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Speed of External Technology Transfer and SME Resilience During Crisis

Abstract

Purpose – Research on how quickly SMEs source and integrate new technology during crises is scant, despite an assumption that speed is important for an SME's ability to cope. Rapid technology transfer may be subject to time compression diseconomies, where accelerating the process becomes less efficient. This study examines how the speed of technology transfer during a crisis impacts two components of SME resilience: response and recovery.

Design/methodology/approach – A questionnaire survey comprising established scales for speed of technology transfer, response and recovery was administered in France during the Covid-19 pandemic. The sample was made up of 229 SMEs operating in a variety of sectors and industries.

Findings – The effect of the speed of technology transfer on resilience depends on the similarity between the source and the SME, as reflected in (1) other firms vs. universities, and (2) technology sources located in the same country as the SME vs. those located in other countries. Results reveal differentiated effects in terms of the relationship between speed of technology transfer and an SME's capability to respond vs. recover.

Originality/value – This research is among the first to examine the effects of the speed of technology transfer on two components of resilience – response and recovery – with a focus on SMEs. It contributes by showing the differential impact of technology transfer speed from various sources on SME resilience.

Practical implications – SMEs should be prepared to use the speed of technology transfer during crises, drawing on relationships with firms and universities as technology providers differently, depending on resilience goals. SMEs should be aware that rapid technology transfer from sources in the same country may be more beneficial for resilience capabilities during a global crisis compared to rapid technology transfer from foreign sources.

Key words: SME; resilience; disruption; response; recovery; speed of technology transfer

1. Introduction

Small and medium-sized enterprises (SMEs) are important actors in modern entrepreneurial economies. But their size means they are highly vulnerable to external shocks and disruptions (Branicki et al., 2018; Clemente-Almendros *et al*., 2025; Lim *et al*., 2020). While small size can be advantageous as it allows flexibility and adaptability during a crisis (Kahveci *et al*., 2024), the numbers of small firms affected by macro-level events such as the global financial crisis and the Covid-19 pandemic are far higher than with large firms (Cowling *et al*., 2020; OECD, 2021). Brown *et al*. (2020) reported up to 60% of SMEs in the U.K. were at risk of using all cash reserves during Covid-19. According to Dörr *et al*. (2022), smaller firms were predominantly affected by financial distress in the early stages of the Covid-19 pandemic in Germany and benefited the most from government support.

Research on how SMEs cope with environmental shocks is diverse. It emphasizes the leveraging of social capital and close relational capabilities with stakeholders (Branicki et al., 2018; Herbane, 2019; Salvato *et al*., 2020; Trunk and Birkel, 2022; Williams *et al*., 2020), the ability to reconfigure the business model (Assefa *et al*., 2022), marketing agility (Bhattarai *et al*., 2025), and the spurring on of entrepreneurial action in the presence of crisis (Shepherd and Williams, 2020). These lines of research all suggest that SMEs need to act fast and under time pressure during a crisis. In parallel, a nascent line of research relates to SME adoption and deployment of new or upgraded technology during crisis, i.e., transfer of technology into the firm. Examples include gaining an online presence for the first time (Morris et al., 2022), the adoption of social media platforms (Ashiru *et al*., 2022; Trawnih *et al*., 2021), the adoption of FinTech and cloud computing (Akpan *et al*., 2022) and accelerating digital transformation in the SME (Khurana *et al*., 2022; Tang and Huang, 2023).

SMEs face various challenges when adopting technology under time pressure; it is not always possible to assimilate new technology quickly, let alone during a crisis. Conversely, being too slow to implement new technology could be harmful. Challenges include upfront costs, developing new technical skills, and gaining support from other organizations, advisers and possibly governments (Shaikh *et al*., 2021). As technology transfer involves the transfer of technology-related knowledge (Autio and Laamanen, 1995), the absorptive capacity of the SME may be challenged, i.e., it may struggle to understand, identify, procure, integrate, and deploy new technology under time pressure (Posen and Chen, 2013). This makes the speed of technology transfer (STT) into the firm particularly salient during a crisis. The dilemma is that technology may be needed quickly to deal with the shock, yet an SME may not be able to assimilate and deploy the new technology quickly. Despite an extensive body of literature on technology transfer (see Bengoa *et al*., 2021 and Battistella *et al*., 2016 for reviews), research on the impact of STT on SMEs' resilience is largely unexplored.

According to resilience theory, on the one hand, a firm under stress needs to respond in the short term when a disruptive event occurs (Linnenluecke, 2017; Wenzel *et al*., 2020), demonstrating *immediate* strategic flexibility and adaptation. On the other hand, firms need to recover and build a stronger platform for the more distant future (Korber and McNaughton, 2018; Linnenluecke, 2017; Zighan *et al*., 2022). While technology transfer into the SME has the potential to help in both response and recovery during crises, little is known about the relationship between STT and response and recovery. Technology transfer research typically focuses on innovation performance, knowledge flows, capability building, while crisis research focuses on strategic responses, financial resilience and organisational flexibility. Furthermore, proximity between technology source and recipient affects STT (Boschma, 2005), raising the

question of whether the type of source providing technology to an SME in a crisis plays a role in how STT influences outcomes. To our knowledge, no prior research has simultaneously examined the effect of STT from different types of sources on resilience in SMEs. Addressing this gap is important because crisis conditions amplify costs and time pressures, potentially altering the effectiveness of external sourcing for SME survival.

This study addresses this gap by examining the direct effect of STT from different types of sources on both response and recovery capabilities in SMEs during a global crisis. Using survey data from 229 SMEs collected during the Covid-19 pandemic, the authors test hypotheses that (1) technology source similarity (whether the technology was sourced from other firms vs. universities) and (2) cross-border proximity (whether the technology was sourced from the same country vs. abroad) will differentiate the effect of STT on shorter-term response vs. longer-term recovery. The core mechanism underpinning such differential effects is time compression diseconomies (Dierickx and Cool, 1989), the notion that certain resources and capabilities (such as technological capabilities transferred from external sources) need time to be accumulated and absorbed and that trying to speed up the process will make it less efficient and more costly. Specifically, the authors argue that time compression diseconomies will be more acute when technology is transferred from dissimilar and distant sources. The results show that STT for technology from firms has a positive impact on response but not recovery, whilst STT for technology from universities matters for recovery but not for response. The authors also find that STT for technology sourced from the same country as the SME is more beneficial for responding *and* recovering while STT for technology sourced from abroad has no association with response or recovery.

