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Is this Time Different?
Corporate Resilience in the Age of Covid-19

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iCite Working Paper 2021-046

Is this time different?
Corporate resilience in the age of Covid-19

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Abstract

We study corporate resilience during the Covid-19 pandemic for a sample of 4100 large global firms (mode: 1-10 billion USD revenue) using a large set of machine learning techniques. As per Hamel and Valikangas (2003), we find that both traits of innovations, as well as of organizational agility (Teece et al. 2016), drive the firm's post-Covid rebound. Remarkably, the Covid-19 pandemic is also exhibiting two extra traits among covid-19 *resilient* firms: they are consolidating their play in business ecosystems, while they are engaged in a "twin transformation" of digitization and sustainability. In general, also the way corporations play those traits matters, i.e. orchestrating the business ecosystems, engaging in disruptive (as opposed to incremental) innovation, and transforming at scale to boost resilience. Finally, there is a large complementarity among "resilience" traits, boosting the probability of resilience by close to 40% versus the sum of only the direct effects.

JEL-codes: L25, M15, M21, 033, I10

1. Introduction

The Covid-19 pandemic has brought about a major health issue with more than 130 million infected worldwide by early April 2021[1]. The pandemic, and the

related lockdown measures to limit its spread, have also significantly adversely hit economic activity (Baker et al., 2020). A recent update by the IMF has estimated that in 2020, GDP growth has contracted in the range of 3.5 percent [2]. Such a drop from sudden disruptive shocks on economies is *above* the range of effects seen from other crises (Reinhart and Rogoff, 2008).

What matters now is how strong and fast economies might be able to recover from the different waves of the pandemic. Extensive vaccination is on its way and should enable the lifting of current economic restrictions. Second, large-scale government spending programmes have been announced to sustain demand recovery. Third, on the supply-side, corporations must quickly find opportunities to recover post-disruption. The ability for firms to rebound is often referred to in the literature as corporate "resilience" (Barrero, et al.,2020 ; Cros et al., 2021). One common factor of resilience is the amount of slack resources, such as cash liquidity. Small and Medium Enterprises are notoriously financially fragile, with at best a few months of cash to finance their operations (Bartik et al, 2020). Another factor predicting resilience is the extent of the adverse shock. As evolutionary economics predict (Boschma, 2015; Martin and Sunley, 2015), resilience is more difficult to achieve when the original shock creates a significant fall in economic activity. Pagano and colleagues (2020) have calculated that, during the first wave of the Covid-19 pandemic in 2020, an economically large spread in equity returns (in the range of 40% to 50%) built up between companies operating in the least resilient industries (such as mining, or water transportation) and firms operating in most resilient sectors such as computer and electronic products. This spread proved to be lasting for months in 2020. Cros et al. (2021) have confirmed such a lasting effect, in terms of economic activities, through changes in credit card transactions (minus 61% for travel agencies, for an increase of 17% say in funeral services during the year 2020).

Still, the resilience literature highlights that the main factor behind resilience is corporate innovativeness supported by organizational agility. Innovation has been promoted as a crucial strategic factor for resilience for firms facing large turbulent environments, e.g. by Hamel and Valikangas, (2003). Note that innovative

activities per se, can also be characterized by resilience, as they are strongly path-dependent and cumulative in nature (Nelson and Winter, 1982). Naidoo (2010) confirms the influence of market-oriented innovation for resilience. Riom and Valero (2020) document that firms engaged in innovations have been the most optimistic in their post-Covid performance. Organizational agility, as described by Parker and Ameen (2018) as the ability of a firm to reconfigure its resources quickly is another factor emphasized by David Teece and colleagues (2016) to further boost the returns to innovation capability[3].

Agility and innovation are often referred to as dynamic capabilities to activate in responses to crises (Helfat, 1997). Alas, these capabilities are often difficult to acquire in a short time frame, leading to only a limited number of companies which have anticipated the risk of adverse effects, and can truly activate innovation at scale, as an agile response. In addition, even if those capabilities prevail, a majority of companies may still want to respond to a crisis with a retrenchment strategy (Wenzel et al.2020 and Breier et al,2021). Archibugi et al. (2012) documented a large drop in innovative capabilities from European firms following the financial prime mortgage crisis of 2008. Only a small minority (10%) of firms went against the trend, expanded their original innovative investment, in particular via collaborative arrangements and exploration of new markets. These companies were the ones who managed to rebound quickly and durably expand their market share as part of their resilience.

This research uses a business survey commissioned by a major consultancy to study the resilience of global firms worldwide during the Covid-19 pandemic. The sample covers a wide range of industries, and firms from a variety of large economies such as US, China, Germany, France, UK. The sample also covers an extensive list of questions that provide measures on possible "markers" of corporate resilience. Finally, one originality of the sample is that it tracks performance of firms from pre-covid, to during (at least two waves of) the pandemic.

This research contribution relates both to new findings regarding the literature on corporate resilience factors, as well as to the predictive methods used.

Regarding new findings, our research confirms that business responses focused on organizational agility and innovation remain strong predictors of resilience, but the study also highlights two *new* traits, and their drivers, of resilience.

1. Resilience is better achieved by engaging in *a twin transformation* (Ollagnier et al. 2021), that is, in the joint acceleration of digitization and sustainability practices. There is an emerging claim that digital transformation has helped Covid-19 business resilience (Raj et al , 2020). In effect, Covid-19 has led to the acceleration of *digital technology adoption*. While Perez (2010) had noted that major recessions feature technological discontinuities, with the Covid-19 pandemic, the technology paradigm push is about digital transformation. One obvious example of the induced technological changes from the Covid-19 pandemic is the major shift towards technologies to support work-from-home (WFH) to ensure work continuity and social distancing compliance (Bloom, et al. 2020 ; Bughin and Cincera, 2020)[4],[5]. In combination with digital transformation, corporations have been accelerating their ESG agenda during Covid (Ding et al, 2020 and Ollagnier et al, 2021). During the prime mortgage crisis, corporate sustainability initiatives spiked too [6], but this time, the investment in ESG seems to be broader than during previous crises. Recent studies claim that companies with stronger ESG activities have resisted better to the Covid-19 shock (Ding et al, 2020). Inversely, Mukanjari and Sterner (2020) show that companies with high dependency on carbon emissions have performed *worse* than others during the virus pandemic[7],[8].
2. The second trait is that resilient firms are often those engaged in *platform-based business ecosystems* that connect a large set of partners' offerings. Business ecosystems have mushroomed, in part through leverage of digitization and sustainability. An example of the later type is the circular economy, -as exemplified by Lindstrom, a leading European textile company which now orchestrates an entire platform for re-use of clothes. Digital

ecosystem examples include Amazon e-commerce marketplaces, the Apple Store, online advertising ecosystems such as Google or the Trade Desk, and industrial examples such as Siemens' MindSphere or Bosch's IoT suite. Ecosystems also have a more fluid/agile structure than traditional bilateral partnerships and are also recognized to be more innovative, which should reinforce resilience (Jacobides et. 2018).

3. Among the four "traits" of corporate resilience (innovation, agility, ecosystem play and twin transformation), our research highlights that the type of play also matters to boost resilience. As an example, an adequate value sharing must be sustained between the orchestrator of a platform, and its participants. The latter in particular needs sufficient incentives to remain on the platform. As an example, the scale of the Amazon marketplace offers such a liquidity for the long tail of merchants that those may find relevant to stick to the platform—in effect, the average third-party merchant profit is growing 13% faster than like-for-like merchants that ate on the platform[9]. Still, the keystone/orchestrator position is advantageous (Iansiti and Levien, 2004) and is actually the privileged role taken by 7 out of the ten largest digital native companies worldwide. We also find that the keystone role favours corporate resilience. Finally, disruptive (as opposed to incremental) innovation affects resilience.

