Innovation as a Crisis Response*

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Abstract

The innovation persistence literature focuses on whether firms reduce, increase, or maintain their innovation activity over time, and in particular through cyclical downturns and crisis periods. This literature mostly addresses whether firms accelerate or decelerate their pre-crisis innovation agenda during these periods. What it tends to underemphasize is that innovation is also a tool firms use to manage the unforeseen circumstances that arise in times of crisis and upheaval. To a considerable extent this will involve implementing unexpected innovations to deal with unexpected conditions. We argue and find that crisis-induced innovation displays patterns that are both similar to and different from the innovation behaviors found in more stable periods. More firms turn to innovation, but with important differences in intensity and expected long-run returns. Pre-crisis experience in innovation and organizational agility are key characteristics leading to higher levels of innovation input, innovation output, and expected post-crisis value of the innovations undertaken. We base our findings on data from firms' innovation responses to the COVID-19 crisis.

Keywords: crisis, innovation, persistence, strategic response, covid-19
JEL: O31, D22, D25, E32, L25

Introduction

At least since Schumpeter (1911; 1942) considerable scholarly interest has been devoted to how economic crises and recessions affect innovation (Amore, 2015; Archibugi et al., 2013a, 2013b; Barlevy, 2004; Geroski et al, 1997). Key questions have been to determine whether aggregate innovation investments and output are pro- or countercyclical (Archibugi et al., 2013a, 2013b; Caballero & Hammour 2001; Cincera et al., 2012; Filippetti and Archibugi, 2011; Guellec & Wunsch-Vincent, 2009; Laperche et al., 2011; Paunov, 2012), which firm and contextual characteristics make a firm more likely to be a persistent or countercyclical innovator (Antonioli and Montresor, 2019; Cefis, 2003; Cincera et al., 2012), the rewards attributable to those firms that are (Madrid-Guijarro et al., 2013), and the impact of recessions and crises on firms' post-crisis innovative performance, behavior, and capabilities (Paunov, 2012; Zouaghi et al., 2018). Underlying the better part of this literature is the notion that faced with a downturn some firms decide to cut innovation activities and use available resources

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elsewhere - including to ensure survival - while some firms are willing and able to press on with their innovation agenda - or even to speed it up.

What is left out is that innovation is also a tool managers can use to handle the unforeseen contingencies that a sudden change in business conditions bring about (Wenzel et al., 2020). We argue that an innovative response during an economic downturn does not necessarily imply maintaining or accelerating an already existing innovation trajectory, although occasionally it might. It can also involve ad hoc and unplanned innovation initiatives, unforeseen before the crisis, motivated by the specific changes in business conditions a given firm is facing, coupled with its inventory of resources and its ordinary and dynamic capabilities. Such crisis-induced innovation responses will in many cases have a shorter planning-, development-, and implementation period than innovations that takes place in ordinary times, simply because they are aimed at solving urgent and unexpected challenges or opportunities created by the crisis. While innovation persistence is usually explained in terms of various forms of path dependency (Crespi and Scellato, 2014), we argue that using innovation to manage unexpected crises will often also require some measure of path independency and organizational agility.

The capacity to undertake crisis-induced innovation can potentially provide managers with an extra degree of freedom with respect to the responses at their disposal, but this capacity is likely to be heterogeneously distributed across firms. In this paper we therefore examine the extent to which firms use innovation as they navigate the impact of the COVID-19 recession. Our main interest is to identify key firm level characteristics that increase the use of innovation as a crisis management tool. We examine the impact of such characteristics for innovation input, innovation output, and the expected value of the innovations undertaken in response to the crisis.

Our primary data source is a survey of about 1100 Norwegian CEOs, capturing their responses to the COVID-19 recession, and key characteristics of the firm before the crisis hit. Our key findings are that a recession can incentivize firms to both increase and decrease innovation investments. Firms with a pre-recession strategy emphasizing innovation are significantly more likely to increase innovation investments in response to the crisis, and significantly less likely to reduce them. Conversely, there is no similarly clear pattern for firms with other strategic orientations such as a customer-centric or a cost-centric strategy. We also find that organizational agility is associated with a higher likelihood that a firm increases innovation investments.

In terms of innovation output, we find that a majority of firms innovated to some degree in response to the recession. However, there are also large differences in how much they innovate. Firms with a pre-crisis strategy emphasizing innovation undertake more innovations in new products and services,

new processes, new market segments and new logistics than firms with other strategic orientations. Moreover, organizational agility and crisis impact is also associated with more innovation output across all four innovation categories. Finally, we find that the expected post-COVID value of innovations tends to be higher for firms that were pursuing innovation strategies and for firms that were organizationally agile going into the crisis.

The remainder of the paper proceeds as follows: In the next section we provide a brief overview of the literature on economic crises and innovation, and we develop in more detail the research questions this paper addresses, followed by our hypotheses regarding the determinants of crisis-induced innovation. We then continue with a methodological section where we start off by describing the empirical setting, our data and sample, and how the variables are measured. The results of our analysis are reported in Section 4 followed by a discussion of the implications of our findings. Finally, we conclude by discussing limitations and suggestions for future research.

Theory

Innovation persistence during recession

Given that innovation is widely considered an engine of economic growth and welfare, it is no surprise that the effects of recessions on innovation has generated a lot of interest among scholars, policymakers, and managers (Archibugi, 2017; Barlevy, 2007; Comin and Gertler, 2006; Geroski et al., 1997; Guellec and Wunsch-Vincent, 2009; Nuño, 2011). There are two obvious questions at the core of this issue; the first is about the aggregate effects, and the second is about the variation underneath these aggregate effects.

The aggregate question is about how aggregate innovation investment and innovation output responds to recessions - and why. This debate seems mostly settled. Innovation is a procyclical phenomenon in the aggregate (Archibugi and Filipetti, 2011; Archibugi et al., 2013a, 2013b; Paunov, 2012; Roper and Turner, 2020). Destruction of demand weakens the incentive to innovate, and more binding financial constraints weakens the ability to innovate (Aghion, et al; 2012; Campello et al., 2010; Knudsen and Lien, 2014). These negative impulses outweigh the positive stimulus arising from innovating in periods when excess capacity in other activities (e.g., production and sales) lowers the opportunity costs of innovating, and the inertial effects stemming from the fact that innovation activities are associated with larger adjustment costs than most other activities (Aghion and Saint-Paul, 1998; Davis & Haltiwanger, 1990; Gali and Hammour, 1993; Hall, 1992). The net effect is therefore a loss of innovative input and output. Aggregate innovation is in other words procyclical and not persistent.

The variation question turns on the realization that despite these findings, a significant minority of firms are indeed persistent innovators (Amore, 2015; Antonioli and Montresor, 2021; Archibugi et al, 2013; Cefis, 2003). These firms maintain or even increase their innovation activities during recessions. This begs the question of who these firms are, and what makes them behave differently from the procyclical innovators? Two findings stand out: The first is that the persistent innovators within a crisis can be characterized as either particularly heavy innovators or fast-growing new entrants before the crisis (Archibugi et al., 2013; Cefis, 2003; Geroski et al., 1997). These firms are the ones that place the heaviest emphasis on innovation and will therefore tend to have the strongest innovation capabilities, routines, and competencies. Maintaining or accelerating their innovation agenda is therefore more attractive than for other firms, for both offensive and defensive reasons.