This study contributes to the literature on SME resilience. Firstly, it shows that STT matters for SMEs' resilience capabilities in a disruptive context – a topic that has not been discussed in any depth both in technology transfer and the SME resilience literatures (Bengoa *et al*., 2021; Dörr *et al*., 2022; Gunasekaran *et al*., 2011; Herbane, 2019; Khurana *et al*., 2022; Lim *et al*., 2020; Williams *et al*., 2020). The findings emphasize the importance of the STT construct as a fruitful research avenue in the SME resilience field. Secondly, the authors present evidence of important nuances in terms of how STT matters for SME resilience. This is most conspicuous regarding the different effects on response versus recovery capabilities, and whether the source of the technology is another firm or a university. The results extend research on the different phases of resilience in time (Conz and Magnani, 2020; Fakhruddin *et al*., 2020; Wenzel *et al*., 2020; Zighan *et al*., 2022), providing encouragement to researchers to be more explicit about the role of STT and its source during different phases of the resilience cycle. Thirdly, the study contributes to the discussion on source similarity and proximity (Boschma, 2005), as far as the speed of technology transfer in SME resilience is concerned. This adds to the literature that underlines proximity to sources of assistance as a vital determinant of resilience capabilities in SMEs (Herbane, 2019; Williams *et al*., 2020).

2. Background and hypotheses

2.1 SME resilience: capabilities that support response and recovery

Scholars note how SMEs are particularly vulnerable economic actors (Dörr *et al*., 2022; Lim *et al*., 2020; Smallbone *et al*., 2012; Williams and You, 2021; Morris et al., 2022), often lacking time and other resources needed to cope with disruptions. They suffer from liability of smallness (Eggers, 2020), resource and liquidity constraints that can be severe. However, they can – and do

– manage to overcome this liability, exhibiting flexibility and agility to navigate and survive crises (Kahveci *et al*., 2024; Pal *et al*., 2014).

Research has used a capabilities-based lens to understand SME resilience and how SMEs overcome liability of smallness. Kahveci *et al*. (2024) identify capabilities in optimizing business models and pursuing technological innovation. Iborra *et al*. (2020) identify ambidexterity as an important driver of resilience in SMEs. These entrepreneurial capabilities include having an underlying learning ability and orientation towards disruptions (Herbane, 2019; Parker and Ameen, 2018). They are regarded as a proactive approach to managing risk (Parker and Ameen, 2018). On the other hand, scholars have emphasized reactive capability and responsiveness: the ability to respond quickly. In times of crisis, the ability of SMEs to react rapidly can be crucial because of resource scarcity and liquidity constraints (Eggers, 2020). Sullivan-Taylor and Branicki (2011) argue that SMEs need to act without delay when crisis unfolds. They describe this as rapidity, an advantage for smaller firms over larger counterparts. Failure to act quickly can be costly for SMEs, if not fatal (Conz and Magnani, 2020).

These proactive and reactive capabilities are echoed by resilience scholars who highlight the distinction between response and recovery; two aspects of a 'resilience cycle' (Ambulkar *et al*., 2015; Fakhruddin *et al*., 2020). Fakhruddin *et al*. (2020) note the conceptual difference between response and recovery. Recovery requires a longer period, an adjustment in political and strategic thinking, and is more holistic in nature. While periods of immediate response to crisis can be associated with despair and uncertainty, recovery is associated with confidence, hope, and optimism (Luthans, 2002). Korber and McNaughton (2018) highlight longer term recovery as one of the key conversations in literature at the intersection of entrepreneurship and resilience. There are also key differences in terms of cost – recovery happens once significant loss has

already occurred (Chowdhury and Quaddus, 2017). Consequently, SMEs first use capabilities to respond – to deal with the immediate crisis at hand – and then different capabilities to build the foundation for recovering in the longer-term.

2.2 Time compression diseconomies, speed of technology transfer, and SME response and recovery

Resource and liquidity constraints mean that SMEs often draw on outside assistance in times of crisis (Williams *et al*., 2020). Increasingly, this dependency on external resources has involved access to new technology – including digital technology (Sinha et al., 2025). This includes new social media platforms (Trawnih *et al*., 2021), emerging digital communication technology (Ashiru *et al*., 2022) and digital transformation, including FinTech, Internet of Things, and cloud computing (Akpan *et al*., 2022; Colovic *et* al., 2025; Khurana *et al*., 2022). The speed with which new technology is adopted and implemented by an SME under duress is a critical factor as SMEs seek to respond and recover from crises (Mavrodieva *et al*., 2019). This is referred to as the speed of technology transfer into the SME, or STT. A limited scholarship has highlighted the importance of STT to resilience during crisis (Mark *et al*., 2009). Immediate response is often facilitated by rapidly altering the use of existing technology (Ashiru *et al*., 2022) or deploying new technology that addresses the effects of the disruption. Recovery can be facilitated by implementing new technology that allows development of new products and services and access to new markets.

A summary of selected recent studies on antecedents of SME resilience is shown in Table 1. While literature highlights general capabilities needed for SMEs to cope with crises and recover, the construct of STT is absent. The role of technology, particularly digital technology adoption and capabilities in digital transformation, is highlighted, albeit not consistently. The

construct of speed is more commonly seen as part of the broader agility of the firm, and not considered in relation to adoption of technology from outside sources.

*** INSERT TABLE 1 HERE ***

A major challenge facing SMEs when adopting technology is the *time* needed to acquire new technical skills and assimilate associated knowledge and support (Shaikh *et al*., 2021). This may involve user assistance, training, and other forms of support given by the technology provider or an intermediary such as a consultant. Indeed, technology transfer requires social exchange between individuals from source and recipient organizations (Battistella *et al*., 2016). In a crisis, the time to absorb the technology from external sources is limited and the challenge of absorbing technology is exacerbated by scarce resources, as SMEs need to address urgent operational issues. The effects of time compression – the inefficiencies and costs of learning under time pressure (Argyres *et al*., 2019; Dierickx and Cool, 1989; Hilmersson and Hilmersson, 2021) – are worsened when firms are smaller, and even more so within a disruptive environment. As Argyres *et al*. (2019, p. 363) note: "Time compression diseconomies apply to the accumulation of any type of asset, including R&D, know-how, reputation, or physical capital." Additional costs and inefficiencies can occur when firms attempt to innovate or accumulate new assets at a faster rate than is ideal for the firm (Dierickx and Cool, 1989). Hence, time compression diseconomies resulting from a high speed of technology transfer can create delays and costs because the assimilation of technology cannot take place in a short period of time. However, it is likely that the effect of time compression diseconomies will be further nuanced depending on the nature of the source from which the technology is transferred.

