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Epidemiological Susceptibility Risk, Adaptive Management and Firm Performance

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This paper uses firm-level information to analyse the impact of epidemic outbreak risk on individual firms' performance. Its impact on performance materializes mainly through consumer perception of risk and the resilience of the supply chain networks. The extent to which countries are prepared to identify and respond to these risks adequately is a critical factor. We therefore construct an index of epidemiological susceptibility risk (ESR), which we use to predict business performance around the world. The index captures the role of infrastructure, demographics, economic activity and institutional governance. It proves a significant predictor of corporate sales growth. It also fares well in explaining business performance during the Covid-19 pandemic. The results remain robust to various sensitivity and endogeneity tests and after controlling for different non-economic and institutional factors. The ESR captures diverse conditions, which may amplify or contain the contagion of epidemiological risk, and therefore it could potentially be a useful tool for predicting and managing epidemic outbreaks and their consequences on business sustainability.

Introduction

The outbreak of epidemics threatens the health and livelihood of people (Morse *et al.*, 2012) and the survival of businesses (World Economic Forum, 2020). The resulting social and economic costs are tremendous. The impact of epidemics on business performance materializes mainly through consumers' perception of risk (Coibion, Gorodnichenko and Weber, 2020; Covello, 1991; Slovic, 1987) and the resilience of the supply chain networks (Baldwin, 2020; Büyüktahtakin, des-Bordes and Kibis, 2018; Rachaniotis, Dasaklis and Pappis, 2012). While often being ignorant or inconsiderate, consumers and firms are becoming increasingly aware of epidemic risks and the importance of resilient conditions, thereby adjusting their behaviour accordingly. Given the social and economic costs of epidemics, it is critical to assess whether countries are prepared to identify and respond to these risks adequately in order to sustain business continuity and survival (Seetharaman and Gallucci, 2020). The World Health Organization (2014) emphasized that country preparedness is key in preventing the spread of epidemics and facilitating the global planning process. Many countries remain unprepared to identify and manage epidemiological risks. The World Economic Forum (2020) argues that firms must include epidemic outbreaks in their consideration of business risk. While it is difficult to predict the next outbreak, it is possible to identify factors that may alert companies to epidemiological risk. Assessing country preparedness emerges as a key policy challenge.

We respond to this challenge by constructing a country-level index of epidemiological susceptibility risk (ESR), which we subsequently use to predict firm performance around the world. We use firm-level information that captures both historical firm behaviour and current Covid-19 behaviour. In order to have useful policy implications, our ESR measure uses objective and reproducible information on infrastructure, demographics, economic activity and governance. Higher values indicate lower epidemiological risk, or better country preparedness to manage it. The empirical results show that the ESR index is a significant predictor of corporate sales growth. The specific characteristics of firms, including those of incumbent management, are significant controls. The ESR effect remains robust after applying sensitivity and endogeneity tests and additional country-level controls.

This is the first research effort, to our knowledge, to link ESR with firm performance worldwide. However, this paper is related to previous studies on the role of uncertainty and risk perception for consumer behaviour (Baker *et al.*, 2020a; Ross, 1975; Shah, 2012) and firm performance (Baker, Bloom and Davis, 2016). Secondly, the paper contributes to the literature on the role of risk and uncertainty for the resilience and integrity of the supply chain networks (Bonadio *et al.*, 2020; Christopher, 2000). Thirdly, it contributes to the scant literature on the conceptualization and measurement of epidemiological risk (Gupta *et al.*, 2018). The key novelty of our ESR measure is the consideration of key structural conditions affecting epidemic contagion. It therefore provides a useful tool for the prediction and prevention of epidemic outbreaks around the world. Finally, the paper adds to the literature on the role of managerial and other characteristics of firms for sustainable performance (Hamori and Koyuncu, 2015; van Mossel, van Rijnsoever and Hekkert, 2018).

The paper is organized as follows: the next section offers a brief background literature; the third section describes the index characteristics, the data and the empirical strategy; the fourth section presents the baseline estimation results; the fifth section applies sensitivity tests and endogeneity analysis; the sixth section applies further checks of robustness; and finally the seventh section concludes. Details on the index's construction are provided in the online Supporting Information.

Related literature

The impact of epidemiological episodes on corporate sales performance materializes mainly through consumers' perception of risk on the demand side and the response of the supply chain networks on the supply side. It also depends on management's response to extreme risk events. We describe briefly each dimension below.

Risk perception and consumer behaviour

Consumers have always made decisions under uncertainty. However, risk appreciation through specific assessments of the probability of events and their consequences is a characteristic of modern times. Nevertheless, realities, personal experience and perceptions, social interactions, culture and personal judgement also influence consumer perceptions of risk (Boholm, 1998; Rogers, 1997; Sjoberg, 2000). Socio-environmental conditions variously affect social interaction and subsequently intelligent learning in risk appraisal. However, many lay people are uncomfortable with probabilistic thinking and have strong preferences for absolute judgements. Further, leader-based groups outperform other groups and individuals in perceiving epidemiological risks (Abdulkareem *et al.*, 2020). These reactions are stronger in conditions of extreme risk, when individual cognitive biases are pronounced. As a result, consumer perception of risk often aligns poorly with that of informed analysts, with unintended consequences for communicating risk and predicting consumer behaviour (Covello, 1991; Slovic, Fischoff and Lichtenstein, 1985). Hazards perceived by consumers as unfamiliar or provoking anxiety are assigned a higher risk than could be demonstrated statistically (Slovic, 1987). Risk communication with consumers must account for their reaction to risks and appreciate the effect of consumer trust, fear (Slovic, 1993) and outrage (Purchase and Slovic, 1999). The Covid-19 pandemic is an extreme risk event, because it unfolded with tremendous speed and breadth. While the Spanish Flu pandemic a century ago offers a reasonable point of comparison (Barro, Ursua and Weng, 2020), that took place in a different socioeconomic context. Baker *et al.* (2020a) document an enormous increase in economic uncertainty due to Covid-19 that far exceeds that of the 2007–2008 financial crisis.

Studies of consumer response to risk have focused mainly on economic factors (Allenby and Leone, 1996; Kumar, Leone and Gaskins, 1995; Lamey *et al.*, 2007). However, these factors affect economic activity mainly through consumers' ability to buy, whilst epidemic outbreaks affect economic activity through both consumers' ability and their psychological willingness to buy. Regarding the former, Coibion, Gorodnichenko and Weber (2020) use US survey data and document that about 50% of survey participants report income and wealth losses due to Covid-19, causing aggregate consumer spending to drop by 31 log percentage points. Cavallo (2020) finds that in 10 countries the pandemic affected consumer expenditure which caused inflation increases. Inflation grew over time, as social distancing has made consumers spend relatively more on goods with rising inflation and less on goods experiencing deflation.

