A STRUCTURAL APPROACH TO ASSESSING INNOVATION: CONSTRUCT DEVELOPMENT OF INNOVATION LOCUS, TYPE AND CHARACTERISTICS

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Abstract

We develop a structural approach to assessing innovation. We develop a comprehensive set of measures to assess an innovation's locus, type and characteristics. We find that the concepts of competence destroying and competence enhancing are composed of two distinct constructs that, although correlated, separately characterize an innovation: new competence acquisition and competence enhancement/destruction. We develop scales to measure these constructs and show that new competence acquisition and competence enhancing/destroying are different from other innovation characteristics including core/peripheral and incremental/radical, as well as architectural and generational innovation types. We show that innovations can be evaluated distinctively on these various dimensions with generally small correlations between them. We estimate the impact these different innovation characteristics and types have on time to introduction and perceived commercial success. Our results indicate the importance of taking a structural approach to describing innovations and to the differential importance of innovation locus, type, and characteristics on innovation outcomes. Our results also raise intriguing questions regarding the locus of competence acquisition (internal vs. external) and both innovation outcomes.

Innovation and technical change are at the core of dynamic organizational capabilities (Teece and Pisano, 1994; Nelson, 1995). Yet after more than 30 years of research on innovation and organizational outcomes, fundamental concepts and units of analysis are often confused and/or ambiguous. As such, empirical results are often inconsistent or difficult to reconcile (Ehrnberg, 1995). Just how are incremental innovations different from competence enhancing innovations (Green et al, 1995; Anderson and Tushman, 1990)? Are architectural innovations different than disruptive innovations (Christensen, 1998; Henderson and Clark, 1990)? To what extent are innovations that involve changes in core subsystems the same as radical innovations (Tushman and Murmann, 1998; Baldwin and Clark, 2000)? Given this conceptual confusion, innovation research often confounds innovation characteristics, innovation types and the hierarchical locus of the innovation. With greater clarity on units of analysis and on innovation concepts and measures, research on innovation and organizational outcomes might be more cumulative and impactful.

There is substantial empirical confusion on the effects of different kinds of innovation on organizational outcomes. For example, some discontinuous innovations destabilize firms while others do not. Radial tires and quartz movements devastated all tire companies in the United States and the entire Swiss watch industry, respectively (Sull, 1999; Glassmeier, 1991; Landes, 1983), and a new propulsion system devastated incumbent airframe firms (Constant, 1980). In contrast, fundamentally different landing gears had little impact on airframe incumbents even as fundamentally different sources of energy (e.g., the automatic movement) had little impact on incumbent watch producers in Switzerland (Vincenti, 1994; Landes, 1983). In the typesetting industry, some technological discontinuities were associated with incumbent failure while others were not (Tripsas, 1997). It appears that the nature of the technological discontinuity and firm competencies each affect the impact of technical change on both innovation as well as organizational outcomes.

Distinct from technological discontinuities, the locus of technological change in a product's architecture and its impact on customers also affect innovation/organizational outcomes. Architectural (Henderson and Clark, 1990) as well as disruptive innovation (Christensen et al, 1999) have been associated with delayed or incompetent innovation in the photolithography, automobile and disk drive industries. Yet Mitchell (1989), Chesbrough (1999) and Tripsas (1997) show that the effects of architectural innovation are contingent on the particular product subsystem the innovation affects and the nature of the firm's competencies and co-specialized assets. Still others, for example Clark (1985), Baldwin and Clark (2000) and Tushman and Murmann (1998), argue that because products are made up of hierarchically ordered subsystems, technical change will differentially affect innovation outcomes contingent on whether the innovation impacts core vs. peripheral subsystems.

To untangle these innovation contingencies we first develop concepts and measures that fit the complexities of the phenomena. We then relate these characteristics to organizational capabilities, and in turn, innovation outcomes. An important impediment to theoretical and empirical advance is confusion on concepts, measures and units of analysis. Basic concepts of radical/incremental (Green et al, 1995) and competence enhancing and destroying (Tushman and Anderson, 1986) are often confounded with innovation types (eg. architectural or disruptive). Further, innovation is often measured and conceptualized at the product level of analysis even as the empirical referent has been at the subsystem level of analysis. For example, while Anderson and Tushman (1990, 2001), Christensen et al (1999), and Van de Ven and Garud (1994) discuss minicomputers, disk drives and hearing aids, respectively, their data are all at the subsystem level of analysis. Thus for any given innovation it is unclear whether innovation outcomes are driven by the locus of innovation, the characteristics of the innovation, or both.

Finally, research on innovation and technical change is frequently done at a distance from the phenomena. Innovations are often assessed by researchers who induce innovation characteristics either by historical analysis (e.g., Anderson and Tushman, 1990; Tripsas, 1997; Van de Ven and Garud, 1994) or by patent data (e.g., Podolny and Stuart, 1995). This distance from the phenomena hinders the ability of researchers to analyze characteristics of an innovation such as its locus in the hierarchy of subsystems or its effects on a firm's competencies.

We develop a structural approach to assessing innovation. We suggest that an innovation can be comprehensively described by distinguishing between product complexity (the number of its subsystems), the locus of the innovation in a product's hierarchy (core/ peripheral), different types of innovation (generational and architectural), and the innovation's characteristics (incremental/radical, competence enhancing and competence destroying). Such a structural approach to describing innovation helps untangle unit of analysis issues as well as the differential effects of an innovation's hierarchical location from its type and characteristics. Further, because of the inherent difficulties of asking researchers to systematically assess innovation characteristics for products/technologies with which they are not familiar, we develop an assessment tool that asks R&D professionals to assess innovations with which they are directly familiar. We develop reliable and valid measures that untangle an innovation's locus in a product's hierarchy, from that innovation's type and characteristics. To explore nomological validity, we investigate the effects these innovation dimensions have on time to market and perceived commercial success.

We show that R&D managers can indeed untangle core from peripheral subsystems, can distinguish between innovation types (architectural from generational), and can separately describe innovation in terms of the magnitude of change (incremental/radical) as well as their competence effects. We find that the concepts of competence enhancing and competence destroying are composed of two distinct dimensions: competence enhancing/destroying and new competence acquisition. These innovation dimensions have quite different impacts on innovation outcomes. The more complex the product, the greater both time to market and commercial success. Those innovations that build on existing competencies are positively associated with commercial success, particularly when they are incremental and/or they are associated with new competence acquisition. Those innovations that affect core subsystems are introduced more rapidly than innovations that affect peripheral subsystems. These effects are accentuated when the innovations involve new competence acquisition and/or when they build on existing competencies. It appears that the acquisition of new competencies from external domains is less organizationally disruptive than adapting existing competencies to competence-destroying technical change. Architectural innovations are associated with increased time to market, particularly when they are also associated with competence enhancing change. As a set, our results indicate the importance of taking a structural approach to describing innovations and to untangling the differential importance of innovation locus, type, and characteristics on innovation outcomes.