Finally, we contribute to the literature on resilience by testing a large set of classified supervised machine learning techniques to predict corporate resilience. Here we find that big data techniques such as Random Forests are more predictive than traditional logistic regressions, on top of having more attractive features such as not imposing a linear relationship between resilience and its drivers, or being robust to collinearity among drivers. The fact that there might be large complementary among the traits of resilience, calls for caution regarding covariates among regressors. Classification techniques have already been used in the case of the Covid-19 pandemic. Davis et al (2020) have developed a supervised machine learning algorithm to retrieve Covid-risk terms out of 10K-filings. They show that those risks are negatively correlated with stock returns. The use of machine learning techniques is however only emerging to assess drivers of firm

performance -such as innovativeness (Gandin and Cozza,2019). This research finds that machine learning techniques are especially more *sensitive to spotting corporate resilience* than traditional regression-based techniques.

Study background and descriptive statistics

We first comment on the sample collection, and then discuss descriptive statistics.

2.1. Sample scope and collection

This study arises from a dedicated research project aimed at understanding how companies have been affected by the Covid-19 crisis, and their post-Covid trajectory. The survey was administered by an independent agency during the Fall of 2020. Survey respondents are top management, mostly CEOs, Chief Strategy or Information Officers. Respondents are not required to answer all survey questions as they may not have an informed viewpoint on each question. An extract of key questions asked to the respondents is provided in Appendix 1. The study covers multiple themes, such as the impact of the Covid-19 pandemic on firms, but especially actions and resources/capabilities required to bounce back from the pandemic. As per the resilience literature, questions have included views on innovation, organizational ability to adapt to the crisis and pivot, but also new domains such as digitization and sustainability planning (see Tables 1.a and 1b).

One advantage of the sample is that it has wide relevance. It covers some key countries in Europe (top 5 countries; France, Germany, UK, Italy and Spain); North America (US and Canada) as well as in APAC, China, Japan, Singapore, Australia. It also covers a wide range of sectors, from automotive, travel, banking health, to high-tech, energy or utilities. The final sample (see Table 1a) includes 4100 respondents (one per firm), of which 1/3 is located in Europe, as well as in the US. One disadvantage of the sample is that the sample is anonymized, so we can not link respondents' firms to other data, e.g. financial statements data.

Table 1.A. about here

The study also covers large companies (Table 1.b). More than 60% of companies generate between 1 to 10 billion USD dollar revenue, and about three out of ten generate more than 10 billion US dollar per year, at pre- Covid. APAC firms are more often global (47% of them) than their counterpart in Europe and US.

Table 1.B. about here

2.2. Descriptive statistics

2.2.1. Resilience patterns

One way to measure business resilience during the Covid-19 pandemic is by stock price movements e.g. Cheema-Fox et al .(2020). Many stock price indices recovered from their fall out of the Covid-19 pandemic shock, in a matter of a few months. For example, the FTSE China 50 index was back to its level just before the crash by mid of August, as were other indices such as the MOEX of Russia, the S&P 500 or Nikkei 400. Contrary to capital markets, profit recovery takes more time than a few months, and often a few years (OECD, 2012, or Cerra and Saxena, 2008).

Here, we use an alternative measure of corporate resilience, based on the *evolution of operating profit*. Contrary to capital markets, profit recovery takes more time than a few months, - and often a few years in case of major crises: see OECD, 2012, or Cerra and Saxena, 2008). In our definition, resilience is achieved when profit growth pre-covid is rebuilt, at the *latest* by Sept, 2021. We use profit as a resilience measure as stock price evolution can be very noisy at times of crises. Stock movements can be driven by many factors, such as changes in expectations or reactions to new crises-related policies, and not by true internal corporate factors (Dahmene et al., 2021).

Work by Foulon (2020) confirms that analyses of drivers of resilience based on extent of stock price recovery, exhibit large bias as well have low explanatory power, in the range of 3-5% of variance explained. Our model (see infra) based on profit evolution, explains up to 7 times more of the corporate performance variance, than a model using stock price measures of resilience[10].

When looking at profit, one other advantage of the data from the questionnaire is that profit evolution can be traced through four "cut off periods". Respondents were asked about their profit evolution in the last three years ago before the pandemic. This defines our "base line" pre Covid-19. The survey has then asked them on how performance got affected by the first wave of the Covid pandemic shock, from March to early Sept 2020. This second cut off period allows us to see how profit got hammered, and how "*fragile*" companies have been in the first months of the pandemic. Further, the survey asks about profit evolution, in the period from September 2020 to March 2021, that defines a window of 6 months, as a period of possible "recovery", but also a period of a second wave of pandemic. The last period concerns the 6 months-period ranging from March to Sept 2021. Respondents had to formulate expectations when asked about profit evolution, for the last cut off period. Thus, answers include respondents' expectations as to how the pandemic might evolve.

Figure 1 reproduces the four cut-off periods for the (unweighted) average sampled company versus the baseline normalized at 100%..We also reproduce the profit evolution by continents. Respondents clearly report that the Covid-19 shock has seriously hit the large companies of the various regions of the world. By Q1-Q3 2020, (the "fragility" period), the pandemic has led the average firm to *lose more than half of* its operating profit. The recovery phase, Q3-2020 to Q1:2021 has looked more like a stabilization period for both US and European firms. Only the APAC firms (mostly China in our sample) managed to re-grow their profit in that period. The rebound phase is expected by all for this year, but only the average APAC firm will be recovering fully by max Q3: 2021, and thus can be called "resilient". Extrapolating the patterns of recovery, the *average* North American firm should return to its pre-covid profit pattern by the end of 2021, but only by early 2022, for the average European firm[11].

Figure 1 about here

Table 2 displays two additional elements on the shape of profit recovery by firms. First, just above 1/3 of companies will be recovering fully by at worst Q3,

2021. Second, regrouping firms around seven major industry domains (manufacturing, B2C, financial services, resource, service and tech and pharma/life science), the most pressed domains are found in sectors such as utilities and natural resources ("Resources bucket"), automotive ("Manufacturing") and transport ("Service" bucket). Those domains that benefited from tail-winds out of Covid-19 are (food) retail ("Consumer" bucket), software ("High-tech"), and pharma ("Pharma and Life Science"). This picture is in line with other research (e.g, Cros et al, 2021).

2.2.2. *Corporate performance dynamics*

We have further split the companies in two groups—the first/second group is composed of firms below ("low performance")/ above ("high performance") average profit growth "pre-Covid". There were 45% of firms with low performance versus the average corporation during pre-covid times, of which 27% (12%/45%) will be recovering at the latest by sept 2021. The odds of recovery is thus typically 50% higher for companies which already exhibited stronger pre-Covid performance (42% /27% from Table 2), implying a path dependence effect. This path dependence may arise from lasting assets and capabilities; innovation is typically such a type of (intangible) asset, for example, which is being tested hereafter in this research.

Table 2 about here

Figure 2 further displays the estimated dynamics of the operating profit for the 16 industries. It does it for 2020 versus pre-covid, as well as estimated 2021 versus pre-covid. The performance of firms remains widespread despite a common shock (Covid-19 diffusion, and its protective measures). This intra-indistry performance spread is what we are interested in- in the next section, where we look at possible antecedents of firm resilience.