The offensive argument is that strong innovation capabilities will lead them to expect more valuable innovations per unit of innovation spending. Combined with the reduced opportunity costs of innovating in a recession, they face stronger positive incentives than where innovation is a more peripheral or intermittent activity. In addition, because innovation is associated with cumulative learning processes, heavy innovators can by investing through a recession solidify and improve their strategic position by pulling away from competitors that reduce their investments. The defensive argument is related to the high adjustment costs associated with innovation and R&D (Dierickx and Cool, 1989; Hall, 2010; Li, 2011). High adjustment costs mean that scaling up and down these activities and investments are costly. If you downsize your R&D-division, you cannot expect to scale it back up later and quickly reach productivity levels like those before the downsizing. The main point here being that the more refined and productive the unit, the higher the adjustment costs will tend to be. Accordingly, firms that have sophisticated, state of the art innovation and R&D activities will have particularly strong incentives to avoid incurring them.

The second main finding is that financing matters. Innovation- and R&D activities are associated with particularly high levels of uncertainty and information asymmetry, which makes them challenging to finance even in normal periods (Czarnitzki and Hottenrot, 2010; Hall, 2010; Kerr and Nanda, 2015; Mazzucato, 2013). When a recession hits, banks tend to ration credit more strictly and equity markets cool down, compounding such financing challenges. Unless government support schemes kick in (Panouv, 2012), internal sources of financing or having unused borrowing capacity in physical assets become crucial for firms' ability to continue or accelerate innovation activities (Cowling et al., 2020). Younger firms, smaller firms and firms that have grown fast will then often be particularly vulnerable (Cowling et al., 2020; Freel 2007; Lee et al., 2014; Schneider and Veugelers, 2010). More generally, the more a firm depends on external finance the less likely that it will be a persistent or countercyclical innovator.

Crisis-induced innovation

What the persistence literature downplays is that during recessions the business landscape changes quite profoundly. While this is generally the case, it has been particularly so during the current COVID-19 recession. Demand evaporates or shifts, supply chains get disturbed, distribution models are left unworkable or even prohibited, employees start working from home, and so on. Firms may deal with such upheavals in different ways. They can cut costs, hunker down, and wait for the storm to pass. Or they can attempt to innovate their products, work processes, target markets, or distribution models to make the best (or avoid the worst) of the new situation.

For some lucky firms this merely means advancing an existing agenda with respect to innovation and development, but it seems unlikely that this is the general case. Rather, many firms will be forced to consider unexpected innovations in response to unexpected conditions. These are innovation activities that would not have been undertaken in the absence of a recession or a crisis. We label innovations attributable to a recession or a crisis "crisis-induced innovation". This can in principle be both accelerating planned innovations and innovating in ways or areas that were not planned. The key element is that it represents a shift in a firm's innovation behavior.

Thus, innovation is a tool firms can use to soften the impact of a recession, to make the best of bad circumstances, or even to exploit new opportunities created by the change in the competitive context. In other words, a recession or a crisis creates a need for adaptation, and innovation is one way of adapting. It is not the only way, though, and for some firms it may not be the best way either. Innovation is never costless, and the outcome is always uncertain. This is true for innovation under normal circumstances, and there is no reason to think that it would not be true for crisis-induced innovation. For some firms, the expected costs will therefore outweigh the expected benefits, and they will prioritize other tools for adaptation and crisis management.

Given its motive of adapting to an unexpected and changed business landscape, we expect that crisis-induced innovations differ from ordinary innovation. Since it is a crisis response, it is likely to be heavily, but not exclusively, necessity based. Furthermore, we believe that the situation will tend to call for innovations that are preceded by a shorter planning period, implemented faster, and probably also less capital intensive. This in turn suggests that they are more likely to be innovations that are new to the firm rather than innovations that are new to the world, and one might expect that the innovations introduced to be of a more "mundane" nature. It also means that firms are likely to favor innovations that do not require heavy investments in the development of new capabilities, but instead favor reallocating, recombining, and reorganizing existing capabilities, or to find new partnerships.

Thus, even if crisis-induced innovation is unlikely to be radical and disruptive, it is likely a major part of how the innovation phenomenon plays out in a recession. Importantly, we also believe that crisis-induced innovation is an approach firms will use to varying degrees, and with varying success. Consequently, the general question we ask in this paper is which firms will do more and which firms will do less crisis-induced innovation?

Crisis-induced innovators

We start out by focusing on heterogeneity with respect to how a firm is affected by a recession. It is a well-known fact that firms and entire industries are affected differently by the COVID-19 crisis. More generally, firms and industries differ in their cyclicality. This has been found in every recession ever studied (Petersen and Strongin, 1996), and it is likely to affect innovation responses.

Crisis Impact and innovation behavior

During a crisis some firms experience a significant loss of income which pushes them to act. For others, operations continue more or less as usual, while a few lucky firms might even experience windfall gains from a crisis. To shed light on how the impact of the crisis affects innovation behavior we can draw on a rich literature that addresses organizational performance and innovation (Argote and Greve 2007; Cyert and March,1963; Bolton 1993; Greve 2003; Laursen 2012) and problemistic search (Posen et al 2018).

Early and seminal work by Cyert and March (1963) postulated that substandard performance fosters innovation. When confronted with poor performance firms are more likely to take risks, search for new opportunities, and adopt new strategies and tactics to turn the tide (Bolton, 1993; Greve, 2003). Well-performing firms have weaker incentives to take such risks, which means they are more likely to prefer staying on their existing path. During periods of crisis, firms that experience a sudden decrease in demand (or ability to supply) will experience a drop in income and substandard levels of performance. Since the substandard performance is purely exogenous, some firms might decide to simply sit out the storm while others will want to take immediate action by adapting to the new situation. Firms that are not negatively affected are not subject to the pressure resulting from underperformance. Prospect theory (Barberis, 2013; Kahneman and Tversky, 1979) makes a related argument by pointing out that decisionmakers have a higher tolerance for risk in the domain of loss than in the domain of gain. In a recession more firms and decisionmakers are operating in the domain of loss, and according to prospect theory this means that their risk tolerance goes up. Risky search and innovation activities that carry a potential for reducing losses will become more attractive for negatively affected firms, while no such increase will be observed for unaffected firms. Indeed, prospect theory predicts reduced risk tolerance for the firms that are positively affected by the crisis.

In combination this leads us to formulate the following hypotheses:

> *H1: firms experiencing a decrease in demand (or ability to supply) are more likely to engage in crisis-induced innovation activities.*

Innovative capabilities

Even if we controlled perfectly for the severity and nature of the crisis impact, we would probably still observe differences in firms' propensity for crisis-induced innovation. So, which are the firm level characteristics that matter? A reasonable place to start is in the literature on innovation persistence and consider whether findings from this literature are likely to hold for crisis induced innovation also. What this literature has demonstrated is that the firms most heavily engaged in innovation before a recession are more likely to continue with these activities within and after a recession - at least as measured using R&D and innovation survey data (Antonioli and Montresor, 2021; Archibugi et al., 2013; Cefis, 2003; Geroski et al., 1997). The reason for such persistence is embedded in two main theoretical arguments: the adjustment cost argument and the competence-based argument. In addition to this, the persistence literature has found that financing constraints matter.

