reinvested in markets i and j but are put into a risk-free account with interest rate r. The second row splits the total value V_T accumulated over the resource lifecycle into the past (normal font) and the future (bold font) parts at time t. With the used utility, only the future part $\tilde{V}_T$ shown in the third row is relevant for the identification of diversification choices.

ONLINE APPENDIX B: Robustness tests

Multiple robustness tests were performed to clarify the generality of the developed hypotheses. The main result, the inverted U-shaped relationship between the diversification propensity and redeployment costs, was checked by re-estimating the probability of diversification with the following alternative values of the parameters reported below Panel A of Figure 1:

- $\beta \in \{0.90, 0.91, ..., 1.00, 1.01, ..., 1.09, 1.10\}$;
- $A_j \in \{0.40, 0.41, ..., 0.59, 0.60\}$;
- $\sigma_i = \sigma_j \in \{0.05, 0.10, ..., 1.00, 1.05\}$;
- $\rho \in \{-0.99, -0.90, -0.80 ..., 0, ..., 0.80, 0.90, 0.99\}$;
- $\gamma \in \{0.05, 0.10, ..., 1.00, 1.05\}$; and
- $T \in \{5, 10, 15, 20\}$.

In addition, the utility in Equation 2 was re-specified as the linear function that has no risk-aversion, $u(V_T) = V_T$. Although the change in the used parameters altered the height of the peak in the relationship of the probability of diversification with redeployment costs, the inverted U-shaped relationship remained very robust supporting the generality of the prediction in Hypothesis 1.

The interaction between redeployment costs and the sharing factor in determining the probability of diversification was tested by re-estimating that probability with the following alternative values of the parameters reported below Panel A of Figure 1:

- $A_j \in \{0.40, 0.41, ..., 0.59, 0.60\}$;
- $\sigma_i = \sigma_j \in \{0.05, 0.10, ..., 1.00, 1.05\}$;
- $\rho \in \{-0.99, -0.90, -0.80 ..., 0, ..., 0.80, 0.90, 0.99\}$;
- $\gamma \in \{0.05, 0.10, ..., 1.00, 1.05\}$; and
- $T \in \{5, 10, 15, 20\}$.

In addition, the utility in Equation 2 was re-specified as the linear function that has no risk-aversion, $u(V_T) = V_T$. Although the change in the used parameters altered the height of the peak in the relationship of the probability of diversification with redeployment costs, the strongest sensitivity of the probability of diversification to redeployment costs was always observed with moderate levels of the sharing factor supporting the generality of the prediction in Hypothesis 2.

The interaction between redeployment costs and the current return advantage in determining the probability of diversification was investigated by re-estimating that probability with the following alternative values of the parameters reported below Panel A of Figure 2:

- $\beta \in \{0.90, 0.91, ..., 1.00, 1.01, ..., 1.09, 1.10\}$;
- $\sigma_i = \sigma_j \in \{0.05, 0.10, ..., 1.00, 1.05\}$;
- $\rho \in \{-0.99, -0.90, -0.80 ..., 0, ..., 0.80, 0.90, 0.99\}$;
- $\gamma \in \{0.05, 0.10, ..., 1.00, 1.05\}$; and
- $T \in \{5, 10, 15, 20\}$.

In addition, the utility in Equation 2 was re-specified as the linear function that has no risk-aversion, $u(V_T) = V_T$. Although the change in the used parameters altered the height of the peak in the relationship of the probability of diversification with redeployment costs, the inverted U-shaped relationship between the probability of diversification and redeployment costs still sifted to higher levels of such costs with stronger current return advantages, as stated in Hypothesis 3.

The interaction between redeployment costs and return volatilities in determining the probability of diversification was explored by re–estimating that probability with the following alternative values of the parameters reported below Panel A of Figure 3:

- $\beta \in \{0.90, 0.91, ..., 1.00, 1.01, ..., 1.09, 1.10\}$;
- $A_j \in \{0.40, 0.41, ..., 0.59, 0.60\}$;
- $\rho \in \{-0.99, -0.90, -0.80 ..., 0, ..., 0.80, 0.90, 0.99\}$;
- $\gamma \in \{0.05, 0.10, ..., 1.00, 1.05\}$; and
- $T \in \{5, 10, 15, 20\}$.