A STRUCTURAL APPROACH TO ASSESSING INNOVATION

A number of concepts have been introduced to assess innovation and technical change: discontinuous or radical vs. incremental (Dewar and Dutton, 1986, Ettlie et al, 1984; Damanpour, 1996), competence enhancing vs. competence destroying (Tushman and Anderson, 1986; Anderson and Tushman, 1990), architectural and generational (Henderson and Clark, 1990), disruptive (Christensen and Rosenbloom, 1995), core/ peripheral (Clark, 1985; Tushman and Murmann, 1998), and modular (Baldwin and Clark, 2000; Schelling, 2000). The boundaries of these concepts are, however, often not clear or consistent (Ehrnberg, 1995).

Because products are composed of a hierarchically ordered set of subsystems and linkage mechanisms (e.g., Alexander, 1964; Sanchez and Mahoney, 1996; Schelling, 2000; and Baldwin and Clark, 2000), we propose a structural approach to assessing innovation. We characterize an innovation in terms of its hierarchical position within the product (core/peripheral), its type (architectural or generational), and its characteristics (competence enhancing or destroying, and incremental/radical). Because of the lack of agreement in the literature on these concepts, many of these measures lack formal validation. We develop and validate measures of these concepts. We place greater emphasis on the competence enhancing and destroying dimensions because no scales yet exist to measure these innovation characteristics. As part of the external validation process, we explore the effects of these innovation dimensions on innovation outcomes.

On Hierarchy

There is a growing literature on products as composed of hierarchically ordered subsystems or modules (Baldwin and Clark, 2000; Clark, 1985; Schelling, 2000; Tushman and Murmann, 1998). As Abernathy and Clark (1985) described in automobiles, central subsystems, such as the engine, pace the development of more peripheral subsystems. Similarly, the source of energy in airplanes (Constant, 1980) and oscillation in watches (Landes, 1983) drive other more peripheral subsystems in both product classes. Much of the innovation literature is, however, silent on subsystem hierarchy. For example, Abernathy (1978), Christensen et al (1999), and Anderson and Tushman (1990) all conceptualize the product as the unit of analysis even as their data is at the subsystem level of analysis.

There are several important exceptions to this unit of analysis and hierarchy confusion. These studies support the notion that core subsystems drive system level innovation. Henderson (1993, 1995) found that optical photolithography was able to remain dominant over time due to shifts in core components (e.g., lens innovation) and linking technologies. Similarly, Iansiti and Khanna's (1995) research on mainframe computers over 20 years, Sanderson and Uzumeri's (1995) work on portable stereos, Langois and Robertson's (1992) work on stereo systems, and Tripsas' (1997) work in typesetting all demonstrate the importance of specifying innovation at the subsystems level of analysis and untangling core from peripheral subsystems.

If products are composed of a nested hierarchy of subsystems and linking mechanisms, some of those subsystems will be more core to the product than other more peripheral subsystems (Tushman and Murmann, 1998). Those more core subsystems are either more tightly connected to or are more interdependent with other subsystems, and/or are associated with strategic performance parameters (see Ulrich and Eppinger, 1995). Core subsystems are strategic bottlenecks (Hughes, 1983; Clark, 1985). In contrast, peripheral subsystems are weakly coupled to or are less interdependent with other subsystems, and/or are not associated with strategic performance parameters. Shifts in core subsystems will have cascading effects throughout the product, while shifts in peripheral subsystems will have minimal system-wide effects. For example, in watches, the oscillation subsystem is tightly coupled to all other subsystems. Changes in this subsystem trigger changes in all other subsystems. In contrast, the bracelet subsystem is weakly connected to other subsystems. As such, shifts in bracelet technology have minor impacts on the product as a whole (Landes, 1983). Constant (1980) described how the success of jet engines drove sweeping changes in other airplane subsystems, while Pinch and Bijker (1987) have shown how technical change in gears and chains triggered major changes in other bicycle subsystems.

> ***Definition*: Core subsystems are those that are tightly coupled to other subsystems. In contrast, peripheral subsystems are weakly coupled to other subsystems.**

On Innovation Types

Based on the notion of products as nested hierarchies of subsystems and linking mechanisms, Henderson and Clark (1990) introduce the notion of different types of innovation corresponding to changes in subsystem and/or linking mechanisms. Architectural innovation involves changes in linking mechanisms between existing subsystems, while generational innovation involves changes in subsystems. Henderson and Clark (1990) show that while both architectural and generational innovation are often quite technically simple, they are associated with devastating organizational effects. Every architectural and generational innovation they studied in the photolithography industry was associated with the leading firm being replaced.

Christensen and Rosenbloom's (1995) work in the disk drive industry also demonstrates the disruptive effects of generational and architectural innovation. Christensen et al (1999) argues that the disruptiveness of these innovation types is rooted in the resistance of current customers and associated resource allocation systems to innovation that is associated with new customer sets. Similarly, Rosenkopf and Tushman's (1998) work in the flight simulator industry describes the disruptive impact of generational innovation on this industry's community structure. Finally, Sanderson and Uzumeri's (1995) research in the highly contested portable stereo industry documents how Sony retained product class leadership through sustained generational and architectural innovations over a ten-year period.

> ***Definition*****: Architectural innovation involves changes in linkages between existing subsystems. Generational innovation involves changes in subsystems linked together with existing linking mechanisms.**

On Innovation Characteristics

An innovation's hierarchical position and its type are determined by the product's set of components and linking mechanisms and by its design hierarchy. Quite distinct from these structural factors are the innovation's characteristics: its magnitude and its effects on the firm's competencies. For more than 35 years scholars have explored differences between radical and incremental innovation (e.g., Nelson and Winter, 1982; Green et al, 1995; Dewar and Dutton, 1986; Damanpour, 1991). Incremental innovation involves refining, improving, and exploiting an existing technical trajectory (Hollander, 1965; Myers and Marquis, 1969). In contrast, a radical innovation disrupts an existing technological trajectory (Dosi, 1982).

While the radical/incremental dimension is well established, the unit of analysis to which it has been applied has not been clear, nor have measures been well specified. Typically the unit of analysis on the effects of incremental/radical innovation has been at the product level (Ehrnberg, 1995). For example, Myers and Marquis' (1969) pioneering work on innovation characteristics defined incremental and radical at the product level (e.g., printers). More recently, Green et al (1995) developed multiple dimensions for radical/incremental but apply these dimensions to product characteristics. Similarly, with few exceptions (e.g., Rosenkopf and Nerkar, 1999), patent data have been extensively used to assess the degree of innovation at the product or invention level of analysis (e.g., Podolny and Stuart, 1995; Flemming, 1998). Independent of these measurement issues, the empirical literature is consistent in demonstrating that radical innovations are riskier (with corresponding returns) and have more profound organizational effects than incremental innovation (e.g., Damanpour, 1996; Cooper and Smith, 1992; Foster, 1986).

