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Measuring firm innovativeness: towards a composite innovation index built on firm innovative posture, propensity and performance attributes

Elias G. Carayannis*

Department of Information Systems and
Technology Management,
School of Business,
European Union Research Centre (EURC),
Global and Entrepreneurial Finance Research Institute (GEFRI),
George Washington University,
Washington, DC 20052, USA
E-mail: caraye@gwu.edu
*Corresponding author

Mike Provance

Robins School of Business,
University of Richmond,
1 Gateway Road,
Richmond, VA 23173, USA

School of Business,
George Washington University,
Washington, DC 20052, USA
Fax: +1-202-318-3087
E-mail: mprovanc@richmond.edu

Abstract: The ability to innovate is generally accepted as a critical success factor to growth and future performance of firms. Yet, this acceptance obscures a comprehensive perspective on how firms can influence their innovation capacity and resulting performance. This paper proposes a '3P'construct of innovation measurement that simultaneously considers the *Posture*, *Propensity* and *Performance* related to a firm's innovation capabilities. We propose and provide empirical support showing that robust measurement of the performance implications of innovation requires the consideration of input, throughput and output factors simultaneously. Single or more limited indicators do not offer the degree of fine-tuning to a firm's innovation system that managers require. Thus, we propose the development, and future research into contingent variations, of a Composite Innovation Index (CII). We further demonstrate its use in comparing innovators and allowing managers to design a firm's innovation system.

Keywords: technology innovation and entrepreneurship; Composite Innovation Index; position-posture-performance innovation metrics model.

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Biographical notes: Elias G. Carayannis is a Full Professor of Science, Technology, Innovation and Entrepreneurship as well as co-Founder and co-Director of the Global and Entrepreneurial Finance Research Institute (GEFRI) and Director of Research on Science, Technology, Innovation and Entrepreneurship, European Union Research Center, (EURC) at the School of Business of the George Washington University in Washington, DC. He has published in *IEEE Transactions in Engineering Management, Research Policy, Journal of R&D Management, Journal of Engineering and Technology Management, International Journal of Technology Management, Technovation, Journal of Technology Transfer, Engineering Management Journal, Journal of Growth and Change, The Review of Regional Studies, International Journal of Global Energy Issues* and others.

Mike Provance is a Visiting Professor of entrepreneurship at the University of Richmond while completing his dissertation at the George Washington University, and an Advisor on organisational innovation to corporations and emerging ventures. His research focuses on the evolution of young firms within markets and regions. Research includes the roles of knowledge, institutions, market structure and competitive dynamics in the formation, operation and trajectories of entrepreneurial ventures. He has also served for more than 12 years as Vice President, General Manager or Advisor to several emerging ventures from information technology, biotechnology and technology investment sectors.

1 Introduction

Organisations use a variety of measures to achieve a better understanding of the value they produce, such as profitability, market capitalisation, new product introduction and patents. Firms consider performance measurement of critical import. Despite this importance, a more elaborated view of organisational performance measurement remains elusive to both practitioners and scholars. In fact, innovation remains one of the most elusive dimensions of organisational routines and performance to quantitatively comprehend (Gatignon et al., 2002). Prior research has developed measures of innovation independently related to each of its inputs, its outputs and the mechanisms that cause it to occur (Baruk, 1997; Leenders and Wierenga, 2002). Other research has connected these parts through a range of proposed relationships (Damanpour, 1991; Sidhu et al., 2007). While all of these studies contribute substantively to our ability to measure innovation, they do not go far enough in disentangling the complex dynamics that confound our ability to measure and thus control the process of innovation. This paper takes small steps towards this goal by presenting conceptual and empirical support for an integrated measurement framework. This framework combines the components of organisational innovation: structural and factor market inputs, mechanisms of transformation and firm-level performance.

We are interested fundamentally in understanding variation within the process of organisational innovation. Then, we develop a construct to measure it. For this reason, we do not focus comparatively on the process of innovation versus other organisational practices or routines (Nelson and Winter, 1982). We also do not distinguish between forms of innovation. We define organisational innovation within this paper as a configuration of organisational capabilities new to the organisation and conceived by management with the intent of producing positive organisational outcomes (Daft, 1978; Damanpour, 1991; Perez-freije and Enkel, 2007). This configuration exists on a continuum ranging from continuous to discontinuous that subsumes other dimensions of innovation like disruptiveness or radicality (Carayannis et al., 2003). Further, our research considers innovation as an organisational routine. This study attempts to explain measurement variance of this process at the firm-level. In this way, we expect to provide scholars a composite perspective on the fundamental components of innovation while providing managers a means to guide their decision-making in the allocation of resources to innovation routines and within these routines to the factors that contribute most to desired organisational outcomes. Our definition of innovation and its place in the organisation are crucial to achieving these research objectives.