The adjustment-cost argument (occasionally labeled the sunk cost argument) argues that previous innovation is associated with investments in an innovation infrastructure, including R&D facilities, equipment, specialized human capital resources, and knowledge investments. These investments tend to be sunk and they are usually costly to scale up and down (Antonioli and Montresor, 2021; Ganter and Hecker, 2013). For example, training R&D personnel often takes a long time, which means that laying off such employees and rehiring when the crisis is over involves a long training period before the new hire reaches full productivity. The more refined and cutting-edge innovation activities are, the more costly they are to switch on and off, and to scale up and down. Under normal times this creates an innovation entry barrier for those who are not innovators, and an innovation exit-barrier for those who are proficient innovators. It also means that the better you are at innovation, the less tempted you are to scale down your innovation activities (Gant and Hecker, 2013; Antonioli and Montresor, 2021). In terms of crisis-induced innovation, as described above, the sunk cost barriers to inexperienced innovators are probably lower because of its mundane and often incremental nature. Even so, experienced innovators will presumably have an extra incentive to keep their innovation personnel and infrastructure active and intact, and if necessary, reallocate some attention to more ad hoc innovation to manage a crisis.

The competence-based argument points out that firms with strong previous innovation experience have engaged in a process of knowledge accumulation and have built the necessary capabilities to innovate (Antonioli and Montresor, 2021; Ganter and Hecker, 2013). Such firms would expect to get

more from their innovation efforts both in the short and longer term, and hence they have stronger incentives to innovate. In terms of crisis-induced innovation, the question becomes whether having competencies and capabilities in ordinary innovation (before the recession) means you are more likely to be good at crisis-induced innovation? If crisis-induced innovation is a faster, less capital intensive and less radical version of ordinary innovation, it seems very likely that this is the case. In sum, this means that previous innovators will find innovation more attractive relative to other ways of adapting to a recession – and they will do more of it than firms without previous innovation experience.

A capability that is likely to increase in importance in the context of crisis-induced innovation is a firm's general ability to adapt and change, which we might label its organizational agility (a term that overlaps significantly with dynamic capabilities) (Rigby et al., 2020, Teece et al., 2016). Because crisis-induced innovation needs to be planned and implemented fast, possibly under severe resource constraints, in a rapidly and unpredictably changing context, firms that have developed a flexible and agile organization prior to the crisis will possess an important advantage, and we predict they will tend to do more of it.

In sum, the above discussion leads to the following two hypotheses:

> *H2a: More innovation experience before the crisis leads to more crisis-induced innovation during the crisis.*
>
> *H2b: Higher organizational agility before the crisis leads to more crisis-induced innovation during the crisis.*

While we expect innovation experience and agility to affect the likelihood of innovating, one might also ask whether the crisis-induced innovations introduced are also qualitatively different. Certainly, all else equal, any firm would prefer to implement innovation projects that not only respond to the immediate demands of the crisis, but also have high expected value after the crisis. Both experience and capabilities in innovation and organizational agility implies that a firm can choose development projects that firms without these qualities would not be able to realize, and that they are likely to get a better outcome from initially similar projects (Hsieh and Tsai, 2007). This implies that firms with these characteristics are more likely to pick projects with higher long-term potential, and also more likely to get long-term value out of similar projects. This suggests the following two additional hypotheses:

> H2c: *More innovation experience before the crisis leads to higher expected post-crisis value of a firm's crisis-induced innovations*
>
> H2d: *Higher organizational agility before the crisis leads to higher expected post-crisis value of a firm's crisis-induced innovations*

Financial position

As noted, the persistence literature has documented that financial constraints matter (Cefis et al., 2020; Ganter and Hecker, 2013). There are well known challenges associated with financing investments in innovation and R&D. Uncertainty, firm specificity, and information asymmetry makes them weak collateral for creditors, and a risky bet for investors, and these challenges tend to become particularly severe during recessions. Dependence on external finance is therefore a negative predictor of R&D and innovation spending in a recession.

This tendency would presumably also be relevant for crisis-induced innovation, but three conditions are likely to make it somewhat weaker. For one thing we expect crisis-induced innovations to be less capital intensive and to have more of a bricolage flavor. Another is that having a strong financial position makes it possible for a firm to hunker down during times of crisis and wait for better times, rather than attempt to use innovation to actively adapt. Finally, a weaker financial position might be a motivator to innovate. In other words, a measure taken to stop the bleeding of an anemic firm quickly. In particular this might motivate innovations that are capital light and have short payback times.

Still, having slack in financial resources allows a firm to engage in innovation, and to finance more of it, so while we believe that crisis-induced innovation is less sensitive to financial constraints than ordinary innovation, we still expect financial strength to be a positive predictor.

> *H3: A stronger financial position at the start of the crisis leads to more crisis-induced innovation during the crisis.*

Methodology

COVID-19 crisis in Norway

We use the outbreak of COVID-19 in Norway as the setting for testing our hypotheses. On the 26th of February 2020, the coronavirus was confirmed to have spread in Norway. As the number of cases rapidly increased, the Norwegian government announced the first national lockdown on the 12th of March. While the health-crisis as measured in deaths and hospitalization was not as severe as in most other developed countries, the economic consequences of the pandemic was. According to the Norwegian Statistical Office, the COVID-19 pandemic resulted in a 4.7 percent lower GDP than pre-pandemic estimates (Frederiksen, 2021a), this number is approximately equal to other Scandinavian countries (Frederiksen, 2021b). The Norwegian government quickly implemented several countermeasures including easing the regulations on furloughing, reducing employer contributions, providing loan and guarantee schemes, and direct financial support for businesses that experienced a significant drop in revenues. The Norwegian Labour and Welfare Administration (NAV) received over 350.000 applications for unemployment benefits in the three weeks after the first lockdown, which

amounts to approximately 12.5 percent of the total labor force. Around 90 percent of these applications concerned unemployment benefits related to furloughing.

Data and Sample

Between the 16th of November and the 13th of December 2020, we conducted an online survey distributed among 16.475 Norwegian CEOs. We limited the sample to CEOs in firms active in the private sector, who employed at least 5 employees. 2.153 CEOs participated in the survey (yielding a response rate of 13%), but this number was subject to attrition since the number of respondents that completed the entire survey is 1149. Both the response- and the attrition rates raise concerns about response bias.

Following a closer inspection, there appears to be no bias in terms of industry, overall size categories, liquidity rates or debt ratio. However, our sample has firms that are on average slightly larger and slightly older. In other words, non-responses are somewhat more common among smaller and younger firms. Still, such firms remain a large share of our sample. In terms of attrition, we examined whether those that abandoned the survey differed from those that completed it in terms of industry membership, firm size, firm age, the severity of the crisis impact (which was question 1, so all 2153 respondents filled out this question), strategic emphasis (which was question 2). We find no significant differences between those that completed the whole survey and those that abandoned it underway. We kept all respondents in our sample, which means that they will not feature in the analyses where survey data on their firm is missing.

Dependent variable

As our dependent variables we created measures that provide us with insights on the crisis-induced innovation response of firms. Here we draw on both input and output measures of innovation. To address innovation input, we created a measure of expected changes in innovation investments compared to pre-crisis intentions - notably *as a consequence of* COVID-19. More specifically, we asked whether they expected a change in innovation investments using a 5-point Likert scale, which varies from “a large reduction” to “a large increase” (see Table 1). Based on the distribution, we observe that most of our respondents expect no change (61 percent) while over a quarter expect an increase.