2.3. Vectors of resilience

We review hereafter the possible drivers of business resilience, and expand the list based on the unique context of the covid-19 crisis.

2.3.1. Literature review

As discussed in Linnenluecke (2017), disasters such as the Exxon Valdez, or Bhopal led to the application of the resilience concept to how corporations might be able to reverse major adverse shocks. The seminal piece originated from Meyer (1982), who showed that organizations can display two forms of adaptability under external risk, either by absorbing the shock (being called, "resiliency"), or by creating new practices ("retention").

Resilience was then studied from an internal organizational reliability viewpoint, and with respect to technology. Sitkin (1992) recommended that resilient firms should have managers able to foster "intelligent failure", so that managers can learn from failure and adjust accordingly. Diane Coutu (2002) described how resilience is a learnable capacity which can be developed within employees through the Morgan Stanley's successful response to the 9/11 attacks. Juettner and Maklan (2011) provide some case evidence regarding supply chain resilience in the global financial crisis.

The works by Hamel and Valikangas (2003), and Gittell et al. (2006) serve as more grounded basis as to the optimal responses of firms to revert from adverse externalshocks. Gittell et al. (2006) emphasized the importance of *slack resources* to be able to adjust and reach resilience. Hamel and Valikangas (2003) highlighted the crucial role of *innovation* as enabling conditions to anticipate and adjust to a broad range of turbulence. Recently, Woods (2020), made the point that *agility* is of paramount relevance to increase the resilience of corporations in volatile environments.

Regarding organizational agility (Table 3), two thirds of global companies' respondents believe that their organization was able to mobilize resources to cope with the Covid-19 crisis. But looking more in depth at technical indicators of agility, such as speed of actions, flexibility in use of resources, risk-taking actions, etc), company agility is not necessary that widespread, with about 6 companies out of 10 considering not to have enough agility to be fully immunized against the risk of the pandemic.

Regarding innovation, the survey has inquired about how companies have relaunched their innovation spending and what specific type of innovations were targeted, e.g. incremental innovation versus breakthrough or disruptive innovations. The average innovation budget spent has been globally in decline in the first year of the pandemic, -by about 8% between pre-Covid period and the recovery period. This decline is in line with the crisis literature, where generally innovation spending is being reduced by up to 5-10%, during crises (OECD 2012)[12] . Not all firms reduced their budgets, however. 45% has reduced their innovation spending, but by a double digits' rate. 55% has increased budget but in single digit growth. For what is spent, we also find that the share of incremental innovation is still large, with 58 % of budgets allocated to incremental innovation. Firms with increasing innovation budgets during the crisis have a higher portion of budget allocated to disruptive innovations.

Table 3 about here

2.3.2 Additional vectors of resilience

The Covid-19 pandemic is also correlated with a few contextual changes in company strategies, which we hypothesize have boosted their resilience. Notably, there has been an increased pivot towards digitization and sustainability, while some companies have been boosting their (presence in) business ecosystems. Ecosystem revenue stood for less than 5% of global corporate revenue in the years before Covid-19 struck. It amounted to 8,5% of revenues of global firms by the end of 2020, leading to an average increase of 25% per year,- even accounting for revenue decline in 2020. The same firms expect to boost their ecosystem play revenue share to 14% by end of 2021, or more than a doubling of the recent growth.

During the Covid-19 pandemic, digitization has also been one (of the only) ways of doing business, while complying to social distancing measures[13]. Second, digitization turbocharges agility: Skare and Soriano (2021) for instance show how digital technological advancements have significantly changed the role of a firm's agility for performance. Finally, digitization supports sustainability ("IT for

green"). Digital maturity lies in the adoption as well as business use of frontier technologies such as the cloud, big data, RPA or Artificial Intelligence. These technologies are the core enabler of successful digital shifts from the Covid-19 pandemic, see Chen and Lin, (2020). Still one company out of three has yet to adopt machine learning analytics, blockchain, or RPA (Table 4a).

Table 4a about here

In addition to digitization, lots of large companies have also been more engaged in ESG practices that can correlate with better profit performance (Berns et al. 2009)[14]. In our sample, 92% of large global companies have an ESG program in place, with about equal focus on either E, S, or G. Energy transition still commands the largest share of all initiatives launched (40%) followed by circular economy measures. 44% of companies engaged in these practices have created a position of a Chief Sustainability officer, in charge of adopting and of deploying the practices. In general, respondents report that sustainability is still in the phase of scaling, rather than being scaled up. This is in contrast to digitization (compare the first column of Table 4b with the one of Table 4a).

Table 4b about here

Using data from Tables 4a and 4b, we have developed a maturity score index (0= fully immature, 100% fully mature), that weights the stage of use (pilot, scaling, scaled) of each initiative launched, and the investment importance for the frontier digital technologies and sustainability measures surveyed. The sample average maturity score is slightly above 50%, that is twin transformation is far from being exhaustive and at scale. Still, the corporate spread is very large, with about 10% of pioneer companies already passing above 70% of maturity. Note as well that sustainability and digitization maturities go hand-in-hand, with any point of extra tech score leading to extra 0,3 score in sustainability (see Figure 3). This correlation reflects the *twin* aspect of both transformations, with the importance of digitization, particularly seen as a key enabler: 90% of respondents claim that their corporations are deploying sustainability practices *with a support* from digital technologies, and about 16% (respectively 61%) of respondents believe that

the synergies between both transformations are high (are existing to a moderate extent).

Figure 3 about here

Predicting corporate resilience

3.1. Model architecture

We now turn to assess the *mix of* traits that might bolster resilience. From this perspective, the predictive model architecture is of a discrete classification form (1)

$$(1)\ R = f(X, \Delta X, C) + u$$

where R=1 (=0) if profit resilience is achieved (or not)., f(.) is the function liaising the vector of "traits", X, and their change ΔX ,during the pandemic, C is a set of control, and u is a disturbance terms capturing all non observable effects.

The vector X includes the hypothesized set of resilience enablers- agility, innovation, twin sustainability/digitization and ecosystem play. Regarding the trait of agility, we have argued to look at two markers, e.g. organizational (i.e. ability to mobilize the full enterprise fast in new direction) and technical (e.g. speed, etc) agility. Regarding the threat of innovation, we also consider a company spending intensity, as well the spent allocation towards disruptive innovations. Regarding ecosystems, we look at how a company is embedded in ecosystem play (share of revenue generation), as well as its platform-based role (keystone versus participant).

Given the induced shock in the economy caused by the pandemic, we are keen to understand the *dynamic* nature, ΔX, of a firm's assets and capabilities. In particular, we focus here on *change a)* in innovation spend intensity (remember from above, that on average spending is declining, meaning that firms have played a retrenchment strategy); b) in ecosystem revenue (on average, increasing), and c)

in technical agility (on average, recognition that agility is lower than expected). We finally include a vector, C, of controls, in function of the survey observables. We include company size, headquarters' region, industry. Finally, as workforce is an important asset to drive productivity during Covid (see Bughin and Cincera , 2021) , we also include a dummy on whether companies have been supporting employees with the workforce emerging better off, post- than pre- the Covid-19 crisis.