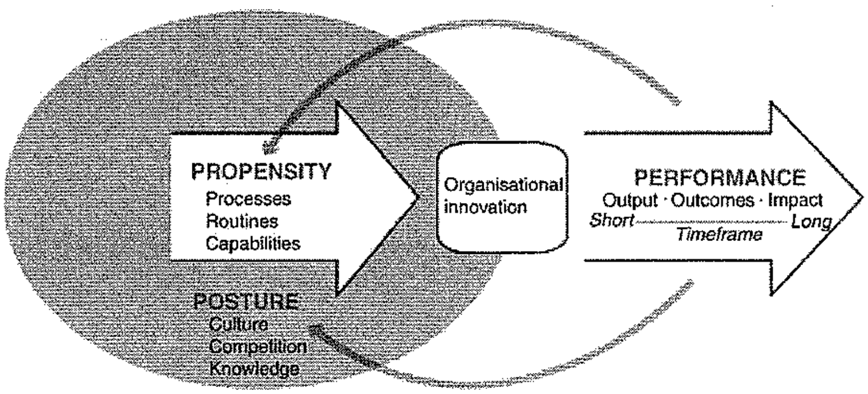
A recent review of the literature on new product development found that in just 21 empirical studies, researchers have developed 15 different constructs for describing various aspects of innovation (Garcia and Calantone, 2002). Some of the distinctions produced by previous authors include administrative versus technical (Daft, 1978), process versus product innovation (Utterback and Abernathy, 1975), incremental versus radical innovation (Hendersen and Clark, 1990), and evolutionary versus revolutionary innovation (Utterback, 1996). As it has been shown repeatedly that innovativeness of the firm is a key success factor for the overall performance and success (Christensen et al., 1998; Jansen et al., 2006), measurement of the innovativeness should lead to a better understanding for the dynamic development and potential of a firm (Carayannis and Alexander, 1999; Heeley et al., 2007). Consistent with prior research, we define innovation as the act of introducing something new to the existing realm and order of things or changing the yield of resources (Drucker, 1998).

1.1 Innovation Posture, Propensity and Performance

We develop our conceptual model of organisational innovation from a resource-based perspective of the firm (Barney, 1991; Penrose, 1959). In particular, we draw upon the concept of knowledge as an intangible resource that flows throughout organisations to render new routines, technologies or structures that affect future performance (Nelson and Winter, 1982). In order to capture the multilayered influence of organisational innovation, we conceive our framework for innovation routines as a procedural model. We focus on intangible resources that contribute inputs to the innovation process. We examine the firm's capabilities for engaging in innovating activities and finally consider the range of organisational outputs from innovation that span short-horizon outcomes to long-horizon lasting impacts.

This composite of measures is housed within a '3P' framework for organisational innovation. Innovation emerges from three critical firm-level factors: *Posture, Propensity*, and *Performance* (see Figure 1).

Figure 1 The 3P framework: a systems view of the innovation process.



'Posture' refers to an organisation's position within the greater innovation system of its environment (i.e. region, industry, technological domain). Specifically, Posture comprises a firm's state along three dimensions: the organisational, technological and market life cycles, reflecting its readiness to both engage in and benefit from innovation (Damanpour, 1991; Hauser et al., 2006). It thus identifies the conditions influencing a specific firm within a specific technology regime serving a specific market.

Each firm's ability to engage in innovative activities will be constrained by its Posture, which is exogenous to the innovation process being measured. That is, regardless of whether and what type of innovation process is employed, a firm exists at a point in its life cycle from formation to failure (organisational life cycle). The firm also selects technologies to employ in the implementation of its strategies and thus is subject to the state of the technology regime life cycle within which these technologies exist (technological life cycle). For example, a handful of stagecoach companies continued operation for a period of time after the introduction of the automobile and thus their place in the stagecoach technology regime could be measured. Finally, the firm exists on a competitive landscape within significant strategic activities in one or more markets. These markets exist at various points in their own life cycle; therefore they also constrain the innovative actions available to the firm.

'Propensity' is a firm's ability to capitalise on its posture based on cultural acceptance of innovation. In this way, propensity is an intangible reflection of processes, routines and capabilities established within a firm. A firm may possess adequate resources and consequently higher externalised innovation stature, yet have an underdeveloped capacity for innovation due to cultural or other constraints.

