A Study of the Association between Level of Slack Reduction Following

Downsizing and Innovation Output

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Journal of Management Studies (forthcoming)

Abstract

Over the years scholars put forward a number of theories to explain the association between slack and innovation. This study extends this body of research by focusing on the effects of reduction in slack level following downsizing on innovation output. We developed two hypotheses to examine the total effects and varied yearly effects. We tested the hypotheses with data from a panel of UK firms that downsized between 1997 and 2003. The results show that the level of downsizing has only temporary effects on innovation output. We discuss the implications of these findings and avenues for future research.

INTRODUCTION

The perennial question of whether slack is good or bad for innovation has generated an extensive body of research. Scholars put forward various propositions to explain the link between slack and innovation. Organizational slack refers to 'the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output' (Nohria and Gulati, 1996, p. 1246). Organization theorists posit that excess resources has a positive impact on innovation (Bourgeois, 1981; Cheng and Kesner, 1997; Mohr, 1969; Singh, 1986). Agency theorists, in contrast, argue that slack breeds inefficiency and inhibits innovation. They thus posit a negative association between the two (Leibenstein, 1969; Thompson, 1967). Scholars seeking to reconcile the two opposed viewpoints propose that the relationship between innovation and slack is contingent on the level and type of slack

available to the organization (Nohria and Gulati, 1996; Tan and Peng, 2003; Voss, et al., 2008).

While prior studies on the association between slack and innovation have yielded valuable insights on this important topic, one of the major shortcomings of these studies is their exclusive focus on the *level* of slack available in organizations to the neglect of exploring the impact of sudden reduction in slack on innovation. In spite of the voluminous body of research on the association between slack and innovation, it is not yet known whether innovation is associated with sudden decline in slack; nor is it known how such an association, if present, maps out over time. This is an important gap in research given that firms regularly adjust their slack level to fit the business environment within which they operate to remain competitive. To address this void, this study focuses on the association between level of reduction in one particular type of slack (i.e. human resource slack) and innovation. We use level of downsizing—defined by Cascio et al. (1997) as a significant intentional reduction in workforce through mass layoffs, representing level of slack reduction (Guthrie and Datta, 2008; Love and Nohria, 2005)—to examine the association between reduction in slack and innovation. Past research posits that in the wake of downsizing firms are left with little or no human resource slack (Cascio and Young, 2003; Lawson, 2001; Love and Nohria, 2005) which may have an impact on their ability to innovate (Amabile and Conti, 1995; 1999; Bommer and Jalajas, 1999; Brockner et al., 1987; Dougherty and Bowman, 1995).

In addition to augmenting the broad literature on slack and innovation, this study makes a significant contribution to understanding the impact of downsizing on innovation. The assertion that downsizing affects organizational innovation has long been espoused but has not been theoretically conceptualized, nor has it been

empirically tested (Cascio and Young, 2003; Lawson, 2001; Love and Nohria, 2005). While past research has focused exclusively on innovation input such as R&D investments (Bommer and Jalajas, 1999) or the innovative environment (Amabile and Conti, 1995; 1999; Brockner et al., 1987; Dougherty and Bowman, 1995), this study furthers our understanding of the impact of downsizing on innovation by focusing specifically on innovation output, drawing on organizational slack literature to theorise and empirically test the accumulative effects of downsizing on innovation output measured by patent count.

To capture the possible varied impact of downsizing over time, we further explore the question of when slack reduction, as a result of downsizing, has most impact on innovation. This approach provides added precision to the durability and nature of the impact of downsizing over time. Typically, with the exception of Amabile and Conti (1999)¹, evidence on the association between downsizing and organizational outcomes rely on aggregated data, or on surveys at one point in time, which may obscure differences in the impact that levels of downsizing has on innovation over a period of time. This study addresses this issue by examining the lagged yearly impact of level of downsizing on innovation. We examine yearly innovation output three years after downsizing is completed, thus more clearly specifying the impact of level of downsizing on innovation. We thereby help unravel when downsizing has most impact on innovation and whether the reported impact of downsizing persists, dissipates or turns around overtime. This process is in line with Amabile and Conti's (1999, p. 637) call for adding a dynamic element to the study of downsizing and innovation.

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¹ Even though Amabile and Conti's (1999) study examined the impact of downsizing on innovativeness overtime, the research team was not able to collect data for more than one year after the downsizing event was completed.

For practitioners the importance of this study is significant and timely. While the study of the relationship between downsizing and innovation is important in its own right, it is of particular relevance in the current economic climate given the recent upsurge in downsizing as a result of the threat of a global economic slow down, coupled at the same time with the ever increasing importance of innovation in providing organizations with a competitive advantage (Brown and Eisenhart, 1995; Cefis and Marsili, 2005; Christensen, 1997; Cumming, 1999; Dougherty, 1992; Higgins, 1995; Hitt et al., 1996; Tushman and O'Reilly, 1997). For new ventures, for example, innovation is a strategic imperative that provides them external visibility and legitimacy, and increases the likelihood of their survival (Heirman and Clarysse, 2007, p. 303).

THEORIZING THE RELATIONSHIP BETWEEN SLACK REDUCTION AS A RESULT OF DOWNSIZING AND INNOVATION OUTPUT

According to Cameron the term downsizing encompasses 'a whole range of activities from personnel layoffs and hiring freezes to consolidations and mergers of organizational units' (1996, p. 1050). This includes both ownership transfer such as downscoping and reduction in workforce through mass layoffs. In this study, we focus on reduction in personnel through layoffs (Cascio et al. 1997) and exclude other restructuring strategies such as downscoping. This is in line with past research which makes careful distinction between downsizing and downscoping (Hoskisson and Hitt, 1994; Johnson, 1996). Downsizing as defined in this study can be thought of as a firm's decision to reduce its human resources capacity which is in excess of the necessary requirements for the efficient operation of the firm (Cascio and Young, 2003; Lawson, 2001; Love and Nohria, 2005, p. 1088).

Slack and Innovation

Organizational slack is arguably one of the key determinants of innovation (O'Brien, 2003). Indeed, Geiger and Makri argue that the concepts of organizational slack and innovation are central elements in the strategic management literature (2006, p. 97). However, existing studies exploring the relationship between levels of slack and innovation has generated mixed results. On the one hand, organization theorists posit that availability of slack improves innovation because slack relaxes managerial control (Cyert and March, 1963; Kay, 1979; Nohria and Gulati, 1996; Rosner, 1968); enables employees to spend more time on innovative projects and indulge in projects that may produce patents (Nohria and Gulati, 1996); 'reduces questioning of the legitimacy of experimentation' (Thompson (1969) quoted in Geiger and Makri, 2006, p. 300); and allows managers to give more discretion as to how the resources are to be used (Nohria and Gulati, 1996). In general, the basic premise of organization theory literature is that reduction of slack following downsizing would have a negative impact on innovation.