In addition, the utility in Equation 2 was re–specified as the linear function that has no risk-aversion, $u(V_T) = V_T$. Although the change in the used parameters altered the height of the peak in the relationship of the probability of diversification with redeployment costs, the inverted U-shaped relationship between the probability of diversification and redeployment costs still expanded onto a broader range for such costs with higher return volatilities, as stated in Hypothesis 4.

The interaction between redeployment costs and return correlation in determining the probability of diversification was explored by re–estimating that probability with the following alternative values of the parameters reported below Panel A of Figure 4:

- $\beta \in \{0.90, 0.91, ..., 1.00, 1.01, ..., 1.09, 1.10\}$;
- $A_j \in \{0.40, 0.41, ..., 0.59, 0.60\}$;
- $\sigma_i = \sigma_j \in \{0.05, 0.10, ..., 1.00, 1.05\}$;
- $\gamma \in \{0.05, 0.10, ..., 1.00, 1.05\}$; and
- $T \in \{5, 10, 15, 20\}$.

In addition, the utility in Equation 2 was re–specified as the linear function that has no risk-aversion, $u(V_T) = V_T$. Although the change in the used parameters altered the height of the peak in the relationship of the probability of diversification with redeployment costs, the inverted U-shaped relationship between the probability of diversification and redeployment costs still expanded onto a broader range for such costs with more-negative correlation, as stated in Hypothesis 5.

ONLINE APPENDIX C: Operationalizations of resource relatedness with industry data

To develop Figures 6 and 7, the sharing factor capturing relatedness in intra-temporal economies was estimated using patent profiles of three-digit U.S. SIC industries compiled by Brian Silverman: http://www-2.rotman.utoronto.ca/~silverman/ipcsic/documentation_IPC-SIC_concordance.htm. The measure assumes that sharing technological knowledge is easier between industries with more-similar knowledge requirements. Accordingly, knowledge dissimilarity between industries *i* and *j* is quantified as an Euclidean distance: $S_{ij}^{P} = \sqrt{\sum_{a}(P_{ia} - P_{ja})^2}$, where $P_{ia}(P_{ja})$ is the frequency of patents from category *a* being used in industry *i*(*j*). To directly capture the ease of the knowledge sharing, the distance is then subtracted from its highest possible value and scaled by that value. The mean (median) of the final measure of the sharing factor is 54% (57%). While the measure of patent similarity effectively captures relatedness between two industries in terms of the knowledge involved, the measure has the following three limitations.

- The used measure of the sharing factor is based on the database compiled by Brian Silverman with patents granted in 1990–1993. The contemporary requirements of SIC industries to patent categories may have changed since then.

- The used measure of the sharing factor is restricted to the possibility for diversifying firms to avoid the costly duplication in the development of only one type of scale free resources, patented knowledge. There are other scale free resources (*e.g.*, reputation and brand names) that can be profitably shared but are not included in the measure.

- The used measure of the sharing factor is restricted to the value-enhancing sharing due to avoiding the costly duplication in the development of scale free resources. The measure does not capture an alternative value–enhancing sharing mechanism with which scale free and non-scale free resources are profitably shared due to the demand-side synergy.

In Figures 6 and 7, redeployment costs representing relatedness in inter-temporal economies are estimated with industry profiles of tangible assets as follows. Balance sheet data are taken from Compustat for firms present in 1989–1996. Then, intangibles are eliminated. A firm's industry is defined as the main three-digit SIC code. Finally, for industry i, the value of assets of category b is summed up, and its weight Q_{ib} in the total asset value in i is computed. Because redeploying resources is harder between industries with less-similar requirements, redeployment costs between industries *i* and *j* are estimated as an Euclidean distance: $S_{ij}^{Q} = \sqrt{\sum_{b}(Q_{ib} - Q_{jb})^2}$.

The distance is then scaled by its highest possible value. The mean (median) of the measure is 30% (27%). That measure has the following three limitations.

- The used measure of redeployment costs is based on the main (rather than the unique) SIC code reported by both single-business and multi-business firms because there are not enough single-business firms to create the cleaner measure.

- The used measure of redeployment costs hinges upon the identifiability of tangible resources in the balance sheet data in Compustat. However, there is a note in the description of the Compustat variable "Intangible Assets" that some intangibles may actually be included in the variable "Property, Plant, and Equipment" assumed to represent only tangible resources in the used measure.

The used measure of redeployment costs can capture some demand-side synergy. The measure may be made less noisy by partialling out the demand-side synergy estimated as the Euclidean distance between industry output profiles (Brush, 1996).