'Performance' is the lasting result of innovation. This part of the framework comprises three levels: output, outcome and impact. Outputs occur as the immediate, internalised results of innovation. New product introductions, patents and technology transfer licenses are among the outputs that emerge. Outcomes include mid-range results such as revenues contributed by new products. Finally, impacts represent more lasting, long-range benefits that accrue to the firm from its innovative competence and are transformed into results for the firm's environment too. Examples of impact performance include status as a top innovator in the industry.

All three factors – Posture, Propensity and Performance – are captured empirically in the form of a combinatorial we define as the Composite Innovation Index (CII). This comprehensive measure demonstrates the superior evaluative results of measuring innovation across all facets of its process in concert (Damanpour, 1991). We begin to validate the CII as a metric of the 3P conceptual framework with an examination of variation in innovative activity among a group of top innovators.

The remainder of this paper unfolds as follows. In the next section we offer support from prior literature regarding this approach to measuring innovation. We then develop an empirical model for an integrated measurement approach to the process of innovation. We report empirical results to support our contentions regarding the 3P framework. We conclude with discussion regarding the boundaries and conditions for applying the CII. Our findings suggest that an integrated measurement framework like 3P offers substantive increases in our ability to assess and comprehend the organisational process of innovation.

2 Literature review

Understanding the role of innovation and innovative capabilities in firm performance has proven a central issue to both strategic management and management of technology disciplines. The issue has a long following in both domains.

2.1 Measurement of innovation

Measurement of innovative performance at the firm level has been paid less attention than at a project level of analysis. Project-level studies provide more nuanced understanding of the mechanisms behind innovation and their impacts on the organisation. Most of these studies exclude the controls managers possess to navigate uncertain and dynamic environments. The disparities of these studies have not led to a generally accepted indicator of innovative performance or a common set of indicators at the organisation level.

Input indicators mainly measure resources that are put into the innovation process. These inputs include intellectual, human and technological capital (e.g. Baruk, 1997; Carayannis et al., 2003; Hagedoorn and Cloodt, 2003; Iansiti, 1997; Leenders and Wierenga, 2002; Parthasarthy and Hammond, 2002). Process indicators reflect the organisational and innovation process management systems. They also embody the design of a firm's innovation system and its innovative (Howells, 1995; Kahn, 2002; Koen and Kohli, 1998). Performance indicators identify the results of organisational innovation. Output indicators represent the realised, *shorter term* success of innovative activity. Indicators of this group count patent numbers and rates, patent quotes, number of new products, percentage of sales with innovations and others (Baruk, 1997; Michalisin, 2001). Outcome indicators represent the realised, *longer term* success of innovative activity, for example, medium to long term – firm profit margins or market share, firm growth rate, dominant designs or technological standards shaped by firm innovations, second and later stage innovations derived from an originating innovation, degree of disruptiveness (Carayannis et al., 2003). The Impact measure indicates the sustained advantage a firm enjoys as a result of innovation.

Many studies use a single input or output indicator to determine the innovative performance of a firm (Coombs et al., 1997; Evangelista et al., 1998; Feeny and Rogers, 2003). It has been shown, however, that there are measurement problems with innovation, especially with input indicators (Coombs et al., 1997). Critical issues include

1 some input measurements that do not capture process efficiency
2 single measurements that do not reflect economic or qualitative value
3 lack of indication of technological complexity in the inputs.

Similarly, Santarelli and Piergiovanni (1996) have shown that output indicators that are based on patents might be problematic because technological level and the economic value of patents are highly heterogeneous, the nature of patent content varies widely across countries, not all innovations are patented, not all patents become innovations and the propensity to patent varies greatly with firm size. Furthermore, output indicators show limitations due to industry-level antecedents when multiple industries or firm sizes are compared. Other studies have criticised the isolated measurement of innovative business functions or parts (e.g. Damanpour, 1991). Advancing the criticism, we have identified three limitations of the existing literature. The emphasis is primarily put on

1 the manufacturing sector
2 product innovations, while ignoring
3 process variables.

As a result, existing innovation measures disregard some important indicators for innovative success and show limitations in considering different sizes, objectives and activities of businesses.

Recent studies have shown the advantage of using multiple or composite indicators in determining a firm's innovativeness (e.g. Hagedoorn and Cloodt, 2003; Hollenstein, 1996). Still, the notion of a composite indicator remains underdeveloped in the literature. Only three studies in this manuscript's review of the innovation literature use composite indicators to capture the diverse determinants of performance based on innovation (Damanpour, 1991; Hagedoorn and Cloodt, 2003; Hollenstein, 1996). Of these, only Damanpour (1991) and Hollenstein (1996) use process indicators. Recent research calls for the development of composite indicators that integrate distinct approaches to measurement and include throughput measures of innovation (Coriat and Weinstein, 2002; Hagedoorn and Cloodt, 2003).