2.3 Proximity between source and recipient SME

Theory of technology transfer highlights aspects of distance that can hinder transfer between source and recipient, including organizational distance (formal alliances or equity relationships allowing greater internalization), knowledge distance (whether partners possess similar knowledge), physical distance (cost and difficulty of communicating face-to-face), and norm distance (whether partners have similar organizational cultures and values) (Cummings and Teng, 2003). This study focusses on two dominant contextual dimensions: whether the source and recipient are the same type of organization (i.e., close in terms of organizational and knowledge distance), and whether the source and recipient are in the same country (i.e., close in terms of physical and norm distances) (Cummings and Teng, 2003).

Firstly, proximity can be viewed with respect to organizational type: is the source another firm or is it a university? This distinction relates to whether technology sourced is already-commercialized technology (from other firms) or earlier-stage research-led technology (from universities) (Battistella *et al*., 2016). Universities have increasingly commercialized their intellectual property and technological breakthroughs, although this is often untested in mass markets and there are high rates of commercial failure (Siegel *et al*., 2003). When the technology is sourced from other firms, the closeness between source and recipient will facilitate its adoption and assimilation. Firm-to-firm technology transfer will be more efficient under crisis and time pressures compared to university-to-firm transfers (Cummings and Teng, 2003); the recipient SME will not have to deal with issues related to newer, relatively untested university-produced technology. Due to higher proximity, speedy technology transfer from other firms will be less prone to inefficiencies and costs of time compression diseconomies. The SME will be

able to understand and assimilate new technology more quickly and therefore use it in immediate response to the crisis. Conversely, technology sourced from universities will help an SME recover in the longer-term through new product or service innovations. If the technology from universities is transferred quickly (i.e., when STT is high), time compression diseconomies will not arise as far as recovery is concerned because the SME will have enough time to absorb the technology given its expected use in longer-term new product and service development, as opposed to immediate response. In sum, organizational proximity between source and recipient SME will mean STT for technology from firms will be beneficial for immediate response, while STT for technology from universities is more likely to provide a basis for longer-term recovery.

H1a: STT for technology sourced from other firms will be more beneficial for an SME's response to crisis compared with STT for technology sourced from universities.

H1b: STT for technology sourced from universities will be more beneficial for an SME's recovery from crisis compared with STT for technology sourced from firms.

Secondly, proximity between source and recipient can be assessed in terms of cross-border transfer. STT during a time of crisis can be conditioned by whether the source is in the same country as the recipient SME or in a different country. Choosing technology sources from the same country means the SME will not have to contend with cross-national distances that can impact international transfer and assimilation of knowledge. Cross-border knowledge transfer is complex and impacted by different sub-dimensions, including geographic, cultural, institutional, linguistic distances (Shi *et al*., 2025).

Technology sources in the same country as the SME will not only be closer geographically; they will also be similar in cognitive, social, organizational, and institutional dimensions (Boschma, 2005). This will foster trust, boosting tacit knowledge sharing between source and recipient (Battistella *et al*., 2016), and reducing the time needed for the transferred technology and knowledge to be deployed. Social capital, important for knowledge transfer, is more easily built and maintained within national boundaries due to shared cultural and institutional frameworks (Nonino, 2013). Such closeness will be useful for deploying new technology under time pressure when an SME responds to crisis. When the source and recipient are proximate, STT is less likely to incur time compression diseconomies because the communication between the actors will be facilitated by geographic, linguistic, time-zone, and cultural proximity, allowing for speedy assimilation and deployment of technology. Efficient tacit knowledge sharing between source and recipient will help resolve misunderstandings about how new technology is to be configured and adopted (Foos *et al*., 2006).

The challenges and costs associated with cross-border technology transfer can undermine the SME's capability to quickly deploy new technology in response to crisis. However, these delays and costs will be less of a concern for recovery. Because recovery takes place over a longer time horizon, time compression diseconomies based on foreign as opposed to domestic sources will be less troublesome as speed of technology transfer is increased. Technology sourced from abroad may provide access to unique or advanced technologies that can help SMEs innovate and develop new products to position themselves strategically for the longer-term (Conz and Magnani, 2020; Zighan *et al*., 2022).

H2a: STT for technology sourced in the same country will be more beneficial for an SME's response to crisis compared with STT for technology sourced in other countries.

H2b: STT for technology sourced in other countries will be more beneficial for an SME's recovery from crisis compared with STT for technology sourced in the same country.

Figures 1 and 2 show conceptual models for the hypothesized effects. In each case the effect of STT on resilience (response or recovery) is conditioned by reducing time compression diseconomies due to the nature of the source of the technology. The expectation is that more proximate sources will reduce inefficiencies caused by time compression as speed of technology transfer increases.

*** INSERT FIGURES 1 & 2 HERE ***

3. Methodology

3.1 Data source and collection

The data is based on a survey of French SMEs collected during the Covid pandemic. A questionnaire was developed in English, based on established scales for response and recovery, and STT. 5-point Likert scale questions were used to measure the constructs. The questionnaire was set up on an online platform and pre-tested on ten respondents from industry and academia to gain feedback and make changes to the instrument's items, wording and flow. Following this, the questionnaire was revised and translated into French by a bilingual scholar. It was then back-translated by an independent bilingual academic editor, a native English speaker, to ensure the consistency and reliability of the procedure (Brislin, 1986; Cascio, 2012). The questionnaire in

French was then pre-tested again on a different set of 12 respondents from industry and academia in France to ensure all questions were well understood. Following minor changes, the final questionnaire was launched on the online platform. The data collection took place in 2022, between March and September. Convenience sampling was used through networks in which the authors had professional connections: (1) through a regional Chamber of commerce, (2) French biotechnology companies, (3) through an alumni association of a French business school, and (4) additional purposive networking. The questionnaire was sent to companies affiliated with professional associations by the management teams of these associations, with only a rough estimate of targets communicated. The target frame estimate is 4000 to 5000 companies, and the response rate is estimated between 4.6% and 5.7%. The relatively low response rate can be explained by the fact that data was collected in 2022, two years after the pandemic outbreak and that SMEs had already been solicited to respond to surveys about the impact of the pandemic.

