Working Paper
2023:8

How do (economic) crises impact the pattern of innovation and why does it matter?

Final Report for the RelinC project

Eric J. Iversen, Michael Mark, Marina Rybalka*, Erik Fjærli*, Mark Knell

*Statistics Norway

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Published by Nordic Institute for Studies in Innovation, Research and Education
Adresse P.O. Box 2815 Tøyen, N-0608 Oslo.
Visiting Address: Økernveien 9, N-0653 Oslo.

Project No. 21201

Customer The Research Council of Norway
Address P.O. Box 564, 1327 Lysaker

Photomontage NIFU

ISBN 978-82-327-0599-3
ISSN 1894-8200 (online)

Preface

The RelinC Project ("The role of research and innovation in the Covid19-crisis") was financed by the Research Council of Norway (Project No 31658) as a "collaborative and knowledge-building project" through the BIA program. Its design and output reflect this.

- The knowledge-building dimension of the project focused on designing and demonstrating better (timelier, more granular, more robust) ways to assess how different economic actors adapt innovation activity through different phases of a crisis.
- The collaborative dimension of the project was based on the scientific community engaging with (i) the business community which could benefit from real-time empirical information about how a given crisis affects e.g., different sectors; and (ii) the public policy and statistical communities, which have important ongoing work to assess how best to adapt and respond to crisis in real time.

NIFU led the project in partnership with Statistics Norway. In addition, the project built on the active participation of two institutional partners: Abelia and Innovation Norway.

The project developed and applied lessons from the scientific literature, both in terms of conceptualization but moreover in terms of an empirical strategy, to help public and private interest to adapt and apply lenses to better understand the effects of crisis on innovation activity and why it matters.

Oslo, 01 December 2023

Michael Mark
Head of Research

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Summary

How do different crises impact the pattern of innovation and why does it matter? The RelinC project joined a growing literature to better appreciate how the innovation activities of enterprises might adapt to improve resilience during crisis. Applied to the COVID19 pandemic in Norway, the RelinC project exploited a wide range of unique data sources:

- To assess the capability of the Norwegian economy to respond to a crisis in real time.
- To analyze how the innovation capacity of Norwegian firms adapts during crisis individually and collectively (in terms of 'patterns of innovation').

The project carried out a set of intermediate activities to achieve this end. It reviewed the relevant (post-Schumpeterian economics) literature; it refined a standard taxonomy of firm-level innovation activity from this literature to better understand how economic crisis affect different types of innovative firms; and it explored and further developed real-time empirical strategies that might be useful to monitor and analyze a pandemic crisis and its consequences.

The project's contribution is primarily empirical. It explored and demonstrated the potential of a range of empirical strategies in light of the clear need for better "lenses" to monitor and analyze the unexpected side-effects of unexpected crises like that of the COVID19 pandemic. Combining different (low and high-frequency, standard and exploratory) types of data, it sought to better understand how the innovative responses of different firms react during a crisis.

A cornerstone of the project is the application of a fine-grained Taxonomy of firm-level innovation activity to the latest Innovation (CIS2020) survey, which included direct questions about the pandemic's effect on innovation. It also analyzed how different types of innovative firms utilized business compensation schemes developed during the crisis and it explored real-time data on employment, on bankruptcies and on the filing of patents and trademarks.

The project findings provide potentially valuable insights. Results underline the importance of differentiating not only between types of firms (large vs small, service vs manufacturing, incumbent vs entrants …) but also among the type of

innovation approach of the firm. Findings confirm that different types of innovative firms indeed react differently through a crisis. For instance, firms that sustain formal R&D activity and collaborate on a regular basis were more resilient to the crisis, particularly when contrasted with firms with lower levels of formal innovation capacity.

This document identifies many other specific areas where subpopulations demonstrate specific strengths (weakness) during crisis. In doing so, we emphasize two general implications that can be useful to policymakers and to the business community.

- Whereas RD&I support tends to be geared to promoting economic performance (~growth) beyond what the firm (the economy) otherwise would have achieved without it, public policy interventions should also consider that the fortification of the innovative responses of firms may furthermore play a significant role in building the capacity (resilience, agility) to respond (meet, weather, react positively) to crisis.
- Whereas we often analyse innovative activities retrospectively, an era of 'polycrisis' emphasises improving monitoring and analysis of the patterns of innovation in a timelier way. Timeliness however tends to exist in a trade-off with quality (robustness, reliability…). The project indicates that combinations of low- and higher frequency data can provide better lenses to understand how different crises impact the innovative responses of a population of enterprises.

1 Introduction

The RelinC project emerged as the economy closed down during the COVID19 crisis. The project focused on how shocks to society (and its economic underpinnings) that ensue from a crisis might also have important impacts on the innovation activity in that society (economy). Amid pervasive uncertainty unfolding under COVID19, it was important that the 'innovation system' adapted to address emerging needs (e.g., hygienic products, distributed working arrangements, and, of course, vaccines). The challenge to the innovation system affected— and involved— both the private and the public sectors.

In this context, RelinC was designed to help better understand the role of firm-level innovation in promoting economic resilience to crisis. Different firms are affected and react differently amid sudden downturns. But which firms, how are they affected, how do they respond? It is important for the public policy community – and the business community itself to better answer these questions.

The literature suggests that RD&I active firms should be better at weathering economic downturns and can even capitalize on new opportunities that emerge in a crisis. This dimension is important to the public support to business R&D and innovation. Despite this fact, other (more growth-oriented) objectives often overshadow this important dimension of innovation.

The crisis associated with COVID19, and the ensuing lockdown of the economy, provide a unique opportunity to empirically explore the differentiated effects of crisis on innovation patterns. This exercise is designed in the hope that it can help inform policymaking and strategic responses to navigate not only through this but through the subsequent crisis.

This Handout provides a condensed overview of the RelinC project and its output. This document is designed to accompany the project's dissemination seminar and to help inform the panel-discussion.

2 Project Design

We start by briefly introducing what the project did and why. The subsequent sections focus on the different types of analysis that were conducted, elaborating a little further on how the analysis was carried out and what was found.

Project foundations and perspectives: The project started by exploring what lessons could be drawn from earlier work.