3.2. Estimation techniques

As the dependent variable and most of the input variables in f(.) are categorical, the function f(.) should be based on the logistic regression. The best function is then computed as the one that minimizes the sum of square of differences between the fit and actual value. One caveat however of traditional regressions is that they assume a linear fit, when the underlying function is possibly not. It also assumes that the classification from the input variables is rather clear-cut, implying that variables have limited multi-collinearity among them. We have shown evidence, like in Figure 3 of a link between digitization and sustainability deployment, that multicollinearity is not to be excluded. Likewise, there are enough factual evidence in the literature of other ties between most of the different traits, e.g., between agility and digitization (Skare and Soriano, 2021), between innovation and ecosystem play (Iansiti and Levien, 2004) or still between sustainability and innovation (Ollagnier et al., 2021), reinforcing the risk of large covariates among possible markers of resilience.

For those reasons, we also have experimented with another set of big data driven machine learning techniques. As methods, we have used Decision Tree (DT), Neural Networks (NN), Bagged Trees (BT), Gradient Boosting (GBM) as well as Random Forest (RF). One powerful method is the latter, RF, that works as an ensemble learning method based on building a range of regression trees that are then averaged out to compose the final forest. From each tree, the smallest root mean square error prediction error variable determines the top of the tree and

recursively to create a full tree. Prediction used the average of the response variable in each leaf of the tree[15].

Table 5 illustrates the predictive fit achieved, using the same set of predictors for each technique. In order to account for all linearities, that are directly tackled by the big data machine learning technique, we include cross-effects between variables in the logistic regression model; further, given risk of multicollinearity, we use a stepwise regression technique that removes the least significant variables through iterations until final model is achieved. That model defines the list of variables for the full prediction model.

Table 5 about here

We find that the logistic regression accuracy scores relatively well. But one clear issue with logistic regression is its low sensitivity (that is, the regression ability to rightly classify resilient firms) compared to other ML techniques. This is rather unfortunate as this is precisely what we wish to know in this research. As already alluded to, except for sensitivity where NN leads, Random Forest is the most effective of the technique, and performs as the best on all four other prediction metrics laid out in Table 5- when showing results beyond logistic regression, we will focus on RF results from now on in this research, versus the average of all techniques and logistic regression. In our case, RF is based on the split of 500 trees.

3.3. Results

3.2.1 Logistic regression

For transparency, Table 6 first presents the results based on backward stepwise logistic regression. The table reports only coefficients that are significant at least at risk α=10%. The vector of control dummies were included but not reproduced in the Table. The regression tests 7 direct effects (X and ΔX) and 21 "2 by 2" cross-(indirect) effects.

Table 6 about here

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A few critical elements emerge from the Table:

1. First, direct effects confirm the importance of agility, and to a lesser extent innovation. Innovation intensity is not a significant predictor, rather this is the fact that companies start to invest more during the pandemic (against the trend of companies in our sample, where the average innovation spent budget has decreased during the pandemic).
2. Second, other direct effects emerge as statistically significant predictors of resilience, e.g. digital transformation and business ecosystem play are found to be material factors for resilience. Sustainability, as well as role in the ecosystem only emerge as a driver of resilience as cross-effects, when linked with innovation (increase) and technical agility. The same for disruptive innovation- the effect is accreditive to resilience when companies boost their innovation spent during the pandemic and when those disruptions are linked to sustainability.
3. There is large nonlinearity to predict resilience, given the number of significant cross-effects (17 out of 21= 81% of them). In general, those cross-effects are positive, demonstrating strong complementarity between resilience traits. The notable exception concerns organizational agility. In general, organizational agility is less effective when combined with factors such as sustainability, and ecosystem play. In one way, this is to be expected as business ecosystems are rather agile and fluid constructs by themselves that are substitutes to their own organizational capabilities. Furthermore, the direct effect of agility is so large that companies are still better off to operate within an agile culture that quickly helps mobilize resources for changes. In general, organizational agility is less effective when combined with factors such as sustainability, and ecosystem play. In one way, this is to be expected as business ecosystems are rather agile and fluid constructs by themselves that are substitutes to their own organizational capabilities.

4. Finally, we compute the marginal effects of change in the existing traits of resilience, at the sample mean (where the probability of corporate resilience is 0,32). To ensure a significant boost in the probability of corporate resilience, a company must master a minimum of 3 out of the 4 domains,-- and in all cases, it must include both agility and business ecosystem play. The good news is that 2/3 of large companies are mastering those capabilities in our sample. Yet, it confirms that agility and innovation may be too short of a skill set to secure with certainty full profit recovery by the end of this year, when it comes to the effects of the Covid-19 pandemic.

3.3.2. Alternative big data machine learning regression results

We provide estimates with big data techniques, in particular RF, which appears to be the best performing among all tried out. For simplicity, we also provide an average computed out of all big data techniques used. Table 7 displays the relative contribution of the four main"traits" of resilience, -- as well as the various components of those four traits" in Figure 4, as computed by their decrease in root mean square error, for predicting resilience. We find that:

Table 7 about here

1. As in the case of logistic regression, we confirm that all traits matter for corporate resilience. Agility seems to be the most important element, and its relative contribution to predicting resilience is higher in big data machine learning than in logistic regression. On the other hand, the role the business ecosystem plays decreases in importance.
2. Agility and innovation account for about 70% of resilience prediction accuracy. Thus, level of plays in business ecosystems as well as degree of twin transformation maturity, add 43% (=30%/70%) of predictive power to resilience. The uplift in prediction ranges between 25% in RF and up to 47% when we take the average of all ML techniques.

3. Further, we show the split of traits contribution, based on their *level* (X), at pre-Covid, and their *change,* (ΔX), -activated during the Covid-19 pandemic. The contribution to resilience is split roughly equally between levels and changes. Change is particularly important for innovation (confirming regression results that what counts is especially the increase in innovation intensity per se) as well as for ecosystem play. This means that activating innovations as well as further boosting ecosystem play during Covid-19 pandemic, matter more than leverage prevailing assets and capabilities before covid-19 to achieve resilience.

4. Looking inside each trait, the disruptive nature of innovation is the largest contributor to innovation- more than innovation spent intensity and its change. The type of role played (keynote, especially) in the ecosystem also contributes to resilience prediction, but here the importance and evolution of the ecosystem absorb the bulk of the prediction.

Figure 4 about here

5. The above blends the direct and indirect effects of the different traits on predicting business resilience. Table 8 breaks down the interaction strength by factors. The general observation is that the *interaction strength* is large, with a weighted average of 25 % for all types of traits and their change activated during the pandemic . Ecosystem play and agility stand for the domains with the most interactions that reinforce (the prediction of) business resilience. Looking at the largest interaction terms, we also find that agility interacts the most with innovation. For twin transformation, the largest interaction arises with ecosystem and innovation disruption. Those domains and those interactions are new features spotted in this research and are in line with new market evolution of digitization, sustainability and ecosystem play.

Figure 8 about here

3.3.3. Extra sensitivities

The above results have been based on resilience being measured on profit, as well as on a classification based on the rebound phase to be completed by Sept. 2021. For robustness, we have looked at revenue instead of profit as the dependent variable. We then have performed the resilience classification based on the recovery phase, by early 2021. We also computed total profit evolution, instead of only using resilience achievement. All results stood out[16].