[Insert Table 1 around here]

From this we created three innovation investment measures: (i) a dummy variable that indicates whether they expect an *increase* in innovation investments; (ii) a dummy variable that indicates whether they expect a *decrease* in innovation investments; and (iii) an ordinal scale where we use the 5-point Likert scale with the “unchanged” category as our benchmark.

To measure innovation output, we draw on survey data that directly asked the respondents to what extent their firm, in response to the COVID-19 pandemic, had: (i) developed new products and services; (ii) developed new or improved processes; (iii) targeted new customer groups; and/or (iv) developed new logistical solutions (see Table 2).

[Insert Table 2 around here]

We used this to create several innovation output variables. First, we created a dummy variable that indicated whether the firm had introduced any innovations in response to the COVID-19 pandemic. The firm received a value of 1 on "*crisis-induced innovation*" if they answered at least "to some extent" to any of our innovation output categories. Clearly, the crisis did spur innovation responses. Measured this way, more than 50 percent of all respondents indicated to have either developed new products and services, new processes, entered new markets and/or developed new logistic solutions in response to the pandemic. Conditional on having innovated, we also created a measure that indicates whether the innovations are expected to be valuable for the firm when the pandemic is over.

In addition to these overall measures of innovation output, we also created a separate measure for each of the four innovation categories. Here we followed the same procedure as for the overall measure, by creating dummy variables for having innovated at least *"to some extent"*. Also, across these more fine-grained categories, we observe that many firms have innovated, especially when it comes to new products, services, and processes. For our final output measure, we kept the ordinal scale in order to allow us to investigate different levels of innovation intensity.

Independent variables

Our main independent variables are firm-specific characteristics which we have theorized would be drivers of innovation responses. One is the extent to which a firm experience (or is expected to experience) a decrease in demand or a decrease in the ability to supply. To measure this decrease we created two proxies of being negatively affected by the COVID-19 pandemic. First, we created a dummy variable called "*reduced capacity*", which gets the value 1 if the firm, due to the pandemic, is not fully utilizing their capacity, e.g. reduced opening hours, reduced service offering or reduced activity level). The dummy variable also received the value 1 if they have temporarily close down their business due to the pandemic. Second, we created a dummy variable called "*downsized*" which gets the value 1 if the organization has downsized due to COVID-19 pandemic, either via layoffs or furloughing.

In Table 3, we present a crosstab that shows the distribution of firms with *reduced capacity* and those that have *downsized*. Nearly 44 percent of our sample has experienced neither. Just over 27 percent stated that they have downsized, but operated under full capacity, while nearly a quarter indicated

that they both downsized and operated with reduced capacity. A small share indicated that they operated with reduced capacity but did not downsize their labor stock.

[Insert Table 3 around here]

A second set of variables concerns the pre-pandemic strategic emphasis of a firm. To identify patterns in firm strategies, we asked the respondents 14 questions about features they emphasized in their competition with their closest rivals *before* the onset of the recession. Instead of using these 14 items separately, or imposing a particular strategy-typology on the data, we conducted a principal component analysis where we identified three overarching strategic profiles in our sample (see Table 4). We labeled these as "innovation-centric", "customer-centric" and a "cost-centric".

[Insert Table 4 around here]

In addition to a firm's pre-pandemic strategy, we also created a proxy for organizational agility. By this we mean the ability of the organization to quickly respond to changes in their competitive environment. In the survey, we included a question about how the firm performed compared to its competitors with respect to its ability to react rapidly to new opportunities and threats (before the crisis). If the respondent answered that they perform stronger or much stronger, we classified the firm as an agile organization. 46 percent of our respondents answered that they regard themselves as more responsive to opportunities and threats than their competitors.

Finally, to test our hypothesis on financial performance and crisis-induced innovation, we also include two financial measure that previous research has found to affect investment behavior of firms, including investments in innovation and R&D. These measures are the pre-pandemic liquidity and debt ratio of the firm. We obtain this information from publicly available financial data from 2019 that could be merged with our survey data.

Control variables

From the publicly available financial data, we are also able to extract series of control variables. First, we included a measure of the size of the organization. Here we create six size categories: 5-9 employees, 10-24 employees, 25-49 employees, 50-99 employees, 100-249 employees and more than 250 employees. Second, we created two sets of industry controls, i.e.: (i) industry controls based on two-digit NACE rev2 industries; and (ii) industry controls where we merged these two-digit NACE industries into a reduced number of broader industries[1].

[1] In this broader industry classification, we make a distinction between low- and high-tech manufacturing; construction; hotels, restaurants, and tourism; wholesale and retail; knowledge intensive and financial services, and other services.

Finally, we created a measure of geographic location, where we identified both economic region and county[2]. The reason for using the broader industry definitions and county controls was motivated by the problem that the low number of observations in some of the more fine-grained categories caused non-convergence problems in our multinominal regression analyses.

In Table 5, we provide a full overview including a correlation table. As mentioned above, we only present descriptive statistics for the observations that we use in at least one of our analyses, meaning that we include 904 observations in this table. In an unreported t-test we did not observe significant differences between the observations included in this table and the full range of responses from the survey.

[Insert Table 5 around here]

Empirical Strategy and Estimation Results

To empirically test the determinants of crisis-induced innovation we applied two different model specifications. Our first model specification is a logit model, which we used to estimate the determinants of an expected increase in innovation investments; and subsequently one on expected decreases in innovation investment. Next, we focused on the probability that firms have introduced any crisis-induced innovations, and we also examine each of our different innovation categories separately. Finally, we undertake an analysis of the expected long-term potential of the innovations undertaken. The second model specification was a multinomial regression model which we apply to uncover more detailed changes in innovation investments and intensity. The results of our regression models are presented in Table 6 through Table 8.

Innovation investments

In Table 6, we present our first set of logit regression models where we investigate the determinants of expected changes in innovation investments. All models include all independent and control variables. First, we turn our attention to the variables indicating whether firms that were negatively affected by the crisis, proxied by reduced capacity and downsizing, expected to increase or decrease their innovation investments (cfr. hypothesis 1). When exponentiating the coefficients, the analysis demonstrates that operating with reduced capacity without downsizing (coeff. = 0.496) raises the odds ratio of expecting to increase investments in innovation to 1.65. When they experience reduced capacity in combination with downsizing, the odds ratio of intending to increase innovation investment increases further, to about 2.0 (coeff. = 0.711).

[2] The county classification prior to the 2020 county and municipality merger.

In Model 2, we turn to examine expected investment decreases. We also observe weak indications that reduced capacity is associated with an expected decrease in investments; though only significant at the 10 percent level. In our more detailed model, Model 3, firms are more likely to expect large reductions and to a lesser extent a small increase, especially when reduced capacity is combined with downsizing.[3] So overall, a decrease in demand appears to lead to decreases *and* increases in expected innovation investments.

When we focus on downsizing, we observe that downsizing alone is associated with an expected decrease in innovation investments in all models. Among CEOs of firms that only downsize, the odds ratio for expecting a decrease is 7.24 (coeff. = 1.98) compared to firms that neither downsized nor experienced reduced capacity. Only when combined with reduced capacity do we observe that it might also be associated with increasing investments - although the effect size is substantially weaker. Thus, we find some confirmation for Hypothesis 1, at least with regards to expected changes in innovation investments. However, the relation appears to be more complicated than initially expected. Being affected by the crisis will make managers reconsider their planned investment levels, and while many expect a decrease there are clearly also some that expect their innovation investments to increase. Furthermore, while downsizing might be associated with a decrease in demand (or ability to supply) the findings reveal another possible relation between downsizing and innovation, that is the relation between the availability of excess capacity in human capital and innovation.