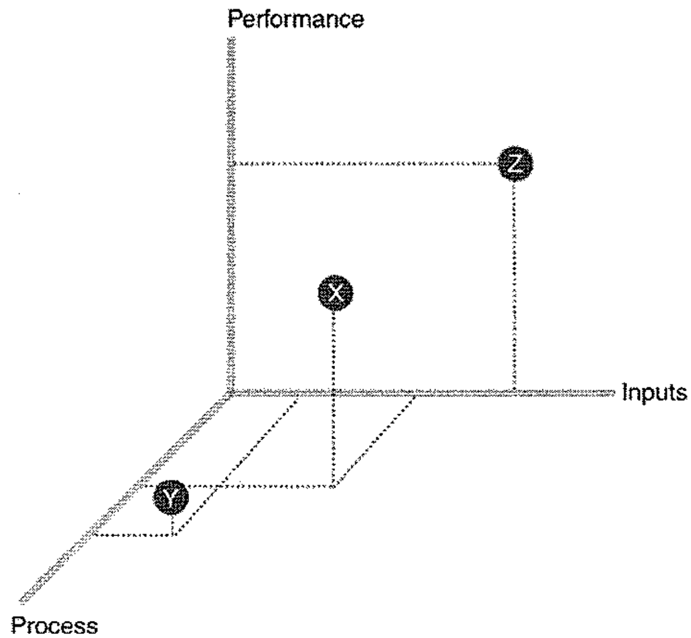
In summary, in the management literature we identified a number of measures of innovation that cover a wide field of firm functions, activities and performance profiles. These measures provide assessments of firm innovativeness, innovative performance and innovative competence that are varied and lacking sufficient coherence across studies to explain innovation as a system of activity within the organisation.

3 Model and methods

3.1 Model for a composite index

Prior research in innovation adoption has shown that truly innovative firms create a climate for innovation across their entire organisations (Damanpour, 1991). Damanpour (1991) further suggests that organisational innovation is more accurately represented when it considers multiple innovations and their corresponding determinants. We extend this contention to stipulate that a model of organisational innovation should consider a composite consisting of all dimensions of the innovation system simultaneously. Prior research posits that superior innovativeness occurs when firms maximise on all dimensions of innovation activity. We theorise – consistent with other scholars – that these dimensions actually run in tension with each other (Garud and Nayyar, 1994; Zahra and George, 2002). Thus, as represented in Figure 2, we demonstrate how a composite index of innovation consisting of input, process and performance measures capture a more comprehensive representation of organisational innovation.

Figure 2 Three 'moments' of firm innovativeness based on the CII



Similar to Kaplan and Norton's 'Balanced Scorecard' (1993), the CII captures the state of the organisation's innovation system along three dimensions. Unlike that strategic management tool, the index we propose here provides a prescriptive means for managers to direct innovation activities within their firms' innovation systems. It also provides a framework for scholars to begin gaining convergence on the wide range of perspectives on measurement of organisational innovation that exist today. As Figure 2 suggests, positions *X*, *Y* and *Z* exhibit varied levels of innovativeness emanating from inputs, process and performance-related outputs from innovation activities. Each state possesses a composite of these innovation factors based on the strategic decisions of managers. In this example, we hypothesise that firm *Y* is a service firm and derives its innovativeness from process improvements. Thus, its innovation index is largely influenced by process indicators. By contrast, firm *Z* participates in a capital-intensive industry and thus its innovation is captured primarily through input and performance indicators. Of these three firms, firm *X* is in the best position with respect to innovation. Its innovativeness is indicated jointly by all three measurement constructs: inputs, process and performance. While the framework does not provide a maximal or ideal recommendation for blending innovation inputs, process and outputs, it does suggest that better organisational performance results for managers when their decisions regarding organisational innovation systems are based collectively on these dimensions. The remainder of this paper provides an empirical explanation of this framework and discusses empirical and managerial implications.

3.2 Sample

Our paper focuses on firms categorised as innovators in order to discern variation within this group in terms of influence of input, process and output factors. Thus, we sample from a collection of German firms listed in a 'Top 100' German innovation benchmarking competition conducted in both 2002 and 2003 ($n = 198$). This competition included 26 firms that participated in both years. In order to remove this sample bias we reduced the sample to the 172 remaining firms from 23 industries. This distribution suggested that 104 firms (60.5%) were from the manufacturing sector and 68 firms (39.5%) came from the service sector. ANOVA tests suggested that this industry bifurcation was not statistically significant ($p < 0.05$). This sample is consistent with the theoretical basis of our study in that they represent firms considered innovative relative to others from the German economy and yet express variation in their level of innovativeness as captured by the externally-directed ranking process.