The results above also pool all industries together, with industries as control. We find that those controls are often a significant predictor of resilience, -especially industries such as pharmaceuticals/healthcare/life science, and software and platforms (benefitting from tailwinds) as well as media and entertainment, and FMCG (facing headwinds). We might also hypothesize that industry interacts significantly with the factors of resilience. In particular, we may think that the mix of domains may be industry specific, as for instance R&D efforts and innovation are usually more frequent out of life science firms and high-tech than say in utilities, while sustainability should be an important factor linked to energy transition. We also discovered that the largest interaction strength with factors of resilience arises with industry dummies, reflecting that industry has an idiosyncratic effect on the mix of factors leading to resilience.

CONCLUSIONS

How do firms respond to a crisis such as Covid-19, and how successful can they be in their ability to recover? The literature on business resilience suggests that innovation and agility are critical for large, and fast, effective rebound. In this research, we extend this literature in multiple ways.

First, we have extended the list of capabilities that act as important recovery catalysts in this period, such as involvement in digital and sustainability transformation. Second, we consider not only prevailing assets and capabilities, but their level of activation during the pandemic. Third, we add specific granular elements as possible drivers of resilience, such as the nature of innovations launched, or the role played in participating in emerging business ecosystems.

Finally, while the literature uses traditional regression techniques to sort out resilience from crisis-plagued firms, we leverage a battery of other data driven machine learning techniques to predict resilience.

Based on those extensions, a few new results have stood out:

1. Predicting resilience is more accurate by leveraging machine learning techniques than by regression only. One reason for superiority of machine learning might be the large co-dependence among resilience factors. This multicollinearity implies large positive externalities among factors that make companies playing the portfolio of "traits", be better off to recover.

2. Among those inter-related factors, agility and innovations matter but new elements such as the extent of twin transformation and business ecosystem play have material relevance as well.

3. Resilience is as much about scaling than having (dormant) capabilities, and is as much about disruption (eg for innovation) and leadership role play (eg in ecosystems) than about engaging in innovation and connecting in new ecosystems. Managers should take notice.

REFERENCES

Archibugi, D, Filippetti, A and Frenz, M (2012) The impact of the economic crisis on innovation: evidence from Europe. Working Paper. Birkbeck College, University of London, London, UK.

Baker, S., N. Bloom , S. Davis, K. Kost, M. Sammo, and Viratosyn, T. (2020), The unprecedented stock market reaction to Covid 19, CEPR, ***Covid economics,*** Issue 1, April

Barrero, J. M., Bloom, N., and Davis, S. J. (2020). COVID-19 Is Also a Reallocation Shock. Brookings Papers on Economic Activity.

Bartik, A.M. Bertrand, Z. Cullen, E. Glaeser, M. Luca, R. Stanton (2020), The impact of COVID-19 on small business outcomes and expectations PNAS July 2020 117 (30) 17656-17666.

Berns, M, Townend, A., Khayat, Z , Balagopal, B., Reeves, M., Hopkins, M, and Krusxhwitz, N, (2009) The business of sustainability- what it means to managers now, MIT Sloan Management Review, 2009,51, 20-26

Bloom, N., Davis, S.and Zhestkova, Y. (2020). Covid-19 Shifted Patent Applications towards technologies that support Working from Home. Working Paper, University of Chicago.

Boschma, R. (2015), 'Towards an evolutionary perspective on regional resilience,' Regional Studies, 49(5), 733–751.

Breier, M., Kallmuenzer, A., Clauss, T., Gast, J., Kraus, S., and Tiberius, V. (2021). The role of business model innovation in the hospitality industry during the COVID-19 crisis. *International Journal of Hospitality Management*, *92*, 10272

Bughin, J. and van Zeebroeck, N (2017), New evidence for the power of digital platforms, McKinsey Quarterly, June

Bughin, J and. M. Cincera, (2021), Fear of Going back to work (FOG) and Work from Home (WFH): Assessing the employment allocation under Covid-19, In-cite, working paper, Solvay Business School, March.

Burnard, K. and Bhamra, R. (2011). Organizational resilience: Development of a conceptualframework for organizational responses. International Journal of Production Research, 49(18), pp. 5581-5599.

Cerra, V., & Saxena, S. C. (2008). Growth dynamics: the myth of economic recovery. *American Economic Review*, *98*(1), 439-57.

Cheema-Fox, A., LaPerla, B. Serafeim, G. and Wang, H (2020), Corporate resilience and response during covid-19, Harvard Business School Accounting & Management Unit Working Paper No. 20-108

Chen, T., & Lin, C. W. (2020). Smart and automation technologies for ensuring the long-term operation of a factory amid the COVID-19 pandemic: an evolving

fuzzy assessment approach. *The International Journal of Advanced Manufacturing Technology*, *111*(11), 3545-3558

Cros, M, Epaulard, A and Martin, Ph. (2021), Will Schumpeter catch Covid-19 ? Covid Economics, Issue 70, Feb.

Coutu, D. L. (2002). How resilience works. Harvard Business Review, 80, pp. 46-55.

Dahmene, M., Boughrara, A and Slim, S (2021), Nonlinearity in stock returns: Do risk aversion, investor sentiment and, monetary policy shocks matter?." *International Review of Economics & Finance* 71 (2021)676-699.

Davis, S J., Hansen, S. and Seminario-Amez, C. (2020) "Firm-Level Risk Exposures and Stock Returns in the Wake of COVID-19." *Capital Markets: Asset Pricing & Valuation eJournal*

Ding, W ,Levine, R and Lin, Ch. and Xie, W. (2020), Corporate Immunity to the OVID-19 Pandemic National Bureau of Economic Research ", Working Paper 27055, April

Fairlie, R, (2020), The impact of Covid-19 on small business owners: evidence of early-stage losses from the April 2020 current population survey Working Paper 27309, NBER, ,June

Felipe, C. M., Leidner, D. E., Roldán, J. L., and Leal-Rodríguez, A. L. (2020). Impact of is capabilities on firm performance: the roles of organizational agility and industry technology intensity. *Decision Science*

Foulon, B. (2020), Environmental performance and resilience to the covid-19 crisis, ESC Clermont Business School

Gandin I .and Cozza, C. (2019), can we predict firms' innovativeness ? The identification of innovation performers in an Italian region through supervised learning approach, PLos One, June, pp.1-16.

Gelenbe, E., & Wang, Y. (2004). A Trade-off between Agility and Resilience. In *Proceedings of the 13th symposium on artificial intelligence and neural networks* (pp. 209-217).

Gittell, J. H., Cameron, K., Lim, S., and Rivas, V. (2006). Relationships, layoffs, and organizational resilience: Airline industry responses to September 11. *The Journal of Applied Behavioral Science*, *42*(3), 300-329.

Groot, S. P. T., J. L. Mohlmann, J. H. Garretsen and de Groot, H. (2011), 'The crisis sensitivity of European countries and regions: stylized facts and spatial heterogeneity,' Cambridge Journal of Regions, Economy and Society, 4(3), 437–456.

Hamel, G. and Valikangas, L. (2003). The quest for resilience. Harvard Business Review, 81(9), pp. 52-65

Helfat, C.E. (1997), Know how and asset complementarity and dynamic capability accumulation : the case of r&D, Strategic Management Journal, 18(5), 339-360.

Iansiti, M. and Levien, R (2004), Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability Cambridge,MA: Harvard Business School Press

Jacobides MG, Cennamo C, Gawer, A (2018) Towards a theory of ecosystems. Strategic Management Journal 39: 2255-2276

Jutnner, U and Maklan, S (2011), Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management: An International Journal*.

Lee, C., Sung, T. (2005), Schumpeter's legacy: A new perspective on the relationship between firm size and R&D, Research Policy, 34, pp. 914–931.