Quite distinct from the incremental/radical dimension, Hollander (1965) and more recently Tushman and Anderson (1986) distinguished between types of innovations that build on existing competencies versus those that destroy existing competencies. This competence anchored innovation characteristic is independent of the radical/incremental dimension. For example, some radical innovations are competence destroying (e.g., quartz movements for the Swiss in the 1970's) while others are competence enhancing (e.g., automatic movements for the Swiss in the 1970's). Competence enhancing/destruction is an innovation characteristic rooted in a firm's particular history. Any one innovation can therefore be competence enhancing to one firm but competence destroying to another firm. Indeed, Tripsas and Gavetti's (2000) analysis of Polaroid's response to digital imaging indicates that competence enhancing/destroying must be assessed at the business unit level of analysis in multidivisional firms. Finally, as with the other innovation dimensions, the literature on competence enhancing/destruction is unclear on units of analysis and confounds the innovation's magnitude. For example, Anderson and Tushman (1990) focus on minicomputers and cement even as their empirical referents are at the microprocessor and kiln levels of analysis. Thus it is unclear whether their results are due to competence effects, the effects of radical technical change in core subsystems, or their interaction.

> ***Definition*: Incremental innovations are those that improve price/performance advance at a rate consistent with the existing technical trajectory. Radical innovations advance the price/performance frontier by much more than the existing rate of progress.**
>
> **Competence enhancing innovation builds upon and reinforces existing competencies, skills and know-how. Competence destroying innovation obsolesces and overturns existing competencies, skills and know-how.**

This structural approach to assessing innovation suggests that it is possible to comprehensively characterize an innovation by its place in the product's hierarchy, its type, and its characteristics. Such a differentiated approach to assessing innovation can help untangle the specific effects of each innovation characteristic on innovation outcomes.

METHODS

Following the typical process of scale construction (Churchill 1979), we divided our empirical analysis into four stages:

- Stage 1: content face validity analysis with expert judges.
- Stage 2: scale purification through exploratory and confirmatory factor analysis.
- Stage 3: assessment of discriminant and convergent validity through analysis of covariance structures.
- Stage 4: nomological validity through the analysis of the effect of innovation characteristics on time to introduction and commercial success.

For Stage 1 we generated a large number of items reflecting innovation types and characteristics. These items were designed to represent the various facets of the definitions discussed above. Because of the lack of competence enhancing and competence destroying measures, an important objective of our analysis was to develop and validate scales of these concepts as well as to assess that these constructs are indeed different from the radical/incremental construct and from innovation types. We generated 37 items for the competence enhancing/destroying construct. A smaller number of items was generated for the other constructs: 9 for radicalness, 6 for architectural linkages and 6 for generational innovations.

These items were submitted to seven academic experts in the field of innovation research to certify the content face validity of the items. We provided each expert with a list of definitions and asked them to accept or reject whether each proposed statement reflected the construct or not. When a majority of the experts responded that an item did not reflect the construct, this item was eliminated. In some cases we reworded an item based on the expert's comments. We also deleted redundant items because they did not add to construct validity (Nunnally and Bernstein 1994) and they made the questionnaire unnecessarily long. As a result, we retained 14 of the 37 items originally generated for competence destroying and competence enhancing. We kept 5 of the original 9 items for radicalness, the 6 items for architectural innovations, and the 6 items for generational innovations.

For Stages 2 and 3 we conducted a web-based survey of R&D managers. The computer interface available through the Web enabled us to customize the questions to reflect the responses to prior questions and to include specific product and company names that bring greater clarity, realism and less abstraction to the questionnaire (see Simsek and Veiga 2001, for a recent analysis of the advantages and disadvantages of such Web-based surveys). Web-based instruments also prevent respondents from looking back at the responses they have given to prior questions. This aspect of web instruments reduces possible common variance problems that could result in inflated reliability measures. Such Web-based data collection has been successfully used without creating biases in the inter-correlations (Stanton 1998).

We used a sample of 141 R&D directors who were participants in executive education programs in the United States, Scandinavia and France.[1] These R&D directors represented over 100 firms in 15 industries including telecommunications (19.5%), medical (17.2%), services (10.9%), aerospace and defense (10.2%), consumer electronics (9.4%), chemicals (8.6%) and computer software (8.6%). The full sample is composed of R&D managers of companies in North America for 64.8%, in Europe for 25.8% and in the rest of the world for 9.4% (including South and Central America, Japan and Africa). Participants were asked to answer our electronic questionnaire via the Web at their convenience. This electronic questionnaire asked the R&D directors to think of a product their business unit was currently marketing and in which they understood the technology well. We asked the director to list the subsystems of the particular product they nominated and to identify the most core and the most peripheral of these subsystems. We then asked respondents to answer a series of questions concerning the most recent innovation introduced in the product's most core and most peripheral subsystems. Our survey concluded with questions about performance outcomes associated with each innovation.[2]

The R&D directors reported on 143 products in which an innovation was introduced. Of these products, 83 were made up of two or more subsystems and 60 could not be subdivided into subsystems. Of the 83 multi-subsystem products, innovations were described for 68 subsystems judged core by the R&D directors and 33 were for peripheral subsystems. Including innovations in products that could not be decomposed into subsystems (and therefore core by definition), complete data was obtained on 146 innovations. The imbalance in the number of innovations in core versus peripheral subsystems is due in part to the number of products made up of a single system. We distinguish in our empirical analysis between effects due to being a core or a peripheral subsystem from the effects due to the number of subsystems that make up the product (ie. its complexity).

To complete Stage 2, we performed exploratory factor analysis on these data. Based on these results, we eliminated some items because they did not load on the same factors. Confirmatory factor analytic models were also estimated for each construct to test the single factor analytic structure of each construct separately. For stage 3, the discriminant validity of the constructs was ascertained by comparing measurement models where the correlations between the construct was estimated with a model where the correlation was constrained to be 1 (thereby assuming a single factor structure). The discriminant validity of the constructs was examined for each pair of constructs at a time. If the model where the correlation is not equal to 1 improves significantly the fit, the two constructs are distinct from each other, although they can possibly be significantly correlated (Bagozzi, Yi and Phillips, 1991).

Convergent validity of the constructs was assessed by comparing a measurement model where the correlation between the two constructs was estimated with a model where the correlation was constrained to be equal to 0. A significant improvement in fit indicates that the two constructs are indeed related, which confirms convergence validity. Combining the two tests (that the correlation is different from 1 and different from 0) demonstrates that the two constructs are different (discriminant validity) although they may be related (convergent validity). These analyses were performed for all our innovation type and innovation characteristics constructs.

Finally, for Stage 4 we estimated the impact of innovation hierarchy, type, and characteristics on two innovation outcomes: commercial success and time to introduction. For these nomological validity explorations we created an unweighted scale for each innovation construct using the items retained in Stages 1-3. We specified a linear regression model to explore the relations between each innovation construct and commercial success[3]. The effects of these innovation characteristics may not be independent of one another. For example, radical innovations may be perceived as more successful when they build on existing competencies. This suggests an investigation of interactions between innovation dimensions[4]. The investigation of the interactions between innovation characteristics was performed using stepwise regression in order to avoid multicolinearity inherent to the multiplicity of possible interaction terms[5]. The main-effect-only model was first run and interaction terms were added, forcing the main effects into the model, until no significant improvement in model fit would result. The time to introduction model was estimated using the duration model SAS procedure LIFEREG. Interactions were analyzed in a stepwise manner, as for the commercial success model, until there was no statistical improvement in fit.