On the other hand, and in sharp contrast to organization theory scholars, agency theory researchers argue for a negative relationship between slack level and innovation for two key reasons. Agency scholars argue that since managers accumulate and use organizational slack for purely self-serving interests (Jensen (1986), they tend to deploy slack resources in ways that decrease risky activities such as innovation and experimentation and pursue activities such as product and marker diversification which are perceived to be less risky and bestow managers with significant personal benefits (Tan and Peng, 2003; Jensen, 1986). Tan and Peng (2003) argue that in their pursuit of prestige, power, job security and financial reward,

managers are more likely to use slack "to engage in excessive diversification and empire-building" rather than risky activities such as innovation. This is because managers benefit from diversification in two ways. Firstly, diversification helps managers diverse their personal portfolio (Shleifer and Vishny, 1989; Denis, Denis, Sarin, 1997) and thus, provides them with higher job security (Ahimud and Lev, 1981; Baysinger and Hoskisson, 1989). Secondly, diversification enhances managers' compensation package because of the challenge and prestige associated with managing larger and complex diversified firms (Tosi and Gomez-Mejia, 1989; Stulz, 1990; Lambert, Larcker, and Weigelt, 1991). Scholars posit that availability of slack has a negative impact on innovation because it fuels firms' expansion through market and product diversification which are found to have a negative impact on innovation (Baysinger and Hoskisson, 1989; Hoskisson and Hitt 1988; Hitt, Hoskisson and Ireland, 1994). Hitt, Hoskisson and Ireland (1994: 301) argued that slack harms innovation by shifting managers' attention from upgrading internal capabilities through innovative activities to buying resources and capabilities from outside the firm to support the diversification strategy.

Second, availability of slack may have a negative impact on innovation because it can create a cushion against external jolts and as a result the organization may lose fit with the external environment (Love and Nohria (2005, p. 1104). According to Jensen and Meckling (1976), the self-serving interests of managers result in the accumulation of slack resources that are wasteful and inefficient, and which may breed complacency and indiscipline in the management of innovative projects and as a result employees may hop from one innovation project to another because they 'get bored or tired and move on to another project before completing

existing projects' (Nohria and Gulati, 1996). Bringing the two points together, agency scholars posit that slack is negatively associated with innovation.

Although agency theory has been used to explain the relationship between slack level and innovation in both mature and new entrepreneurial firms (see, Phan and Hill, 1995), a number of scholars argue that the theoretical rationale of agency theory is not relevant to new ventures and leveraged buyout (LBOs) (van Osnabrugge, 2000; Zahra, 1995; Wright, Thompson and Robbie, 1992; Wright et al., 2001), where managers are partial owner and or 'responsible to a small but powerful group of shareholders' (Gupta and Rosenthal 1991, p. 70). However one could argue that even though agency arguments regarding potential misuse of slack may not hold for new ventures (Arthurs and Busenitz, 2003; Phan and Hill, 1995; van Osnabrugge, 2000), the core assumption regarding the possible negative association between high level of slack and innovation remains valid. Schoonhoven, Eisenhardt and Lyman (1990) report that while availability of resources is identified as an important factor for innovation, availability of slack makes new ventures less disciplined in speeding the first product to launch because of lack of urgency compared with ventures strapped for resources.

Scholars that sought to reconcile the above two perspectives posited that the association between slack and innovation is contingent upon the level and types of slack available to the firm (Geiger and Makri, 2006; Nohria and Gulati, 1996). The level-of-slack line of argument contends that when it comes to innovation, slack can be both a blessing and a curse (Geiger and Makri, 2006, p. 97). Nearly three decades ago Bourgeois (1981) proposed the curvilinear relationship between slack and innovation. More recently, Nohria and Gulati (1996) extended the argument and

found an inverted U shaped relationship between the level of slack and innovation. They report that moderate levels of slack had a positive impact on firms' innovation but, at some point, high levels of slack led to a decrease in innovation activities. That is, innovation diminishes as slack increases beyond a certain point. They reasoned that after a given level of slack, decision making becomes more relaxed; incentive for innovation decreases; and a strong sense of security may lead to complacency and an undisciplined allocation of resources, which subsequently result in a decline in innovation. They concluded that 'too little slack is as bad for innovation as too much slack' (Nohria and Gulati, 1996, p. 1246). Overall, the above analysis implies that the relationship between the level of slack reduction and innovation output can be represented by an inverse U shape.

Love and Nohria (2005) examined the interaction between slack reduction following downsizing and organizational performance and found that human resources slack prior to downsizing induced creative behaviour, widened the search for new ideas and encouraged experimentation with new products. Conversely, as slack levels depleted after downsizing, competition for resources escalated, work volume intensified and innovative projects were disrupted. This study, however, did not consider level of slack reduction. Cheng and Kenser (1997) looked at level of downsizing and reported that significant workforce reduction strategies are often associated with a sharp decrease in organizational innovation ability because of the loss of a significant level of skills with consequent negative effects on a firm's ability to innovate. This may be linked, at least in part, to the effects of downsizing on role overload and time pressure. Cheng and Kesner (1997) argued that severe downsizing leads to an increase of work load which may influence the time and efforts employees spend on innovation activities. This is because a reduction of workforce is not always

accompanied by a reduction of tasks. Consequently, when the organization downsizes there will usually be fewer people available to carry out the tasks.

In addition to high work overload as a result of high level downsizing, extant research reports that high level downsizing also triggers behavioural reactions that have an impact on innovation output. High level downsizing is expected to stifle innovation because, as put by Trevor and Nyberg 'larger downsizings are more jarring, shocking, and threatening than are smaller downsizings' (2008, p. 260). Studies report that large downsizing trigger behaviours that hold back innovation such as rigidity of decision-making processes and willingness to take risks (Subramanian and Nilakanta, 1996), and anxiety and anger among surviving employees (De Meuse et al., 1994, p. 160). Similarly, Cody et al. (1987) report that severe downsizing of 30-50 per cent was related to a significant decrease in employees' morale and commitment and a significant increase in role stress. Therefore, it is reasonable to expect that high reduction in slack as a result of high level downsizing would hinder organizations' experimenting with ideas and products and prevent them allocating resources to innovative but highly-uncertain long-term projects.

In contrast, a number of scholars posit that, although a small reduction in workforce reduces the level of human resource slack and as a result surviving employees are required to carry out more tasks, the small increase in work load is perhaps surmountable and employees may ably accommodate the new tasks without being sufficiently distracted from carrying out innovative activities (Moore et al., 1996). However, as the level of downsizing increases so does role overload (Ashforth, 1996; DeRue et al., 2008; Maslach, 2003) until downsizing level reaches a tipping point beyond which surviving employees' ability to carry out the day to day tasks and still be able to innovate decreases. Under such excessive workload pressure,

employees would struggle to complete their tasks, let alone carry out new tasks that may lead to innovative activities. Similarly Andrews and Farris' (1972) study of R&D scientists found that time pressure to carry out tasks was related positively with high creativity until the pressure reached an undesirably high level beyond which the relationship became negative. In similar vein, a number of researchers suggest that modest workforce reduction results in changes that are conducive to innovation. These include formation of multi-skilled teams, enriched jobs for surviving employees, and flatter organization structures (Baumol et al., 2003; Love and Nohria, 2005) which may create an internal environment favorable to the generation and survival of new innovative ideas (Ross, 1974; Hackman and Oldham, 1980). Overall, the above analysis on the association between levels of human resource slack reduction and innovation suggests an inverted U shape relationship between level of slack reduction and innovation. This leads to the following hypothesis:

Hypothesis 1: The relationship between level of slack reduction as a result of downsizing and innovation output is inverse U-shaped.