Linnenluecke, M. K. (2017). Resilience in business and management research: A review of influential publications and a research agenda. *International Journal of Management Reviews*, *19*(1), 4-30

Martin, R. and Sunley, P (2015), 'On the notion of regional economic resilience: conceptualization and explanation,' Journal of Economic Geography, 15(1), 1–42

Meyer, A. D. (1982). Adapting to environmental jolts. Administrative Science Quarterly, 27,pp. 515-537.

Mukanjari, S., & Sterner, T. (2020). Charting a "green path" for recovery from COVID-19. *Environmental and Resource Economics*, *76*(4), 825-853.

Naidoo, V. (2010). Firm survival through a crisis: The influence of market orientation, marketing innovation and business strategy. *Industrial marketing management*, *39*(8), 1311-1320.

Naudé, W. (2020). Entrepreneurial recovery fromCOVID-19: decentralization, democratization, demand, distribution, and demography.

Nelson, R. and Winter, S. (1982). An Evolutionary Theory Of Economic Change, the University of Chicago Press.

OECD, (2012), Innovation in the crisis and beyond, in : OECD Science and technology outlook 2012.

Ollagnier, J.M, Berjoan, S., Bughin, J. and Xiong, Y. (2021) Why fixing the planet is also about seizing business opportunities, European Business Review, MarchParker, H., & Ameen, K. (2018). The role of resilience capabilities in shaping how firms respond to disruptions. *Journal of Business Research*, *88*, 535-541.

Perez, C. (2004). Technological revolutions, paradigm shifts and socio-institutional change. *Globalization, economic development and inequality: An alternative perspective*, 217-242.

Raj, M., Sundararajan, A., & You, C. (2020). COVID-19 and digital resilience: Evidence from Uber Eats. *arXiv preprint arXiv:2006.07204*.

Reinhart, C. M., & Rogoff, K. S. (2008). Is the 2007 US sub-prime financial crisis so different? An international historical comparison. *American Economic Review*, *98*(2), 339-44.

Riom, C and Valero, A. (2020), The business responses to covid-19: the CEP-CBI survey on technlogy adoption, Lobdon School of Economics, working paper CEPCOVID-19-009, Sept.

Sharma, D. , Bouchaud, JP., Gualdi, S., Tarzia, M and Zampon, R. (2020), V -, U -, L - or W-shaped economic recovery after COVID-19? Insights from an agent-based model, Covid Economics, July 30

Škare, M., and Soriano, D. R. (2021). A dynamic panel study on digitalization and firm's agility: What drives agility in advanced economies 2009–2018. *Technological Forecasting and Social Change*, *163*, 120418.

Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. Research in Organizational Behavior, 14, pp. 231-266.

Wang, Y., Hong, A., Li, X., and Gao, J. (2020). Marketing innovations during a global crisis: A study of China firms' response to COVID-19. *Journal of Business Research*, *116*, 214-220.

Wenzel, M, Stanke, S and Lieberman, M. (2020), strategic responses to crisis, Strategic Management Journal,41, v7-V18

Woods, David D. The strategic agility gap: How organizations are slow and stale to adapt in turbulent worlds. In : *Human and Organisational Factors*. Springer, Cham, 2020. p. 95-104.

Xiao, J. R. Boschma and Andersson, M. (2018), Resilience in the European Union: the effect of the 2008 crisis on the ability of regions in Europe to develop new industrial specializations, Vol. 27, No. 1, 15–47

Zoller-Rydzek, B., & Keller, F. (2020). COVID-19: guaranteed loans and zombie firms. *CESifo Economic Studies*, *66*(4), 322-364.

Appendix 1 : Questionnaire extract

General

Primary industry your organization (or business unit) operates in?

Split of your company's revenue by region

Global organization revenue in the latest financial year

Percentage split B2B, B2C, B2B2C of your business

Revenue and profit evolution

Expected form of recovery in the next 12 months?

Annual revenue evolution and operating margin(EBIT)

In the past 3 years before COVID-19

In the past 6 months during COVID-19

In the next 6 months

In the next 12 months

Priorities

Priorities driving strategy in next 3 years

Growth achievement by the end of 2021

Actions taking in the next 6 months to achieve 2021 growth

Main barriers to achieving your recovery/growth goals

Organizational fit

Agility of organization's culture provision to meet growth

Agility level (Speed of decision making, flexibility of making changes , Entrepreneurial spirit, Efficiency)

Digital technology maturity

Digital state of adoption (pilot, scaling, scaled up)

Level of investments in each of these technologies (Artificial intelligence (AI) technologies, Blockchain Cloud-based (ERP) technologies , Data storage technologies and tools, Machine learning tools, Predictive data analytics , Robotic process automation (RPA), workflow automation, and optimization technologies, Data security and privacy solutions ,Edge computing/Fog computing, Augmented Reality (AR)/Virtual Reality (VR),Quantum computing, Internet of Things, 5G, Big data advanced analytics)

Ecosystem business model use

Adoption

Revenue share associated with ecosystem)

Sustainable business practices

ESG (Environmental, Social, Governance) performance
Action in place for adopting and scaling sustainable business practices?

Leadership position for sustainable business agenda

Adoption (pilot, scaling, scaled up) in terms of

1. Increase procurement of resources and materials with lower environmental footprint
2. Switch to renewable energy
3. Deploy resource and energy efficiency measures in your operations
4. Reduce emissions of company vehicles (e.g. by adopting electric vehicles)
5. Reduce the carbon footprint of IT systems and technology investments
6. Adopt sustainable design principles to reduce the environmental footprint of your products/services (e.g. by increasing recyclability and durability)
7. Launch new products and services that deliver environmental and/or social benefits
8. Adopt product-as-a-service/leasing business models
9. Offer services to enable reuse and second life applications of products
10. Collaborate with suppliers and waste management companies to increase recovery and recycling of products at the end of the lifetime
11. Orchestrate reverse logistics for recycled, secondary materials
12. Work with suppliers to improve their sustainability footprint throughout the supply chain (e.g. reducing environmental impacts, improving labor conditions)
13. Initiate partnerships and build consortia for developing innovative sustainable solutions

Link digitization and sustainability

Top 5 technologies supporting adoption sustainable business practices?

Extent digital technologies help achieve sustainable business practices?

Circular economy platform play

Innovation related initiatives.

Innovation as a percentage of revenue (before the COVID-19 crisis (2020) and in rebound phase (next 12 months)
Innovation allocation (Incremental innovation: enables small improvements on existing offerings; breakthrough innovation: Enables new product or service variations, using a new technology (e.g. the first iPhone), disruptive innovation: Enables an entirely new offering to address an unmet need (e.g. High-speed transport such as Hyperloop)

Table 1a: Industry and country sample, %

Sectors		**Countries**		**Respondents**	
Banking	7	United States	34	Chief Executive Officer	15
Media/Entertainment	7	Australia	9	CS Officer/CIO	15
Health	7	Japan	9	CTO	15
Industrial Goods	7	Germany	7	COO	13
Insurance	7	Spain	7	CMO	13
Pharma/Life Sciences	7	France	7	CHRO	13
Software/Platforms	7	UK	7	CDO/CAO	3
Airline/Transport	5	Italy	7		
Consumer Goods	5	Canada	4		
Retail	5	China	4		

Note: 16 sectors, only top 10 sectors and countries displayed
Source: Accenture Research, Covid-19-resilience, 2020, wave 3, 4100 firms

Table 1b: Global features of sampled firms, % firms

Globalisation distribution pre-Covid,	
	Outside own continent
Asia	47
Europe	13
US	18
Revenue distribution pre Covid, % firms	
$500 to $999 million	6
$1 to $10 billion	67
$10.1 to $30 billion	24
$30.1 to $50 billion	2
Greater than $50 billion	1

Source Accenture Research, Covid-19 resilience, 2020, wave 3, 4100 firms

Table 2: Profit resilience, %

		probability of	
Pre-covid performance	size	recovering	not recovering
Lower performance pre-Covid	45	27	73
Higher performance pre-Covid	55	42	58
High level industry domain			
pharma/lifescience	16	51	49
Service	12	39	61
Tech	10	34	66
Consumer	10	28	72
financial services	21	25	75
manufacturing	16	22	78
Resources	15	19	81

Note: 7 domains aggregated out of 16 industries; resilience based on operating profit metric, expected by sept 2021 or revised latest; pre-covid performance is average of 2017 to 2019.