- Review: An extensive literature review was conducted. This work raised several issues about how patterns of innovation adapt under crisis and what this might mean for public policy interventions. We used these lessons to orient our study.
- Taxonomy: An initial assumption was that innovation is needed to cope with a pandemic crisis and that it was therefore important to understand and account for the diversity that exists within innovative firms. Following the lead of earlier work, the project pursued a data-driven taxonomy.
    - The project started by categorizing a sample of Norwegian firms (respondents to the Innovation Survey CIS2018) using a combination of firm-characteristics and observed research, development, and innovation patterns.
    - Bootstrapping on this approach, the remaining population of Norwegian firms were allocated to categories largely by inferring largely based on the skills of the workforce.
    - The trajectory of these firms was then observed across time to better understand how different types of innovators actually respond to crisis.

Literature: A fundamental pillar of the project was a deep literature review. We centered our literature review on the Schumpeterian approach to innovation studies, while also encompassing a comprehensive survey of other pertinent and related works, including the 'resilience' literature that appeared in the 1970s (Holling, 1973). In all 160 articles were reviewed, of which 47 references relate exclusively to innovation-related activities. The complete bibliography is included as an appendix to this report. The interested reader will also find work from the project that discusses this material (see Knell, 2023).

It is important to emphasize a key point in this context: during times of significant structural change, having strong theoretical foundations becomes even more crucial. In contrast, relying too heavily on recent data and purely empirical approaches can be less effective and potentially misleading.

A few observations about the literature are therefore useful at the outset to help orient the subsequent steps the project took. A heterodox approach, with its unique characteristics, is particularly well-suited to help us understand how patterns of innovation in the economy respond and take initiative in times of crisis. Within the framework of evolutionary economics, innovation stands out as a central force that links economic resilience with various dynamic factors. Specifically, adaptability, diversity, and competitiveness together empower economies to effectively manage challenges, recover from disruptions, and engage in forward-looking transformations. Innovation, in this context, drives adaptable approaches, diversifies economic systems, sparks technological advancements, aligns with the idea of constructive change, fosters learning and adaptability, influences the development path of economies, and nurtures a competitive environment. The interconnectedness of these factors significantly boosts economic resilience by equipping economies with the ability to adjust to change, prosper in varied situations, and bounce back from disruptions. Vibrant and innovative economic environments consistently display heightened resilience when dealing with uncertainties and adapting to change.

This foundation provides a solid starting point for gaining a comprehensive understanding of "how changing patterns of innovation affect companies, industries, and economies, both locally and nationally" (Antonelli, 2022). It not only illuminates the role that innovation can play during crises but also underscores the vital function of innovation policy in effectively adapting to and addressing crises.

Data and general approach: Earlier work, notably Archibugi et al (2003), emphasized the need to use better (more timely, higher granularity, more robust) data to study how innovative patterns are affected during crisis. The project sought to assess how best to design a study that could understand the various effects that crisis could have on innovation activity.

From this perspective, several sets of time-series microdata were recruited to gauge how different types of innovative firms had responded to different crises during the past 25 years (following the ICT bubble, financial crisis, stark fall in the oil-price). Due to its proximity in time, the greatest challenge was to understand this in the context of the COVID19 pandemic that continued to play out.

Statistics Norway maintains a range of relevant firm- linked microdata that were recruited both to carry out the taxonomy and much of the analysis. In addition, the project utilized firm-level IPR data compiled by NIFU in coordination with

the Norwegian patent office (The Norwegian Industrial Property Office NIPO). In using the different data sources and approaches, the aim was two-fold:

- to improve on ways to conduct better retrospective analysis to understand how different types of innovators reacted before, during, and after earlier downturns for the Norwegian economy.
- but, moreover, to develop timelier approaches that could be used to shape innovation policy responses and help firms to navigate the uncertainty during the different phases of a crisis. Two main types of data were compiled with these objectives in mind.

Low-frequency datasets: RelinC started by assembling official data compiled by Statistics Norway. Comprehensive Linked Employee-Employer data (LEED) were at the core of the approach. These firm-level data provide at the one level basic firm-level information (e.g., location, industry) while also incorporating important microlevel parameters across time such as employment, employee characteristics, and financial information such as turnover. These high resolution and high-quality data are the gold-standard for retrospective exercises. They are updated and generally published (semi) annually.

- In a crucial step, they were linked to responses to biennial waves of the Norwegian Innovation Survey (CIS). A cornerstone of innovation studies, the CIS provides a battery of questions about innovation activities (what, how much, with whom) which firms must answer in Norway.
- Special attention was directed to the latest wave of the survey. Statistics Norway was innovative in its response to the crisis. It managed to include a battery of questions about the COVID19 crisis in time for the CIS2020 survey. The responses to these questions by the different types of innovators identified in the taxonomy is a centerpiece of the project.

High-frequency datasets: These established low-frequency datasets have notable limitations. Crucially, they will tend to substantially lag events. In the context of a quickly unfolding crisis, these limitations can prevent them from providing timely input to the public-policy and the business communities. Therefore, the project went on to explore timelier, but more experimental datasets suggested by recent work.

- LEED data include some components that are updated more often. The registration of bankruptcies is a case in point which will be reported at the seminar.
- LEED data were linked to ancillary data sources including the Public Support for R&D Register which compiles temporal details of the firm's use of public support. These data are updated continuously. On the one hand, they act as a proxy for innovation activity: firms that apply/are granted support provide credible plans to innovate or otherwise adapt activities. On the other, this form

of support was adapted to specifically encourage adaptive behavior in the face of the COVID19 pandemic. The project applies the taxonomy to these data, leveraging these two aspects to study how different categories of innovative firms adapted during COVID. Information on use of COVID19-related compensation schemes was used to indicate which innovative firms were less resilient to the crisis. The more extensive use the less resilient.

- Intellectual Property Rights (IPR) is also a tried, if not completely 'true' proxy of innovation activity. The project also piloted an approach using fine-grained (daily), firm-linked patent and trademark data to study the effects of different downturns. In this case, firm-level information was sourced from the Brønnøysund Register. Following recent literature, the project pursues the promise of real-time analytical approach based on trademarks.

Interviews and discussion: In a final complementary step, we triangulated by talking to a small set of companies. The project then extended its outreach in the business community to carry out a set of interviews among different types of innovative firms.

3 Analysis & Results

The COVID19 pandemic has led to a significant fall in economic activity. The global economy contracted by an estimated 3.0 percent in 2020 according to the IMF (2020). By way of contrast, the global economy fell by an estimated 0,1 percent in the immediate wake (2009) of the financial crisis.