Regarding the latter, little is known about how a specific psychological factor (e.g. fear of epidemiological contagion) influences consumer behaviour (Galbraith and Tkacz, 2013). During the Covid-19 outbreak, the news media reported that consumers emptied supermarket shelves in an effort to stockpile durable goods (BBC, 2020; CNBC, 2020). Available evidence is limited. Jung *et al.* (2016) use credit card data and find that epidemics cause substantial disruptions in consumer expenditure, with large variations across expenditure types and goods. Baker *et al.* (2020a) find that as the number of Covid-19 infections increased, consumers changed their spending patterns. Initially spending increased sharply, particularly in retail and food items, financed by credit, but subsequently spending decreased sharply altogether. They also find that consumption patterns exhibited heterogeneity across levels of social distancing, partisan affiliation, demographics and income. Chang and Meyerhoefer (2020) find that the rise of Covid-19 infections in Taiwan increased home-prepared food sales by 5.7%, which benefitted online food shopping businesses and small farms over agribusinesses. Debter (2020) and Singh (2020) note that the rise in food sales worldwide has been facilitated by the rapid increase in online trading platforms. Uhler (2020) shows that the shift in consumer demand resulted in shortages and declining inventory levels of certain food products.

Finally, some studies emphasized the effect of epidemics-induced uncertainty on investor risk attitude (Amstad *et al.*, 2020). The latter reflects investors' natural inclination to evaluate a risk situation in a favourable or unfavourable way and to act accordingly (Rohrmann, 2002). It captures investors' risk mindset in situations of uncertainty. It is different from investors' typical behaviour towards risk aversion. These risk attitudes affect market behaviour and financing, thereby influencing firm performance (Baker *et al.*, 2020b; Ramelli and Wagner, 2020).

Risk, supply chain structure and capacity reallocation

The economic consequences of epidemic risk contagion extend to the whole economy. Brahmbhatt (2005) argues that the economic impact of pandemics arises less from the social costs of actual sickness or death and more from the uncoordinated strategies for disease prevention and control by both the public and private sectors, domestically and globally. As a result, open and highly trade-dependent economies will face simultaneous demand and supply shocks, often leading to a severe reduction in economic activity. In the era of globalization, these supply shocks depend on the connectedness of the global supply chain networks. The global economy today is closely integrated through intermediate and final goods trade. A global economic downturn could therefore affect countries and firms, even if they experience low levels of epidemic contagion.

The breakdown of the supply chain manifests itself primarily in resource allocation problems (Büyüktahtakin, des-Bordes and Kibis, 2018; Mamani, Chick and Simchi-Levi, 2013; Rachaniotis, Dasaklis and Pappis, 2012). Baldwin (2020) argues that the Covid-19 supply chain effect is more severe. As countries simultaneously and extensively suppress economic activity by imposing domestic lockdowns, the simultaneous shortages in the foreign supply of domestic intermediate and final imports and in the foreign demand for domestic intermediate and final exports exacerbates the downturn. Bonadio *et al.* (2020) study the role of global supply chains in the impact of the Covid-19 pandemic on GDP growth for 64 countries. They estimate that the Covid-19 shock will reduce real GDP by 31.5%, of which 10.7% is due to the disruption of the global supply chain. The lack of coordination in the management of supply chain networks causes amplified disruption.

Recent studies provide some initial evidence on the role of supply chain structure in explaining the effect of the Covid-19 pandemic on firm performance. Hassan *et al.* (2020) quantify the key concerns of senior US executives, which include rising uncertainty, negative demand shifts, supply chain disruptions and capacity underutilization. These managerial concerns vary across firms and industries. Ramelli and Wagner (2020) trace the heterogeneity in market reactions to Covid-19 developments to specific risk exposures, such as reliance on disrupted supply chains, exports to China and the regulation of food, energy and finance. Barrero, Bloom and Davis (2020) draw on survey-based expectations of US firms with a 1-year forecast horizon and show that the pandemic has caused a sharp supply-side reallocation shock in the pattern of corporate sales.

Following epidemic outbreaks, many firms responded by introducing supply chain resilience measures. These firms fared better in the struggle for post-epidemic recovery (Ho *et al*., 2015; Hosseini, Ivanov and Dolgui, 2019). However, the Covid-19 outbreak posed the novel challenge of needing to secure, in addition to resilience, the viability of supply chains too. Viability integrates resilience, adaptation and sustainability considerations of a supply chain (Ivanov, 2020b; Ivanov and Dolgui, 2020; Sarkis *et al*., 2020). It remains an open question whether the global supply chain can adapt quickly to secure the minimal economic survival needs of firms (World Economic Forum, 2020). The emergence and widely used digital technologies could mitigate the adverse effects of epidemiological risk on propagating supply chain disruptions (Araz *et al*., 2020; Ivanov, 2020a). Overall, epidemiological risk has greatly affected the global supply chain networks, causing disruption in the supply of goods domestically and abroad.

Risk perception and managerial decision-making

Given transforming demand and supply conditions, managerial decision-making faces several challenges. Davenport (2020) stresses that in crisis times, managerial decision-making becomes especially challenging. One reason is the likely appearance of individual cognitive decision biases adversely affecting business decisions. In the context of the Covid-19 pandemic, cognitive biases that might lead to inefficient managerial reactions include the bias of maintaining the status quo and adherence to political communication stereotypes that often frame risk in bipolar terms (e.g. save lives or save the economy). Additional cognitive biases include the bandwagon effect, whereby decision-makers accept an aggregate but unobserved convention beyond their personal experience, as a driver of their own attitude and preference formation (Rüdiger, 2015). An example is the growing and unfounded excitement of consumers and producers about using the old drug chloroquine for malaria treatment as an antidote to Covid-19. Another cognitive bias is the normalcy bias, which leads people to disbelieve or minimize threat warnings (Drabek, 1986). As a result, decision-makers underestimate the likelihood and consequences of extreme risk, when it might affect them. The normalcy bias causes decision-makers to inadequately prepare for extreme risks. About 70% of people reportedly display normalcy bias during an extreme risk event (Omer and Alon, 1994). Even though dangerous global pandemics have occurred in the past (e.g. the 1918 Spanish Flu outbreak) and more recently (e.g. SARS and MERS), most political and business leaders have ignored the possibility of further epidemic episodes. This particular bias is perhaps the most important one in preparing a firm and a country to achieve epidemiological resilience.

Kahneman (2011) points out that knowing about general decision biases does not necessarily mean that individual decision-makers can identify their own biases. Thus, during extreme events, the identification of cognitive biases in decision-making should rather be a collective and interactive effort. There is also the possibility of letting a machine make the decisions, driven by data or heuristics (Taniguchi, Sato and Shirakaw, 2018). However, with the fast-changing Covid-19 situation, there is not enough data or trustworthy rules to rely upon for generating automated decisions. Instead, humans must make diligent efforts to avoid common decision pitfalls. Recent modelling of Covid-19 risk mitigation strategies underlined that the best outcomes would result from a combination of interventions implemented by 'adaptive management' (Anderson, 2020; Blanchet, 2017; Ferguson *et al*., 2020). The latter refers to the collective identification of combinations of interventions that work best, and of their consequences. Experience shows that policy assumptions often do not match people's perceptions and interventions seldom proceed as planned. Instead, strategies must be designed for adapting to change for a significant period (Ramalingam, 2013). This would help buy time to learn more about how to best treat and respond to the pandemic. This would be more important in low-income countries, characterized by weak health systems, difficulties in enacting measures for long periods (e.g. social distancing is harder in densely populated areas lacking adequate communication and transportation infrastructure) and low adaptation capacity. Adaptive management has proved efficient in managing epidemic outbreaks, most notably Ebola in West Africa (Shea, 2014). Strategic adaptation and learning were instrumental in eradicating the smallpox epidemic (Hopkins, 1988). An adaptive management style adopting an open, inclusive and unconventional stance to addressing the Covid-19 challenge is a key factor in safeguarding the sustainability and performance of firms.