RESULTS

Exploratory and Confirmatory Factor Analysis of Each Scale

Exploratory Factor Analysis

The items retained from Stage 1 above were factor-analyzed construct by construct. Table 1 lists the items corresponding to each factor with the basic descriptive statistics (we do not report descriptive statistics for core/peripheral because it is a discrete (0,1) variable).

Insert Table 1 About Here

Competence Destroying and Competence Enhancing Innovation. The 14 items loaded on 3 factors with eigenvalues greater than one. Only two items loaded on the third factor that had an eigenvalue close to one and only about half of the second highest eigenvalue. These items were phrased in a way that could be interpreted as reflecting a lack of real innovation. Consequently, we dropped these items from further analysis[6]. The other items fell into the first two factors in a way that is consistent with the concepts of competence enhancing and competence destroying.

One factor reflects competence enhancing/competence destroying technical change. This 6 item factor concerns the extent to which the innovation builds on or renders obsolete existing competencies, skills and knowledge in the firm. This corresponds precisely to the definition of the construct. However, a second factor picks up separately other items that were also part of the definition of the competence enhancing/destroying construct. This 6-item factor is composed of items that reflect the innovation requiring the firm to reach outside its existing experience base to acquire new concepts, skills, and knowledge (see Table 1).

These results indicate that the concepts of competence enhancing and competence destroying technical change are made up of two distinct dimensions. The first dimension concerns the degree to which the innovation builds on existing competences or the degree to which it makes them obsolete, these two notions being in opposite directions of the same competence enhancing/destroying scale. The second dimension, which we label new competence acquisition, concerns the extent to which the innovation requires the firm to reach beyond its existing experience base to acquire new competences. Although this second dimension is part of the definition of competence enhancing/competence destroying technical change, it appears that there are two distinct competence-associated dimensions. As such, we employed both competence dimensions, competence enhancing/destroying and new competence acquisition, in exploring the effects of innovation characteristics on innovation outcomes.

Generational Innovation. Six items concern changes in the number of subsystems. When submitted to factor analysis, a three-factor structure emerged. The first factor is characterized by a consolidation of subsystems with the three items concerning a decrease in the number of product subsystems. We labeled this factor generational consolidation. The two items indicating the addition of subsystems clearly loaded on a second factor. We labeled this factor generational expansion. The third factor was made of a single item that concerns neither the addition not the deletion of subsystems and, therefore, was not considered further.[7]

Architectural Linkage. We factor analyzed the 6 items concerned with architectural or linkage innovations and a single factor structure emerged.

Incremental/Radical Innovation. The five items yielded a single factor solution.

Confirmatory Analysis

The measurement models performed separately for each of the constructs yield a structure that replicates well (i.e., none of the chi squares are significant at the .05 level). The covariance matrices implied by the single factor structure fit the data for the constructs of competence enhancing/destroying innovation, new competence acquisition, architectural innovation, and radicalness.[8]

The factor analytic models we estimated are the standard models without correlations between error terms of the measures except for two estimated error term correlations for the new competence acquisition construct and three others for the competence enhancing/destroying construct. In both cases, the introduction of these additional parameters improved the fit without any impact on the other estimated parameters. Furthermore, only two items were removed from the prior analysis for the architectural linkage construct. Although the original six items loaded on a single factor, the measurement model fit improved after removing these two items. The four remaining items provided a stronger measure of the construct. Similarly, one item was further deleted from the radicalness measure to obtain a non-significant chi-square in the confirmatory factor analytic model, leaving four items to form the scale of radicalness.

The goodness of fit measures are satisfactory in all cases, with values of the Goodness of Fit Index (GFI) respectively of .98, .97, .99 and .99 for the new competence acquisition, competence enhancing/destroying, architectural, and radicalness scales (see Table 1). Scales built with these items for each construct have satisfactory reliability: coefficient alpha of .87 for new competence acquisition, .83 for competence enhancing/destroying, .67 for generational consolidation, .77 for generational expansion, .75 for architectural linkages and .78 for radicalness. The generational scales were not subjected to confirmatory factor analysis because of the limited number of items. However, the reliability coefficient alpha for the generational consolidation and for the generational expansion construct is acceptable (α = .67 and .77 respectively).

Discriminant and Convergent Validity

To verify that the constructs are different from each other, we estimated a measurement model for each construct pair. This pairwise confirmatory factor analysis with oblique factors provides estimates of the correlation between the two factors which corrects for the bias (attenuation effects) that would be introduced if errors in measurement were not explicitly considered. The estimated correlations (in absolute value) between the competence enhancing/destroying and new competence acquisition constructs with the other dimensions of innovation vary between 0 and .56. All the pairwise confirmatory factor analytic models (where the correlation between the two constructs are estimated) fit well with Chi-squares which are generally non significant. These overall results indicate that the correlated factor structure is supported by the data. Table 2 provides the chi-squares values for all pairs of constructs.

Insert Table 2 About Here

Some of the pairwise analyses involved non-zero additional error term correlations. This can lead to instability in other parameter estimates and to problems of interpretation. However, this was not the case. The confirmatory factor analyses involving the generational consolidation scale were improved (leading to a non-significant chi-square) by freeing the error term correlation between two items within this construct. In the case of the generational consolidation with generational expansion pair, a correlation between the error terms of the measurement equations for the different constructs was necessary to obtain a non-significant chi-square, although it did not affect the estimate of the correlation between the two constructs. It is only in the case of the radicalness-generational expansion pair that freeing the correlation between the measurement errors of two items belonging to each construct resulted in unstable parameter estimates. Because of that problem, the correlation estimate reported in Table 2 is the one obtained from an imperfect fit but clearer interpretation.

Results shown in Table 2 demonstrate that competence enhancing/destroying and new competence acquisition are two distinct dimensions of innovation, although they are negatively correlated ($\Phi = -.56$). Competence enhancing/destroying and new competence acquisition are not a unidimensional innovation characteristic. This is confirmed by a significantly (at the .01 level) improved confirmatory factor analytic model when the correlation is estimated compared to a measurement model where the correlation is constrained to 1 (which is equivalent to a single factor structure) ($\chi^2 = 126.75-54.78 = 71.97$, df=1).

Where new competence acquisition concerns the extent to which an innovation necessitates concepts, skills, knowledge which the unit did not have before, competence enhancing/destroying reflects the extent to which an innovation builds on existing concepts, skills and knowledge or renders them obsolete (see Table 1). Because these are distinct dimensions, it is possible for an innovation to require new competences as well as be either competence enhancing or competence destroying for a particular organization. This is apparent in Figure 1 where we plot the distribution of innovations by competence enhancing/destroying (vertical axis) against new competence acquisition (horizontal axis).[9] The observations across the four quadrants (determined by the average of each dimension) indicate that a single innovation can be both high or both low on competence enhancing/destroying and new competence acquisition for a particular organization.