The literature on organizational slack has argued that slack can represent an opportunity to take on more risky projects and allow more resources to be devoted to problem solving and search behavior (Bourgeious, 1981; Nohria and Gulati 1996). A somewhat similar reasoning has been used in economics, where periods of excess capacity in non-innovation activities lower the opportunity costs of innovating. Idle human capital can be reallocated to innovation without sacrificing their normal output (Aghion & Saint-Paul, 1998; Davis and Haltiwanger, 1990; Gali and Hammour, 1993; Hall, 1992). As the crisis unfolds, the firms that experience a decrease in demand will also be confronted with idle human capital, or in other words slack. The firm then faces the decision about whether to remove that slack through downsizing. If it decides not to do so, it will have incentives to reallocate the excess capacity to new activities, including innovation.

When testing Hypothesis 2a and Hypothesis 2b, we observe that firms with an innovation-centric strategy are more likely to expect an increase in innovation investments. Although principal components loadings are difficult to interpret, we nevertheless can expect that a one standard

[3] In Model 3 we use broader categories for industry and geography due to convergence issues of our multinomial model compared to the logit models applied in Model 1 and Model 2.

deviation increase in the factor loadings would lead to more than a doubling of the likelihood of innovating in response to the crisis[4]. We also observe that firms with a pre-pandemic innovation-centric strategy are less likely to decrease investments with an odds ratio of 0.82. Model 3 provides additional support by showing that firms with an innovation-centric focus are more likely to expect both a small and a large increase in investments in response to the COVID-19 crisis. Thus, we find support for Hypothesis 2a that firms with prior innovation experience are more likely to expect an increase in innovation investments.

Besides having innovation experience, we also find evidence that agility is a driver for expecting an increase in investments. CEOs of agile organizations are 1.55 (odds ratio) times more likely to indicate that they expect an increase. In Model 3, we observe that agile organizations are more likely to expect a small increase in innovation investments (but not large increases). Agility is thus associated with making smaller adjustments, rather than making large and radical changes to investment decisions. We thus find confirmation for Hypothesis 2b. A valid question that is whether interaction effects are present between organizational agility and our strategy variables. In unreported regression analyses we did not observe such effects.

Finally, we turn our attention to variables concerning the financial position of the firm. We find limited evidence that debt ratio and liquidity prior to the outbreak COVID-19 had a major impact on whether the CEO expects a change in innovation investments. There is a small effect visible in Model 3, where a higher debt ratio is associated with larger expected decrease in innovation investments. We interpret this as (surprisingly) weak support for our third hypothesis.

[Insert Table 6 around here]

Innovation output

While expected changes in innovation investment might be one measure of crisis-induced innovation input, in Table 7 we focus on realized innovation output instead. In Model 4 we estimate a logit model with the dependent variable indicating if the firm introduced an innovation regardless of the innovation category. In this model, we observe that both our reduced capacity and downsize variable are associated with a higher likelihood of innovating. Firms that only downsized were 2.67 times more likely to introduce an innovation, firms that only experienced reduced capacity were 1.79 times more likely to introduce an innovation, while firms that experienced both had a 3.47 higher likelihood of innovating compared to the baseline measure. Thus, based on innovation output, Hypothesis 1 is supported.

[4] Exp(0.437*1.874)=2.267

This picture, again, gets more nuanced when we look at the specific type of innovation introduced. Indeed, reduced capacity is associated with the development of new products and services, new work processes, as well as the entry into new markets. The use of new logistical solutions is only limited. Downsizing, however, is only associated positively with the introduction of new work processes, which is nearly 6 times higher compared to firms that experienced no downsizing nor reduced capacity, and nearly 3 times higher compared to firms that only experienced reduced capacity. A possible explanation for this strong association with process innovations might be due to the changes in work processes required when working with a reduced labor stock.

Similar to the models presented in Table 6, we observe that firms with an innovation-centric strategy are more likely to introduce crisis-induced innovations. As mentioned above, interpreting the principal component loadings is not straightforward, but firms with one standard deviation higher loadings on innovation-centric focus (pre-pandemic) are associated with 1.70 higher likelihood of innovating. When looking more closely at the different innovation categories, we observed that the impact of strategy and organization have different associations with our innovation output measures. First of all, an innovation-centric strategy is positively associated with the likelihood of innovating in all the innovation categories, particularly for product & service and process innovations. We also observed that organizational agility is associated with 1.78 higher likelihood of innovating. This positive effect is mostly associated with the development of new product and services and to a lesser extent with entry into new markets and developing new logistical solutions. Thus, we confirm Hypothesis 2a and Hypothesis 2b. Regarding the expected long-term value of innovating, firms with an innovation-centric strategy (odds ratio of 1.56) and those that are more agile (odds ratio of 2.15) expect their innovations to be valuable when the crisis has passed. Consequently, not only are firms with pre-existing innovation capabilities and organizational abilities better able to innovate, they also expect to extract more long-term value from the innovations they launch. Consequently, we also find support Hypothesis 2c and Hypothesis 2d. We do not find consistent support for Hypothesis 3.

[Insert Table 7 around here]

In Table 8, we estimate four multinomial models where we compare those who did not innovate on any of the innovation categories with firms that innovated to a little extent, some extent, and large extent in developing new products, services, and processes; entering new markets; and developing new logistic solutions. The purpose is to further test whether firm characteristics affect the intensity of innovating. Overall, these models provide additional confirmation of our previous findings as firms that are hit by the crisis are more likely to innovate to a large extent. Also, the results show that both innovation-centric firms and agile organizations are more likely to engage in developing innovations to a large extent.

[Insert Table 8 around here]

Discussion and Conclusion

We have argued that there is more to innovation in recessions than whether firms cut, maintain, or accelerate their pre-recession innovation agendas. This is what the persistence literature mainly addresses. Our focus has been to open a discussion about how firms use innovation as a tool to manage the unexpected and adverse changes that occur in such periods. We have offered some glimpses into the use of the innovation tool, and what creates variation in its deployment.

One finding is that a crisis period - such as the one following the COVID-19 pandemic - seems to drive a large number of firms to innovate. The majority of firms in our sample have engaged in crisis-induced innovation, at least to some extent. Apparently, then, the phenomenon of crisis-induced innovation is quite widespread, and not limited to the firms that were experienced innovators before the onset of the crisis. Since crisis-induced innovation is mostly undertaken to handle negative fallout from the recession, and since firms need and want the associated benefits to appear quickly, crisis-induced innovation will typically be innovation projects that can be realized fast. This furthermore implies that they are systematically less likely to involve heavy investments in physical or human capital. In other words, firms are unlikely to try to manage a recession by developing radical and disruptive new technologies, or venture into something that requires a long program of building entirely new sets of capabilities. We are talking about reaching for low-hanging fruit that might help, and probably mostly about doing things that are new to the firm rather than new to the world.

We have also found systematic differences in how firms used the innovation tool during the recession. Firms that were adversely affected are generally more motivated to innovate. However, it also appears that there is a somewhat complicated relationship between innovation and downsizing. Overall, it might seem that downsizing makes a firm less likely to innovate, and that a firm that innovates is less likely to downsize. However, firms that do downsize appear to engage in innovation activities, but this seems mainly to involve developing new work processes, possibly to create a work around of the fact that they have downsized. When it comes to other types of innovation, removing excess capacity appears to be a substitute for using it as a motivation for innovation.