The Impact of Downsizing on Innovation Over Time

A second objective of this study is to shed some light on the varied impact of downsizing on innovation over time. The current body of research on the impact of downsizing, either implicitly or explicitly, assumes relative permanence of the effects of downsizing and does not distinguish between the possible varied impacts over the years (Amabile and Conti (1999) is an exception here). Thus, the change in impact of downsizing over time is often ignored or, at best, obscured, and as a result it leaves open the question of whether different levels of downsizing have different impacts over time.

We argue that downsizing initially has a large impact on innovation but the magnitude of the impact declines over time. For high level downsizing, it is arguable that during the first year, innovation processes do not adjust fast enough to deal with the impact of sudden reduction in slack. However, once the shock of significant slack reduction has subsided, and organizations have 'healed the wounds' (Noer, 1993), innovative activities gradually bounce back as firms incrementally adjust to their low level of slack by building new organizational routines and structures that are more-suited to the new level of slack.

Our reasoning is in line with Amabile and Conti's (1999) study of employees' perceptions of the innovative environment over three different time periods—before, during and after downsizing—in a very high downsizing firm. They found that although, overall, large downsizing harmed the innovative environment, the organization started to heal from downsizing after one year. They report that during and just following the downsizing event, creativity significantly declined as employees were not able to obtain resources to carry out innovative projects, and excessive workload limited employees' freedom to work on innovative ideas. They reported that during downsizing innovativeness suffered most where all stimulants for creativity declined and barriers for innovation increased. However, they reported that after downsizing was completed 'the trend seems to be slowly reversing' and over time they observed a recovery pattern as their respondents described it: 'the creativity stimulants are increasing, and organizational impediments are declining'(1999 p636). During the third wave of the study (five months after the downsizing ended) the work environment for creativity improved 'to some extent' and there was 'a high level of sufficient resources and a lower level of workload pressure'. They note that the drop in slack level tended to be absorbed over time (Amabile and Conti, 1999). The results

of this study suggest that the negative impact of high downsizing on innovation declines over time as firms rebound from the effects of downsizing.

For low level downsizing, we argue that the proposed positive impact of low level downsizing on innovation also declines overtime. In the short term, the above discussed changes in work systems such as flatter organizational structures, multiskilled teams, and enriched jobs for surviving employees as a result of low downsizing combined with allocation of savings from downsizing to innovative projects (Mellahi and Wilkinson, 2010) would lead to an initial significant increase in innovation output. However, the sustainability of post-downsizing improvement in innovation output will be constrained by inertial pressures which impede firms from implementing required changes to support new innovation activities in the long term (Dougherty and Heller, 1994; Christensen and Raynor, 2003; Anthony, Johnson, Sinfield, 2008). Research shows that for a firm to sustain a temporary improvement in innovation it must augment its innovative capability by investing in capability building activities (Anthony, Johnson, Sinfield, 2008), develop new mechanisms and dynamics to support the new processes of innovation (Christensen and Raynor, 2003) and create an innovation climate that pervades every part of the organization (Humble and Jones, 1989). Most post downsizing firms, however, are "too rigid and inert" to change their resource bundles and accommodate the learning and creativity necessary to sustain the increase in innovation output (Dougherty and Heller, 1994, p.200). Along with inertial pressures, it is reasonable to assume that in the long run, because of the pressure on organizations to maintain optimum individual short term performance, surviving employees are assigned more roles which, as a consequence, distract them from new innovation projects and put a strain on carrying out the extra innovation projects (Goode, 1960). Therefore, we posit that post-low downsizing increase in innovation declines over time. Based on the above we propose that:

H2. The yearly impact of downsizing on innovation output declines overtime.

That is the yearly positive impact of low level downsizing is less positive overtime and the negative impact of high level downsizing is less negative over time.

STUDY DESIGN

In this study we combined both panel data and interview methods to test our hypothesis on the association between severity of downsizing and innovation output. We use patent count to measure innovation output. In spite of attempts by researchers to find a better quantifiable measure for innovation output, patents remain the most used measure (Acs and Audretsch, 1989; Basberg, 1987; Comanor and Scherer, 1969; Griliches, 1990; Hall et al., 2001; Jaffe, 1986; Pavitt, 1985; Scherer, 1965). We accept that there are other innovation outputs that could be used, such as new product development, but these are beyond the scope of this study. Further, this paper does not consider the economic value of patents. While a large body of literature shows that patents in themselves may be relatively unimportant because they vary greatly in their economic values, and a large number of all patents granted are worthless or become worthless shortly after being granted (Hall et al., 2001), the focus of this study is not on innovation effectiveness or ability of firms to capitalize on patents. Rather it concerns the relationship between workforce reduction and the ability to produce patents. Thus, we used patent counts, rather than patent economic value. To examine the relationship between downsizing and the number of patents granted to a particular firm we constructed panel data that has the total number of patents granted to a particular firm in a given year, over a number of years.

Data and Variable Definitions

Dataset

The panel data used in the study comprises 258 UK firms with nine years of downsizing from 1997 to 2003 and six years of patent data from 1999 to 2004. The sampling frame for this study included all UK medium and large firms that met our four criteria listed below. We believe our dataset offers a good setting to study the impact downsizing has on innovation output. The observation period enabled us to look for considerable lag effect, and distinguishes between differences across firms in the propensity to produce patents. For a firm to be included in our dataset it had to meet four key criteria. First, because small firms are sensitive to the usual small fluctuations in the number of their employees that would have shown as downsizing, the firm had to be at least a medium-sized firm employing 250 employees or more (Curran and Blackburn, 2001, p. 9). Second, for two key reasons the firm had to be a single business located in the UK. This condition eliminated the risk of including in our dataset firms relocating their activities abroad and firms downsizing in one line of business but expanding or not changing other lines of business. Also, single line business are the most appropriate population because only in this population we are able to clearly identify downsizing effects; in multiple businesses downsizing and downscoping effects could not be clearly separated² (see, Lerner, Sørensen and Strömberg, 2008). Third, the firm must have downsized by at least five per cent in any given year during the observed period (Cascio et al., 1997). Fourth, the firm must

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² We thank one of the reviewers for this useful comment.

have had at least one accepted patent during the research period, to be considered suffice to include in the panel. Previous research shows that the probability of progressing from zero to one patent is uniformly much lower than achieving further patents after the first has been awarded (Cefis, 2003). As Cefis' (2003) study of 577 UK manufacturing firms noted that 'it is much more difficult to apply for the first patent than to go from n to n+1 patents, with $n\geq 1$ '. Moreover, Cefis (2003) shows that innovative output measured by patents is persistent, i.e. firms that produce patents tend to do it regularly.