Insert Figure 1 About Here

Other pairwise confirmatory analyses of constructs indicate that architectural, generational consolidation, generational expansion, competence enhancing/destroying, new competence acquisition, and radicalness are different dimensions from each other. A few of these innovation dimensions are correlated with each other. Competence enhancing/destroying innovation is inversely associated with both generational expansion ($\Phi = -.30$) and consolidation innovation ($\Phi = -.40$). Generational innovation appears to be disruptive to existing competencies. The more the innovation adds or subtracts subsystems, the less existing skills and competencies are employed.

The competence enhancing/destroying dimension is independent of the other innovation characteristics. The difference in the chi squares of the models where the correlation is estimated and the model where the correlation is constrained to zero is insignificant for the pairs of competence enhancing/destroying innovation with both architectural innovation ($\chi^2 = 31.05-30.01 = 1.04$, df=1) and with radicalness ($\chi^2 = 36.51-36.04 = 0.47$, df=1). It appears that radical innovations can be competence enhancing as well as competence destroying, and that architectural innovations have no direct association with building upon or destroying existing competencies.

Innovations requiring the acquisition of new competences, in contrast, are significantly associated with both architectural and generational innovation as well as with the radicalness of the innovation. Architectural and both types of generational innovation types (consolidation and expansion) are positively associated with innovations that require the acquisition of new competencies (Φ = .38, Φ = .23, Φ = .28 respectively). Similarly, the more radical the innovation, the more the innovation is associated with the acquisition of new competencies (Φ = .54). For the models with correlations between new competence acquisition with radicalness, architectural innovation and generational consolidation, the difference of chi squares relative to the model where the correlation is constrained to be one is significant at the 0.01 level, respectively for radicalness (χ^2 = 114.12-37.55 = 76.57, df=1), architectural innovation (χ^2 = 210.3-38.21 = 172.09, df=1) and generational consolidation (χ^2 = 51.81-22.63 = 29.18, df=1). Evidently, the implementation of different innovation types as well as radical innovation disrupt existing competencies and skills and are associated with the acquisition of new competencies and skills. While these innovation dimensions are correlated, they each constitute distinct innovation characteristics.

Architectural innovations are positively associated with both types of generational innovation (expansion, Φ = .55 and consolidating, Φ = .19), but they are not related to radicalness. The model with such an estimated correlation between architectural innovations and generational consolidating fits significantly better than a model with zero correlation (χ^2 = 31.34-18.29 = 13.05, df=1) or unit correlation (χ^2 = 54.68-18.29 = 36.39, df=1). Reflecting the structural nature of products, innovations that affect subsystems also are significantly associated with innovations involving linkage mechanisms. Finally, both types of generational innovations are positively associated with each other (Φ = .33), although only generational expansion innovations are positively associated with radical innovation (Φ = .52).

In summary, this analysis demonstrates that these innovation constructs are indeed different from each other and can be measured with scales that discriminate well. We now use these scales to explore the relationships between these distinct innovation constructs and innovation outcomes.

Nomological Validity

To explore the effects of the different innovation dimensions on innovation outcomes we estimated models of perceived commercial success (measured by a three item scale with a reliability coefficient alpha of .91) and time- to- introduction (measured in months from the first mover in industry) as a function of the six innovation dimensions and a core/non-core dummy variable.[10] Table 1 contains the details of the questions used for these outcome measures. Although self-assessment measures may be prone to bias, they are the most commonly used form of performance assessment because (1) the presumably more objective accounting measures and sources can also be biased, (2) financial data are typically not available at the unit of analysis desired and (3) these perceptual measures have been shown to be reliable (Doyle et al. 1989; Dess and Robinson, 1984; Venkatraman and Ramanujam, 1986). The ordinary least squares estimates of the commercial success model are shown in Table 3, as well as the maximum likelihood estimates of the parameters of the duration model for the time- to- introduction variable.

Insert Table 3 About Here

Time to introduction is significantly affected by innovation type, characteristic, and the locus of the innovation. Those innovations that are more complex (number of subsystems) take longer to get to the market (b= .30). Those innovations that affect core subsystems are executed significantly more rapidly than those that affect peripheral subsystems (b= -.70). The effects of innovation in core subsystems are accentuated when the innovation is associated with new competence acquisition (b = -1.08) and the greater the innovation builds on existing competencies (b= -1.47). In contrast, innovations in peripheral subsystems take longer to execute, particularly if they are also associated with either new competence acquisition or building on existing competencies (b= 1.01, 1.03, respectively). Architectural innovations, innovations that involve linking mechanisms, tend to be associated with increased time to introduction (b= .35), although marginally at the 0.1 significance level. These effects tend to be accentuated when the architectural innovation builds on existing competencies (b= .38) (also only significant at the 0.1 level). Neither generational innovations nor the degree of radicalness of the innovation are associated with time to introduction.

Perceived commercial success is also affected by innovation type and characteristics, but not by the locus of the innovation (core/peripheral). The more complex the product and/or the more radical the innovation, the greater its perceived commercial success (b= .15, .37, respectively). Where competence-enhancing innovation are positively associated with perceived commercial success (b= .30), this effect is accentuated when the innovation also involves new competence acquisition (b= .40). In contrast, when competence-enhancing innovations are also associated with either generational consolidation or radical innovation, perceived commercial success is significantly diminished (b= -.45, -.27 respectively). Finally, innovations that add subsystems (generational expansion) are positively associated with perceived commercial success (b= .26). Where architectural innovations take longer to introduce to the market (b= .35), they are not associated with commercial success.

As a set, these results support untangling the centrality of an innovation from its type (architectural or generational) and its characteristics (incremental/radical, competence-enhancing/destroying, and new competence acquisition). The more complex the innovation, the greater its perceived success yet the longer it takes to introduce. Product complexity seems to be appreciated by the market even as it challenges organizational capabilities. Innovations in core subsystems have no significant impact on perceived commercial success. However, innovations that affect core subsystems seem to be strategic to the firm and are executed rapidly. This speed of introduction is significantly affected by the innovation's impact on organizational competencies. Competence-enhancing innovations and innovations that require new competence acquisition accentuate the speed of introduction of innovation affecting core subsystems. In contrast, competence-destroying innovations in core subsystems are associated with increased time to market. For innovations in core subsystems, the acquisition of new competencies from external domains is less organizationally challenging than adapting existing competencies to competence destroying change. Innovations in core subsystems that are associated with both new competence acquisition and with building on existing competencies are associated with the greatest commercial success. Thus organizations that not only build on existing competencies but also acquire new competencies execute strategic innovation rapidly and with commercial success. These results complement research that has found great value in the external acquisition of new competencies (eg, VonHipple, 1988, Tripsas, 1999; Cohen and Levinthal, 1990).