It is also quite clear from our data that innovation experience before a recession has a strong impact on how much it is used as a tool during a recession. A strategic emphasis on innovation leads to higher investments in innovation activities, more innovation output of all four types, and a more optimistic view of the long-term value of the crisis-induced innovations undertaken. It seems that those with innovation experience are better able to find crisis-induced innovation projects that have long-term value and simply that more projects are considered attractive for a firm with preexisting innovation

experience. So, while a crisis leads more firms to innovate, there is a sense in which the key finding from the innovation persistence literature is upheld for crisis induced innovation: Innovation expertise matters.

Another finding is that organizational agility also matters. This is not surprising given the premise that we are talking about innovations that need to be implemented fast, probably to a large extent by reconfiguring existing resources and capabilities. Being a flexible organization with experience in quickly adapting to new threats and opportunities should (as we indeed find) provide important advantages in setting up and implementing the required changes.

A more surprising non-finding was that financial strength seems to have a very limited effect on crisis-induced innovation. This may partly be because we are for the most part not talking about capital intensive innovation projects, but rather resource light innovations more akin to bricolage. It may also be the case that firms with highly robust financing tend to press on with their pre-crisis innovation agenda, and simply do not adapt their innovation activities to handle the recession. Still, we acknowledge that we presently do not have the data required for an in-depth understanding of the reasons underlying the weakness of this relationship.

Implications and limitations

Practical implications

When managers decide which strategy to pursue, they also shape which capabilities their firm will develop. Which capabilities they develop will in turn heavily influence which tools they turn to in a recession or other kinds of unanticipated shocks. Those that emphasize innovation and agile organizing will be the ones that use the innovation tool the most, and those that emphasize costs, price, and efficiency will be the ones that emphasize it the least. The potential value of using the innovation tool to solve unexpected problems, crises, and shocks, should therefore be factored in already at the strategy formulation stage. It further suggests that if and when firms believe their environment will become more prone to unexpected shocks, cyclical turbulence, or other types of hard to anticipate crises, they should consider increasing their emphasis on developing these two characteristics. Our findings are also potentially useful for managers as a basis to foresee how their competitors, suppliers, business customers, and complementors are likely to react once an environmental shock hits.

For policymakers it is presumably important to understand how different support schemes affect the behavior of the firms they target. Our findings reveal new information about how innovation responses are likely to be influenced by different support schemes. We find that financing is not as big a constraint for crisis-induced innovation as it has been found to be for ordinary innovation. The constraints seem to be more rooted in lack of innovation experience and the necessary organizational perquisites. We

also find evidence that downsizing leads to lower expected investments in innovation. Support schemes that keep human capital slack in the firm, and thereby maintain a firm's ability to reallocate capacity to innovation and other types of development work will stimulate crisis-induced innovation. Support schemes that merely compensate employees for not going to work will result in less innovation and possibly weakened or forgone innovation capability in the wake of a crisis (Klein et al., 2020). A relevant issue for policymakers is therefor to consider how retention schemes can be implemented in a way that does not lead to human capital that could have helped innovate becoming passive.

Research implications

The big question that towers over all these findings is whether crisis-induced innovation is worthy of scholarly attention at all, or whether it is a trivial and fleeting phenomenon that can be ignored in favor of more important matters. It is perhaps not entirely surprising that we believe that this is an important aspect of the wider innovation phenomenon that warrants attention, and we also believe it raises many questions that we have been unable to answer here. We believe the phenomenon is important because a major part of the innovation behavior that takes place in a recession is presumably overlooked or severely underemphasized in existing empirical work. What we call crisis-induced innovations are for the most part unlikely to have a strong scientific and technological basis. Consequently, they are not likely recorded in patent statistics. Much of it is probably not recorded as R&D-expenses, either (Abreu et al 2010; Nesta 2007). We even suspect that much of this is not fully captured by data from periodic surveys such as the Community Innovation Survey. Some of these innovations might have been forgotten by the time such surveys are distributed, because their purpose has been served by helping the firm manage through a difficult period and they are subsequently abandoned. They may also no longer be considered innovations because the innovations are to a large extent tied to improvements of ongoing practices (Saidi et al. 2021). Finally, the majority of firms in our study are active in services and non-high-tech industries, a sector where one traditionally observes high levels of hidden or invisible innovation (Djellal and Gallouj 2010; Gallouj and Djellal, 2011; Nesta 2007). Engaging in efforts to understand this particular innovation phenomenon also aligns with the call to include innovation activities that move beyond tech-savy, R&D intensive to include less glamorous innovations that for many firms are more appealing and realistic (Martin, 2016).

The ability to use innovation - even if it is a mundane form of innovation – as a tool to manage the effects of a crisis can have positive effects if it helps mitigate the negative effects it brings, or if it makes the selection effects that takes place in recessions more efficient. It can also have positive effects by giving non-innovators the impetus to gain some early innovation experience, which might lead them towards more ambitious innovation activities later. It can of course also have negative effects. Crisis-

induced innovation might mainly crowd out innovation with larger potential in the long run, or it might simply be a costly distraction for most of those who engage in it. At this point in time, we still do not have data on whether (or for who) these innovations bring material long run benefits in terms of survival, growth or profitability – or not. But we do think our data shows that there are significant and interesting changes in innovation patterns taking place during a recession such as the COVID-19 crisis, and that these changes have mostly flown beneath the radar of the existing innovation literature.

Limitations

Our study revolved around innovation-responses of Norwegian firms during the COVID-19 crisis. This raises the question of whether our findings are specific to either Norway or to the COVID-19 recession. We believe that the risk of the latter is higher than the former. The impact of COVID-19 on the Norwegian economy was - as we have shown - quite similar to its impact in other developed economies. It seems more reasonable to question to what extent our findings are generalizable to other crises. The causes and the nature of the COVID-19 crisis were arguably different than, say, the financial crisis. Still, it seems that any crisis that has adverse effects on many firms, and where innovation might be a tool to manage its impact, should result in what we have called crisis-induced innovation. Nevertheless, we strongly recommend replications and extensions to future crises, and if data allows also on previous crises. Replication in other geographical contexts would also be useful.

Another set of limitations is the inherent constraints associated with the survey method. For one there are concerns over response biases. As discussed in the method section we believe that while our sample is not completely free from response- and attrition biases, these seem too small to seriously distort our findings. Our survey data is also cross-sectional. This does not provide us with clear cut time variance and limits our ability to clearly determine causality. We have attempted to address this problem by specifically asking for information referring to the pre-COVID situation, and by asking specifically about responses and decisions that were taken in response to the crisis. This should mean that reverse causality is unlikely to be a problem. However, we cannot rule out that omitted variables have influenced our findings. Retrospective survey data may also suffer from recall bias. We minimized this problem by conducting our survey while the COVID-19 crisis was in its second wave, less than a year after the onset of the crisis. While the relatively short time span covered is helpful in terms of ensuring accurate recall about responses and strategies before the crisis, it also means that we have not been able to observe the real long-term impact of the innovations. Consequently, it is not possible to assess whether innovators are more resilient or otherwise successful than their non-innovating counterparts. This is obviously a relevant question to address in future research.