In subsequent scale analysis, statistical differences for key variables of interest across the partitions of the data were checked; there were no significant differences. An examination of the correlation matrix conformed to expectations, suggesting the sample is representative. After filtering for firm size (to remove observations from firms over 500 employees and over 250 employees – tests reported below), a final sample of 229 usable responses was obtained, corresponding to French SMEs operating in a variety of industries across France during the Covid pandemic. The sample size is comparable to recent studies conducted on SMEs with a questionnaire survey (Chumnangoon et al., 2023; Nautiyal and Pathak, 2024). It reflects diversity in terms of industries represented and geographic location within France.

3.2 Variables

Dependent variables: Two four-item scales were constructed for response and recovery, drawing on existing operationalizations (Ambulkar *et al*, 2015; Chowdhury and Quaddus, 2017; Golgeci and Ponomarov, 2013). *Response* was constructed from four items indicating capabilities that allow the SME to respond quickly: (1) we have the ability to detect disruptions quickly, (2) we can respond quickly to disruptions, (3) we can undertake adequate response to crisis, (4) we have a response team for mitigating crisis ($\alpha = 0.79$). *Recover* was constructed from items indicating ability to bounce back over a longer-term: (1) we have the ability to absorb huge loss, (2) we can reduce the impact of loss, (3) we can recover from crisis at low cost, (4) we can quickly return to our original state after being disrupted ($\alpha = 0.80$). A rotated principal components factor analysis was used to establish discriminant validity between these two scales. This retained two orthogonal factors with the loadings of items as expected. The factor solution is shown in Table 2.

*** INSERT TABLE 2 HERE ***

Independent variables: The four independent variables for speed of technology transfer (STT) from universities (STT Universities), firms (STT Firms), technology sources in the same country (STT Same country) and technology sources abroad (STT Abroad) were captured using questionnaire items adapted from the speed construct used in Khan *et al*.'s (2015) study. Three header items used were: (1) the rate that new technology is transferred to us from the following organizations is very fast, (2) new technology is transferred to us from the following organizations in a timely fashion, and (3) it takes our company a short time to acquire and implement the technology provided from the following organizations. The sub-lines for different sources were then (1) firms in other countries, (2) firms in this country, (3) universities in other

countries and (4) universities in this country. Consequently, the number of items used for each STT scale was six. For instance, the scale for STT Firms was constructed by the two 'firms' responses for each of the three header items. This design meant that STT Universities and STT Firms always contain exclusive items, and that STT Same country and STT Abroad always contain exclusive items.

Control variables: Controls were used for age and size of the SME (log transformed); these have been argued to influence the firm's ability to cope with disruption (Herbane, 2019). A categorical variable was used to capture 14 different industry types on the questionnaire (plus one variable "Other – please specify") and this was used as a control variable in all models. Industry variables were adapted from the ISIC – International Standard Industrial Classification of all Economic Activities. Family-owned firms may have different resource profiles from non-family-owned firms when coping with crisis, including different successional planning, long-term orientation, and social capital (Chrisman *et al*., 2011). A dichotomous control variable was included to indicate if the SME was a family business. The authors also controlled for whether the SME was publicly listed; listed SMEs will have access to non-bank debt financing instruments (Nassr and Wehinger, 2016). Finally, a control was included for prior performance of the SME using a single item capturing the respondent's perception of outperforming competitors in terms of return on investment. Prior performance can have a path-dependent effect on the ability of firms to cope with disruptions (Khurana *et al*., 2022).

3.3 Analysis

A multiple equation approach is beneficial where residuals may not be independent (Zellner, 1962), this being possible when capabilities for response and recovery are being assessed. A Seemingly Unrelated Regression (SUR) approach was used with two equations for *Response* and *Recover* entered simultaneously. SUR improves estimation efficiency when modelling two interdependent outcomes (response and recovery) is influenced by shared, unobserved factors. The first test was for STT from universities and firms, and the second test was for STT from sources in the same country, versus sources in other countries. The Breusch-Pagan test of independence of residuals was used to confirm this in both tests. For the first test (universities versus firms), chi2 = 54.82 ($p<0.001$), and for the second test (same country versus abroad), chi2 = 51.10 ($p<0.001$). This suggests residuals are not independent and supports the use of SUR. The authors used a size cut-off of 500 employees (US definition) for the main analysis (n=229) and ran tests for a constrained sample with size>10 and <250 (n=160) to be consistent with the EU definition of SMEs. Variance Inflation Factors (VIFs) were also examined in individual regression models, and these were all found to be acceptable and in the range of 2.02 – 2.20.

One limitation of the self-evaluation approach in SME resilience research is that common method bias can influence the reliability of responses, particularly when dealing with the sensitive topic of how the firm copes with crises (Kahveci *et al*., 2024; Troise *et al*., 2022). This raises the chance of social desirability bias, and a tendency amongst raters to respond uniformly (Podsakoff and Organ, 1986). One way to deal with this is by using different data sources for dependent and independent variables. However, there are no externally verifiable secondary data sources that would give quantitative measures for STT at firm level. The authors attempted to reduce social desirability by asking respondents to answer as carefully as possible, while guaranteeing their anonymity and confidentiality. The authors also did not inform respondents

that the study related to perceptions of STT, thereby limiting their ability to second-guess the model (Podsakoff and Organ, 1986). Finally, Harman's single factor test was run on all variables of interest for both partitions of SMEs < 500 employees and < 250 employees. If common method bias is present then one factor would emerge in an unrotated solution, accounting for most of the covariance (Podsakoff and Organ, 1986). It was found that the first factor explained 34.9% of the overall variance, and 34.4% for the smaller partition, less than the 50% threshold. This suggests that common method bias will not affect the interpretation of results.

4. Results

Descriptive statistics and bivariate correlations between variables of interest are shown in Table 3. Response and Recover are positively correlated (r=0.55). None of firm size, age, industry, family owned, or listed status are correlated with either of the two dependent variables. Prior performance is positively correlated with both Response (r=0.36) and Recover (r=0.34), indicative of depth of capabilities and financial assets in the SMEs being useful in crisis situations. All the STT scales (Universities, Firms, Same country, Abroad) are positively associated with Response (0.34 <= r <= 0.45) and Recover (0.17 <= r <= 0.25). As expected, older SMEs are larger (r=0.31), and family SMEs smaller (r=-0.31). Listed SMEs are larger (r=0.19). Prior performance is positively associated with the STT scales (0.25 <= r <= 0.33). Overall, this profile of correlation coefficients is broadly consistent with expectations and suggests a positive role that STT from different sources plays when SMEs respond and recover in a disruptive context.