Consistent with Henderson and Clark (1990), architectural innovations seem to challenge organizational capabilities. Architectural innovations are associated with increased time to introduction. This effect is accentuated for innovations that build on existing competencies. It may be that even though architectural innovations that build on existing competencies may be technologically quite simple, they do challenge organizational linking capabilities. Architectural innovations that are also associated with competence destroying change tend to be executed more rapidly than those that are associated with competence enhancing change. It may be that competence-destroying technical change triggers organizational changes that facilitate dealing with both competence as well as organizational linkage issues. Holding other innovation dimensions constant, architectural innovations are not associated with perceived commercial success. Where architectural innovations seem to challenge organizational capabilities, generational innovations do not. Those innovations that add subsystems, that make a product more complex, are positively associated with perceived commercial success.

Paradoxically, innovations in peripheral subsystems are associated with increased time to market. These effects are accentuated when the innovation builds on existing competencies and/or when it involves acquiring new competencies. It may be that innovation in peripheral subsystems are not seen as strategic and are starved for resources and managerial attention. If so, it may be important to contract out innovation in peripheral subsystems and focus scarce resources on core subsystems and on the organizational challenges of architectural innovation.

Where the extent to which an innovation is radical has no significant impact on speed of introduction, radical innovations are perceived as significantly more successful than incremental innovation. As opposed to architectural innovation, radical innovations seem not to impose organizational challenges even as they have important performance impacts (see also Christensen, 1998). In contrast to much existing literature (e.g., Green et. al, 1995), holding the coreness of the innovation constant, radical innovations are positively associated with commercial success. The impact of radical innovation on perceived commercial success is accentuated for innovations also associated with competence destroying technical change. The market appears to put a premium on innovations that are both radical and associated with competence destroying change. While competence-destroying change in core subsystems may be difficult to execute, if firms can manage to take advantage of both competence enhancing as well as destroying technological change, there are significant positive impacts on commercial success.

Finally, even as new competence acquisition and competence enhancing/destroying are inversely related, building on and acquiring new competencies have distinct impacts on innovation outcomes. While competence-enhancing innovations are significantly associated with perceived commercial success, those most successful innovations are those that both build on extant competencies as well as involve the acquisition of new competencies. It may be that those most successful innovations involve both exploitation of existing capabilities as well as exploring new capabilities from outside the firm (Cohen and Levinthal, 1990; March, 1991). Further, for innovations involving core subsystems, it appears that it is easier to import new competencies from external domains than it is to initiate competence-destroying change within the firm. Organizational inertia seems to retard the development of innovations that destroy existing competencies more than it retards the acquisition of new competencies from outside the firm. If so, future research could explore the managerial and organizational challenges in building capabilities that can both build on existing competencies as well as acquire fundamentally new ones (Tripsas and Gavetti, 2000; Benner and Tushman, 2001).

CONCLUSION

This study contributes to innovation research by providing researchers with scales to measure competence enhancing/competence destroying and new competence acquisition. It also provides several insights regarding the relations between innovation locus, type and characteristics, and on the relations between these innovation dimensions, competence processes and innovation outcomes. Research design choices were made in order to achieve our main objectives. These choices are, however, associated with several limitations.

We used single key informants, as R&D directors are the most knowledgeable individuals within the firm about innovation characteristics and innovation outcomes. Multiple informants are typically recommended to validate the information obtained. Difficulty in obtaining information from multiple knowledgeable sources prevented us from using multiple informants in this study. This difficulty is due to the fact that other individuals in an organization may be knowledgeable about some aspects of the innovation but not others; the R&D managers were the best placed in the organization to provide that information. It is also due to our desire to obtain heterogeneous innovations in order to distinguish separate effects of the various innovation dimensions. This required a multiplicity of firms and industries which made it difficult to mobilize a team of respondents. The bias that could be introduced by a single informant is, however, negligible when these informants are key informants (in fact, the bias could be worse when multiple informants provide the information, even if this information has minimal variance across respondents).

A second issue is the common variance bias that could be introduced by having the same respondents provide information for what become the independent and dependent variables in the regression analyses, especially when using perceptual performance measures. While this is theoretically possible, only one of our dependent outcome measures is perceptual. The other measure of performance is factual (time to introduction) and Crampton and Wagner (1994) show the near absence of correlation inflation for such self-reported data. Even in the case of perceived commercial success, prior studies have demonstrated the high correlations of perceived measures with objective measures of performance (Doyle et al. 1989, Dess and Robinson 1984, Venkatraman and Ramanujam 1986). In addition, this possible bias issue is minimized due to the measurement of perceived success for the commercialized product while the innovation measures are assessed at the subsystem level of analysis. Furthermore, as the nomological results are different for different innovation types and characteristics, it is difficult to attribute them to a common variance problem. Finally, the assessment of our scales' nomological validity requires the existence of relationships with other constructs in a systemic fashion. Our results do provide such a system of relationships with our two innovation outcome variables.

Another critique of our study concerns our sample size. While a larger sample may be useful to increase the statistical power of our analyses, our power is sufficient to establish significance in the results. Furthermore, the analysis of covariance methodology is problematic with large samples, as the fit of the model (insignificant chi squares) becomes difficult when the sample becomes larger. Although not huge, our sample size is reasonable, especially given the variance in the data obtained through the diversity of firms, industries and countries. Finally, given the nature of our data, we can make no inferences on the impact of these innovation dimensions on products that are completely new to the firm, nor can we speak to those non-technical innovations that impact a firm's set of complementary assets (Afuah, 2000; Teece and Pisano, 1994).

Even with these limitations, our results support a structural approach to assessing innovation. It appears that R&D directors, those most likely to have a deep understanding of technology and organizational issues, are capable of untangling product subsystems and classifying these subsystems into those that are core and those that are peripheral. Further it appears that it is important to distinguish between innovation locus, types and characteristics. The concepts of competence enhancing and competence destroying appear to be made up of two distinct dimensions. We developed psychometrically distinct and reliable scales for competence enhancing/destroying innovations and innovation associated with new competence acquisition. The acquisition of new competences is distinct from competence enhancing /destroying, even as these dimensions are inversely correlated. We also developed distinct and reliable scales for architectural and generational innovation and for an innovation's radicalness. These scales demonstrate convergent and discriminant validity.

It may be that the contradictory empirical results in the innovation literature can be clarified by untangling the specific effects of innovation type from innovation characteristics and from the innovation's locus in a product's hierarchy. Indeed, innovation type, characteristics, and locus in a product's hierarchy have contrasting effects on innovation outcomes. Innovation in core subsystems seem to be treated as strategic and are executed rapidly. Where architectural innovation seem to challenge organizational capabilities, organizations seem to quickly execute both competence enhancing and new competence acquisition innovation in core subsystems. Where competence-destroying change seems to be difficult to execute, acquiring new competence seems to be less so. Indeed those most successful innovations were those that both built on existing competencies as well acquired new competencies from outside the firm.

In sum, these results provide motivation to continue to explore a structural approach to assessing innovation. They support untangling innovation locus, type and characteristics as well exploring those organizational characteristics that are associated with building capabilities to both acquire new competencies from external domains as well as build upon existing competencies. Research exploring the determinants and consequences of building and re-building organizational competencies and on dealing with the consequences of an innovation's structural location may be particularly fruitful.