A final limitation is the measurement of innovation. We do not have detailed information on how incremental or radical the innovations are. Given the context driving crisis-induced innovation we have

argued that these innovations are likely to be more incremental, less time consuming and less capital intensive. We admittedly base this on theoretical reasoning, not observations. It would clearly be useful to establish if our reasoning holds empirically, and it would also be useful to learn more about what makes firms launch more (or less ambitious) crisis-induced innovations.

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Table 1: Expected changes of innovation investments

Investments in innovation, research and development	Change	--	-	0	+	++
	n	49	57	552	194	49
	%	5.44 %	6.33 %	61.27 %	21.53 %	5.44 %

Table 2: Development of new products, services, process markets and logistic solutions

	No		To a small extent		To some extent		To a large extent	
	n	*%*	n	*%*	n	*%*	n	*%*
Developed new products and services	420	*46.46 %*	219	*24.23 %*	213	*23.56 %*	52	*5.75 %*
Developed new or improved processes that differ significantly from previous processes?	408	*45.13 %*	241	*26.66 %*	208	*23.01 %*	47	*5.20 %*
Targeted existing products or services to new customer groups or segments?	466	*51.55 %*	196	*21.68 %*	198	*21.90 %*	44	*4.87 %*
Developed new or significantly changed logistics, delivery or distribution of products and / or services?	471	*52.10 %*	215	*23.78 %*	164	*18.14 %*	54	*5.97 %*
Crisis-induced innovation	446 *(49.34 %)*				458*(50.66 %)*			

Table 3: crisis impact on demand and slack

Reduced capacity	Downsized		Total
	0=no	1=yes	
0=no	394	**247**	641
	43.58 %	***27.32 %***	*70.91*
1=yes	38	**225**	263
	4.20 %	***24.89 %***	*29.09 %*
Total	432	472	904
	47.79 %	*52.21 %*	*100 %*

grey areas: higher probability of decrease in demand or ability to supply

Table 4. Principal Component Analysis on Competitive Strategies (varimax rotation)

Variable	Comp1	Comp2	Comp3	Unexplained
Higher customer service		0.4513		0.3920
Broader product/service segment				0.5189
Lower price			0.7930	0.2293
High product/service quality		0.4943		0.3087
Customization		0.4345		0.4409
Reducing operating cost			0.4662	0.5700
Quality control		0.3403		0.4750
Branding				0.4477
Innovation/R&D	0.4317			0.4417
Reputation building		0.3368		0.4442
Process improvement	0.3856			0.4134
Implementation of new solutions	0.4806			0.3347
Development of existing products and services	0.3950			0.3421
Launching of new products and services	0.4127			0.3782
Classification	*Innovation-centric*	*Customer-centric*	*Cost-centric*	

Table 5: Descriptive statistics and correlation table

Variable	Obs	Mean	Std. Dev	Pearson Correlation Table															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Increase innovation investment	901	0.270	0.444	1.00															
2 Decrease innovation investements	901	0.118	0.322	**-0.22**	1.00														
3 Changes in innovation investment (likert)	901	0.152	0.831	**0.77**	**-0.71**	1.00													
4 Innovation (high)	904	0.507	0.500	**0.27**	-0.01	**0.19**	1.00												
5 New products and service	904	0.293	0.455	**0.25**	0.00	**0.17**	**0.64**	1.00											
6 New processess	904	0.282	0.450	**0.23**	**-0.02**	**0.18**	**0.62**	**0.43**	1.00										
7 New markets	904	0.268	0.443	**0.14**	**0.03**	**0.09**	**0.60**	**0.41**	**0.38**	1.00									
8 New logistic solution	904	0.241	0.428	**0.18**	**-0.04**	**0.16**	**0.56**	**0.34**	**0.47**	**0.41**	1.00								
9 Expected future value of innovation	451	0.807	0.395	**0.16**	**-0.09**	**0.14**	**.**	**0.17**	**0.11**	**0.04**	0.01	1.00							
10 Innovation-Centric Strategy	837	0.036	1.874	**0.25**	**-0.09**	**0.23**	**0.29**	**0.27**	**0.27**	**0.24**	**0.22**	**0.19**	1.00						
11 Customer-Centric Strategy	837	0.026	1.745	**0.12**	**-0.05**	**0.12**	**0.25**	**0.19**	**0.15**	**0.21**	**0.18**	**0.16**	**0.61**	1.00					
12 Cost-Centric Strategy	837	0.004	1.105	**0.06**	**0.06**	0.01	**0.12**	**0.12**	**0.08**	**0.14**	**0.10**	-0.02	**0.25**	**0.34**	1.00				
13 Agile organization	899	0.473	0.500	**0.13**	**-0.04**	**0.11**	**0.18**	**0.16**	**0.14**	**0.13**	**0.11**	**0.17**	**0.17**	**0.16**	**0.04**	1.00			
14 Reduction in operations	904	0.291	0.454	**0.09**	**0.25**	**-0.08**	**0.19**	**0.12**	**0.10**	**0.16**	**0.11**	-0.03	**0.10**	**0.14**	**0.14**	**0.03**	1.00		
15 Downsized	904	0.522	0.500	**0.10**	**0.15**	**-0.03**	**0.19**	**0.18**	**0.10**	**0.17**	**0.12**	0.01	**0.08**	**0.16**	**0.19**	**0.04**	**0.43**	1.00	
16 Debt ratio	904	5.426	37.939	0.00	**0.04**	**-0.03**	-0.01	0.00	**-0.05**	0.01	**-0.03**	**0.03**	0.02	**-0.01**	**-0.03**	**-0.04**	-0.01	0.01	1.00
17 Liquidity	904	1.787	1.386	**-0.03**	**-0.04**	0.00	**-0.03**	**-0.03**	**-0.03**	**-0.08**	**-0.02**	**0.04**	0.01	-0.02	-0.01	**-0.03**	**-0.03**	**-0.06**	0.00

p<0.05 highlighted in bold

Table 6: binominal and multinomial logit regression analysis on innovation investments

	Model 1	Model 2	Model 3			
	logit	Logit	Mlogit			
	expected Δ Innovation Investments	expected Δ Innovation Investments	expected Δ Innovation Investments			
	increase	decrease	Large decrease	small decrease	small increase	large increase
Innovation-Centric Strategy	0.425***	-0.197*	-0.148	-0.0120	0.380***	0.445**
	(0.07)	(0.10)	(0.11)	(0.11)	(0.07)	(0.15)
Customer-Centric Strategy	-0.126+	-0.139	-0.0660	-0.159	-0.197**	0.106
	(0.08)	(0.11)	(0.13)	(0.12)	(0.07)	(0.16)
Cost-Centric Strategy	-0.015	0.234	0.169	0.328*	0.048	-0.033
	(0.09)	(0.15)	(0.19)	(0.16)	(0.09)	(0.19)
Agile Organization	0.442*	-0.117	-0.011	0.077	0.449*	0.451
	(0.20)	(0.32)	(0.36)	(0.32)	(0.19)	(0.39)
Reduced capacity=0 downsize=0	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark
Reduced capacity=0 downsize=1	0.333	1.980**	2.737**	1.896**	0.306	1.385
	(0.52)	(0.67)	(1.04)	(0.60)	(0.56)	(0.90)
Reduced capacity=1 downsize=0	0.496*	0.772+	1.812**	0.375	0.393+	0.324
	(0.24)	(0.43)	(0.64)	(0.45)	(0.22)	(0.44)
Reduced capacity=1 downsize=1	0.711*	2.058***	3.784***	1.584***	0.926***	1.599***
	(0.28)	(0.43)	(0.61)	(0.43)	(0.25)	(0.46)
Debt ratio	-0.001	0.002	0.006**	-0.003	-0.000	-0.005
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Liquidity	-0.021	-0.293	-0.272	-0.261	0.00161	-0.177
	(0.09)	(0.21)	(0.18)	(0.19)	(0.07)	(0.22)
Constant	-1.023	-1.584	-3.442***	-2.386*	-2.171**	-2.164*
	(2.13)	(1.34)	(1.03)	(1.02)	(0.68)	(1.00)
Industry dummies (2 digit)	yes	yes	no			
Industry dummy (7)	no	no	yes			
Economic region dummies	yes	yes	no			
County dummies	no	no	yes			
Employee size dummies	yes	yes	yes			
N	745	654	873			
Pseudo R-sq	0.158	0.256	0.180			