Conceptualizing and measuring epidemiological susceptibility risk

Given the social and economic risks posed by epidemics, it is critical to systematically assess the preparedness of countries to identify, coordinate and respond to these risks. Resilience to external shocks is a key factor for maintaining consumer confidence and the efficiency of the supply chain, both of which contribute to maintaining firms' operations and their ability to compete effectively as a participant in a supply chain (Christopher, 2000). Despite significant investments, many countries remain less prepared to manage epidemiological risks (Chan *et al.*, 2010). Indeed, few countries comply fully with the World Health Organization's 2005 International Health Regulations (Gupta *et al.*, 2018). Recent efforts have provided various measures of epidemiological risk (Hashim, Alsuwaidi and Khan, 2020; Khan *et al.*, 2020). However, the World Health Organization regulations assess country preparedness based mainly on health-related monitoring, whilst other measures focus on the incidence of related diseases and medical phenomena alone. A more suitable measure should account for wider and objective infrastructure capacities, economic activity and structural conditions, as essential building blocks of an effective monitoring and response strategy to epidemics.

In response, we develop a country-level index of ESR. The construction of the ESR index uses six building blocks: health care infrastructure, environmental safety infrastructure, communications infrastructure, demographics, economic activity and governance institutions. An effective health care infrastructure is key for timely detection and containment of infectious people through proper surveillance and analysis of outbreak patterns (Morse, 2007). This capacity requires international cooperation for monitoring large populations and geographies and adequate financing (Kruk and Freedman, 2008). An effective health care system improves economic resilience, social inclusion and inter-sectoral production sustainability through its effect on labour productivity (Boyce and Brown, 2019). An effective communications infrastructure improves market surveillance, raises epidemic awareness and facilitates policy by managing information, labour mobility and medical supply chains (Greiner *et al.*, 2015; Rainwater-Lovett, Rodriguez-Barraquer and Moss, 2016). An effective transportation infrastructure facilitates the monitoring of the movement of infectious people but also facilitates timely response (Meyer and Elrahman, 2019). An effective clean water infrastructure contains the spread of epidemics by adhering to high sanitary standards (Phelps *et al.*, 2017). An effective institutional governance capacity facilitates the management and coordination of response and the efficient allocation of containment resources during outbreaks (Pritchett, Woolcock and Andrews, 2013). Effective public governance structures facilitate the identification, prioritization and mitigation of risks subject to the constraints of political influence and partisan conflict (Gayer *et al.*, 2007).

Demographics play a role too. The demographic structure is changing due to declining fertility and increasing life expectancy. This has created smaller households and older populations. These transformations affect the structure of consumption and the spread of epidemics. For example, Geard *et al.* (2015) find that declining fertility is associated with a lower incidence of disease infection but also a higher average age of infection, depending on vaccination and other prevention measures. Rising urbanization, while associated with better health infrastructure relative to rural areas, provides fertile grounds for the emergence of new pathogens that, due to tighter human interaction, cause rapid spread of zoonotic diseases (Neiderud, 2014). Economic activity also facilitates the spread of epidemics. Adda (2015) finds that epidemics spread faster during economic booms, when people move more and faster. Higher economic activity increases personal interaction and trade volumes, thereby expanding transmission sources and speed. Suhrcke *et al.* (2011) review the evidence and argue that epidemics exert adverse economic effects during downturns, due to worsened living conditions and health care access.

Along the aforementioned dimensions, we construct an index of ESR. The ESR index reflects the extent to which economic and non-economic structural conditions provide an indication of the extent to which countries are susceptible to epidemiological risk. Then we explore the impact of the ESR index on firm performance. The key channels of influence include consumers' perception of risk, the resilience and safety of supply chains and adaptive management responses. We describe the construction of the index in the next section.

Data, index construction and empirical strategy

We obtain firm-level data from the Enterprise Surveys (ES) administered by the World Bank. The basic dataset includes 168,057 non-financial firms operating in 144 developing countries during 2006–2019. The data are collected over several survey rounds. These rounds are essentially independent collections of cross-section data, where only a few firms systematically appear throughout the successive surveys. The data panel structure is unbalanced but has the advantage of containing consistent information across all survey years. The data have the important strength of including different firms by size, sector of activity, ownership structure and other characteristics, specific to them. The responses of the firms reflect their managers' experience and perception of the surrounding business environment and the constraints therein. In order to contain self-selection bias, the ES data use random samples of representative firms with different characteristics, which are updated for each country and properly brought into consistent form. Further, as a test of external validity, we use an additional similarly structured, but much smaller, ES dataset that captures firm behaviour under Covid-19 conditions.

The outcome variable for measuring firm performance is the firm's real annual growth of sales (%), SALESGR. Based on the ES explanation, SALESGR represents the real annual growth of sales reported during the current fiscal year from a previous period. The variable captures a dynamic aspect of performance. The difference between the two fiscal periods for most ES countries is 2 years, whilst for a few countries the interval is 3 years. Hence, we use an annualized measure. All values for SALESGR are converted to USD using the exchange rate that corresponds to the fiscal year of the survey. SALESGR is then deflated to year 2009 using the USD deflator. Table 1 presents the average index values per country. The real growth of sales is higher in Liberia (+37.9%), followed by Angola (+23.1%) and Congo (+19.7%), lowest in South Sudan (−56.8%), followed by Iraq (−40.4%) and Eritrea (−10.1).

The key explanatory variable is the index of ESR. The index reflects the importance of seven building blocks of epidemiological risk: health infrastructure; environmental safety infrastructure; communications infrastructure; transport; demographics; economic activity; and institutional effectiveness. We construct the index in four steps (see the online Supporting Information). First, we selected objectively measured and reproducible variables that, given the relevant literature, best capture the extent to which a country may be susceptible to epidemiological risk and for which there is adequate and continuing information and country coverage. We use 17 time-varying variables to construct the ESR index. We capture health infrastructure effects by using the value of health expenditure per capita; the extent of health care access and quality; the response rate to public health hazards; and the number of physicians and hospital beds per 1,000 people. We capture transport effects by using the (inverse of the) number of air passengers as a percentage of total population. We capture demographic effects by using the urban population as a percentage of total population; the number of people per square kilometre of land (population density); and the population of 65+ years of age as a percentage of total population. We capture environmental safety infrastructure effects by using the number of people using safely managed drinking water services as a percentage of total population; and the number of people using safely managed sanitation services as a percentage of total population. We capture relevant economic activity effects by using the value of trade in goods and services as a percentage of total trade. We capture communications infrastructure by using the number of individuals using the Internet as a percentage of total population. Finally, we capture institutional effectiveness by using the extent of human capital development; and the value of government effectiveness and the rule of law indicators. The online Supporting

Table 1. Real annual sales growth and epidemiological susceptibility risk index (mean country values)