The dataset is composed of firm level information, industry level data and a count of successful patents granted to respective firms. We combined data from three major datasets to produce the panel. Firm level information is drawn from FAME (Financial Analysis Made Easy) database, which provides required data such as yearly number of employees, size, age, and ownership of the firm on about 2.8 million firms in the UK. Industry level data such as innovativeness of the sector of activity is based on the Department of Trade and Industry's (DTI) classification, and market share is obtained from the Office of National Statistics Annual Business Inquiry and measured at the 3-digit UK Standard Industrial Classification (SIC) level. The count of successful patents is obtained from the European Patent Office database.

The data analysis was followed by interviews with managers of firms that were involved in downsizing. In 2006, we sent a letter to the managing directors of the 258 firms in our data set and asked them for interviews. Three companies agreed to participate in the study granting us access to two senior managers in each who were involved in the downsizing process and have intimate knowledge of the impact of downsizing on the innovative environment in their respective companies. These managers were asked to discuss the impact downsizing had on the firm's innovative

capability. Given that downsizing strategies are developed and executed by top management and the impact of downsizing is felt in different departments—human resources, operations, R&D, finance and so forth—general managers are ideally positioned to provide reliable information on all the issues examined in the study.

Several studies on organizational innovativeness used R&D managers and engineers as key informants (see for example, Bommer and Jalajas, 2002), but we believe while R&D managers might be able to report on investment in research and innovation climate in their particular department, they would not be able to report on issues located in other departments such as morale of employees, and loss of skilled people throughout the organization. All interviews were recorded and transcribed. The qualitative analysis of interview transcripts enabled us to gain insights into the causal dynamics that drive our empirical results and helped in the interpretation of our empirical findings. Interviews lasted from between two and three hours.

Variables

The dependent variable, the count of successful patents granted to a particular firm in a given year (Hausman et al., 1984). It is a non-negative integer ranging from zero to ninety in the sample.

The independent variable—downsizing—is the percentage of employee reduction by five per cent or more (Downsizing = 0 if employment reduction < 5 percent; Downsizing = the percentage of employment reduction if reduction is \geq 5 percent).

Control Variables

We controlled for seven variables. First, organizational innovativeness and level of slack after downsizing are influenced by the level of slack before downsizing. Thus,

we controlled for the initial slack level prior to downsizing. Wellbourne, Neck and Meyer (1999) argue that human resource slack is reflected in the number of employees relative to sales. As noted earlier, we adopted a relative measure of slack. That is, we used average sales per employees in the industry as a benchmark for slack level. We measured slack as sales per employee ratio compared with the average in the industry in the year prior to downsizing using the following formula: human resource slack = firm size (number of employees)/firm sales – average industry size/average industry sales. Our measure is similar to that of Mishina, Pollock and Porac (2004, p. 1187). Larger positive values indicate greater levels of slack and vice versa. We used yearly peer comparison data from FAME to obtain average industry size and sales for each firm in our dataset. We believe our measure of slack captures the extent to which human resources are embedded in firms as excess costs compared to competitors. This is in line with previous research arguing that 'absorbed slack corresponds to excess costs in the organization and can be observed in a firm through higher cost levels compared with firms with similar output levels' (Ozcan, 2005, p. 6; see also, Greve, 2003). Further, although direct measure of human resource slack is difficult if not impossible, measure of relative slack is by contrast quite feasible (Mishina et al., 2004), because this method avoids relying on organizational efficiency and is not biased towards the size of the firm.

Our second control variable was sector of activity, since past research shows that innovation output is different across sectors (Cefis, 2003). We categorised sector of activity into three levels of innovativeness (*sector* = 1 if firm is in low innovation sector; 2 if firm is in medium innovation sector; and 3 if firm is in high innovation sector). This categorisation is based on the UK DTI's compilation of International Top Ten sectors by proportion of total R&D where we defined the top five sectors as

the high innovation sector, the next five sectors as the medium innovation sector, and the remaining sectors as the low innovation sector. Respective firms in the sample were correspondingly grouped under these categorisations based on their principal operating industry reported in FAME.

Our third control variable is the size of the firm (*fmsize*). We used the number of employees to measure the size of the firm. Past research (Bound et al., 1984; Chabchoub and Niosi, 2005) reported that the size of the firm has a positive and significant impact on the firm's ability to innovate. For instance, Bound et al's. (1984) study of 2582 US firms found that large firms are more likely to produce patents than smaller firms.

Similarly, scholars have long explored the association between exporting and ability to innovate, using patents as a proxy for innovation. Past research consistently shows that exporting firms tend to innovate more than non-exporting firms (Salomon and Shaver, 2005). Therefore we controlled for export (export = 1 if firm exported during period of research, 0 if it did not), our fourth control variable.

Firm age (*fmage*) is also included as our fifth control variable. Past research shows that older firms have more experience in managing the production of patents and therefore may be more efficient in their patenting activities (Katila and Shane, 2005; Sorensen and Stuart, 2000).

Firm ownership constituted the sixth control variable. A dummy variable was created for firm ownership (*ownship* = 1 if firm has some level of foreign ownership, 0 if no). With few notable exceptions (Harris and Trainor, 1995; Love et al., 1996), extant research provides evidence to suggest that foreign ownership tends to have an adverse effect on innovation because locally owned firms are more likely to invest in

factors that foster innovation such as R&D than foreign owned firms (Bishop and Wiseman, 1999).

Finally, we controlled for market share (*mktshr*) measured by the proportion of sales in each firms principal operating industry. Past research suggests that firms with high market share are more likely to finance the search for innovation in a particular industry than firms with low market share (Blundell et al., 1999).

Data Analysis

We assessed the relationship between level of downsizing and innovation output by regressing our measures of innovation output (i.e. patents on lagged values of downsizing). We used lagged values of downsizing to take into consideration the delay in granting patents after firms apply for them, and to account for the lagged impact an event like downsizing has on producing patents (Hall, et al., 1986; Hall et al., 2001; Pakes and Griliches, 1984).

We used the Negative Binomial model to test our hypotheses. The model is appropriate for this research for at least two reasons. First, our patent data is count data, and the model used is the appropriate model in handling count data. This type of model has been widely used by past research examining count patent (Hausman et al., 1984). Second, our regressors are exogenous, i.e. our independent variable (downsizing) is not predetermined by the dependent variable (number of patents), thus the Negative Binomial model is deemed appropriate (Hausman et al., 1984; Cameron and Trivedi, 1986; 1998; Montalvo, 1997).