*** INSERT TABLE 3 HERE ***

Table 4 shows the SUR tests. Model 1 shows the results for the control variables. Here, only prior performance has a significant effect on both Response and Recover. None of the other control variables find significance. This supports the correlation matrix suggesting that prior financial success will give an SME an edge when coping with disruption. It reinforces prior work in the field of SME resilience identifying financial health and liquidity as beneficial in times of crisis (Eggers, 2020; Herbane, 2010; Smallbone *et al*., 2012). Model 2 shows the result for STT from Universities and Firms. There is a positive effect of STT from Universities on Recover, but not on Response, while there is a positive effect of STT from Firms on Response, but not on Recover. This provides support for H1a and H1b, and for the models shown in Figure 1. Higher levels of STT from other firms is beneficial for an SME's capability to respond, while higher levels of STT from universities is positively linked with longer-term recovery.

Model 3 shows the result for STT from sources in the same country versus abroad. STT Same country has significant and positive effects on both Response and Recover, while STT Abroad does not have a significant effect on either. This does not support the right-hand model in Figure 2 and suggests only within-border proximity to the source of new technology transferred into the SME matters for how STT will help the SME in both response and recovery aspects. It supports H2a but not H2b. Overall, higher levels of STT from firms or universities in the same country benefit both response and recovery. Robustness tests in Models 4 and 5 show the results for the constrained sample where size >10 and < 250. The profile of coefficients is the same compared to Models 2 and 3, although the strength of STT Universities on Recover in Model 4 reduces significance to p=0.19.

*** INSERT TABLE 4 HERE ***

5. Discussion

This study examines how the speed of technology transfer (STT) from different sources influences SME resilience under conditions of time compression. The findings contribute to the growing body of work on SME resilience (Dörr *et al*., 2022; Eggers, 2020; Gunasekaran *et al*., 2011; Herbane, 2019; Khurana *et al*., 2022; Lim *et al*., 2020; Williams *et al*., 2020) by uncovering how characteristics of the source of transferred technologies shape how STT influences capabilities for response and recovery. Although previous studies have noted the importance of SMEs' close relationships with external stakeholders for assistance (Herbane, 2019; Salvato *et al*., 2020; You and Williams, 2023), as well as capabilities in digital transformation and IT in strengthening resilience (Kahveci *et al*., 2024; Tang and Huang, 2023), the phenomenon of technology transfer into the SME under during crisis has remained under-researched and under-theorized, despite its recognized importance (Argyres *et al*., 2019; Conz and Magnani, 2020; Dierickx and Cool, 1989; Fakhruddin *et al*., 2020; Hilmersson and Hilmersson, 2021).

These deficits are surprising given the growing evidence of the role of new or emerging technology adoption by SMEs during crisis (Akpan *et al*., 2022; Ashiru *et al*., 2022; Khurana *et al*., 2022; Trawnih *et al*., 2021). The connection between STT and resilience is also an under-investigated issue in technology transfer literature (Battistella *et al*., 2016; Bengoa *et al*., 2021). By bringing these two literature streams together, this study highlights the time compression issues that SMEs face when sourcing and deploying new technology (Posen and Chen, 2013; Shaikh *et al*., 2021). The authors build on different literatures – SME resilience (Dörr *et al*., 2022; Gunasekaran *et al*., 2011; Herbane, 2019; Khurana *et al*., 2022; Lim *et al*., 2020; Williams

et al., 2020), technology transfer (Akpan *et al*., 2022; Battistella *et al*., 2016; Posen and Chen, 2013; Shaikh *et al*., 2021) and time compression diseconomies (Argyres *et al*., 2019; Hilmersson and Hilmersson, 2021) – to develop an original framework that explains the impact of STT from different sources on SME resilience. The core mechanism is time compression diseconomies, which is used to hypothesize a differential impact of STT from different sources on SMEs' response to and recovery from crisis.

The findings align with and extend prior research. The positive impact of firm-sourced technologies on response supports earlier studies emphasizing relational proximity and shared routines as enablers of resilience (Herbane, 2019; Salvato et al., 2020). However, the present study advances this by showing that it is not only the presence of external ties that matters, but also proximity between the organizations involved. Conversely, the positive influence of university-sourced technologies on recovery supports evidence that collaborations with knowledge institutions foster longer-term innovation and adaptive learning (Akpan et al., 2022; Ashiru et al., 2022). This study refines the SME resilience literature by demonstrating that technology sources matter: commercialized technologies from firms enhance shorter-term continuity, whereas research-based technologies from universities align with longer-term renewal.

The non-significant effects of cross-border technology transfer contrast with studies highlighting the benefits of global knowledge diffusion for digital transformation (Kahveci et al., 2024; Tang and Huang, 2023). This divergence can be explained by time compression diseconomies (Argyres et al., 2019; Dierickx and Cool, 1989), which become more acute when SMEs attempt to absorb technologies from foreign sources under crisis conditions. This result supports the argument that differences in institutional frameworks, legal environments, and trust

networks increase assimilation costs and put boundaries on the speed with which external knowledge can be operationalized (Boschma, 2005).

5.1 Implications for Theory

The present study brings new concepts into SME resilience literature by incorporating time compression diseconomies. First, it extends understanding of how SMEs cope in disruptive contexts not only on the assimilation of new technology, but on the speed with which it is assimilated. It expands understanding of determinants of SME resilience that have not been identified in previous work (e.g., Dörr *et al*., 2022; Eggers, 2020; Lim *et al.*, 2020; Smallbone *et al*., 2012; Williams and You, 2021). Time criticality is encapsulated into models of the resilience lifecycle (Conz and Magnani, 2020; Fakhruddin *et al*., 2020; Wenzel *et al*., 2020; Zighan *et al*., 2022). However, its application to SMEs, particularly in relation to the impact of STT on resilience, has been overlooked (Korber and McNaughton; 2018; Linnenluecke, 2017).