Country	SALESGR	ESR	Country	SALESGR	ESR	Country	SALESGR	ESR
Afghanistan	2.19	−1.71	Gambia	−0.81	−0.73	Pakistan	−1.18	−1.15
Albania	5.56	0.36	Georgia	5.56	0.36	Panama	3.08	0.07
Angola	23.10	−1.07	Ghana	−0.77	−0.95	Papua New Guinea	−3.88	0.01
Antigua & Barbuda	−4.70	0.01	Greece	4.96	0.82	Paraguay	−5.15	−0.58
Argentina	1.79	0.78	Grenada	1.67	0.68	Peru	5.77	−0.41
Armenia	8.31	0.73	Guatemala	1.01	−1.34	Philippines	2.62	−1.58
Azerbaijan	0.25	1.16	Guinea	1.17	−2.12	Poland	3.46	1.20
Bahamas, The	2.06	0.38	Guinea-Bissau	12.77	−1.22	Portugal	3.55	0.49
Bangladesh	0.86	−1.99	Guyana	2.02	−0.15	Romania	2.04	1.17
Barbados	1.99	1.19	Honduras	3.96	−1.17	Russian Federation	2.03	1.49
Belarus	2.55	1.74	Hungary	4.37	1.29	Rwanda	5.49	−0.34
Belize	3.09	−0.64	India	1.40	−0.95	Samoa	−1.69	−0.07
Benin	6.10	−1.58	Indonesia	0.52	−0.64	Senegal	4.06	−2.66
Bhutan	11.55	−0.33	Iraq	−40.39	−0.55	Serbia	4.53	1.00
Bolivia	6.95	−0.79	Israel	3.85	0.38	Sierra Leone	16.60	−1.82
Bosnia & Herzegov.	4.23	0.49	Italy	5.44	0.52	Slovak Rep.	4.49	1.10
Botswana	5.97	−0.21	Jamaica	−5.14	−0.21	Slovenia	8.31	0.81
Brazil	4.46	0.10	Jordan	−1.72	−0.24	Solomon Islands	14.79	−0.47
Bulgaria	4.86	1.22	Kazakhstan	−0.38	1.34	South Africa	5.68	0.27
Burkina Faso	2.66	−0.95	Kenya	−6.07	−0.34	South Sudan	−56.83	0.01
Burundi	−5.88	−1.16	Kyrgyz Rep.	−1.52	0.86	Sri Lanka	0.92	0.31
Cabo Verde	−8.52	−0.04	Lao PDR	−9.65	−0.91	St. Kitts & Nevis	1.13	0.84
Cambodia	1.83	−1.22	Latvia	4.16	1.22	St. Lucia	1.05	0.27
Cameroon	7.41	−0.48	Lebanon	−5.10	0.40	Vincent & Grenadine	3.95	0.19
Central African Rep	13.38	−0.84	Lesotho	7.01	−0.55	Sudan	13.62	−1.22
Chad	2.85	−1.82	Liberia	37.87	−1.15	Suriname	−8.92	0.42
Chile	2.42	−0.02	Lithuania	8.05	1.31	Sweden	1.59	0.31
China	3.44	0.70	Madagascar	−0.19	−1.76	Tajikistan	7.66	0.98
Colombia	5.33	−0.55	Malawi	−1.22	−0.55	Tanzania	−6.98	−1.05
Congo, Dem. Rep.	7.75	−0.93	Malaysia	−4.35	−0.15	Thailand	−1.12	0.01
Congo, Rep.	19.72	−0.33	Mali	12.85	−2.53	Timor-Leste	7.33	1.07
Costa Rica	−5.42	−0.64	Malta	3.13	0.85	Togo	9.48	−1.22
Croatia	3.11	1.02	Mauritania	−0.98	−1.82	Tonga	−5.39	0.19
Cyprus	10.16	0.61	Mauritius	11.72	0.44	Trinidad & Tobago	10.02	−0.04
Czech Rep.	5.43	1.28	Mexico	2.77	−0.30	Tunisia	−1.16	−0.08
Côte d'Ivoire	2.60	−1.82	Micronesia	2.64	0.41	Turkey	4.51	0.18
Djibouti	0.02	−0.47	Moldova	−1.61	1.08	Uganda	−8.21	−1.01
Dominica	−1.72	0.59	Mongolia	−0.90	1.15	Ukraine	−8.17	1.50
Dominican Rep.	2.98	−0.19	Montenegro	1.86	0.67	Uruguay	5.91	−0.10
Ecuador	1.62	−0.35	Morocco	10.52	−0.97	Uzbekistan	−0.42	0.80
Egypt, Arab Rep.	−7.76	−1.39	Mozambique	5.28	−1.15	Vanuatu	12.00	0.57
El Salvador	4.19	−1.03	Myanmar	3.60	−1.27	Venezuela	−0.31	−0.66
Eritrea	−10.03	−1.22	Namibia	5.33	0.44	Vietnam	3.10	0.26
Estonia	4.02	1.07	Nepal	0.50	−2.45	West Bank & Gaza	−0.62	0.01
Eswatini	7.35	−0.04	Nicaragua	3.36	−0.94	Yemen, Rep.	−9.84	−1.22
Ethiopia	5.36	−0.72	Niger	0.87	−2.12	Zambia	0.94	−0.12
Fiji	7.58	−0.04	Nigeria	−4.91	−1.58	Zimbabwe	−5.50	−0.27
Gabon	14.66	−0.55	North Macedon.	7.00	0.79	*Total average*	*1.28*	*−0.20*

Information provides information on the data sources.[1] Higher values of all these variables imply lower risk of a country's epidemiological susceptibility. While there may be other important variables, the selected ones are highlighted by the literature, are objectively measured, have a very low incidence of missing values and are reproducible for future use. Second, we used a multilevel imputation method to impute missing values of the

[1]The authors have experimented with combining many potentially relevant variables in constructing the ESR index. The chosen combination has been the most efficient one with the greatest predictive power.

variables (Johnson and Young, 2011). We restricted our sample to the 2000–2019 period, because the incidence of missing values was very low. Third, we normalized all variable values to vary within the [0, 1] interval by using the min/max normalization factor; and finally, we extracted the first principal component of the resulting dataset. Higher index values imply a lower risk of a country's susceptibility to epidemiological contagion. Alternatively, higher index values imply that a country is better prepared to manage epidemiological risk. We make the reasonable hypothesis that, as firms carry the experience of the past and face the future health and economic costs of temporary and endemic disease outbreaks and their contagion, they pay closer attention to the conditions of ESR in a country and adjust their overall behaviour mindful of these conditions. Table 1 presents the average index values per country. The index value is lowest in Senegal (−2.66), followed by Mali (−2.53) and Nepal (−2.45). The index value is highest in Belarus (1.74), followed by Ukraine (1.50) and Kazakhstan (1.34). Guyana (−0.15), Malaysia (−0.15) and Uruguay (−0.10) lie in the middle. A casual observation shows that the index values are broadly consistent with the historical evidence of epidemiological contagion episodes. We expect a positive effect of the epidemiological susceptibility index (lower risk) on firm performance.