The descriptive statistics in Table I provide an overview of our sample. About one in five of the firms were from the high innovation sector, 43 per cent from the medium innovation sector and 38 per cent from the low innovation sector. The

majority of firms—four out of five—were engaged in export activity. Our data captures 811 downsizing events ranging from five per cent reduction in workforce to 95.7 per cent. Average downsizing is 14.82 per cent. Four per cent of downsizings incorporate a 45 per cent plus reduction in workforce. The firms in our sample produce an average of just over two patents per year. Slack level prior to downsizing varies from 0.338 per cent in 1996 to just over 0.08 per cent in 2003. As one would expect, this indicates that on average firms in our sample had low but positive slack prior to downsizing.

Our initial analysis of the distribution of downsizing revealed that a small proportion of extreme downsizing (outliers) could distort the results; as noted above, the highest downsizing in our sample was 95.7 per cent. Further, these outliers which represent just over four per cent of the total observations are widely dispersed and therefore were excluded to reduce the high noise in the data that could be caused by this small sub-sample and allow us to focus on the impact of typical (96% of observations) downsizings behaviour on innovation. Further, unlike simple regression, there are no robust estimation methods to deal with such a problem for inverse binomial models.

The independent variable (downsizing) is based on the percentage layoff of employees. It is equated to zero if the layoff is less than five per cent and equals the actual percentage layoff in absolute value. The dependent variable is the number of patents. To test our first hypothesis, we analysed the accumulative effects of downsizing on innovation output over a three year period. We estimate a model where the dependent variable is the three-year total patents³.

The model is given by the following equation: $E(\text{CumPatents}_i(t,t+2) \mid \mathbf{x}_{it}) = \exp(\beta_0 + \beta_1 D_{t-1} + \beta_2 D_{t-1}^2 + Control_t)(1)$; where $\text{CumPatents}_i(t,t+2)$ is the total number of patents in the three years between t and t+2.

In the first analysis (Table II) we lagged downsizing by one year on aggregate patent data in the following three years. This way, for example, the downsizing that took place in year_{t-1} is posited to affect total patents in years_{t+(t+1)+(t+2)}. Missing values were treated with listwise deletion in all models. We entered the lagged downsizing for t-1, t-2, and t-3 in the same model to account for their simultaneous effects on the dependent variable (Golden and Viega, 2005). Our main hypothesis of an inverted U-shaped relationship between level of downsizing and innovation output is tested by using the linear and quadratic terms of downsizing. We included all control variables, the main effect of downsizing, and the squared term of downsizing. Contrary to our expectations, the results presented in Table II show that level of downsizing has no significant impact on innovation output. Therefore, the assumption that level of downsizing has an inverted U-shaped relationship with innovation output is not supported. As one expects, the sector of activity is significantly related to innovation output.

[Insert table I about here]

[Insert Tables II and III about here]

To test our second hypothesis we repeated the first analysis with yearly patent data. We observed the number of patents $y_{it.}$ in year \underline{t} for firm i. The conditional mean of number of patents for firm i and year t is given by:

$$E(yit|xit) = m(xit,\beta)$$
 (1)

Where x_{it} is a vector of explanatory variables, such as downsizing and other control variables and β is a vector of parameters.

Because the conditional mean must be positive, it is often convenient to use

$$m(\mathbf{x}_{it}, \boldsymbol{\beta}) = \exp(\beta_{0+} \beta_1 \mathbf{x}_{1t+...+} \beta_k \mathbf{x}_{kt})$$
 (2)

The log-likelihood function for observation i is then given by

$$l_i(\beta, \eta^2) = \eta^{-2} \log[\eta^{-2} / (\eta^{-2} + m_{it})] + y_{it} \log[m_{it} / (\eta^{-2} + m)] + \log[\Gamma(y_{it} + \eta^{-2}) / \Gamma(\eta^{-2})]$$
 (3) where $m_{it} = m(x_{it}, \beta)$ and $\Gamma(.)$ is the gamma function.

The estimated model will therefore be:

$$E(Patents_{it} | x_{it}) =$$

$$\exp(\beta_0 + \beta_1 D_{t-1} + \beta_2 D_{t-1}^2 + \beta_3 D_{t-2} + \beta_4 D_{t-2}^2 + \beta_5 D_{t-3} + \beta_6 D_{t-3}^2 + Control_t)^4$$
(4)

The results of the Negative Binomial models reported in Tables III and IV provide partial support to our second hypothesis. The results show that level of downsizing has no significant impact one year after the downsizing event, an inverted U-shaped relationship between level of downsizing and innovation two years after the downsizing takes place, and no significant impact three years after downsizing. The inverted U-shaped relationship between downsizing and innovation two years after the downsizing is evidenced by the positive and significant coefficients for downsizing, and the negative and significant coefficients for squared downsizing. As shown in Table III, two years after the downsizing, the coefficients for downsizing are significant and positive (2002: Coef = 0.097, p< 0.1; 2003: Coef = 0.131, p<.001; 2004: Coef =0.054, p< .05) coupled with a negative and significant values for the squared downsizing coefficients (2002: -0.006, p< .05; 2003: Coef=-0.008, p< .01;

22

⁴ The variable control includes lagged slack, size, market share, age, and other dummies variables representing ownership, export, sector 2, and sector 3.

2004: Coeff= -0.003, p< .01) suggesting an inverted U-shaped curve characterizing the impact of downsizing level on patents.

Table IV presents the results of restricted Negative Binomial models for the lagged effects of level of downsizing on yearly innovation output. In the restricted model we dropped all control variables that were found to be insignificant in the full models. Similar to the full models as shown in Table III, in 2002, 2003 and 2004 the results show a positive value for downsizing (2002: Coef = 0.091, p< .1; 2003: Coef = 1.30, p< .05; 2004: Coef = 0.065, p< .05) coupled with a negative value for the squared downsizing coefficients (2002: -0.006, p< .05; 2003: Coef=-0.008, p< .01; 2004: Coeff= -0.003, p< .001), suggesting an inverted U- shaped curve characterizing the impact of level of downsizing on patents two years after the downsizing. Overall, the results did not change in the restricted model. Our results show that the impact of downsizing on innovation output is temporary.

The significant results in Table III and IV are illustrated in Figure I. Figure I plots the association between level of downsizing and a two-year lag patent predicted by the negative binomial model. The y axis represents the predicted number of patent two years after the downsizing. This was calculated as $E(Patents_{2002} | Control = 0) = \exp(0.097D_{t-2} - 0.006D_{t-2}^2)$; $E(Patents_{2003} | Control = 0) = \exp(0.131D_{t-2} - 0.008D_{t-2}^2)$; and $E(Patents_{2004} | Control = 0) = \exp(0.054D_{t-2} - 0.003D_{t-2}^2)$ for 2002, 2003 and 2004 respectively. Figure I, shows only the predicted number of patent based on a negative binomial regression of downsizing on patent without the other covariates. The figure reveals some interesting insights on the association between level of downsizing and innovation. It shows that low downsizing—5 to 8 per cent—had a very marginal positive impact on innovation output.

Therefore the relationship between level of downsizing and innovation two years post-downsizing is more of an inverted ' $\sqrt{}$ ' than a 'U'-shaped relationship.