Second, the study contributes to phase-based understanding of resilience. Findings highlight nuanced yet important differences between the capabilities required for immediate response to crisis, and those needed for longer-term recovery. The technology source acts as a vital qualifier of the relationship between STT and different phases of the resilience cycle because of the extent of its proximity to the SME. Building on existing literature that differentiates between different phases of coping with adversity over time (Conz and Magnani, 2020; Fakhruddin *et al*., 2020; Wenzel *et al*., 2020; Zighan *et al*., 2022), this analysis reveals that the impact of different technology sources (firms vs. universities) can vary across these phases.

Third, the study advances understanding of how proximity and source characteristics influence SME resilience. Building on insights from geographical and institutional proximity in

technology and knowledge transfer (Battistella *et al*., 2016; Cummings and Teng, 2003; Foos *et al*., 2006; Siegel *et al*., 2003), the findings show the distinct effects of different technological sources (firms vs universities, same country vs other countries) on the relationship between STT and resilience capabilities in SMEs. This suggests that proximity acts as an enabler of resilience, allowing SMEs to overcome time compression and absorptive capacity constraints by reducing coordination costs, regulatory frictions, and cognitive distance. The findings for H2 suggest that under crisis conditions, even longer-term recovery may depend more on proximate, trusted, and institutionally familiar technology sources than on more distant foreign sources.

5.2 Implications for SME managers

Implications for SME managers emanate from this study. First, managers can reflect on the traditional assumption that faster technology transfer is always beneficial during crises. While speed can enhance short-term response, crises also increase coordination costs, strain absorptive capacity, and reduce the time available for organizational learning. Managers should balance urgency with integration capability when managing STT for resilience building. They can review routines and resources necessary for STT, including scanning for - and appraisal of – technology sources, maintaining an information repository or knowledge management system for these sources, and identifying and dealing with obstacles that could hinder STT, including organizational culture and incentive systems for key employees.

Second, SME managers must recognize time compression as a vulnerability during crises. Limited slack resources, lower redundancy and reliance on external knowledge mean that rapid technology adoption can overstretch organizational capacity. Managers should be aware of time compression diseconomies as a specific vulnerability and recognize that urgency to deploy new

technology will interact with source characteristics. Addressing this vulnerability may involve making trade-offs between fast-to-implement firm-sourced technology, and slower-to-implement university-based technology. Before attempting to accelerate inward technology transfer, SME managers should ensure that internal processes for procurement account for the nature of technology sources.

Third, managers should acknowledge resilience objectives when considering source selection for new technologies under crisis conditions. If the goal is immediate operational continuity, speed will play a more prominent role, and technology sources from other firms, or sources located in the same country may offer benefits. However, if the objective is sustainable recovery and long-term repositioning, deeper integration and learning may be more important and sources in universities can be considered. Crisis strategy should align technology transfer speed with technology sources and resilience goals rather than adopting a uniform 'move fast' approach.

5.3 Limitations and future directions

This study has limitations and provides new research avenues. First, the French sample may bias the interpretation of results, especially in countries with weaker public R&D infrastructure or fewer university-industry collaborations. National culture, especially attitudes towards change, risk and entrepreneurship, could skew the interpretation of results, as countries recognized as having a higher entrepreneurial culture than France (e.g., United States or United Kingdom) may naturally emphasize STT. The present study can be replicated using multiple samples from different countries. Second, the study does not capture how micro-processes within the firm exhibit the effects of time compression during the crisis. It does not directly measure assimilation costs, learning overload, implementation strain, coordination inefficiencies, integration failure, or

other indicators of time compression diseconomies. Future studies using rich qualitative data, diary methods and case studies can explore the phenomenon at a micro-level and capture direct observations and context-specific examples of time compression diseconomies. Third, STT may impact resilience capabilities in stable times, not just during crisis. Future research could compare the effects of STT in stable times vs crisis. Fourth, the authors did not assess other mechanisms that may impact inter-organizational knowledge transfer, especially cross-national distance. It would be meaningful to take a more fine-grained approach to examining technology sourcing from organizations based in foreign countries, considering sub-dimensions of cross-border distance. Finally, the STT sources used may capture both source-specific effects and a general perception towards rapid external technology acquisition. Future work can test whether STT is best represented as a multidimensional construct with source-specific dimensions, or as a higher-order construct with nested source effects.

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TABLES

Article	Topic	Method	Findings	Examines technology transfer into the SME in a time of crisis?	Examines time compression or speed of tech transfer?
Pal et al. (2014)	Antecedents of economic resilience	Mixed-methods approach: a survey followed by interviews with 8 textile SMEs in Sweden	Resourcefulness, relational networks and material assets, along with 'dynamic competitiveness' through strategic and operational flexibility are enablers of resilience and financial performance. Indirect influence of 'soft' learning and cultural aspects such as attentive leadership and collectiveness on economic resilience.	Not directly, but technological capabilities are found to influence resilience.	No
Iborra et al. (2020)	Impact of ambidexterity and strategic consistency on resilience of SMEs	Quantitative analysis on a dataset of 2765 Spanish manufacturing SMEs	Positive effect of organizational ambidexterity on resilience (resistance to crisis and recovery from crisis). Supports the positive role of strategic consistency in recovering but not in resistance. Resilience influenced by interaction between ambidexterity and strategic consistency.	No	No
Trunk and Birkel (2022)	How SMEs combine contractual and relational investments across their supply chain flows of product, finance and information to improve resilience	Multiple case study approach of eight German SMEs	Companies that made the largest investments in relational aspects of their partnerships while safeguarding product and financial flows perform best. The combination of contractual and relational investments depends on the business model, the business philosophy of the CEO, and the allocation of power within the supply chain.	Partially, investment in technology resources is considered important for resilience.	No
Troise et al. (2022)	Navigating VUCA: Antecedents of agility (digital technologies capability, relational capability and innovation capability)	Survey of 204 SMEs in Italy	Digital technologies capability, relational capability and innovation capability are significant antecedents of organisational agility in navigating VUCA environments.	No, but digital technology application (e.g., Blockchain, cloud computing) considered part of	Speed of adoption of latest technological innovations is considered one