During a crisis, we know that firm-level innovative activity tends on average to shrink. The literature[1] confirms this while also emphasizing an important point, namely that innovation activity does not fall across the board. Some firms will seek to pursue opportunities that emerge during a crisis, while competitors retract or, indeed, exit from markets. It is important to better understand how a crisis affects the pattern of innovation in the economy.

As a society and economy, the need for innovation and adaptation is heightened. A problem is that, on average, the capacity to deliver the resilience this entails is reduced. Particularly among some populations of firms. To understand the potential to promote greater resilience under crisis, it is necessary to start by understanding at a sufficiently high level of resolution how different firms adapt their economic activities, not least their innovation activities. Standard low-frequency data provide an initial impression of how crises affect firm-level activity at a more disaggregated level.

In this light, we start by looking at the general effect that a crisis has on employment. This initial step uses register data to measure job-flows at the enterprise level (i.e., job destruction and job creation within groups of companies in both private and public sector). The hypothesis is that some firms will shed workers during downturns while others will pick up employment to further commercial goals.

The figure (3.1.) measures employment once a year (in November). Job creation (destruction) is measured in terms of the change in firm-level employment across a two-year period. It also includes the effects of entry (exit) of firms. The focus is on enterprises with at least 5 employees. Due to right truncation, we have included the 1-year change from 2019 to 2020 when measuring job flow effects.

[1] Archibugi et al, (2013) in the context of the financial crisis and by authors such as Thorgren and Williams (2020) in that of Covid19.

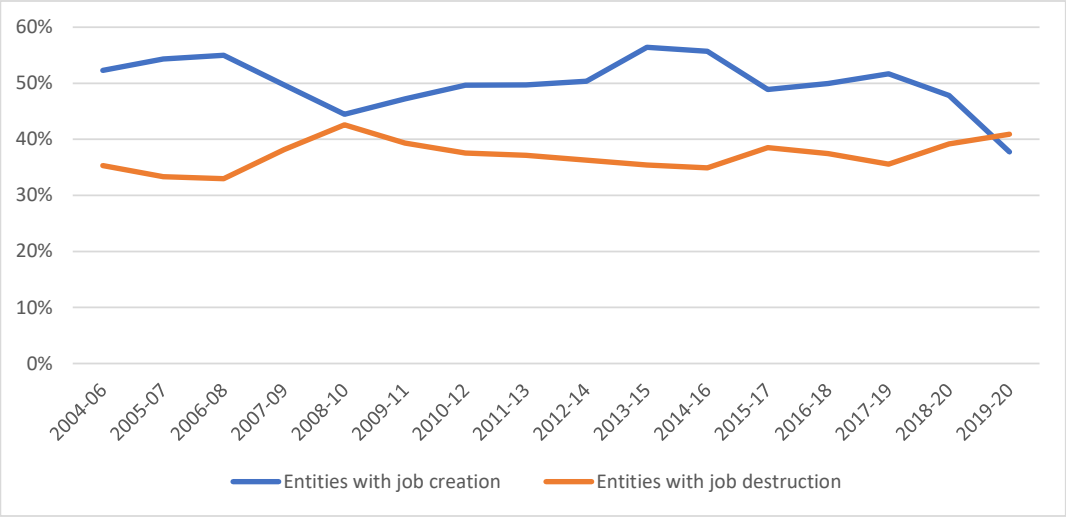

Figure 3.1 Share of private and public entities with job creation and job destruction measured by 2-year period.

Source: NIFU, based on register data from SSB

This initial figure demonstrates that employment-generation and employment loss diverged among Norwegian firms during the financial crisis (2008-2010) and, less so, during the oil-price crisis in Norway (2015-2017). The effects of the COVID19 crisis appear as the two curves invert by November 2020. The indication is that the onset of the pandemic led to a potentially more pronounced divergence between the two at the latest reading (November 2020) of these low-frequency data.

The Linked Employer-Employee data (LEED) help to unpack these tendencies further. The next figure compares the job destruction effects across industry and firm-size across periods.

This first step indicates that the financial crisis led to job outflows in Industry but also in mid to larger sized firms (over 50 employees). Employment in the public sector was far more stable through the financial and ensuing oil-price crisis (2014). The figure furthermore suggests that the first stages of the COVID19 Crisis particularly affected firms operating in the "other" category, including the Wholesale and retail, Hotels and restaurants, other services, the Petroleum Industry, as well as the primary sector. The effects of the early stages of the COVID19 period, appear to affect the smaller firms whereas the larger ones remain at levels comparable to the high activity period 2005-2007.

This generally confirms our expectations. But it also raises the question about how this plays out in terms of the activity of innovative firms. Does the pattern of innovation adapt in important ways?

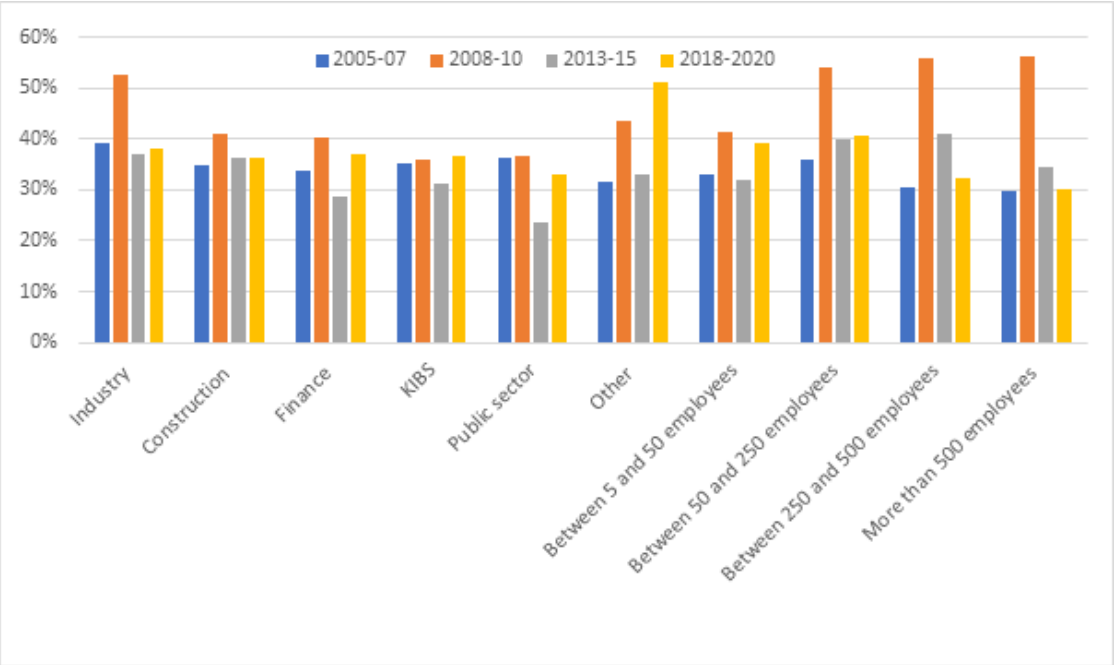

Figure 3.2 Share of companies with job destruction by sector and size class, selected years.