While the epidemiological risk in a country is expected to affect firm performance, we do not directly observe the effect. Therefore, we control for characteristics of firms that mitigate the effect. A key characteristic is the management of firms. The ES data provide information on the years of experience of the top manager in the firm, which we use as a control. We conjecture that in times of crisis, incumbent top management with long service time in the firm may exhibit cognitive biases in decision-making and therefore be inadequately responsive and less adaptive to the challenges posed by extreme risks. In their review essay, van Mossel, van Rijnsoever and Hekkert (2018) show that incumbent management often acts as a deterrent factor in the transition of firms towards sustainability. Hamori and Koyuncu (2015) show that due to succession and learning issues, prior CEO experience adversely affects post-transition firm performance. We therefore expect a negative effect of managerial longevity in the firm-on-firm performance. Additional characteristics of firms used as controls include firm age, size, sector of business activity, auditing of accounts and ownership structure. Mertzanis and Said (2019) document a significant effect of the specific characteristics of firms on their sales performance using ES data. In order to control for the possibility that the ESR captures other country-level factors in affecting sales growth, we include the GDP per capita (GDPCAP) and the annual growth rate of GDP (GDPG) as controls. Acemoglu and Johnson (2007) stressed the historical link between diseases and economic development. Xu (2013) documents a significant association between business cycle and health outcomes. Muley *et al*. (2020) provide a review of the role of infrastructure in containing epidemic outbreaks. Appendix A provides detailed definitions of all variables. Table 2 (Sample A) displays summary information of all variables. The mean country value for SALESGR is 1.28% and the standard deviation is 26.3%, indicating large variation. Further, the ESR index has a mean of −0.20, a standard deviation of 1.08 and min/max distance of 5.05, also exhibiting large variation. The mean log years of managerial experience is 2.64, with a standard deviation of 0.78. About 46.9% of covered firms are small firms and about 54.9% of firms are operating in manufacturing.

Identifying the causal effect of the ESR index on firm-level performance is challenging due to the possible presence of unobserved characteristics in the large cross-section of countries that correlate with both the ESR and the SALESG. Initially, we include country, year and sector fixed effects to control for time-invariant heterogeneity in alternate model specifications. Further, in order to show that firm-specific characteristics may not affect the ESR effect significantly, we estimate baseline models with and without firm-level controls. We fit an ordinary least squares (OLS) regression model to estimate the baseline model's parameters (Greene, 2012). The disadvantage of the OLS linear estimation is that it does not account for nonlinearities, has poor extrapolation properties, is sensitive to outliers and produces biased estimates of the outcome variable, due to attenuation bias. However, the OLS estimation is simpler to interpret (Angrist and Pischke, 2008), facilitates comparison (Acemoglu and Johnson, 2007) and avoids the problem of incidental parameter bias embedded in nonlinear estimations using fixed effects. The OLS estimates are useful for showing

Table 2. Summary statistics

Variable	Obs.	Mean	SD	Min	0.25	Mdn	0.75	Max
Sample A: Original Enterprise Surveys dataset (2006–2019)								
SALESGR	124,235	1.28	26.31	−100.00	−9.73	0.06	10.62	100.00
EMPLGR	149,964	4.44	16.36	−100.00	0.00	0.00	11.11	100.00
ESR	167,314	−0.20	1.08	−3.30	−0.95	−0.21	0.78	1.75
MANAGEXP	163,457	2.64	0.78	0.00	2.30	2.71	3.22	4.25
SIZE	168,057	1.72	0.77	1.00	1.00	2.00	2.00	3.00
SECTOR	168,057	1.71	0.86	1.00	1.00	1.00	3.00	3.00
OWNPRV	165,256	89.21	28.87	0.00	100.00	100.00	100.00	100.00
OWNFOR	165,256	7.87	25.07	0.00	0.00	0.00	0.00	100.00
OWNGOV	165,256	0.67	6.52	0.00	0.00	0.00	0.00	100.00
EXPORTER	168,057	0.07	0.26	0.00	0.00	0.00	0.00	1.00
GDPCAP	165,753	8.15	1.06	5.12	7.36	8.17	8.98	11.00
GDPGR	167,426	4.38	3.60	−14.81	2.59	4.50	6.61	18.33
CONSM	160,104	12.14	1.84	6.55	10.59	12.24	13.54	15.77
FOREX	163,515	0.19	0.39	0.00	0.01	0.03	0.17	4.55
GEOPOL	168,057	94.23	37.83	53.78	67.19	74.65	121.54	192.21
BCRISIS	168,057	0.03	0.17	0.00	0.00	0.00	0.00	1.00
MALARIA	142,827	−0.16	4.16	−7.78	−3.23	0.20	2.80	6.31
TUBERCULS	166,954	4.32	1.26	0.10	3.43	4.49	5.39	7.10
TEMP	161,510	2.86	0.53	−0.50	2.49	3.11	3.22	3.39
RAINFALL	168,057	4.13	1.01	0.75	3.71	4.20	4.81	5.77
IMMUNITY	158,715	91.57	11.05	26.00	89.00	96.00	98.00	99.99
Sample B: Covid-19 Enterprise Surveys dataset (May 2020–January 2021)								
SALESGR1	22,168	−26.48	32.27	−100.00	−50.00	−20.00	0.00	300.00
ESRC	32,945	0.49	0.94	−2.19	−0.27	0.85	1.20	1.81
SIZE	32,945	1.75	0.78	1.00	1.00	2.00	2.00	3.00
SECTOR	32,945	1.79	0.88	1.00	1.00	1.00	3.00	3.00
OWNFOR	32,338	11.04	31.33	0.00	0.00	0.00	0.00	100.00
EXPORTER	32,383	22.42	41.71	0.00	0.00	0.00	0.00	100.00
FEMMAN	32,877	17.94	38.37	0.00	0.00	0.00	0.00	100.00
GDPCAP	32,945	9.07	1.04	6.33	8.18	9.39	9.95	10.48
GDPGR	32,945	2.53	2.48	−8.1	1.96	2.48	4.15	5.9

Notes: Sample A presents the summary statistics of the original ES dataset that comprises 144 countries during 2006–2019. Sample B presents the summary statistics of the restricted Covid-19 ES dataset that took place during May 2020–January 2021 and comprises 37 countries. *Source*: World Bank.

the unqualified correlations in the data and for comparing the parameter estimates of the different structural models applied by sensitivity and endogeneity analysis. The fixed effects will contain OLS potential estimation bias in relative terms. Subsequently, we check the robustness of the baseline results by deploying alternative measurement of variables, sample structures and estimation methods as part of our subsequent sensitivity and endogeneity analysis. We use additional country-level controls to capture the effect of other institutional factors. In order to contain the statistical bias resulting from measuring the effect of aggregate policy variables (ESR) on individual firms (Moulton, 1990), we cluster standard errors at the country level. In the regression, we consider only non-missing observations of our variables. Our estimation model uses the following regression equation:

$$Y_{ij}= \alpha + ESR_j{}^{*}\beta_1+X_{1ij}{}^{*}\beta_2+X_{2j}{}^{*}\beta_3+\mu_{it} \qquad (1)$$

The outcome variable Y_{it} ($SALESGR_{it}$) represents the real growth of sales of firm i in country j; ESR_{it} is the index of ESR in country i; X_{1ij} is the vector of the specific characteristics of firm i in country j used as a first set of control variables; X_{2j} is the vector of the country-level factors in country i used as a second set of controls; and the term μ_{it} is the regression's error term that encompasses the sum of η_j, λ_t and $e_{i,t}$ terms. The term η_j accounts for unobservable country effects, the term λ_t accounts for time effects and the term ε_{itl} is the residual error term that is assumed to fluctuate across country-years and follow the normal distribution.