ENDNOTES

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1. The participants to each program were introduced to the general topic of innovations as part of the course and were told that they could contribute data to a current research project on this issue by answering a few questions over the Web. The Web address was made available and the instructor was available during the program to answer questions. Some debriefing was performed individually for those who had completed the survey before the end of the program. Those R&D managers who answered the questionnaire after the seminar were debriefed by phone and/or e-mail.

2. Note that our methods are oriented to modifications of existing products. As such, our results do not speak to brand new products.

3. All data refer to an innovation which was introduced so that there is no censoring. Further as the dependent variable is a composite scale of standardized variables, the normality assumption is not violated. A Tobit model with truncation of the normal distribution does not affect the results.

4. We thank an anonymous reviewer for this suggestion.

5. Another possibility is to dichotomize all the innovation characteristics into low and high groups according to a median split on each variable. In the context of assessing nomological validity of a scale, we believe it is more logical to preserve the nature of the scales developed. Furthermore, the poor fit of the main effect-only model of success with dummy variables demonstrates the loss of information due to re-coding.

6. The items dropped are: 1) "Business Unit" introduced "innovation" by making simple adjustments to existing technology and 2) "Innovation" built on technical know-how that existed widely among firms competing in this category.

7. The item concerned the fact that the "innovation" led to significant changes that were principally limited to the "subsystem".

[8] The factor structure could not be confirmed for generational consolidation because the measurement model is saturated with three items only, exhausting all the degrees of freedom. For generational expansion, confirmatory factor analysis could not be performed either because of the too few number of items which leads to insufficient degrees of freedom.

[9] The scales are the unweighted average of the items composing each scale.

[10] A model of perceived commercial success with time to introduction as an explanatory variable was estimated. In this model time to introduction was not a significant predictor.

Table 1 – Items Composing the Scales

New Competence Acquisition Scale

Items	Retained in final scale	Mean	STD	Mi	Max
INNOVATION involved fundamentally new concepts or principles for BUSINESS UNIT	✓	4.56	2.06	1	7
INNOVATION required new skills which BUSINESS UNIT did not possess	✓	4.06	1.96	1	7
INNOVATION required BUSINESS UNIT to develop many new skills	✓	4.09	1.85	1	7
INNOVATION required BUSINESS UNIT to learn from completely new or different knowledge bases	✓	3.69	1.88	1	7
INNOVATION required BUSINESS UNIT to adopt different methods and procedures	✓	4.70	1.78	1	7
INNOVATION required BUSINESS UNIT to carry out a great deal of retraining	✓	3.90	1.83	1	7
GFI	.98				
Reliability α	.87				

Note: PRODUCT, INNOVATION, SUBSYSTEM and BUSINESS UNIT correspond to the specific example described by the specific R&D director. NA= Not Available.

Table 1 – Items Composing the Scales (Continued)

Competence Enhancing/Destroying Scale

Items	Retained in final scale	Mean	STD	Mi	Max
BUSINESS UNIT introduced INNOVATION by making simple adjustments to existing technology					
INNOVATION built a great deal on BUSINESS UNIT'S prior technological skills	✓	5.29	1.77	1	7
INNOVATION built heavily on BUSINESS UNIT'S existing experience base	✓	5.19	1.61	1	7
INNOVATION rendered BUSINESS UNIT'S experience base obsolete **(Reversed)**	✓	2.08	1.53	1	7
INNOVATION built heavily on BUSINESS UNIT'S existing technological knowledge	✓	5.04	1.69	1	7
INNOVATION built on technical know-how that existed widely among firms competing in this product category					
INNOVATION rendered obsolete the expertise that was required to master the older technology **(Reversed)**	✓	2.81	1.65	1	7
Mastery of the old technology did not help BUSINESS UNIT master INNOVATION **(Reversed)**	✓	2.80	1.70	1	7
GFI	.97				
Reliability α	.83				

Table 1 – Items Composing the Scales (Continued)

Generational Consolidation Scale

Items	Retained in final scale	Mean	STD	Mi	Max
PRODUCT no longer contains at least one subsystem that it used to contain before INNOVATION was introduced	✓	2.55	2.05	1	7
PRODUCT now contains at least one subsystem that combines what used to be separate subsystems before INNOVATION was introduced	✓	3.42	2.29	1	7
PRODUCT now contains fewer subsystems than it did before INNOVATION was introduced	✓	2.65	2.03	1	7
INNOVATION led to significant changes that were principally limited to SUBSYSTEM					
GFI	NA				
Reliability α	.67				

Table 1 – Items Composing the Scales (Continued)

Generational Expansion Scale

Items	Retained in final scale	Mean	STD	Mi	Max
PRODUCT now contains at least one subsystem that it did not contain before INNOVATION was introduced	✓	4.27	2.43	1	7
PRODUCT now contains more subsystems than it did before INNOVATION was introduced	✓	3.43	2.27	1	7
GFI	NA	2.65	2.03	1	7
Reliability α	.77				

Architectural Scale

Items	Retained in final scale	Mean	STD	Mi	Max
INNOVATION led to significant changes in at least one subsystem other than SUBSYSTEM					
INNOVATION led to significant changes in the linkages between SUBSYSTEM and at least one subsystem in PRODUCT other then SUBSYSTEM	✓	4.54	2.16	1	7
INNOVATION led to significant changes in the way SUBSYSTEM interacts with other subsystems	✓	4.55	2.14	1	7
INNOVATION led to tighter integration between SUBSYSTEM and at least one other subsystem	✓	4.57	2.16	1	7
INNOVATION made it significantly more difficult to integrate SUBSYSTEM with at least one other subsystem					
INNOVATION made the integration of SUBSYSTEM with at least one other subsystem a more important factor influencing the overall performance of product	✓	4.87	2.04	1	7
GFI	.99				
Reliability α	.75				

Table 1 – Items Composing the Scales (Continued)

Radicalness Scale

Items	Retained in final scale	Mean	STD	Mi	Max
INNOVATION is a minor improvement over the previous technology **(Reversed)**	✓	3.13	1.79	1	7
INNOVATION was based on a revolutionary change in technology					
INNOVATION was a breakthrough innovation	✓	3.74	1.69	1	7
INNOVATION led to products that were difficult to replace with substitute using older technology	✓	4.73	1.99	1	7
INNOVATION represents a major technological advance in SUBSYSTEM	✓	4.83	1.75	1	7
GFI	.99				
Reliability α	.78				

Perceived Product Commercial Success Scale

Items	Retained in final scale	Mean	STD	Mi	Max
INNOVATION was successfully implemented by UNIT	✓	5.41	1.32	1	7
INNOVATION has been commercially successful for UNIT	✓	5.44	1.28	1	7
INNOVATION has met UNIT's expectations regarding the innovation's impact on sales	✓	5.19	1.45	1	7
Reliability α	.91				

Time to Introduction

Items	Retained in final scale	Mean	STD	Mi	Max
How long was the lag between the initial introduction of the INNOVATION in your industry and your firm's adoption of the innovation (in months)?	✓	24.43	52.14	0	360