Source: NIFU, based on register data from SSB

3.1 The Capasso-Rybalka Taxonomy

There is some ambiguity linked to the notion of innovation and the 'innovative firm'; this ambiguity risks getting in the way of attempts to target scientific interest, business concern and/or public policy responses. A first aim was thus to categorize the heterogeneity of innovative activity in a fine-grained and robust way that could be effectively used to study the effects of crisis. The project built on earlier approaches to create a more fine-meshed taxonomy of innovative activity at the firm-level.

Starting from firm-linked responses to the Norwegian Innovation survey (CIS2018), eleven distinct approaches to innovation were identified in the Norwegian sample. The approach for this data-driven taxonomy is laid out in this article. The main assumption in Capasso and Rybalka (2022) is that each firm may practice distinct approaches to innovation. This in turn suggests that factor analysis scores at the firm-level could reveal how the firm approaches innovative activity during a crisis. The box associates the eleven categories with their main characteristics.

Table 3.1 Capasso-Rybalka Taxonomy: 11 approaches to innovation and their main characteristics.

Name	Main characteristics
1. Active R&D doers	• Practise formal R&D activities on a regular basis (both intramural and extramural) • Cooperate often with others • Receive mainly public support for R&D and innovation • Main market: outside Norway
2. Process developers	• High score on all types of process innovation • Main strategy: improving existing goods or services • Cooperate within own group on the local/regional level • Innovation expenditures go mainly to machinery, equipment and software based on new technolc
3. Innovation suppliers	• Use actively different types of IPR • Sell, license out and exchange their own IPRs to/with others • Innovation expenditures go mainly to purchasing services from others • Main market: not local/regional
4. Strategic adaptors	• Main strategies: focus on developing high-quality products, on improving existing products and or • Practise customization of their products • Implement machinery, equipment and software based on new technology
5. Radical innovators	• Conduct formal R&D activities on a regular basis • Introduce product innovation with a high degree of novelty (new product on the national or interr • Engage in active patenting and license out their IPRs • Cooperate with customers outside Norway • Main market: outside Norway
6. Customer-oriented service suppliers	• Main strategy: focus on customer-specific solutions • Practice "co-creation" and "customization" of their products • Introduce service innovation with local/regional/national novelty • Cooperate with private customers and public sector
7. Hard-trying innovators	• Irregular R&D activity, innovation expenditures go mainly on own personnel • High score on all types of factors that hamper innovation • Try to cooperate with competitors locally • Introduce product innovation that is new for firm or for the local market
8. Knowledge absorbers	• Use actively all channels for the knowledge acquisition • Offer goods and services co-created with users, often public sector organisations • Practice skills upgrading, regular brainstorming sessions, cross-functional work groups or teams • No formal R&D activities or significant innovation expenditures and no innovation introduced • Implement machinery, equipment and software based mainly on existing technology
9. Innovation promisers	• Have not introduced any innovation, but have plans to increase their innovation spending • Have recently obtained funding (both private and public) for innovation • Have some formal R&D activities • Main strategy: focus on one or a small number of key goods or services • Main marked: outside the EU
10. Individual standard services suppliers	• Main strategy: introducing new goods or services • Oriented towards households and individuals as main customers • Innovation spending mainly on own personnel • Introduce service innovation with novelty at local/regional/national level • Main market: Norway
11. Early technology adopters	• Invest in machinery, equipment and software based on new technology • Expect reduction in innovation expenditures in the next period • Have recently obtained funding for innovation through a loan • Introduce new products that are new to the firm • Cooperate with suppliers

Source: Capasso & Rybalka, 2022

Innovation activity is known to be heterogenous. The Capasso-Rybalka taxonomy disentangles some of this heterogeneity into distinct approaches at the firm-level associated with markets, investments, capital access, cooperation etc. These are important constituent parts of the pattern of innovation.

These dimensions of a firm's day-to-day work are expected to be affected differently during the phases of a crisis. As a result, firms that are more sensitive to

one dimension than another are likely to respond differently over time. Therefore, the project went on to study how the COVID19 crisis affected firms that employed the different approaches. The project leveraged the strength of the new taxonomy in conjunction with standard, low-frequency data but also in applications involving high-frequency data. The two main approaches are presented here.

3.1.1 Approach 1 (low frequency data): Innovation Survey

The taxonomy is first used in conjunction with CIS2020 to understand how different Norwegian firms were affected and responded to the pandemic in terms of innovation.

A crucial contribution of the project is that it combined the Taxonomy with how firms using the different innovation approaches were affected and responded to the crisis. This step took advantage of the Norwegian Innovation Survey (CIS2020). The CIS Survey has for more than 25 years been the main tool to monitor and analyse innovation in Europe and beyond. The 2020 wave coincided with pandemic.

The project leveraged the fact that the questionnaire had been adapted during the pandemic and put into the field at an early stage of the crisis. The instrument prompted Norwegian firms (who are required to respond) to answer specific questions about the effects of COVID19 on innovation activity. When viewed in light of the Taxonomy, the responses provide unique insight into how firms were affected and how they adapted their innovative activities. Did they introduce new innovations as a direct reaction to the situation created by COVID19? What sort of shocks did the crisis pose for them?

The responses can be arranged into three general types of responses based on key questions.

- Negative shock as a result of COVID19 ('push' factors)
  - Has the company faced negative financial consequences that will impact its business operations in the long term?
  - Has the company lost competitive strength due to the situation around COVID19?
- Positive shock as a result of COVID-19 ('pull' factors)
  - Has the company had direct commercial gain as a result of the situation surrounding COVID19?
  - Has the company strengthened its competitive position due to the situation around COVID19?
- Strategic Response
  - Has the company sought new customer groups or new markets due to the situation around COVID19?

- Has the company sought new suppliers or other new external relations due to the situation around COVID19?