Table 3. Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ESR (1)	1.00									
MANAGEXP (2)	0.05***	1.00								
SIZE (3)	0.06***	0.12***	1.00							
SECTOR (4)	0.07***	−0.06***	−0.13***	1.00						
OWNPRV (5)	0.03***	0.03***	−0.16***	−0.01***	1.00					
OWNFOR (6)	−0.01***	−0.03***	0.17***	−0.01***	−0.85***	1.00				
OWNGOV (7)	0.04***	−0.02***	0.09***	0.00*	−0.22***	−0.01***	1.00			
EXPORTER (8)	−0.10***	0.08***	0.29***	−0.01***	−0.12***	0.13***	0.04***	1.00		
GDPCAP (9)	0.38***	0.13***	0.05***	0.05***	0.01***	0.00	−0.01***	0.01***	1.00	
GDPG (10)	−0.28***	−0.08***	−0.02***	−0.08***	0.02***	−0.02***	0.01***	0.04***	−0.27***	1.00
VIF	1.82									
N	168,057									

Notes: The table reports the pairwise correlations between the independent variables in the baseline model. It also provides the VIF mean value. VIF values above 4 indicate collinearity.
*$p < 0.1$;
**$p < 0.05$;
***$p < 0.01$.

Due to potential endogeneity bias, we are careful to interpret our estimates as indications not of outright causation but of strength of association between the outcome variables and the regressors. In the text, we may use the terms ‘cause’ or ‘predict’ only to facilitate discussion. Table 3 presents the matrix of correlations between ESR and the firm-level controls. They are less than the 0.5 value and therefore the variables do not exhibit severe collinearity.

Analysis of the results

The parameter estimates report the marginal changes in real sales growth of firms resulting from changes in the ESR index across countries. Table 4 presents the baseline estimates. In all models, the ESR is a positive and significant predictor of real sales growth of firms. Lower values of the index (higher ESR) are associated with lower sales growth and vice versa. The different fixed effects influence the magnitude but not the direction of the ESR effect. Small differences exist in the ESR effect across the different model specifications. For instance, in model (6) that includes all types of fixed effects, a unit change in the ESR is associated on average with a 6.22% unidirectional change in corporate sales growth. It appears that overall country preparedness to deal with epidemiological risk affects the risk perceptions of consumers and producers, thereby influencing firm performance. These results corroborate and generalize those of other contemporary studies that document broadly negative effects of Covid-19 on consumer expenditure (Cavallo, 2020; Coibion, Gorodnichenko and Weber, 2020) and supply chain disruptions (Barrero, Bloom and Davis, 2020) with dampening effects on corporate sales in individual countries. Further, the firm-level controls appear mostly significant with the expected sign. Firms managed by executives with long experience in the firm are associated with lower sales growth. This finding is in line with the views of van Mossel, van Rijnsoever and Hekkert (2018) and the findings of Hamori and Koyuncu (2015), and may be taken to support the adaptive management view. Moreover, larger firms that are exporters are associated with higher sales growth. Sales of manufacturing firms are affected more than sales in other sectors. Private and government ownership is associated with lower growth of sales, whilst foreign ownership is not significant. Finally, the macro controls are significant predictors of corporate sales growth in most models. The level of economic development exerts a small adverse effect on sales growth, whilst economic growth exerts a strong positive effect on sales growth.

Under varying conditions of epidemiological risk, sales may vary in accordance with the mismatch between supply and demand, the nature of goods (e.g. medical equipment vs. entertainment), the size of the firm (small vs. large firms) and its sector of activity (manufacturing vs.

Table 4. Baseline models

	(1)	(2)	(3)	(4)	(5)	(6)
ESR	0.660*	6.488***	6.487***	0.642*	6.203***	6.223***
	(0.740)	(2.361)	(2.362)	(0.736)	(2.337)	(2.336)
MANAGEXP				−0.684*	−1.299***	−1.305***
				(0.409)	(0.212)	(0.211)
SIZE				1.511***	1.031***	1.011***
				(0.378)	(0.228)	(0.225)
SECTOR				−0.005	−0.226*	
				(0.294)	(0.181)	
OWNPRV				−0.064***	−0.048*	−0.046***
				(0.037)	(0.028)	(0.025)
OWNFOR				−0.055	−0.046*	−0.046***
				(0.036)	(0.027)	(0.027)
OWNGOV				−0.090**	−0.066**	−0.066**
				(0.040)	(0.032)	(0.032)
EXPORTER				1.071	0.893*	0.864*
				(0.697)	(0.674)	(0.683)
GDPCAP	0.001	−0.001*	−0.001*	0.001	−0.001*	−0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	−0.096	0.370*	0.371*	−0.094	0.453*	0.452*
	(0.156)	(0.389)	(0.382)	(0.154)	(0.412)	(0.410)
Country effects	No	Yes	Yes	No	Yes	Yes
Year effects	No	Yes	Yes	No	Yes	Yes
Sector effects	No	No	Yes	No	No	Yes
adj. R^2	0.001	0.081	0.081	0.005	0.084	0.084
F-stat	2.276			4.989		
N	102,240	102,240	102,240	99,680	99,680	99,680

Notes: The table reports the baseline OLS results under different fixed effect specifications. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The key independent variable is the measure of epidemiological susceptibility risk, ESR. The sample period is 2006–2019. Appendix A defines the variables. Models (1) to (3) include only macro controls, whilst models (4) to (6) include both macro and firm-level controls. Models (1) and (4) include random effects, models (2) and (5) include country and year effects and models (3) and (6) include country, year and sector effects.
*$p < 0.1$;
**$p < 0.05$;
***$p < 0.01$.

service firms), among other factors. Moreover, diversifying sales products or policies is voluntary, and therefore firms may self-select in to/out of certain sales practices and products, introducing potential selection bias. Following Asiedu, Freeman and Nti-Addae (2012), we account for potential diverse effects by estimating our baseline model for different subsamples by firm size and sector of activity. Table 5 reports the results. The ESR index remains a significant and positive predictor of real sales growth, whose effect differs among firm sizes and sectors. It is stronger in larger firms and in non-manufacturing firms. Fairlie (2020) finds that 2 months after the Covid-19 outbreak, 15% of US small business owners faced a huge and heterogeneous reduction in sales, causing many of them to become inactive. Overall, our results document the existence of nonlinearities in the ESR effect on firms' sales growth associated with firm size and sector of activity.