Descriptive statistics suggest that, within the span of firms in the sample, size is an important characteristic. Measured in terms of sales the sample exhibits a mean of €50.48 Million ($s = 102.41$) with a mean number of employees of 324.05 ($s = 695.52$). The sample exhibits a bias towards smaller firms and presents a left-censoring problem. Further analysis suggests that these issues are minor because of the setting and intent of our study. Our interest is primarily in understanding variation between innovators. With this sample we have defined innovators as the newer, smaller entrants to an industry, ones that would traditionally appear on innovation benchmarking lists. In fact, more than 80% of the respondents produced either radical or incremental innovations over the period of this study. On average, firms in the sample produced 19 radical innovations and 33 incremental innovations over the three years prior to the ranking. Additionally, process innovation activities provide an important facet of the CII measurement of innovation. This sample exhibits variation in process innovations; only 59.6% of the respondents implemented any process innovations during the period of this study.

4 Measures

We developed our measures from a survey that included items on innovation inputs, process capabilities and performance. We selected 24 measures that reflected our theoretical basis for creating a CII (Table 1).

Table 1 Innovation metrics

Indicator	*Definition*	*Type of measurement*	*Value range*
Input oriented measures			
INRD	Sales share of R&D expenditures (%)	Metric	0, 100
INVC	Sales share of internal venture capital (%)	Metric	0, 100
INTD	Average training days	Metric	0, 100
	Employees		
	Top management		
INTMWT	Top management working time on innovation	Metric	0, 100
Process oriented measures			
PDES	Design of innovation management	Ordinal	1, 5
	Idea evaluation		
	Concept test		
	Profitability analysis		
	Innovation strategy		
	Construction/development		
	Ex post-analysis		
PPM	Project management and controlling	Ordinal	1, 5
	Project management employed		
	Project controlling employed		
PMINV	Involvement of marketing in innovation process	Ordinal	1, 5
Output oriented measures			
ONEW	Newness of innovation	Ordinal	1, 5
	New to the firm		
	New to the industry (national)		
	New to the industry (international)		
	Innovation has set a new industry standard		
	Innovation cannot be imitated		
OEXS	Expected sales most important innovation of past three years	Metric	≥0
OSALE	Sales share of innovations of the past three years	Metric	0, 100
	Sales share of radical innovations		
	Sales share of incremental innovations		
OPROF	Profit share of innovations of the past three years	Metric	0, 100
	Profit share of radical innovations		
	Profit share of incremental innovations		
OPAT	Number of patents in the past three years	Metric	≥0

4.1 Independent variables

The independent variables comprised two factors: innovation inputs and innovation process mechanisms. Innovation inputs include expenditures in R&D, investment of internal venture capital, commitment of human capital to training on innovation and top management attention to innovation. We measure R&D expenditure as a ratio of actual expenditures to sales. Similarly, we measure internal capital investment in innovation as the ratio of internal venture capital to sales. We separately capture the average number of training days for employees and for managers. Finally, the survey captures respondents' estimates of top management time devoted to firm innovation activities.

Innovation process variables include innovation management system elements and project management facilities. We measure the constructs of idea evaluation, concept testing protocols, profitability analysis, innovation strategy setting, implementation of innovations, ex post analysis, use of project management, organised development paths, project controls and marketing involvement. These items are measured through self-reported assessments. All items had been rated on a five point Likert scale ranging from 'is always done'/clearly organised to 'seldomly used').

4.2 Dependent variables

Output measures include the novelty of content of firms' innovations (new to firm, new to industry nationally, new to industry internationally, became a new industry standard, inimitable) and to firm performance contribution through firm innovation (sales, profits and patents).

4.3 Correlations

Innovation crosses many dimensions of a firm's resource configurations. Thus, we anticipated some correlation between independent measures. 'R&D expenditures relative to sales' correlates strongly with the amount of time that top management is dedicating to the innovation process (0.499). The more funds the firms use for innovations, the more time is spent by the top management on it. Similarly, there is a correlation with average training days for top management (0.276). It also correlates with internal venture capital that is provided for innovative ideas (0.485).