Table 2. Pairwise Confirmatory Analyses: Estimates of Correlations

	New Competence Acquisition				Competence Enhancing				Architectural Linkages				Generational Consolidation				Generational Expansion			
	ϕ	χ2	DF	P-value	ϕ	χ2	DF	P-value	ϕ	χ2	DF	P-value	ϕ	χ2	DF	P-value	ϕ	χ2	DF	P-value
Competence Enhancing Innovation	**-0.56**	54.78	48	0.23																
	0	84.34	49	0.0013																
	1	126.75	49	<0.001																
Architectural Linkages	**0.38**	38.21	32	0.21	-0.12^{NS}	30.01	31	0.52												
	0	50.88	33	< 0.05	0	31.05	32	0.51												
	1	210.3	33	<0.001	1	237.94	32	<0.001												
Generational Consolidation	**0.23**	22.63	23	0.48	**-0.4**	25.06	22	0.29	**0.19**	18.29	12	0.11								
	0	48.94	24	0.0019	0	38.7	23	0.021	0	31.34	13	0.003								
	1	51.81	24	<0.001	1	45.64	23	<0.001	1	54.68	13	<0.001								
Generational Expansion	**0.28**	27.28	17	0.054	**-0.3**	11.44	16	0.78	**0.55**	10.45	8	0.23	**0.33**	3.57	2	0.17				
	0	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–				
	1	84.97	18	<0.001	1	63.95	17	<0.001	1	46.81	9	<0.001	1	30.14	3	<0.001				
Radicalness	**0.54**	37.55	32	0.23	-0.08^{NS}	36.04	31	0.24	0.18^{NS}	29.04	19	0.065	0.11^{NS}	24.19	12	0.02	**0.52**	40.1	13	<0.001
	0	64.17	33	< 0.001	0	36.51	32	0.27	0	29.99	20	0.07	0	25.28	13	0.02	0	–	–	–
	1	114.12	33	<0.001	1	159.87	32	<0.001	1	62.32	20	<0.001	1	152.31	13	<0.001	1	41.07	14	<0.001

NS = Not Significant

Table 3. Effects of Innovation Characteristics, Type, and Hierarchy on Commercial Success and Time to Introduction (in months)

	COMMERCIAL SUCCESS (OLS)		TIME TO INTRODUCTION (LIFEREG)	
Variable	**Parameter Estimate**	**Standard Error**	**Parameter Estimate**	**Standard Error**
Main Effects:				
Intercept	0.05	*0.21*	*** 2.23	*0.38*
Core Dummy	-0.32	*0.20*	* -0.70	*0.34*
New Competence Acquisition	-0.02	*0.12*	** 1.01	*0.32*
Competence Enhancing vs. Destroying	* 0.30	*0.13*	** 1.03	*0.40*
Radical	** 0.37	*0.12*	-0.28	*0.24*
Architectural	-0.01	*0.11*	† 0.35	*0.20*
Generational Consolidation	0.09	*0.10*	-0.29	*0.20*
Generational expansion	** 0.26	*0.10*	-0.02	*0.17*
Number of Subsystems	* 0.15	*0.07*	* 0.30	*0.13*
Interactions:				
Competence Enhancing vs. Destroying × New Competence Acquisition	** 0.40	*0.15*	--	
Competence Enhancing vs. Destroying x Generational Consolidation	** -0.45	*0.17*	--	
Competence Enhancing vs. Destroying x Radical	* -0.27	*0.13*	--	
Competence Enhancing vs. Destroying x Core	--		** -1.47	*0.47*
Competence Enhancing vs. Destroying x Architectural	--		† 0.38	*0.21*
New Competence Acquisition x Core	--		** -1.08	*0.39*
Scale (Normal)	--		1.35	*0.09*
R^2	0.26			
Res. Sum of Squares	74.11			
Log Likelihood			-183.55	
F-value	** 3.62			
Nbr. of obs.	124		107	

† $p<0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

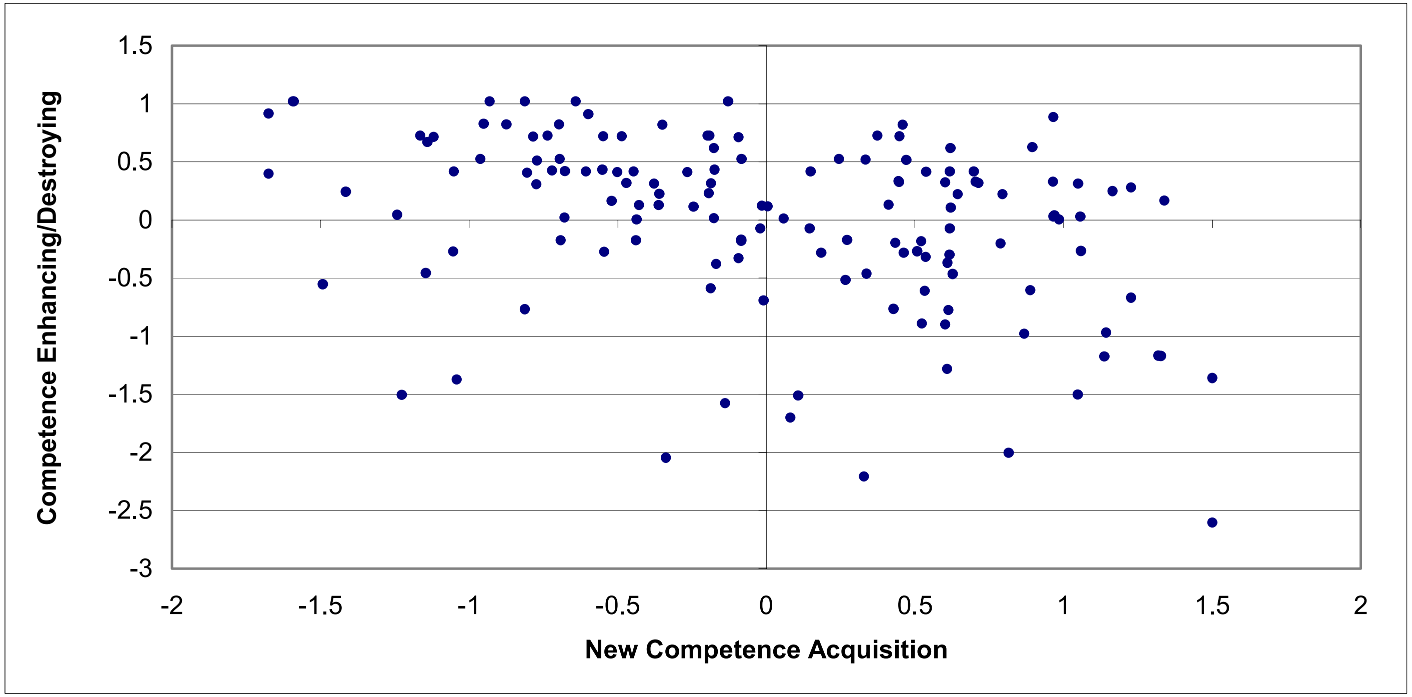

Figure 1. Plot of Innovations on New Competence Acquisition Scale vs. Competence Enhancing/Destroying Scale

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