Sensitivity and endogeneity analysis

The robustness of the estimates depends on addressing several potential econometric biases. First, the potential problem of reverse causality implies a possibility that sales growth influences endogenously the constituent elements of the ESR index, causing a correlation between the explanatory variables and the regression's error term. We argue that such concerns of endogeneity due to reverse causality are not sound. It is unreasonable to accept a feedback effect from the growth of sales of individual firms to the epidemiological susceptibility conditions in a country. Further,

Table 5. Baseline models by firm size and sector

	Firm size			Sector of activity	
	Small firms	Medium-size firms	Large firms	Manufacturing firms	Non-manufacturing firms
ESR	5.909**	5.624**	9.438***	5.583**	7.085**
	(2.545)	(2.615)	(3.035)	(2.275)	(2.925)
MANAGEXP	−1.786***	−1.310***	−0.427	−0.983***	−1.851***
	(0.275)	(0.300)	(0.332)	(0.242)	(0.278)
SIZE				0.885***	1.254***
				(0.237)	(0.313)
SECTOR	−0.113	0.433**	0.361		
	(0.257)	(0.206)	(0.336)		
OWNPRV	−0.053	−0.053*	−0.027	−0.040	−0.055**
	(0.037)	(0.030)	(0.034)	(0.033)	(0.026)
OWNFOR	−0.061*	−0.042	−0.024	−0.034	−0.056**
	(0.035)	(0.029)	(0.033)	(0.032)	(0.025)
OWNGOV	0.063	−0.082**	−0.065*	−0.052	−0.077**
	(0.101)	(0.032)	(0.038)	(0.043)	(0.030)
EXPORTER	2.700*	0.342	0.233	0.215*	3.655*
	(1.523)	(0.890)	(0.492)	(0.576)	(1.736)
GDPCAP	−0.001	−0.001**	−0.001**	−0.001*	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	0.434	0.521	0.446*	0.460	0.427
	(0.522)	(0.372)	(0.248)	(0.469)	(0.374)
Country effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
adj. R^2	0.107	0.071	0.057	0.069	0.107
N	44,844	34,644	20,192	57,294	42,386

Notes: The table reports the results after we split the sample by firm size and sector of activity. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The key independent variable is the measure of epidemiological susceptibility risk, ESR. The sample period is 2006–2019. We use OLS models with fixed effects. We do not report the fixed effects. Appendix A provides the definition of variables.
$^{*}p < 0.1$;
$^{**}p < 0.05$;
$^{***}p < 0.01$.

the large cross-section sample of countries also reduces the likelihood of reverse causality. Second, time-invariant countrywide factors, such as geography and institutions, may wield significant unobservable effects on firms' sales performance and therefore be correlated with the regression's error term. It is possible that firms may change sales practices or sales composition for different reasons (e.g. technology) or incentives (e.g. tax policy), thereby affecting their volume. We therefore include fixed effects and add various control variables.

In order to check further our estimates' robustness, we apply additional tests of sensitivity. The sensitivity tests use alternative measurements of variables and sample structures. Table 6 presents the new results. Model (1) presents the results after raising ESR to its square value to capture nonlinear effects across the whole sample. Both the direct and squared effects of ESR are significant with opposite sign, indicating that as the epidemiological risk gets lower, its positive effect on sales growth gets weaker. Model (2) presents the results after using a 1-year lagged value of the ESR index to capture dynamic effects. The results show that both the contemporaneous and lagged values of the ESR exert a positive and significant effect on sales growth. It appears that the effect of epidemiological risks on firm performance has a dynamic nature. Model (3) uses firm-level employment growth (EMPLGR) as an alternative outcome variable. It is conceivable that the performance of a firm is reflected in the growth of its permanent, full-time labour force. However, we do not find a significant effect of the ESR index on employment growth. It appears that, in the

Table 6. Sensitivity analysis

	(1)	(2)	(3)	(4)	(5)	(6)
ESR	7.568***	9.147***	0.649	5.812**	6.256**	6.870***
	(2.355)	(3.226)	(0.726)	(2.503)	(2.964)	(2.401)
ESR^2	−4.066*					
	(2.447)					
$ESR_{\_1}$		1.529*				
		(1.387)				
MANAGEXP	−1.282***	−1.298***	−1.791***	−1.316***	−1.255***	−1.393***
	(0.212)	(0.213)	(0.170)	(0.225)	(0.283)	(0.193)
ESR***MANAGEXP						−0.240*
						(0.234)
SIZE	1.020***	1.033***	1.705***	1.006***	0.952***	1.029***
	(0.227)	(0.228)	(0.186)	(0.240)	(0.284)	(0.227)
OWNPRV	−0.048*	−0.048*	−0.016**	−0.050	−0.061	−0.048*
	(0.029)	(0.028)	(0.006)	(0.032)	(0.039)	(0.028)
OWNFOR	−0.046*	−0.045*	−0.024***	−0.046	−0.059	−0.046*
	(0.027)	(0.027)	(0.007)	(0.031)	(0.037)	(0.027)
OWNGOV	−0.066**	−0.066**	−0.075***	−0.066*	−0.096**	−0.066**
	(0.032)	(0.032)	(0.014)	(0.035)	(0.042)	(0.032)
EXPORTER	0.908	0.888	0.842***	0.953	0.618	0.895
	(0.671)	(0.673)	(0.284)	(0.721)	(0.638)	(0.673)
GDPCAP	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	0.544*	0.427	0.233**	0.377	0.265	0.454*
	(0.432)	(0.418)	(0.091)	(0.462)	(0.504)	(0.412)
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Sector effects	Yes	Yes	Yes	Yes	Yes	Yes
adj. R^2	0.085	0.084	0.052	0.081	0.120	0.084
N	99,680	99,680	120,397	92,066	35,426	99,680

Notes: The table reports the baseline OLS results with fixed effects after applying sensitivity tests. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The sample period is 2006–2019. Model (1) uses additionally a 1-year lagged value of the key regressor, $ESR_{\_1}$. Model (2) uses additionally a squared value of the key regressor, ESR^2, to capture nonlinearities. Model (3) uses firm permanent employment growth (EMPLGR) as an alternative outcome variable. Model (4) restricts the sample to large countries only with more than 500 firms. Model (5) restricts the sample so that all countries have equally at most 500 firms each. Model (6) introduces an interaction effect between ESR and managerial experience.

$^{*}p < 0.1$;

$^{**}p < 0.05$;

$^{***}p < 0.01$.

presence of epidemiological risk, firms are less reluctant to adjust the number of permanent, full-time workers. This is also expected and consistent with most accounts. Model (4) presents the results after including only the larger countries, with more than 500 firms each, to capture small-country size bias. This reduces the sample size by about 8%. The coefficient of ESR remains positive and significant, with a somewhat weaker magnitude. It appears that variations in ESR affect sales growth regardless of the size of overall domestic demand. Model (5) presents the results after including all countries with an equal number of at most 500 firms each. This helps contain large country bias, whereby some countries (e.g. India, China) have a large number of firms in the sample and others (e.g. Belize, Bahamas) have only a small number of firms. This reduces the sample size considerably, by about 44%. The effect of ESR remains positive and significant, with a roughly similar magnitude. Finally, model (6) introduces an interaction effect between ESR and managerial experience. The effect of ESR remains positive and significant, whilst the interaction effect is negative and significant. It appears that managerial experience helps moderate the reaction of firms' sales performance in the presence of epidemiological risk, and thus lends support to the adaptive management hypothesis.

In all alternative models, the ESR effect is positive and significant, thereby confirming the baseline results. Managerial experience also remains a significant and negative predictor throughout.

However, the standard least squares regression generates estimates based on the average ESR effect on the average firm's sales growth. However, since the growth of sales is skewed, we use a quantile regression to assess the ESR effect. The quantile regression has the advantage that the results are robust to outliers and account for the entire conditional distribution of sales growth (Coad and Rao, 2011). We therefore assume that error terms are not identically distributed at all points of the conditional distribution and that slope parameters vary across the different quantiles of the distribution. We apply Koenker and Bassett's (1978) estimation model adjusted by the Parente and Santos Silva (2016) (PSS) procedure to identify intra-cluster correlation of data sampled from i.i.d. clusters (qreg2). Table 7 presents the results. Interestingly, the ESR is positive and significant only in the 20th percentile and the upper percentiles (60th to 80th), indicating significant heterogeneity of the ESR effect across the statistical distribution of the outcome variable. In our sample, the PSS test demonstrates significant intra-country correlation.