We did not expect correlation between dependent and independent variables or controls. Our analysis sustains our assumptions. Our dependent variables exhibit little correlation with the independent and control measures. The number of patents, for instance, correlates only with two measures, revenue (0.636) and expected sales (0.493). On the output side R&D expenditures correlate with the percentage of sales with radical innovations (0.311), which is an indicator for the importance of a throughput measure and the value that firms create through innovation. We address these limited correlations by producing a derived set of dependent variables – patent intensity, radical innovation intensity and incremental innovation intensity – consistent with prior use of intensity variables to remove the effects of firm size.

One indicator that seems to be a good alternative to traditional output measures is the percentage of turnover that is achieved with radical innovations. For that indicator we could identify correlations with different variables from the input, the process and the output side of indicators. It correlates for instance with average training days of employees (0.299), average training days of top management (0.258), percentage of internal venture capital (0.208), working time spent by top management (0.462), R&D expenditure (0.311), the percentage of marketing time spent in the innovation process (0.259). The percentage of turnover achieved with radical innovations might therefore be used in smaller and medium sized firms instead of output of patents and as a dependent variable for other indicators on the input and process level.

5 Results

As a basis for the factor analysis of indicators we use a list of input, process and output indicators that encompass different aspects of the innovativeness of firms (Table 1). We start with a factor analysis of input indicators that includes the R&D expenditure relative to sales, internal venture capital relative to sales, the percentage of working time spent by top management on the innovation process, average training days of employees and average training days of top managers in the firm. From that group we derive a two factor solution: financial input and personnel input (Table 2).

Table 2 Factor analysis for input variables

Item	*Factor 'financial input' factor loading*	*Factor 'personnel input' factor loading*
R&D expenditures, relative to sales	0.812	
Internal venture capital, relative to sales	0.854	
Percentage of working time spent by top management on innovation	0.670	
Average training days of employees		0.816
Average training days of top managers		0.894

Rotated factor analysis (varimax), KMO value: 0.646, Bartlett-test (χ^2): 124.090, df: 10, $p < 0.000$, total explained variance: 70.78%, Cronbachs α: 0.71

The 'financial input' factor is loading on one of the traditional indicators, R&D expenditures, internal venture capital (the amount of finance that is internally provided for innovative projects) and finally also on the percentage of working time spent by top management in the innovation process. The combination of financial aspects and working time of top management is an indication that input of the top management is important when critical resources are planned and used in the innovation process. The other factor, 'personnel input', captures the impact of human capital on innovation. It shows that not only financial metrics can be indicators for innovativeness but that also the more subjective face of innovation is important to a firm's performance. The personnel input reflects the learning aspect of the adaptive organisation that develops as a result of the innovation process.

The second construct is the innovation process variable. The results of the factor analysis produce about a two factor solution (Table 3). One of them is denominated 'innovation management' while the other is denominated 'project management'.

Table 3 Factor analysis for process variables

Item	*Factor 'innovation management' factor loading*	*Factor 'project management' factor loading*
Innovation strategy defined	0.772	
Idea evaluation clearly regulated	0.750	
Concept tests clearly regulated	0.696	
Profitability analysis clearly regulated	0.672	
Ex-post analysis of innovation projects	0.580	
Project management employed		0.834
Construction/development clearly organised		0.786
Project controlling employed		0.707
Involvement of marketing in innovation projects		0.493

Rotated factor analysis (varimax), KMO value: 0.851, Bartlett-test (χ^2): 505.485, df: 36, $p < 0.000$, total explained variance: 54.23%, Cronbachs α: 0.85

The 'innovation management' factor loads on variables that describe different steps in the innovation process (e.g. idea evaluation, concept test, etc.). It can be described as the 'what' in the innovation process. The 'project management' factor is mainly loading on variables in the management process, the 'how' in the innovation process. So basically, the two factors describe different perspectives on the innovation process. One builds on the phases of innovation – a progression of actions; the other addresses overall management conceptions – the support and supervision of the process. A very high Alpha shows that especially in the resource section of the indicators, a grouping of variables can represent the meta construct that is the basis for single indicators. Thus, we have identified distinct and independent process factors.

Factor analysis of performance indicators was carried out with different items on the newness of the most important innovation of the past three years (new to the firm, new to the national industry, new to the international industry, new industry standard and possibility of imitation), sales and profits of both radical and incremental innovations of the past three years, number of patents and expected sales with the most important innovation of the past three years. Newness has been rated on a five point-Likert-scale. All other items are metric. We derive a four factor solution (Table 4): newness, incremental innovation, radical innovation, future potential.