[Insert Figure 1 about here]

Our qualitative data can help us shed light on causal effects of level of downsizing and innovation. Our interviewees came from organizations that were involved in high level downsizing, and given this, employees in most functions and at levels were affected by the job cuts. The six interviewees held senior managerial position in their respective organization. Interviewees attributed the possible impact of downsizing on innovation to lack of planning and poor execution of downsizing. While the planning of downsizing was instigated at the top level of the organization, the execution of downsizing, especially deciding who to lay-off, was delegated to line managers and direct supervisors across departments. However, since line managers used different selection processes, this process was not coherent or consistent. The process of identifying who to downsize varied from one firm to another and from one department to another. Our respondents reported that there were no conscious or formal decisions about retaining the stock of knowledge or possible impact downsizing may have had on innovation beyond keeping operations going through the disruption of downsizing. Maintaining the organization innovation capability perhaps was the least of their worries. Although our respondents were members of the top management team, they reported that front line managers face significant difficulties in identifying candidates to be downsized. Given the speed of implementation there was little attention paid to the impact of downsizing on front line and working relationships, and the rationale for the layoff was not communicated effectively, impacting survivors' perception of procedural fairness. In the three cases respondents

were not able to describe the rationale of management action during the layoff processes. In short, the process was fragmented. In one organization the execution was described as 'chaotic' because of urgency to downsize and diminishing employee morale and lack of support from line managers for the downsizing. This was the first time the firm had to downsize and went against its long history of paternalism. Also, downsizing came somewhat unexpectedly after the organizations exhausted other options to revive the organization. Ironically, the organization initially adopted what was described as 'a ruthless' downsizing approach with little support for downsized employees or survivors. Given that the organization lacked skills in downsizing, and the mass layoff went against its long held corporate values, they recruited external consultants to help them manage the post-downsizing process.

Thus, it appears that the lack of planning coupled with urgency of implementation explains part of the short-term impact of downsizing on innovation in high level downsizing. In the three cases, downsizing was introduced hurriedly and no attention was paid to the impact of downsizing on the firm's stock of knowledge or its innovative capability. Further, all interviewees reported that managers underestimated, and as a result did not consider, the impact of downsizing on their innovative capability.

In addition to lack of planning and urgency of implementation, interviewees reported that the impact of downsizing on innovation during the post downsizing period was a result of four interrelated factors: cut in resources allocated to innovation activities; depletion of slack after downsizing; disruption of innovation processes; and deterioration in employee relations. First, the interviewees reported that during and soon after a high level downsizing, management focused primarily on productivity gains, cost reduction and activities that that yield short term gains, and as a result,

investments in innovative activities fell. As put by one senior manager in an industrial organization that engaged in very high level downsizing:

My enthusiasm has been to get competitive advantage by innovation. Now when you're not making money and when there isn't like a sort of mapped out longer term future of more than two or three years, it's difficult to justify when the shareholders are saying, 'We've got to stop losing money. You've got to find a way of turning the business around', then long term innovation is going to play second fiddle to just finding a way of surviving. So I would say, you know, what we've done has compromised the innovation...So a lot of the focus of the business, I guess, at that time was around short term profits and cash. If you didn't have that, the job was off.

Second, in addition to allocation of resources, interviewees suggested that high level downsizing reduces human resource slack which subsequently leads to an increase of work load, and hence, reduces the time and efforts people spend on innovation activities resulting in low innovation output. As illustrated by an operations manager at a specialty chemicals and decorative paints organization:

(in) the mid 90s, we weren't very lean. We had lots of slack. It probably didn't feel like it because then we were pretty [inefficient], but the reality was we had lots of slack...but without any question the amount of slack evaporated... We used to have a thing called the business development team where we had three or four teams which were multi-functional teams and they had commercial people, quality people, product engineers, process engineers and I think we had four at one time... Now we haven't got anything like that... In product engineering we probably had a dozen. We've probably now got two.

Process engineering, we probably had a dozen. We've probably now got six or something else.

Third, all interviewees suggested that downsizing breaks up existing innovation processes which, as a result, interrupts innovation activities. The break up may be caused by key people leaving the organization, restructuring activities after downsizing or both. Further, downsizing firms did not build up their innovation processes because of lack of investment in the latter. As put by senior manager in an industrial organization:

If you had a process that did a certain thing, it's gone because the person operating it is no longer there anymore and the company is building itself at the company level and things like the detailed processes don't happen until later. So we're now finding ourselves that we're looking, as it happens, looking at patents at the moment and what we've just done and we realise that we have a long list of things we said we would patent because we've done them, but it hasn't happened because we don't have the process. The process has disappeared and we haven't built it up again.

Fourth, in addition to allocation of resources and depletion of human resource slack, interviewees suggested that high downsizing damages the employment relationship, and that it is much harder to maintain a positive employment relationship after a high downsizing event. This is due to increased conflict between management and employees, sense of betrayal anger and hurt over the handling of downsizing, and feelings of victimization and unfairness. Further, downsizing creates high job insecurity causing a reduction of information sharing between employees, increased

secrecy, and deterioration in teamwork and cooperation. As described by the innovation manager at a specialty chemicals and decorative paints organization:

So you can look at why did some people survive; and they survived because they were clever at continuing to have things to do for the company, yeah. So there is a bit of protectionism. So the immediate thing is to cover yourself you make sure that you're the one who's needed not the other person and this is yourself who might be at a team level or.... There might be a reluctance to suddenly open up and become all part of one group because you're still not sure what's happening to you or to your team. You've seen a lot of change happen and you've seen people disappear and come and re-shuffle and so you protect yourself by having your own value that you're bringing where it's clear that this is who's doing it. So that doesn't help people work together.

In the three organizations studied, management took a number of actions to manage the aftermath of downsizing. In one organization, known for its paternalistic management style and strong pastoral responsibility towards its employees, interviewees reported that a number of groups were set up to deal with the 'toxic' level of resentment and anger, and feeling betrayal following downsizing. The groups with a help of an external consultant facilitated grieving and venting sessions and worked on rebuilding trust and re-assurance in the organization by explaining to remaining employees the rationale for downsizing and signalling the end of the downsizing episode. In another case where downsizing had a significant negative impact on the organization's innovative capabilities, management formed strategic alliances with local universities and research centres to address the deficit in its ability to innovate. In the third organization, management reported that a number of

initiatives were taken to adjust to the new level of human resources by developing multi-skilled teams, stream lining and eliminating redundant activities. These post-downsizing activities may explain the erosion of the impact of high downsizing on innovation over time.