Source: Accenture Research, Covid-19 resilience, 2020, wave 3, 4100 firms

Table 3: Corporate agility statistics, %

Agility dimensions			
Organizational agility:			
	No	Yes	
	33	67	
Technical agility:			
	Low	Medium	High
Speed	5	54	41
Flexibility	4	56	40
risk taking	6	62	33

Note: organizational agility is based on answer to the question- Is your organization's culture provision sufficiently agile to reallocate talen
to recover/meet new growth, technical agility level is based on questions regarding Speed of decision making, flexibility of makin
changes, and prevalence of entrepreneurial spirit,
Source Accenture Research, Covid-19 resilience, 2020, wave 3, n-4100 firms

Table 4a: Corporate digital maturity, %

	Scaled	Scaling	Total
Frontier tech			
AI	51	29	80
Cloud	49	32	81
IoT	41	37	78
Cybersecurity	39	41	80
data storage	37	40	77
Machine learning analytics	29	42	71
edge computing	24	44	68
Blockchain	20	34	54
quantum computing	20	40	60
5G	18	28	46
RPA	18	32	50
AR/VR	15	27	42

Note: Only frontier tech displayed
Source: Accenture Research, Covid-19 resilience, 2020, wave 3, n-4100 firms

Table 4b: Corporate sustainabilitymaturity, %

Sustainability initiatives	Scaled	Scaling	Total
Increase procurement of resources and materials with lower environmental footprint	27	44	71
Launch new products and services that deliver environmental benefits	28	43	71
Reduce the carbon footprint of IT systems and technology investments	28	43	71
increasing recyclability and durability	27	44	71
Work with suppliers to improve sustainability footprint	27	43	70
Deploy resource and energy efficiency measures in your operations	26	45	71
Collaborate with suppliers to increase recycling of products	25	43	68
Adopt product-as-a-service/leasing business models	26	42	68
Offer services to enable reuse of products	26	41	67
Initiate partnerships and build consortia for developing innovative sustainable solut	26	43	69
Reduce emissions of company vehicles (e.g. by adopting electric vehicles)	25	42	67
Switch to renewable energy	24	43	67
Orchestrate reverse logistics for recycled, secondary materials	24	40	64

Source: Accenture Research, Covid-19 resilience, 2020, wave 3, 1100 firms

Table 5: Corporate resilience Predictive performance comparison , %

Metric	Logistic Regression	Decision Tree	Bagged Trees	RF	GBM	NN
Accuracy	0.76	0.76	0.77	0.78	0.78	0.77
Sensitivity (resilience)	0.40	0.46	0.60	0.57	0.57	0.61
Specificity (non resilience)	0.93	0.89	0.85	0.88	0.87	0.84
Kappa	0.37	0.38	0.46	0.47	0.45	0.46
AUC	0.83	0.79	0.85	0.86	0.84	0.84

Note:RF: Random Forest; NN: Neural Network; GBM= Gradient Boost Prediction based on 1230 firms (30%). RF based on 500 trees process

Source: Accenture Research, Covid-19 resilience, 2020, wave 3,

Table 6: Profit resilience logistic regression fit

Antecedents	coefficients	P-value		coefficients	P-value
direct effects			indirect effects		
agility culture	11,23	0,00%	agility cuture with:		
tech score	0,64	3,21%	agility technical	-0,28	3,08%
ecosystem role	5,34	6,92%	Sus-core	-0,66	8,28%
agility tech change	0,41	3,21%	ecosystem revenue increase	-1,46	0,21%
Innovation intensity increase '	3,91	2,56%	innovation intensity increase	-1,6	5,01%
			technical agility with		
			Techscore	-0,08	2,49%
			Suscore	0,13	5,26%
			ecosystem role	-0,41	1,98%
			innovation intensity	0,31	2,29%
			ecosystem revenue increase	-0,13	5,32%
			techscore with		
			ecosystem revenue	0,44	0,36%
			suscore with		
			innovation disruption	0,14	0,11%
			innovation intensity	-1,07	0,42%
			innovation disrupt with		
			innovation intensity increase	0,25	9,16%
			ecosystem revenue with		
			innovation intensity	1,61	0,51%
			innovation intensity increase	1,08	9,97%
			ecosystem role with		
			innovation intensity increase	2,72	1,61%
			innovation intensity wirth		
			ecosystem revenue increase	1,48	3,08%

Note: Based on 70% of total sample for the regression fit (2870 firms). Model P-value=0,000; constant=7,5, P-value of 0,22%
Backward-stepwise regression method
Source: Accenture Research, Covid-19 resilience, 2020, wave 3,

Table 7: Traits contribution to corporate resilience, %

Traits	Logistic	RF	Average of all ML techniques
Agility	41	63	55
Ecosystem	35	16	13
Innovation	17	15	21
Twin transformation	7	5	11

Note: Relative contribution computed as contribution to total RMSE reduction of resilience prediction
Source: Accenture Research, Covid-19 resilience, 2020, wave 3

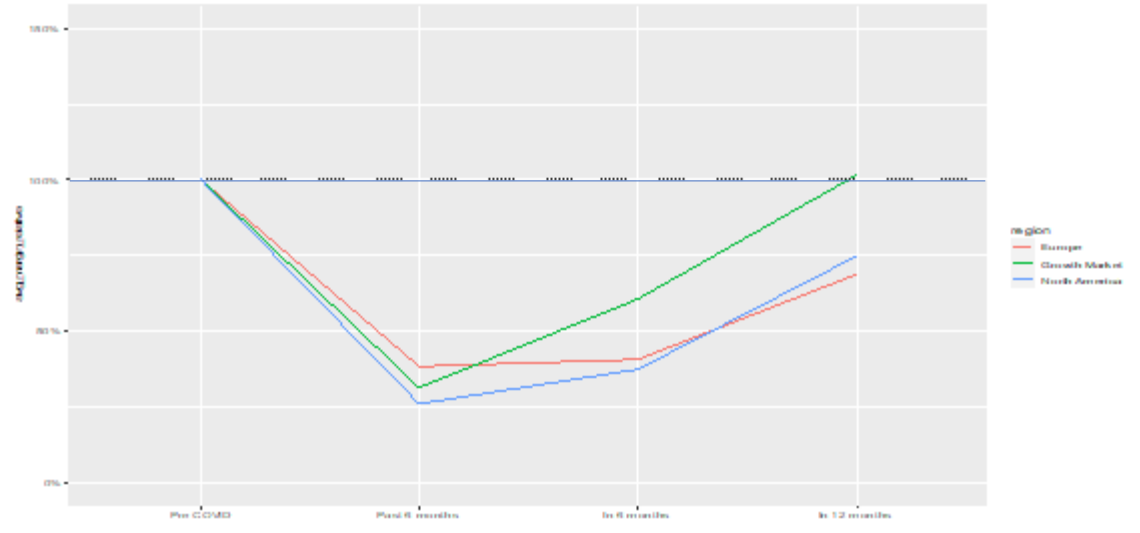
Table 8 : Interaction strength contribution, %

Traits	Pre-covid	Change
Agility	35%	18
Ecosystem	17%	23
Innovation	17%	17
Twin transformation	21%	n.a.