Table 4 Factor analysis for output variables

Item	*Factor 'newness' factor loading*	*Factor 'incremental innovations' factor loading*	*Factor 'radical innovations' factor loading*	*Factor 'future potential' factor loading*
Innovation is new to the firm	0.696			
Innovation is new to the industry (national)	0.841			
Innovation is new to the industry (international)	0.804			
Innovations has set new industry standards	0.656			
Innovation cannot be imitated	0.629			
% of sales with incremental innovations		0.980		
% of profits with incremental innovations		0.980		
% of sales with radical innovations			0.953	
% of profits with radical innovations			0.959	
Number of patents				0.877
Expected sales with most important innovation				0.835

Rotated factor analysis (varimax), KMO value: 0.622, Bartlett-test (χ^2): 928.366, df: 55, $p < 0.000$, total explained variance: 73.99%, Cronbachs α: 0.68

The factor 'newness' is loading on all variables describing the degree of newness of the most important innovation of the past three years (e.g. newness to the industry). The factor 'incremental innovations' refers to the profit- and sales-shares of incremental innovations and the factor 'radical innovations' describes the profit- and sales-shares of radical innovations. The fourth factor, 'future potential', is loading on the number of patents and on the expected sales with the most important innovation of the past three years. This factor is interpreted as the ability of a firm to realise future profits from innovative activity.

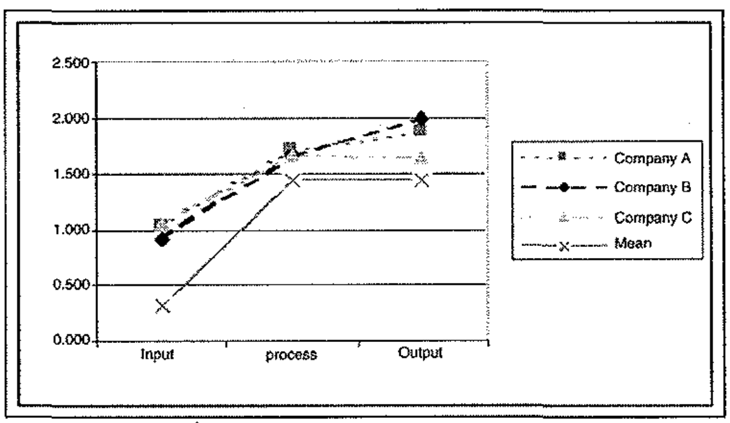
By creating factors of input, process and output indicators we have reduced a larger number of single indicators, enabling a simpler approach to further analysis. We are now able to generate a CII or to calculate a throughput indicator. A composite index, such as the CII, can be generated by simply adding values or by applying a certain mathematical function that is theoretically relevant and consistent with environmental, contextual and related conditions of the local firm.

5.1 Using the indicator

We do not propose the CII as a unifying algorithm for the composite index that applies in all circumstances. Rather, we seek to demonstrate the importance of a CII and leave for future research the identification of the appropriate combinatorial applicable to specific contingent environmental, industry and firm conditions. The indicator can be used to explain the innovativeness of different parts of the business as the overall figure can be broken down into separate input, process and output (sub-) indices and further into single indicators. The CII can be used to generate a ranking of firms and it can also serve as an analysis tool for individual firms. The CII does not show a significant correlation with firm size unlike the correlations found in the case of single or multidimensional indicators.

For demonstration purposes, we have selected the top three firms (ranking based on our CII) out of the data set. The top ranked firms of this example are relatively small both according to sales and number of employees. Two of the firms are in the services industry; the third one is located in manufacturing. The top three firms find themselves in the upper quartile of input, process and output factors. Nevertheless, each one is characterised by an individual innovation profile (Figure 3).

Figure 3 Innovation profiles of top three firms in innovator sample



We apply a simple summation function to generate the index. In these examples, the metrics computed for input, process and output factors are added together. Firm B possesses the highest output index. This is due to the fact that it is the only firm of the top three that has had patents granted in the past three years (three patents). Furthermore, the sales and profit shares of radical innovations of the past three years are considerably higher than at firms A and C (B: 85/94% versus A: 50/70% and B: 50/30%). Firms A and C achieve similar ratings in the input index. There is a difference, however, as to how the firms achieved their high valuation. While firm A disposes of considerable internal venture capital, firm C distinguishes itself by relatively higher training days for employees. The most efficient firm in terms of innovation is firm B: It 'produces' the highest innovative output with the lowest innovation input.

The discrepancies in the process index are marginal. All of the three top ranked firms have clearly defined innovation processes and modern tools of project management. Only a comparison with firms in the lower percentile will show significant differences and the effects of these differences on innovativeness.