The analysis that matched survey responses with categories from the Capasso-Rybalka taxonomy confirmed that different types of innovators experienced the crisis in different ways. The approach and some results can be found in Norwegian here[2]. A summary is presented in the table below. The results stress that all groups of innovative companies are affected by the crisis. Long term changes to business are reported by all firms regardless of approach to innovation. All but one reported a strategic reaction (in terms of exploring new markets and/or new suppliers or other collaborators).

The table further shows that three groups experienced negative shock. "Strategic adaptors", "Innovation suppliers" and "Hard-trying innovators" all reported adverse financial consequences and/or reduction in competitive strength. Conversely, "Radical innovators", "Process developers", "Knowledge absorbers" and "Individual service suppliers" reported having experienced a positive shock in terms of commercial gains and strengthening the competitive position.

Table 3.2: How did the corona crisis affect different innovative companies?

Approaches to innovation	Negative impact from Covid-19	Positive impact from COVID-19	Strategic response due to Covid-19	Introduction of different types of innovation due to Covid-19			Efficiency improve-ments	Long-term changes
				New good	New service	New process		
"Active R&D doers"	-		+			+	+	+
"Radical innovators"		+	+	+	+	+		+
"Process developers"		+	+	+	+	+	+	+
"Strategic adaptors"	+	+	+	+	+		+	+
"Innovation suppliers"	+		+		-			+
"Hard-trying innovators"	+	-	+		+		-	+
"Knowledge absorbers"	-	+	+	-			+	+
"Individual services suppliers"	-	+		+	+			+

Source: Rybalka (2022)

All categories report that the Crisis would have long term effects to their businesses, while nearly all reported a strategic response. The work (presented in Rybalka (2022)) indicate that the "Active doers" and "Radical innovators" are the two groups that found new markets in the wake of the crisis, and that they had increased their innovation the most compared with earlier waves of the survey. This is a first indication of the types of innovators that are more agile in response to the crisis.

[2] An English version is in draft under the title: Rybalka (2022): "How did the corona crisis affect different innovative companies?" It will be published in 2023.

3.1.2 Approach 2 (high frequency data): Use of compensation schemes

The taxonomy is used to study how the use of compensation schemes and public R&D&I support measures differed among Norwegian firms during the pandemic.

The approach (above) benefited from the fact that the collection and availability of low-frequency data coincided with the crisis and that both coincided with this project. Coincidence can of course not be relied on to monitor and analyse the effects of future crises on innovation patterns. In addition, the use of a survey responses, which is self-reported, may have some methodological limitations.

The second approach therefore applied the Taxonomy to an exploratory set-up using timelier data. The project applied month-on-month data to study how different innovators used compensation schemes introduced during the pandemic. The approach and the results are presented in Rybalka & Mark (2023). The analysis considers the propensity of the different types of innovators to use compensation schemes as well as the duration which they utilized them. The time-period (March 2020 to February 2022) by and large covers the period of the crisis.

The Capasso-Rybalka Taxonomy was used to investigate whether the resilience (in response to COVID) varied between different innovation approaches either in the short-run (just after lockdown) and/or in the long-run (duration of use). It assumes that firms were more resilient if they either did not use the compensation schemes or used them for a briefer period than the less resilient firms. The figure* shows that firms with different approaches to innovation had distinct propensities to use these measures. It includes only those that diverged most from the average for purposes of presentation.

This work indicates that “Active R&D doers” as well as “Radical innovators” were least likely to receive COVID19 related compensation, suggesting higher resilience to shock both in the short- and the long-term. “Strategic adapters”, on the other hand, had the highest probability of receiving COVID19 related compensation throughout, suggesting lower levels of resilience. The latter also stayed longer in the compensation scheme, again indicating lower than average levels of resilience.

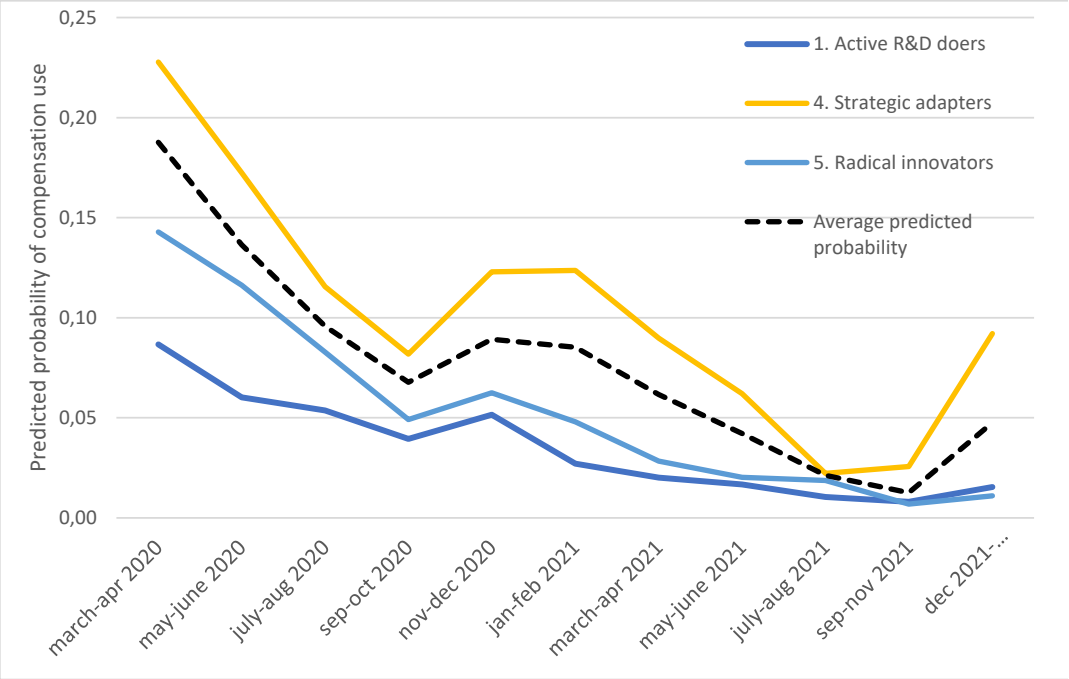

Figure 3.3 Average predicted probabilities of COVID19 related compensation use by sub-period and approach to innovation.