Note: Relative contribution computed as contribution to total RMSE reduction of resilience prediction, based on Random Forest technique in lu

Source: Accenture Research, Covid-19 resilience, 2020, wave 3

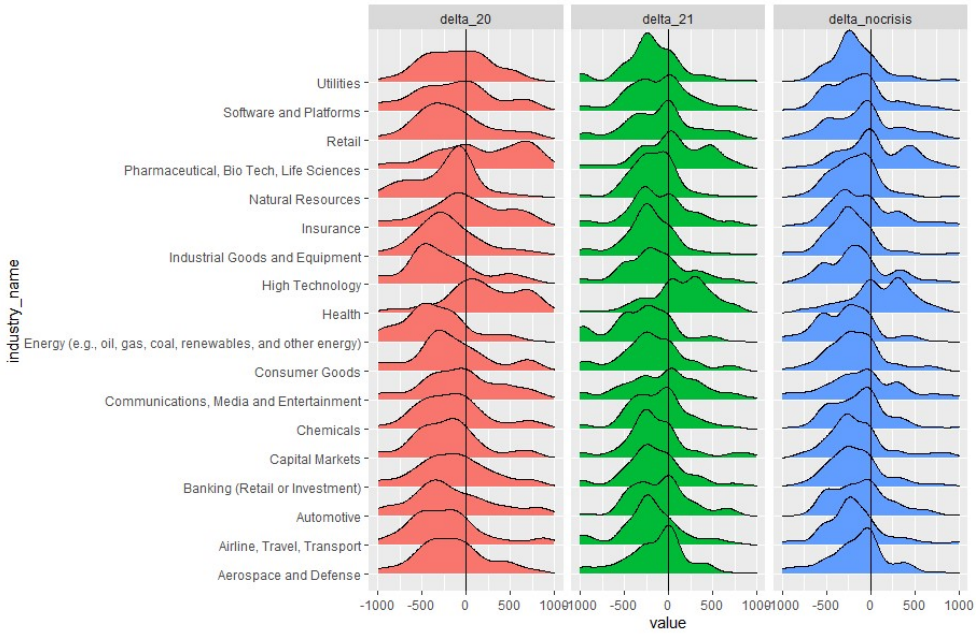
Figure 1: Evolution of profit dynamics, average pro-forma, 100%= average profit achieved last 3 years precov



Note: Simple average of all firms, based on headquarter location

Source: Accenture Research, Covid-19 resilience, 2020, wave 3

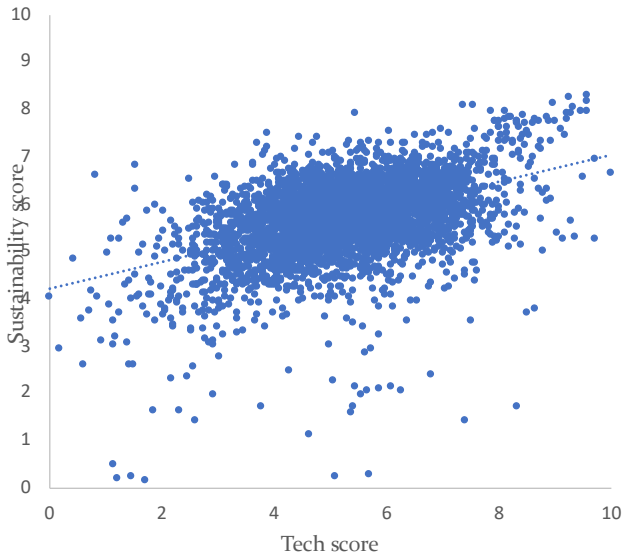
Figure 2 : distribution of profit changes by sector during covid -19 pandemic



Note: Delta 20/21 : profit 2020 /2021 versus average 3 years precovid, Delta no crisis: profit 2021 versus average 3 years precovid boosted by precovid profit growth

Source: Accenture Research, Covid-19 resilience, 2020, wave 3

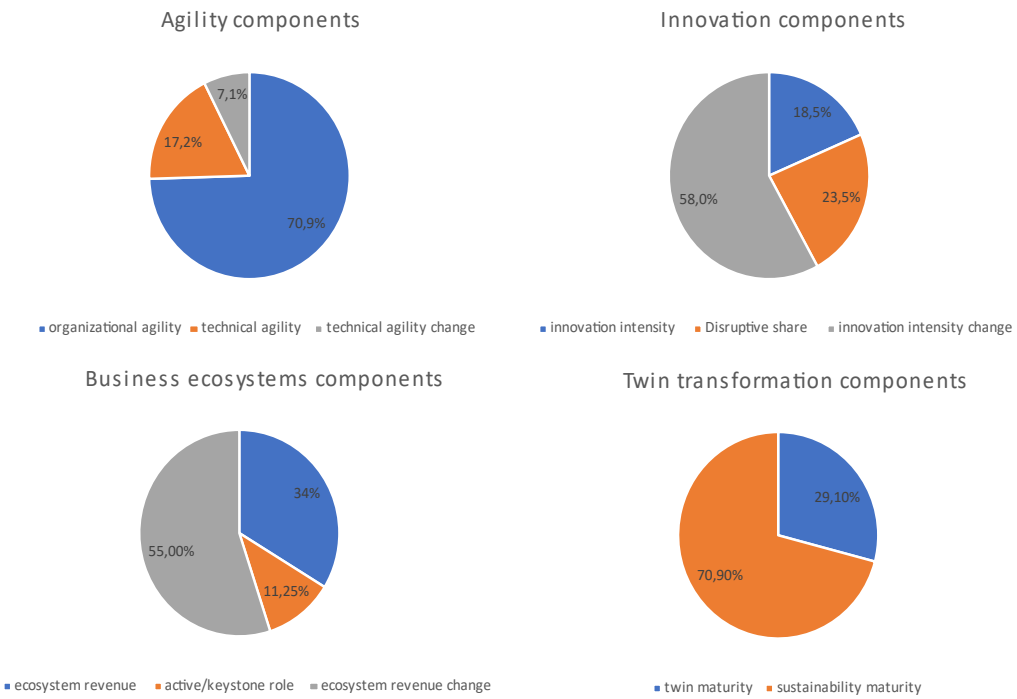
Figure 3 : Correlation digital and sustainability maturity score



Note: Score based on tech and sustainability practice adopted weighted by level of scalability. Maximum score normalized at 10.

Source: Accenture Research, Covid-19 resilience, 2020, wave 3, n-4100 frims

Figure 4 : Antecedents of corporate resilience, %



Note: Computed based on the average of all machine learning methods, based on contribution to RMSE reduction
Source: Accenture Research, Covid-19 resilience, 2020, wave 3

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