Article	Topic	Method	Findings	Examines technology transfer into the SME in a time of crisis?	Examines time compression or speed of tech transfer?
	and the influence of agility on financial performance, product and process innovation			digital technology capability.	element of process innovation
Morris et al., (2022)	Digital connectivity of SMEs in rural areas and how this influences economic resilience	Questionnaire sample of 110 SMEs in Wales	Proximity to urban areas important for digital connectivity; rural SMEs are at a disadvantage.	No, but mentions adoption of technology as being important for diversification in uncertain times.	No, but mentions speed of adoption of ICT
Tang and Huang (2023)	Influence of digital transformation on the resilience and sustainability of tourism companies	Quantitative analysis performed on 43 tourism companies in China	Digital transformation mitigates the negative impact of the Covid-19 pandemic on resilience. Effect is consistent across company sizes.	Yes, adoption of digital technologies positively related to resilience.	No
Kahveci et al. (2024)	How crisis response strategies are related to flexibility and digitalisation during and after the pandemic	Survey of 206 SMEs in manufacturing and services industries in Turkey	Crisis response strategies mediate the impact of strategic flexibility, digitalisation, digital technology adoption, and Covid-19 perception on firm strategy after the pandemic.	Yes, implicitly. Digital technology adoption positively influences crisis response strategy but not firm strategy after the pandemic.	No
Sinha et al. (2025)	How digitalization influences SME resilience during a crisis	Survey of 245 US SMEs	SMEs leverage digital tools for resilience; digital scope and depth have curvilinear effects on resilience.	Yes, implicitly. Digital scope is count of digital technologies adopted by the SME; digital depth proxied through level of digital expertise.	No, but mentions the "rapid development of digital technology strategies" (p. 223)

Table 1. Selected recent empirical studies on SME resilience

Item	Factor 1 Immediate Response	Factor 2 Future Recovery	Uniqueness
We have the ability to detect disruptions quickly	**0.79**	0.07	0.38
We can respond quickly to disruptions	**0.83**	0.27	0.24
We can undertake adequate response to crisis	**0.84**	0.22	0.25
We have a response team for mitigating crisis	**0.56**	0.30	0.59
We have the ability to absorb huge loss	0.11	**0.83**	0.30
We can reduce the impact of loss	0.37	**0.78**	0.25
We can recover from crisis at low cost	0.13	**0.85**	0.27
We can quickly return to our original state after being disrupted	0.45	**0.59**	0.45

Sources: Ambulkar et al, 2015; Chowdhury and Quaddus, 2017; Golgeci and Ponomarov, 2013

Table 2. Principal components factor solution

	Mean	Std.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Response (1)	3.41	0.75											
Recover (2)	3.11	0.81	0.55										
Employees (ln) (3)	3.49	1.41	0.03	0.08									
Age (ln) (4)	3.19	1.09	-0.06	0.07	0.31								
Industry (5)	8.99	4.92	-0.07	-0.10	0.02	0.12							
Family (6)	0.36	0.48	0.01	0.02	-0.31	-0.15	0.01						
Listed (7)	0.06	0.23	-0.03	0.00	0.19	0.00	-0.05	-0.11					
Prior Performance (8)	3.14	0.90	0.36	0.34	-0.09	-0.06	-0.02	0.07	-0.08				
STT Universities (9)	3.00	0.77	0.36	0.24	0.04	0.05	-0.05	-0.02	0.01	0.27			
STT Firms (10)	3.01	0.77	0.43	0.18	-0.11	-0.09	-0.04	0.11	-0.04	0.32	0.70		
STT Same country (11)	3.01	0.77	0.45	0.25	-0.01	0.01	-0.06	0.07	0.00	0.33	0.83	0.84	
STT Abroad (12)	2.80	0.83	0.34	0.17	-0.04	-0.04	-0.03	0.01	-0.03	0.25	0.86	0.84	0.67

n=229

Table 3. Descriptive information and correlations

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Response	Recover	Response	Recover	Response	Recover	Response	Recover	Response	Recover
Employees (ln)	0.05	0.06	0.05	0.05	0.04	0.05	-0.07	0.05	-0.10	0.03
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.06)	(0.07)	(0.06)	(0.07)
Age (ln)	-0.04	0.05	-0.03	0.05	-0.04	0.05	-0.05	-0.01	-0.05	-0.00
	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Industry	-0.01	-0.02*	-0.01	-0.02*	-0.01	-0.01*	-0.01	-0.02	-0.01	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Family	0.00	0.06	-0.02	0.07	-0.03	0.05	-0.16	0.11	-0.19	0.09
	(0.10)	(0.11)	(0.09)	(0.11)	(0.09)	(0.11)	(0.13)	(0.14)	(0.12)	(0.14)
Listed	-0.07	0.03	-0.08	0.02	-0.10	0.01	-0.16	-0.06	-0.18	-0.07
	(0.20)	(0.22)	(0.19)	(0.22)	(0.19)	(0.22)	(0.21)	(0.23)	(0.20)	(0.23)
Prior Performance	0.30***	0.31***	0.20***	0.28***	0.19***	0.27***	0.18**	0.28***	0.17**	0.28***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)
STT from Universities			0.08	**0.15***			0.10	0.13		
			(0.08)	**(0.09)**			(0.11)	(0.12)		
STT from Firms			**0.29*** **	-0.02			**0.23** **	-0.01		
			(0.08)	(0.10)			**(0.11)**	(0.12)		
STT from same country					**0.32*** **	**0.15***			**0.36*** **	**0.17** (p=0.11)
					(0.08)	**(0.09)**			**(0.09)**	**(0.11)**
STT from abroad					0.05	-0.00			-0.02	-0.05
					(0.07)	(0.08)			(0.09)	(0.10)
Cons	2.52***	1.91***	1.69**	1.67***	1.74***	1.60***	2.47***	1.86***	2.56***	1.89***
	(0.25)	(0.28)	(0.28)	(0.37)	(0.27)	(0.31)	(0.41)	(0.47)	(0.41)	(0.47)
R2	0.13	0.13	0.26	0.16	0.26	0.16	0.24	0.16	0.26	0.16
N	229	229	229	229	229	229	160	160	160	160

*p<0.1, **p<0.05, ***p<0.001; standard errors in brackets; STT = speed of technology transfer

Table 4. Results of multiple equation tests using Seemingly Unrelated Regression (SUR)