** Note: Averages are calculated among 10 per cent firms with highest scores on the corresponding approach to innovation.*

Source: Rybalka & Mark (2023)

This part of the project (reported in Rybalka & Mark, 2023) also looked at how successful the different categories of innovators were at receiving funding from public R&D and innovation schemes in 2020. Obtaining public support for new R&D and innovation in 2020 is used as an indicator for *agility*. Findings indicate that "Active R&D doers" and "Radical innovators" have the highest probabilities for getting R&D support from the Research Council of Norway and EU, and Skatte-FUNN ("Active R&D doers") and getting innovation support from Innovation Norway and SIVA ("Radical innovators"). Firms with above average shares of high educated employees were also found to more agile in this sense.

3.2 Exploratory combinations involving real-time data

In addition to the work that hinged on applying the Taxonomy, the RelinC project furthermore explored several other potential approaches involving high(er)-frequency data. Two exercises that demonstrate the utility of real-time data are presented here.

3.2.1 Approach 3 (high frequency): bankruptcies

Register (LEED) data are used to explore timelier (real-time) monitoring & analysis on bankruptcies.

The incidence of bankruptcies is a good starting point to assess how well the Norwegian economy responded to the crisis. The approach, laid out in Dalbro & Fjærli (2022), used the registration of bankruptcies in real time, under the widespread expectation that the lockdown of the economy would increase the number of firms that exited the market.

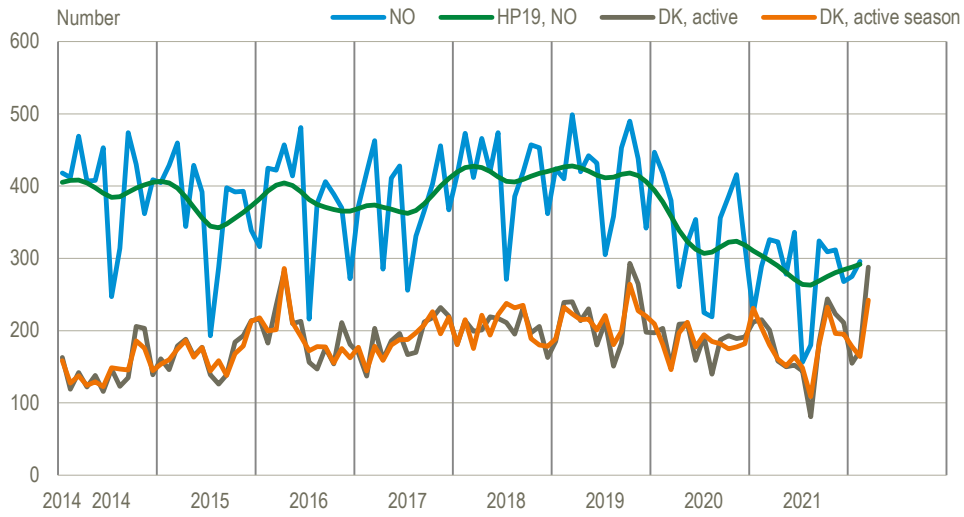

Figure 3.4 Bankruptcies in Denmark and Norway 2014–2022

Source: Dalbro & Fjærli (2022)

Surprisingly, bankruptcies fell immediately after the shut down in Norway and continued to decline through 2020 and 2021 compared to previous years. The figure* compares the week-on-week changes in bankruptcy filings in Norway from 2019 to 2020. The lockdown started in week nr 11 (orange vertical line). It indicates that bankruptcies remained below 2019 levels after lockdown for all industries. Despite Retail trade following the average tendency for a firm to go bust, the segment of retail sale of clothing exhibited a strong increase in bankruptcies.

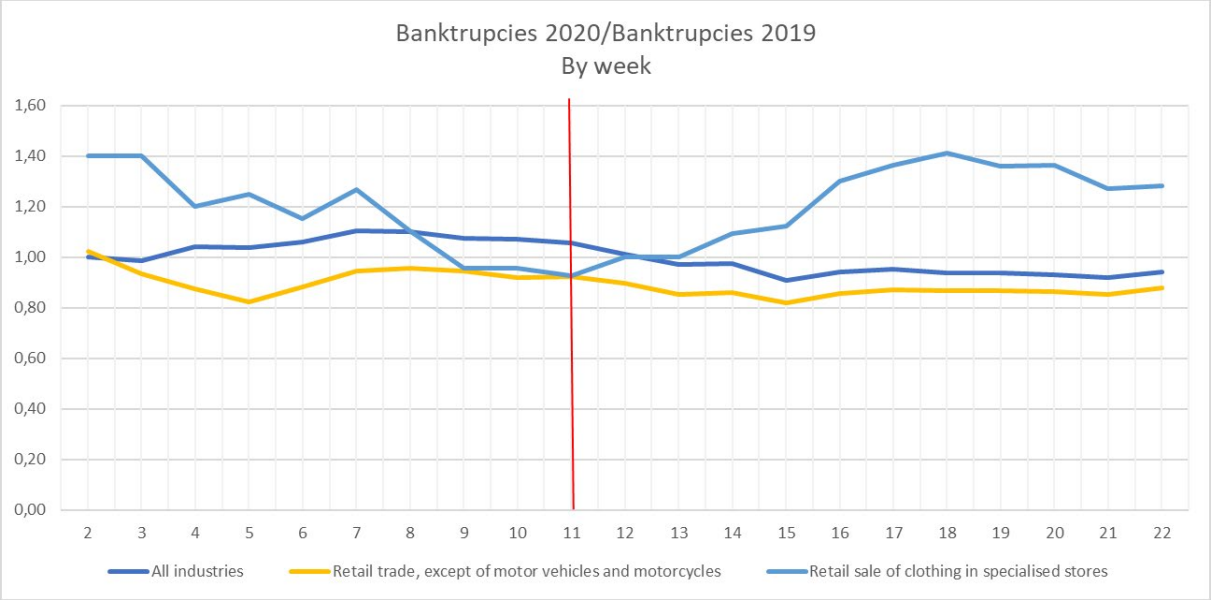

Figure 3.5 Week on Week comparison of bankruptcies in Norway in 2020 in relation to a year earlier: All Industries and two areas of retail trade

Source: Fjærli & Wong (2022)

The timeseries data for consumer demand suggest different reasons for the counterintuitive fall in bankruptcies (see Fjærli & Wong, 2022). These include administrative issues. What is clear is that different (sub)sectors fared differently in the face of the crisis and ensuing lockdown. Pre-existing structural differences in the firms of these sectors together with differential effects of the crisis on consumer behavior are elements that may explain the patterns that emerge. In short, a combination of external (demand factors) and internal factors (financial strength) are involved. The point here is that the high frequency data exposes apparent anomalies (bankruptcies fell during lockdown) and highlights the fact that different areas of the economy fared differently, even in the same segment (e.g., retail trade). These approaches cast light on the need for more research.