DISCUSSION

What is the impact of slack reduction as a result of downsizing on innovation? Does the impact of slack reduction vary over time? If so, what is the nature of this variance? To answer these questions, we examined the relationship between level of slack reduction as a result of downsizing and innovation output. Contrary to our expectations, the results show that the level of downsizing does not have a significant impact on innovation. These results are generally consistent with Lerner, Sørensen and Strömberg's (2008) study which found that the quantity of patents does not change significantly as a result of a buyout by a private equity investment. Although their study was primarily concerned with the change in quantity of patents following private equity investment, they reported that employment shrunk significantly as a result of the buyout (Lerner et al., 2008, p. 44). They reasoned that the lack of significant decline in patents is because 'innovation becomes more targeted' and 'more focused' in the years after the buyout (p. ix).

The lack of support for the total effect hypothesis does not provide a full explanation of the association between level of downsizing and innovation. Our analysis of the association between downsizing and innovation overtime reveals that excessive downsizing has a significant effects on innovation but this impact is temporary. Specifically, the results show that there is a critical period—two years after downsizing—during which small downsizing has a positive, albeit very weak,

impact on innovation and large downsizing has its greatest negative impact on innovation. However, this relationship between downsizing and innovation disappears after the second year. These results add some necessary refinement to the findings on the total impact by showing that though variation in slack reduction may not have an overall impact on innovation, it has a significant, albeit short-lived ' $\sqrt{}$ ' shaped relationship two years after the downsizing. These results are consistent with Amabile and Conti's (1999) findings suggesting that while the work environment for innovation declines significantly during and following high downsizing, organizations tend to rebuild their innovative capabilities.

Interview data suggest that initially innovation output diminishes soon after high level downsizing because of lack of planning and urgency of implementation. In addition, four post-downsizing factors were reported to cause the temporarily decline in innovation in high level downsizing: allocation of resources to innovation activities decreases, starving innovation projects of required resources; human resource slack depletes resulting in a reduction in risk taking and experimentation with innovative ideas; established innovation processes break up which in turn disturb innovation activities; and employment relations deteriorates creating an environment that is not conducive to innovation.

The analysis of interview data shows that the three high downsizing organizations tried to rebuild their innovative capabilities post-downsizing. One organization tried to rebuild its innovative capability by making a shift from exclusive reliance on in-house innovation activities to an outward-oriented innovation strategy relying on strategic alliances and collaborations with scientific institutions such as universities and research centres. Extant research shows that collaboration with scientific institutions does not only enable resource strapped firms to access external

resources, but is also 'associated with active patenting behaviour' (Peeters and van Pottelsberghe de la Potterie, 2006, p. 110; see also, Brouwer and Kleinknecht, 1999). The other two organizations reconfigured their operations to fit the new level of slack, and tried to rebuild employees' trust and morale. These post-downsizing initiatives may explain the non-significant results two years after downsizing.

THEORETICAL CONTRIBUTION

This study enriched the prior theoretical research on the association between organizational slack and innovation (Cheng and Kesner, 1997; Love and Nohria, 2005; Nohria and Gulati, 1996; Singh, 1986; Tan and Peng, 2003) by examining the impact of variation in slack reduction on innovation. What makes our contribution unique is our focus on the impact of *sudden decline in slack* as a result of downsizing on innovation. As such, our findings extend extant research that so far has focused exclusively on the association between *slack level* and innovation. Further, we enrich extant research on the impact of downsizing by examining the pattern of the mpact of level of downsizing overtime.

Although downsizing level has a significant impact on innovation three years after downsizing, this impact does not persist. This finding is especially intriguing, because it shows that over time the relationship between level of downsizing and innovation output is more complex than is typically posited. Thus, over time, firms tend to revert to their normal level of innovation regardless of the level of slack reduction. Further, the temporary effects of downsizing reveal previously unnoticed dynamics of the impact of downsizing on organizational outcomes and highlight the importance to scholars and practitioners for distinguishing between the temporary effects and persistent effects of strategic actions such as downsizing. Further, our

study underscores the importance of longitudinal studies of downsizing and highlights the risks of relying on surveys carried out during a particular period of time and a result providing only a snap shot of the association between downsizing and innovation.

The study has several limitations and opens up further questions that cannot be readily answered with our data. First, we consider only the level of downsizing to examine the association between downsizing on innovation output. By so doing, our study excludes other factors that are likely to have considerable effects on innovation such as the management of the downsizing process. For example, the effects of downsizing are likely to be different in organizations that handle the downsizing process well and those that do not. Second, our study does not take into consideration the types of jobs being downsized. It would be worthwhile for future research to distinguish between downsizings that target innovation activities such as R&D staff and downsizings that cut across the whole organization, and downsizings that target part-time workers and those that target core employees or both. Third, this study is based on data collected from a single country, and this limits generalizability. Downsizing like other management actions are influenced by the country's institutional environment. For example, although firms in transition economies downsize to reduce slack (Meyer, 2002), different research approaches are needed to examine the impact of downsizing on innovation output in transition and developing countries where research is often carried out in large research centres. Further, given that firms in transition and developing countries tend to patent their innovations less than their western counterpart, patents may not be the most appropriate measure of innovation output. Fourth, in this study we focus on the production of patents. Accordingly, our findings apply to this type of innovation alone. Future research may use other innovation output such as new product development. Finally, the design of the study meant that we did not account for minor downsizing below five per cent and extreme downsizing above 45 per cent. Therefore, one cannot exclude the possibility that very low slack reduction and extreme slack may have a different impact on innovation. One must bear this important limitation in mind when interpreting our results.

Conclusion

In conclusion, the current study is the first to examine the association between reduction in slack through downsizing and innovation output. Our results produce an intriguing picture of the impact of slack reduction on innovation output. The results show that the level of slack reduction only has a temporary effect on innovation output where two years after the downsizing event small downsizing has little positive effects and large downsizing had a significant negative effects. Our results suggest that greater consideration of the varied impact of downsizing overtime is vital for a more complete understanding of how downsizing impacts organizational outcomes. This study complements extant research on the association between slack and innovation and highlights important features of the association between slack and innovation that require further empirical examination.

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Table I. Summary Statistics and Source of Data

	Description of variables		Std			
		Mean	Deviation	Minimum	Maximum	
Continuous Variables						
Downsizing ¹	The yearly percentage of employee reduction by five per cent or more.	14.82	11.15	5 %	95.7%	
Patent (avg. per firm) 4	Total number of patents granted to a particular firm in a given year	1.96	6.30	1	88	
Slack ¹	Sales per employee ratio compared with the average in the industry in the year prior to downsizing	0.23	1.21	-9.290	4.300	
Firm size ¹	Number of employees	5220	14101.22	250	116946	
Market share ²	Firm sales over total industry sales in the respective 3-digit UK Standard Industrial Classification (SIC) category.	.06	.12	0.001	0.922	
	The number of years a firm had operated	40.01	20.70	0.001	0.822	
Age	· · ·	a firm had operated 48.91 30.79 6			120	
Categorical Va			37 1		Percentages	
Sectors ¹	Description of variables Number of firms in low innovation sectors		97	Number 97		
	Number of firms in medium innovation sec	112	112			
	Number of firms in high innovation sectors				19% 73%	
Export ³	Number of exporting firms		119			
Foreign Ownership ¹	Number of firms with some level of foreign ownership				43%	