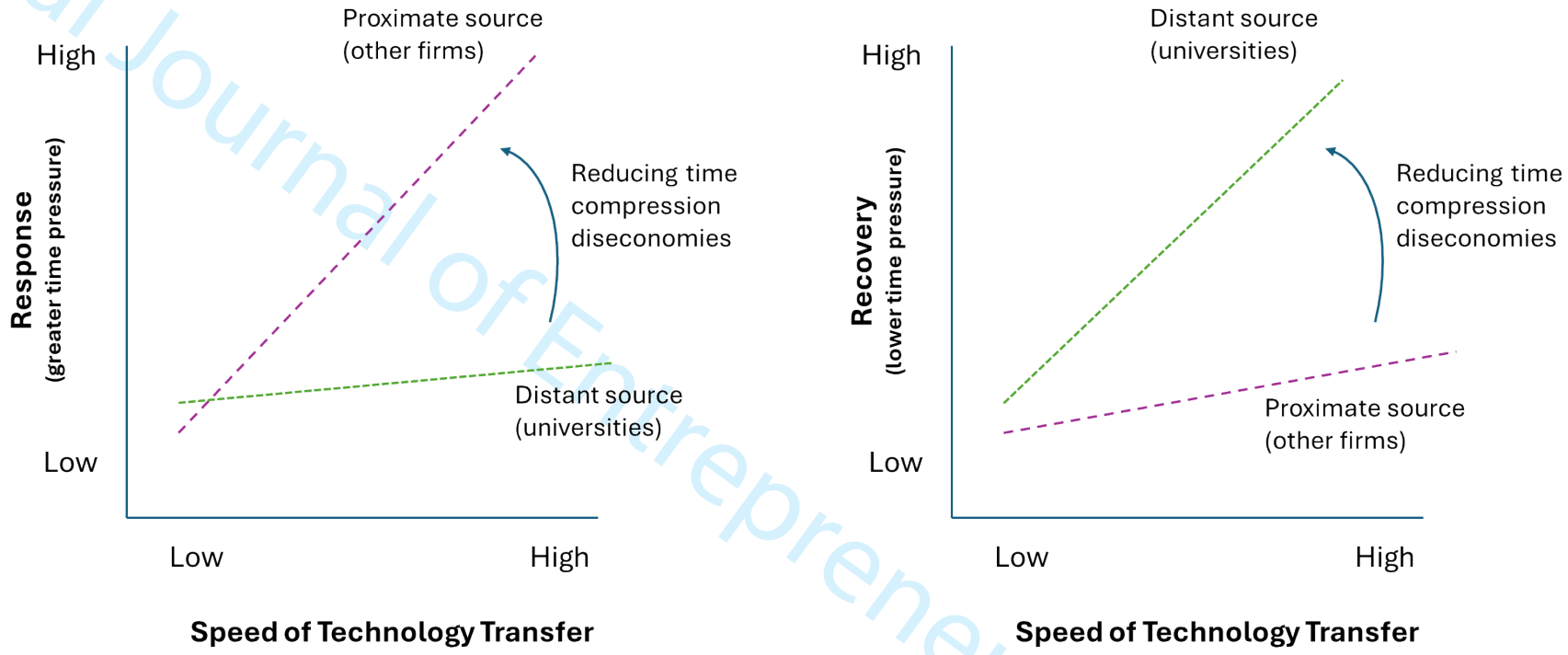

Figure 1. Hypothesized effects for SME resilience based on STT from other firms versus universities

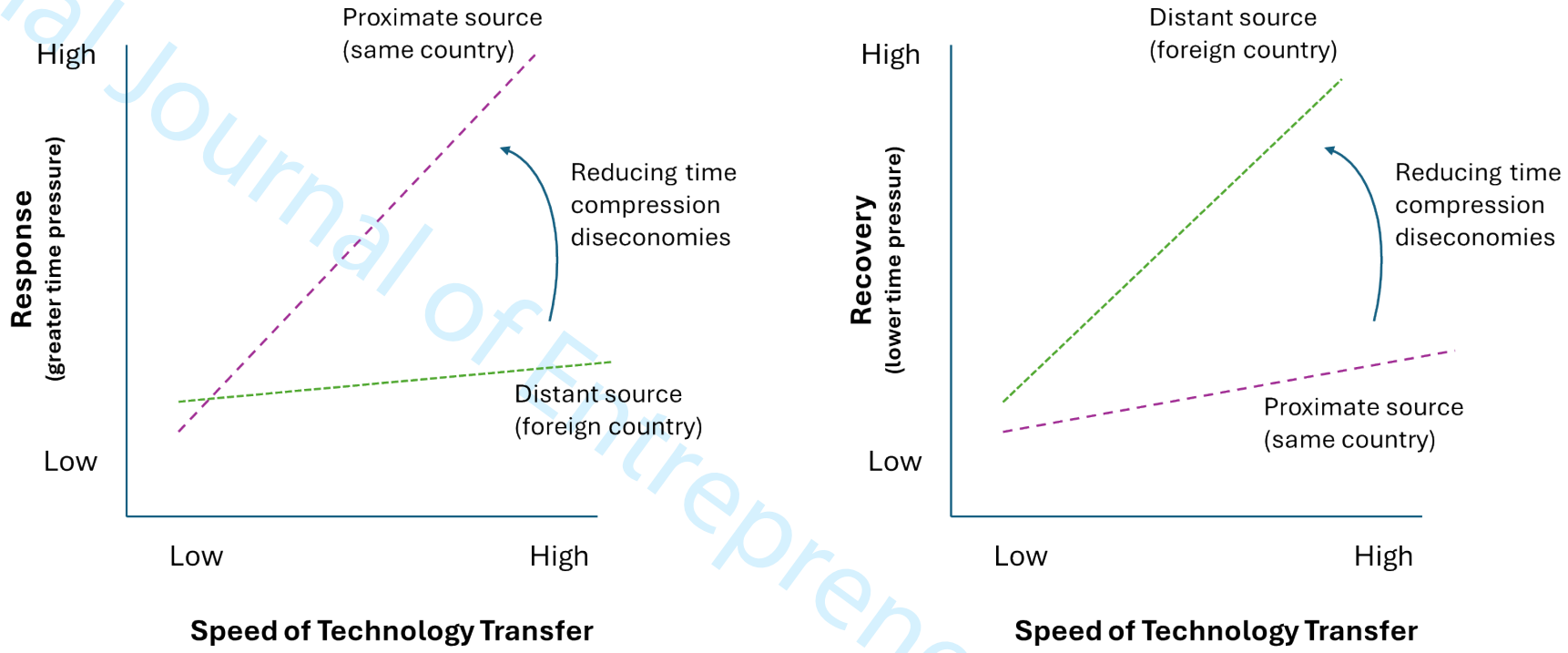

Figure 2. Hypothesized effects for SME resilience based on STT from sources in the same versus other countries