3.2.2 Approach 4 (high frequency): Intellectual property rights (IPR)

Domestic Firm-linked IPR data are used to explore timelier (real-time) monitoring & analysis of innovative and commercial activity.

A final approach that was piloted in RelinC utilized high-frequency IPR data. Patents are a traditional 'innovation indicator' with a set of recognized limitations, including that of 'timeliness'. Collaboration with the Norwegian PTO (NIPO) allowed the project to explore this mainstay of innovation indicators in a timely manner by providing very basic information from filings that had not yet been

published. This allowed the project to explore this mainstay of innovation indicators in a timely manner.

In addition, the project explored a new source of data, namely domestic trademark filings. Firm-level trademark filing behavior has been recognized in recent literature as a complementary source of information to that of patents. The literature indicates that trademarks offer a sensitive barometer of the competitive landscape of the firm, of innovation and business cycles, and of regional diversification. Iversen & Herstad (2021) present the basic rationale for using trademark data to study innovation and firm-level dynamics.

The approach set out there is extended in RelinC. It linked firm-level information to patent and trademark filings. The firm-linked IPR data provide a day-to-day account of the extent and types of IPR that different actors utilize. The project used this lens to study how different crises have affected the pattern of innovation in Norway across time. Two inter-linked datasets were used: (i) trademark data from the national patent and trademark office for 1996-2021, inclusive (source NIPO) and (ii) micro-data for all enterprises in Norway (sources: BREG and Statistics Norway).

In the 25-year period, roughly 31,000 registered Norwegian firms were associated with about 35,000 trademark and 20,000 patent applications filed with the NIPO. The figure (3.6) presents IPR filings on a month-by-month basis, highlighting periods associated with three different crises. The left axis tallies distinct IPR active firms (colored columns) while the right tallies IPR filings (blue lines). The figure confirms that trademarks reflect the ups- and downs associated with the ICT bubble and the Financial Crisis.

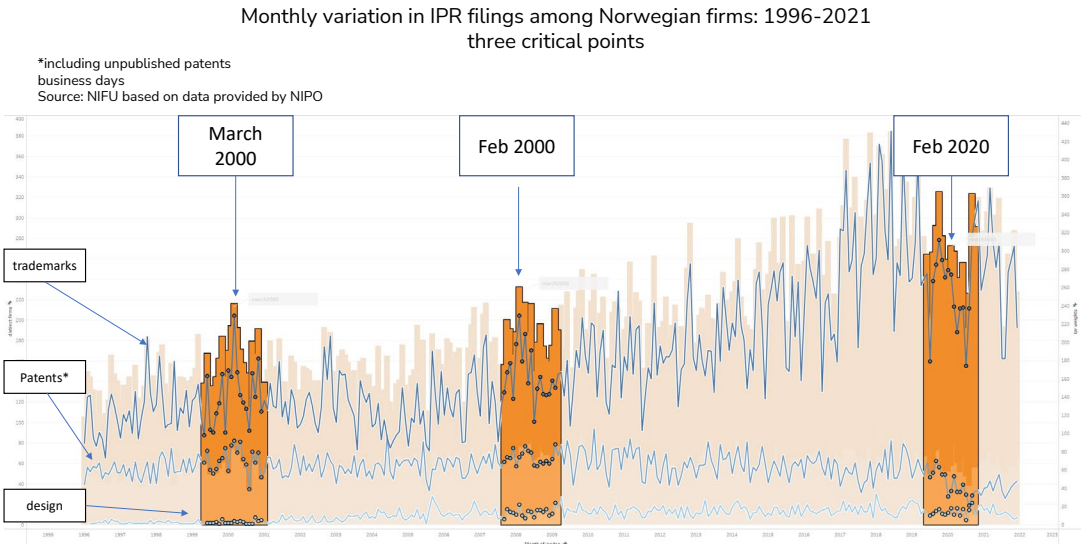

Figure 3.6 Firm-linked IPR data 1996-2021. Domestic applications for patents (including unpublished), design rights, and trademarks.

Source: Iversen (2022)3

This rough view shows that the overall volume of trademarks was falling going into 2020. The lockdown associated with COVID19 crisis however, led to a deep drop in filings of both trademarks and patents. One can discuss the administrative reasons for it. But in general, the figure indicates that the effect of the crisis extended beyond the initial shock. Trademark filings fell sharply for most of the rest of 2020 before spiking briefly and settling into a lower level intensity in 2021. The fall in patent filings was also precipitous and appears to be more long lasting.

Firms that do not have registered employment (sole-proprietorships, 'start-ups') are overrepresented in domestic patenting and trademarking activity. They can be important to national inventiveness and commercial dynamics. But they are unlikely to be able to scale up during a crisis. The study confirms that these non-employing firms contribute substantially to increased IPR activity in high-conjuncture settings, such as during the buildup of the ICT bubble. They are, as expected, sensitive to crisis and generally more variable. They tend to accentuate the trend (and any dead-cat bounce effects).

Stripping out these firms for present purposes, we focus on how IPR active firms that report employment reacted during two crises. To illustrate, the figure* breaks IPR filings (patents, trademarks, design) down by applicant firm-size. The week-on-week filings are tallied with running averages for the 52 weeks of 2000

3 Iversen, Eric J. (2022) The impact of economic downturns and other shocks on innovation: using trademarking patterns as a real-time indicator, Asia Pacific Innovation Conference (APIC), Incheon, S.Korea 28-29 October 2022

(ICT-bubble) and 2020 (COVID19 lockdown). The shock itself occurs in March-April in both crises.