Robust standard errors in parentheses

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 7: Logit regression on innovation output

	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Variables	Crisis-induced innovation	New product and services	New processess	Enter new markets	New logistic solutions	Expected post-crisis value of innovation[1]
Innovation-Centric Strategy	0.283***	0.403***	0.500***	0.348***	0.319***	0.243***
	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(011)
Customer-Centric Strategy	0.127*	-0.004	-0.112	0.111	0.101	0.177
	(0.06)	(0.07)	(0.07)	(0.08)	(0.08)	(0.13)
Cost-Centric Strategy	-0.0320	0.116	0.0379	0.185+	0.0415	-0.035
	(0.09)	(0.09)	(0.10)	(0.10)	(0.10)	(0.16)
Agile Organization	0.577***	0.648***	0.311	0.447*	0.394*	0.768**
	(0.17)	(0.20)	(0.19)	(0.20)	(0.20)	(0.30)
Reduced capacity=0 downsize=0	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark
Reduced capacity=0 downsize=1	0.982*	-0.547	1.738***	0.0843	0.699	0.221
	(0.43)	(0.57)	(0.46)	(0.58)	(0.47)	(0.86)
Reduced capacity=1 downsize=0	0.581**	0.533*	0.624**	0.417+	0.418+	-0.194
	(0.21)	(0.24)	(0.24)	(0.25)	(0.25)	(0.39)
Reduced capacity=1 downsize=1	1.244***	0.919***	0.414	0.899**	0.447	-0.391
	(0.26)	(0.27)	(0.28)	(0.28)	(0.28)	(0.38)
Debt ratio	-0.000	0.002	-0.010	0.002	-0.004	0.002
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Liquidity	-0.018	0.038	-0.082	-0.137	-0.083	0.161
	(0.08)	(0.08)	(0.09)	(0.10)	(0.09)	(0.11)
Constant	-1.623	-1.117	-4.137***	0.220	-3.818**	0.220
	(1.07)	(1.13)	(1.14)	(1.18)	(1.17)	(0.94)
Industry dummies (2 digit)	yes	yes	yes	yes	yes	no
industry dummies (7)	no	no	no	no	no	yes
Economic region dummies	yes	yes	yes	yes	yes	no
County dummies	no	no	no	no	no	yes
Employee size dummies	yes	yes	yes	yes	yes	yes
N	824	754	768	763	755	407
Pseudo R-sq	0.205	0.211	0.190	0.196	0.158	0.162

Robust standard errors in parentheses

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

[1] Conditional on innovation

Table 8: Multinomial Logit on Innovation Output

	Model 10			Model 11			Model 12			Model 13		
Dependent Variable	New Product and Service			New Processes			Entering new markets			New Logistic solution		
	little extent	some extent	large extent	little extent	some extent	large extent	little extent	some extent	large extent	little extent	some extent	large extent
Innovation-Centric Strategy	0.205**	0.418***	0.595***	0.200**	0.475***	0.733***	0.165**	0.321***	0.400**	0.123*	0.359***	0.316**
	(0.06)	(0.07)	(0.15)	(0.06)	(0.07)	(0.17)	(0.06)	(0.07)	(0.13)	(0.06)	(0.07)	(0.12)
Customer-Centric Strategy	-0.053	-0.003	-0.112	-0.032	-0.121	-0.111	-0.063	0.063	0.140	0.027	0.011	0.248+
	(0.07)	(0.07)	(0.15)	(0.07)	(0.08)	(0.16)	(0.07)	(0.08)	(0.13)	(0.07)	(0.08)	(0.13)
Cost-Centric Strategy	0.133	0.035	0.321+	0.211*	0.080	0.283	-0.008	0.085	0.307+	0.147+	0.0614	0.103
	(0.09)	(0.10)	(0.19)	(0.09)	(0.10)	(0.18)	(0.09)	(0.10)	(0.19)	(0.09)	(0.10)	(0.17)
Agile Organization	0.399*	0.819***	1.232***	0.612***	0.672***	1.126**	0.783***	0.827***	0.667+	0.390*	0.584**	0.702*
	(0.19)	(0.19)	(0.36)	(0.18)	(0.19)	(0.38)	(0.19)	(0.20)	(0.37)	(0.18)	(0.21)	(0.33)
Reduced capacity=0 downsize=0	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark
Reduced capacity=0 downsize=1	0.817+	0.205	-14.08***	0.245	1.018*	2.315*	0.763+	0.418	1.519+	-0.0568	0.608	0.817
	(0.44)	(0.57)	(0.53)	(0.51)	(0.50)	(0.95)	(0.42)	(0.56)	(0.84)	(0.48)	(0.54)	(0.77)
Reduced capacity=1 downsize=0	-0.0745	0.542*	1.435**	0.576**	0.553*	1.364**	0.363	0.573*	0.963*	-0.0507	0.294	0.576
	(0.23)	(0.23)	(0.46)	(0.22)	(0.23)	(0.52)	(0.23)	(0.24)	(0.48)	(0.21)	(0.25)	(0.43)
Reduced capacity=1 downsize=1	0.692**	1.153***	1.934***	0.367	0.373	1.389**	0.559*	1.099***	1.825***	0.214	0.592*	0.987*
	(0.24)	(0.28)	(0.52)	(0.25)	(0.27)	(0.54)	(0.26)	(0.27)	(0.53)	(0.23)	(0.29)	(0.47)
Debt ratio	0.000	0.001	0.000	0.002	-0.009	-0.033*	0.000	0.002	-0.022*	0.003	-0.001	-0.025***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)
Liquidity	-0.036	0.058	-0.176	0.022	0.001	-0.676*	-0.059	-0.113	-0.257	-0.020	0.017	-0.314
	(0.08)	(0.07)	(0.20)	(0.07)	(0.09)	(0.33)	(0.07)	(0.09)	(0.23)	(0.07)	(0.09)	(0.19)
Constant	-0.949+	-1.698**	-4.042***	-1.045*	-2.996***	-3.173**	-1.759**	-1.364*	-1.804+	-0.829	-3.515***	-1.742+
	(0.56)	(0.63)	(1.05)	(0.52)	(0.66)	(1.14)	(0.65)	(0.61)	(1.05)	(0.57)	(0.89)	(0.99)
Industry dummies (7)		yes			yes			yes			yes	
County dummies		yes			yes			yes			yes	
Employee size dummies		yes			yes			yes			yes	
N		875			875			875			875	
Pseudo R-sq		0.141			0.138			0.136			0.101	

Robust standard errors in parentheses

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001