6 Discussion

There are certain limitations to this research project. At this stage of analysis we have analysed innovation indicators in literature and developed a CII. We used a sample of 172 innovative firms (TOP 100 project in Germany) to develop the indicator and to show shortcomings of single indicators. As a first step we built a ranking of firms that included input, process and output indicators. One limitation of our work at this stage is the sample (i.e. the number and characteristics of the firms analysed). Further studies are needed to extend the conceptual model to larger sets of firms, including lesser innovative. Otherwise self-selection effects might distort the results of an overall ranking.

We also had to consider how best to employ factor analysis with the data from the survey of this sample. The variables were constructed in the formation of the original survey. As we used the publicly available data in our study without the benefit of designing the survey, the framework of innovation inputs, process and outputs as assignment of the variables in the questionnaire were predetermined. Thus, we opted in our research design to use factor analysis within each of the categories rather than across the entire set of variables. This approach was not inconsistent with a literature on organisational innovation that seemed to be divided along similar lines of input, process and output.

Another limitation in our work that should be considered in further studies is the inclusion of an external measurement instrument for innovation-related performance of the firms like an expert rating. We already included an expert rating, but it was limited to the most innovative project for each of the firms analysed. Therefore, we cannot clearly interpret the overall innovativeness of the firms with this data set. With an external rating of the overall innovativeness of the firms, additional statistical tools can be used to account for the structure and dependencies of innovation indicators (e.g. regression) as well as endogeneity of innovation activities in the industry. Furthermore, future work could involve collecting longitudinal data to examine the influence of short term innovative performance (output) on long term innovative performance (outcome) and at collecting latitudinal and longitudinal data to study interactions and inter-dependencies of innovation capabilities and innovation-related performance.

What is the use of an overall indicator of the innovativeness and innovative performance of a firm? How can it be used for innovation management? From an external perspective of the firm, the CII can generate a ranking of innovative firms that is unbiased by the size of the firm and certain environmental conditions (industry, growth, etc.). Innovative firms can be identified that would never be detected by single innovation indicators. Our cases have shown that very small firms can be identified and analysed along all three dimensions: input, process and performance. By ranking firms across different sizes and industries we are able to separate out causes for innovativeness that account for organisational innovativeness and not for other, more idiosyncratic causal effects.

From an internal perspective, the CII can be used to manage and optimise the innovation process internally. Innovation is not an isolated phenomenon but an ongoing system within a firm. Ultimately, the relationship between innovation Posture, Propensity and Performance is a complex system dynamic (Anderson, 1999) rather than the simplified model depicted in Figure 1 for this study. There exist certain triggers, drivers and impediments to the innovation process in the firm (Carayannis et al., 2003). Some of the effects might emerge at the input side. Some of them might be traced during the production or service process in the firm. Others will have an impact on the output side.

Firms are dynamic learning systems (Carayannis, 2000; Carayannis and Alexander, 1999). Therefore, managers should not seek to maximise any single dimension or limited region of the firm's innovation system. Rather, managers should analyse and continually monitor the full innovation process appropriate to the unique innovation system configuration of that firm. As an example, a large firm might be able to spend a large budget on innovative activities on the input side but not generate the innovation performance needed. Without analysing the innovation processes internally, we will not be able to generate knowledge to improve the management of innovation activities. In contrast, a small firm might be able to act very innovatively without having a large R&D budget or aiming at patenting its innovations. The essential element of this perspective is that learning can occur from innovation processes, regardless of firm size or industry focus.

7 Conclusion

In this work we have provided conceptual and empirical frameworks that advance the literature on measurement of organisational innovation. We have proposed a means to construct CII based on simultaneously on individual indicators from the input, process and performance aspects of innovation systems. We have criticised single and limited sets of indicators (e.g. R&D expenditure, patent counts) for being susceptible to size and industry effects. Single indicators isolate innovation characteristics that should be interpreted within a larger system of firm characteristics. Studies that analyse single indicators usually focus on innovation projects or the innovativeness of special product categories. Additionally, many innovation indicators account for large firms and cannot be used for SMEs (e.g. patent counts).

We have provided a point of departure for further analysis in a current, relevant and rich field of research. We assume that firms are able to develop and learn from innovative processes (Carayannis and Alexander, 2002; Carayannis et al., 2006) and use that foundation in order to examine variation in the innovativeness of the firms. Innovativeness is determined by a number of key indicators on the input, process and output side of innovation. Understanding that innovation is not a certain stage in the life time of a firm but an ongoing process should help to further identify triggers, drivers and impediments of innovation and to manage innovation in firms.

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