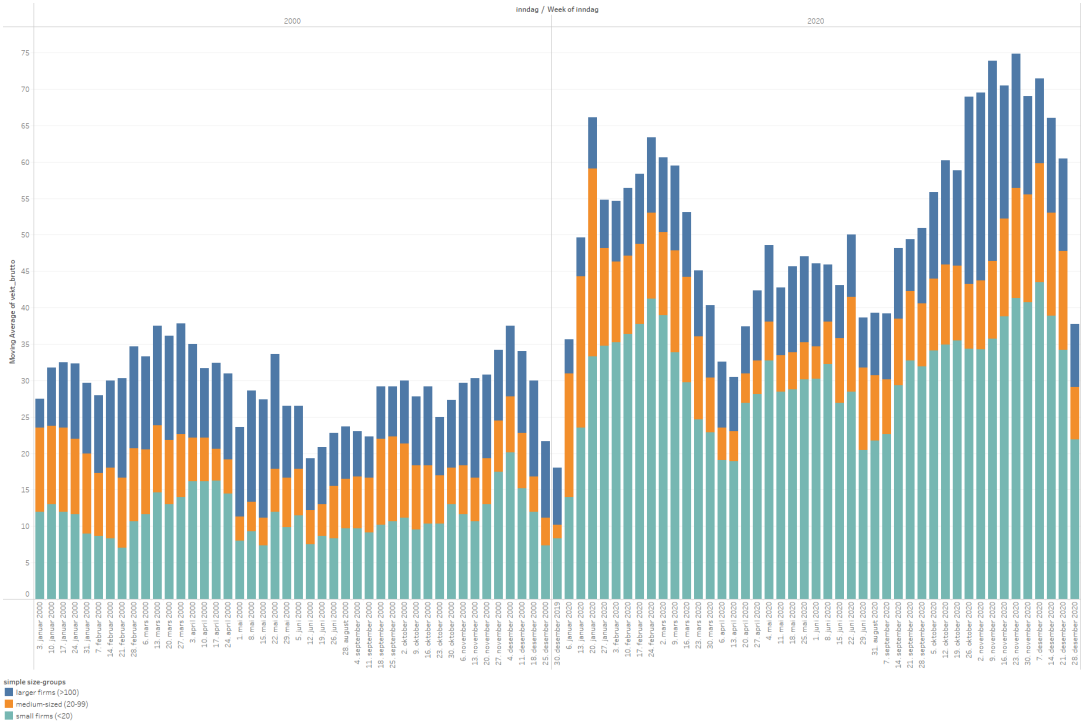

Figure 3.7 Firm-linked domestic filings for patents (including unpublished), design rights, and trademarks: Month on Month in 2000 (left) and 2020 (right) by firm-size*

* August is excluded, workdays. Firms with no reported employment are excluded.

Source: Iversen (2022)

The two shocks have different profiles when viewed in this rough way. Peak-to-trough is more distinct in the case of the COVID19 lockdown, but IPR activity recovers to pre-shock levels more quickly. Different firm-types (size and industry) appear to experience the run-up and aftermath of the crises differently.

- In the aftermath of the ICT bubble,
  - the IPR activity of firms with at least 50 employees fell and did not regain pre-shock levels until 2003, after which levels moved sideways. The mid-sized firms were most affected.
  - the IPR activity of smaller firms (0-49 employees) fell after the shock. Although the week-on-week levels (not seasonally adjusted) recovered later in the year the real story emerges in the longer term. Quarter-on-quarter, the smaller firms did not return to pre-shock levels until 2008.
- In the aftermath of the COVID19 crisis,
  - the smaller firms returned to a pre-shock level of IPR activity by the end of the year, on a week-to-week basis. They fell back further in 2021.

- the larger firms returned to pre-shock levels later. IPR activity again see pre-shock levels in the second quarter of 2021. However, they again fall back after that (perhaps due to some right truncation at the end of the period).

The study looks into how different types of firms reacted differently beyond the question of firm-size. It indicates that the sector and the age of the firms react differently in the run-up to and aftermath of these two different crises.

4 Conclusions

The RelinC project exploited a wide range of unique data sources:

- To assess the capability of the Norwegian economy to respond to crisis in real time.
- To analyze how the innovation capacity of Norwegian firms adapts during crisis individually and collectively (in terms of 'patterns of innovation').

The project carried out a set of intermediate activities to achieve this end. It reviewed the relevant (post-Schumpeterian economics) literature; it refined a standard taxonomy of firm-level innovation activity from this literature to better understand how economic crisis affect different types of innovative firms; and it explored and further developed real-time empirical strategies that might be useful to monitor and analyse a pandemic crisis and its consequences.

Whereas RD&I support tends to be geared to promoting economic performance (~growth) beyond what the firm (the economy) otherwise would have achieved without it, public policy interventions should also consider that the fortification of the innovative responses of firms may furthermore play a significant role in building the capacity (resilience, agility) to respond (meet, weather, react positively) to crisis.

An important dimension is whether innovation activity can promote greater resilience and/or agility to the firm in the face of profound uncertainty. The project identified clear differences between different types of innovators along these dimensions. Firms that regularly engage in formal R&D activities tended to be more agile and more resilient during the pandemic. The response of these traditional innovators was notably different to that of more incremental innovators, which appeared less resilient during crisis. In line with this, we find that resilient companies are better able to survive and thrive during and after a market downturn. Comparisons within sectors (such as retail trade), indicate that strong balance sheets and sustainable sources of earnings are decisive. Identifying resilient companies in times of crisis, a complementary issue is firm agility. Innovative firms appear more agile, but their ability to respond to push-and pull factors during crisis differs across categories.

Moreover, we find that new data-sources are useful to gauge the effects of crisis on innovative activities of different firms. Whereas we often analyse innovative activities retrospectively, an era of 'polycrisis' emphasises improving monitoring and analysis of the patterns of innovation in a timelier way. Timeliness however tends to exist in a trade-off with quality (robustness, reliability…).

The project explored both more conventional measures (Innovation Survey) as well as novel empirical lenses that are timelier. These included firm-level datasets covering the use of different support interventions by innovative firms, bankruptcy data, and domestic IPR filings. This work for instance confirms that domestic IPR filings are sensitive to socio-economic downturns. As an indicator or innovation response, IPR filing behavior differs among different types of firms. We find that micro firms account for much of the churn in the run-up to and following a crisis. Larger manufacturers as well as knowledge intensive service firms appear more resilient than small service sector firms, for example. Age (and persistence of innovation) also seem to play a role.

The project indicates that combinations of low- and higher frequency data can provide better lenses to understand how different crises impact on the innovative responses of a population of enterprises. A main take-away is that a composite approach that includes a detailed taxonomy describing innovative approaches of firms together with an array of conventional slower moving datasets and higher frequency datasets such as IPRs provide readings about how different firm-level innovation activities react in the face of crisis.

5 Annex

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Note: Blue = Preliminary Review; red = key literature, purple = Growth theory literature; black = other.

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