Source of data: 1 = FAME (Financial Analysis Made Easy) database; 2 = Office of National Statistics Annual Business Inquiry; 3 = Department of Trade and Industry (DTI)'s classification; 4 = European Patent Office database

Table II. Estimates of the Negative Binomial Model: Total Effects of Downsizing Level on Patents

Downsizing	Period 1*	Period 2*	
level/lagged patents			Period 3*
D(t-1)	0.027	0.048	-0.026
$D^2 (t-1)$	0.001	-0.003	0.001
Slack(t-4)	-0.055	0.134	-0.035
Size(t-1)	0.001	0.001	0.001
M. share(t-1)	3.128	3.169	2.889
Age	-0.002	0.000	-0.001
Own	-0.025	0.321	0.254
Export	0.198	0.090	0.348
Sector 2	0.817***	0.172	0.433
Sector 3	0.822**	0.065	0.965***
Constant	0.773**	1.119***	1.067***
Variance	2.095	1.806	1.867
Log – lik	1407.34	1322.41	1755.92
Estimated variance	4.34	3.79	4.07
Usable Observations	135	135	136

^{***}Coefficients significant at the 1% level, **significant at the 5% level, *significant at the 10% level.

^{*}Period 1= Total Patent_{2000, 2001, 2002}; Period 2 = Total Patent_{2001, 2002, 2003}; Period 3= Total Patent_{2002, 2003}, 2004

Table III: Estimates of the Negative Binomial Model: Lagged Downsizing and Yearly Patents (Full Model Estimation Results).

	MODEL 1. Evil Model					
	MODEL 1: Full Model					
	Pt ₂₀₀₀	Pt ₂₀₀₁	Pt ₂₀₀₂	Pt ₂₀₀₃	Pt ₂₀₀₄	
D(t-1)	0.039	0.126**	0.02	-0.063	-0.007	
D^2 (t-1)	-0.001	-0.009***	-0.004	0.005	0	
D(t-2)	-0.074	-0.093	0.097*	0.131***	0.054**	
D^{2} (t-2)	0.005	0.007	-0.006**	-0.008***	-0.003***	
D(t-3)	-0.097	-0.094	-0.077	0.063	-0.022	
D^2 (t-3)	0.003	0.006	0.007	-0.006	0	
Slack(t-4)	0.01	0.303***	0.102**	0.042	0.168*	
Size(t-1)	0	0	0	0	0	
M. share(t-1)	3.081	2.002	7.538***	2.528	0.341	
Age	-0.006	-0.001	0.001	-0.006	-0.009**	
Own	-0.08	0.303	0.167	0.137	0.402*	
Export	0.078	0.22	0.094	-0.084	0.195	
Sector 2	1.256***	0.549*	1.027***	0.255	0.7***	
Sector 3	1.095***	0.407	0.908***	0.088	1.154***	
Constant	-0.273	-0.457	-0.757	0.599	0.374	
Variance	2.53	2.229	2.184	2.008	2.751	
Log – lik	106.69	121.1	144.54	161.35	228.17	
Estimated variance	2.68	2.44	2.41	2.52	2.7	
Usable Observations	121	127	125	120	126	

^{***}Coefficients significant at 1% level, **significant at 5% level, *significant at 10% level.

⁻ Sample includes: - firms that downsized between 1997 and 2003 ($D_{t(2000\,\text{-}3)}$ to $D_{t(2004\,\text{-}1)}$).

⁻ Patent data from 2000 to 2004

⁻ Slack data for each firm from 1996-2003

Table VI: Estimates of the Negative Binomial Model: Lagged Downsizing and Yearly Patents (Restricted Estimation Results).

	MODEL 2: Restricted Model					
	Pt ₂₀₀₀	Pt ₂₀₀₁	Pt ₂₀₀₂	Pt ₂₀₀₃	Pt ₂₀₀₄	
D(t-1)	0.041	0.122*	0.018	-0.069	-0.022	
$D^2(t-1)$	-0.001	-0.008**	-0.004	0.005	0.000	
D(t-2)	-0.076	-0.085	0.091*	0.130**	0.065**	
D^{2} (t-2)	0.005	0.007	-0.006**	-0.008***	-0.003***	
D(t-3)	-0.118	-0.078	-0.079*	0.061	-0.025	
D^{2} (t-3)	0.004	0.005	0.007**	-0.006	0.000	
Slack(t-4)		0.317***	0.090		0.226**	
Size(t-1)		0.000***		0.000*	0.000	
M. share(t-1)	4.211***		7.105***	2.651		
Age					-0.004	
Own					0.567**	
Export						
Sector 2	1.257***	0.531*	1.033***		0.740***	
Sector 3	1.090***		0.936***		1.371***	
Constant	-0.267	-0.303	-0.567	0.638	0.246	
Variance	2.532	2.260	2.198	2.018	2.939	
Log - lik	109.11	120.57	144.37	161.23	313.93	
Estimated variance	2.63	2.41	2.4	2.54	2.82	
Usable Observations	117	127	125	120	143	

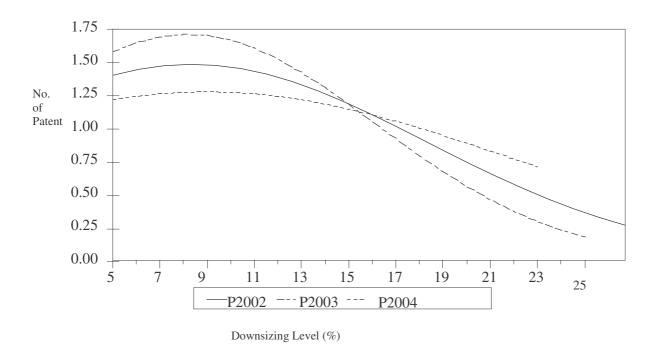
^{***}Coefficients significant at 1% level, **significant at 5% level, *significant at 10% level.

⁻ Sample includes: - firms that downsized between 1997 and 2003 ($D_{t(2000 - 3)}$ to $D_{t(2004 - 1)}$).

⁻ Patent data from 2000 to 2004

⁻ Slack data for each firm from 1996-2003

Figure 1. The Inverted U-Shaped Effect of Downsizing (t-2) on Patent



Notes: The figure plots the level of downsizing (t-2) on the x-axis against patent counts (t) on the y-axis. Means and (standard deviations) for downsizing in 2000 and 2001 and 2002 are 14.08 (11.21), 13.32 (11.45) and 15.17 (9.52) respectively. Expected patents for each year were obtained from table two as follows:

P2002: E(Patents₂₀₀₂ | Control = 0) =
$$\exp(0.097D_{t-2} - 0.006D_{t-2}^2)$$

P2003: E(Patents₂₀₀₃ | Control = 0) =
$$\exp(0.131D_{t-2} - 0.008D_{t-2}^2)$$

P2004: E(Patents 2004 | Control = 0) =
$$\exp(0.054D_{t-2} - 0.003D_{t-2}^2)$$