It might be argued that the ability of the ESR index to predict firm performance depends on the timing of epidemics and the confounding effects of other factors. After all, epidemic outbreaks were observed during some periods in recent history and not others. Further, other factors (i.e. infrastructure, vaccination policies) may affect the epidemic's contagion risk. We check these conjectures by applying further robustness testing. First, we split the total sample across 3-year consecutive periods and estimate again our baseline model. Table A3 in the online Supporting Information provides the results. The ESR index remains positive and significant, but with considerable variation: it is considerably stronger during periods of epidemic outbreaks. This result confirms the ESR index's predictive power. Second, we explore the effect after reconstructing the ESR index to include other potentially relevant factors. We produce a revised measure, which is the principal component of 18 variables, comprising the original 17 ones plus a new variable that measures overall quality infrastructure (INFRAS). The latter is a composite measure produced by the World Economic Forum (2020). The addition of this new variable is intended to explore the overall effect of infrastructure on the ESR index construction. Table A3 shows that after loading the new variable, the ESR index fails to provide a significant prediction of firm performance. We repeat our restructuring experiment by generating yet another different version of the ESR index that comprises the original 17 ones plus a new variable that measures the vaccination rate in each country. The results (not shown) confirm the ability of the ESR index to predict firm performance, albeit less strongly. Overall, it appears that the structure of the ESR index matters in predicting firm performance. Our chosen structure shows the highest predictive power, which however might be further improved by future research on the factors that comprise the index's construction.

In order to check the validity of the ESR index in predicting firm performance under the current Covid-19 conditions, we use a recent dataset that comprises the results of a new enterprise survey that assessed specifically the Covid-19 effects on firms and took place during May 2020–January 2021 (World Bank, 2021). The structure and method of information collection of the Covid-19 sample is the same as with the original sample. However, the new dataset is smaller and includes 37 selected countries and few firm-specific characteristics. It comprises 32,945 firms. The new outcome variable is the average change in monthly sales compared to 1 year ago (2019–2020), SALESGR1. Table 2 (Sample B) provides summary statistics for the variables in the Covid-19 sample. We regress the new outcome variable on the 2019 value of ESR (ESRC), using an OLS model with and without fixed effects. Table 8 presents the results. We document a significant and positive effect of the ESR index on SALESGR1. It is also consistent with the dynamic nature of the ESR effect.

Despite the inclusion of fixed effects controlling for invariant country factors, the OLS estimates will not produce unbiased assessments of the ESR effect on corporate sales growth, because of the possible presence of time-varying factors affecting epidemiological outcomes and sales growth simultaneously. For example, countries that may have seen in recent years an improving firm performance may have invested more in health and other infrastructure, which improved their preparedness for managing epidemiological risk, thereby

Table 7. Quantile analysis

	10%	20%	30%	40%	50%	60%	70%	80%	90%
ESR	1.047	1.724*	1.482	0.829	0.445	0.421*	0.522*	0.773*	0.909
	(2.678)	(1.003)	(0.940)	(0.911)	(0.755)	(0.622)	(0.664)	(0.778)	(1.331)
MANAGEXP	0.619	0.001	−0.015	−0.041	−0.199	−0.410***	−0.885***	−1.697***	−3.380***
	(0.804)	(0.478)	(0.227)	(0.203)	(0.187)	(0.215)	(0.260)	(0.464)	(0.917)
SIZE	4.833***	3.098***	1.841***	1.293***	0.770***	0.343	0.048	−0.507	−1.680**
	(0.953)	(1.121)	(0.284)	(0.313)	(0.220)	(0.209)	(0.239)	(0.319)	(0.845)
OWNPRV	0.167	0.086	0.040	0.012	−0.008	−0.038*	−0.086*	−0.262***	−0.581***
	(0.352)	(0.077)	(0.029)	(0.020)	(0.024)	(0.022)	(0.045)	(0.100)	(0.094)
OWNFOR	0.116	0.067	0.034	0.013	−0.002	−0.029	−0.071	−0.237**	−0.532***
	(0.333)	(0.077)	(0.029)	(0.020)	(0.024)	(0.022)	(0.045)	(0.098)	(0.087)
OWNGOV	0.041	0.050	0.013	−0.013	−0.032	−0.074***	−0.129***	−0.284***	−0.565***
	(0.268)	(0.064)	(0.029)	(0.025)	(0.028)	(0.025)	(0.046)	(0.095)	(0.082)
EXPORTER	−0.218	0.050	0.335	0.905*	1.077**	1.258***	1.714***	2.019**	5.277***
	(1.137)	(0.656)	(0.522)	(0.480)	(0.450)	(0.449)	(0.526)	(0.806)	(1.560)
GDPCAP	0.001	0.001	0.001	0.001	0.001	0.001	0.001	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	0.059	0.076	0.089	0.054	0.054	0.068	0.097*	0.144*	0.025
	(0.488)	(0.237)	(0.173)	(0.180)	(0.168)	(0.169)	(0.198)	(0.222)	(0.343)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.062	0.040	0.025	0.014	0.010	0.010	0.011	0.017	0.034
Wald F-stat	30.988	3.930	6.098	3.207	3.847	5.928	6.709	5.502	18.539
PSS stat	465.0***	455.7***	433.9***	415.7***	338.0***	259.6***	213.0***	170.9***	151.9***
N	99,680	99,680	99,680	99,680	99,680	99,680	99,680	99,680	99,680

Notes: The table reports the results of the quantile analysis. We split the sample among 10 quantiles. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The key independent variable is the measure of epidemiological susceptibility risk, ESR. The sample period is 2006–2019. Appendix A provides the definition of variables. The Wald F-statistic tests for the equality of coefficients across different quantiles. The PSS statistic tests for intra-cluster correlation.

*$p < 0.1$;

**$p < 0.05$;

***$p < 0.01$.

Table 8. External validity: Covid-19 sample

	(1)	(2)	(3)
ESR	7.171***	2.912***	2.796***
	(1.376)	(0.513)	(0.663)
SIZE			4.487***
			(0.772)
SECTOR			−2.797***
			(0.651)
OWNFOR			0.005
			(0.009)
EXPORTER			0.007
			(0.012)
FEMMAN			−0.031***
			(0.011)
GDPCAP	0.001***	0.001***	0.001***
	(0.001)	(0.001)	(0.001)
GDPG	0.769	0.925***	0.852***
	(0.503)	(0.107)	(0.111)
Country effects	No	Yes	Yes
Monthly effects	No	Yes	Yes
Sector effects	No	Yes	Yes
adj. R^2	0.108	0.188	0.200
F-stat	28.645		
N	22,168	22,168	21,586

Notes: The table reports the baseline OLS results based on an alternative dataset under different fixed effect specifications (country, month, sector). The new dataset includes 37 countries: Albania, Belarus, Bulgaria, Chad, Croatia, Cyprus, Czech Republic, El Salvador, Estonia, Georgia, Greece, Guatemala, Guinea, Honduras, Hungary, Italy, Jordan, Latvia, Lebanon, Lithuania, Malta, Moldova, Mongolia, Morocco, Mozambique, Nicaragua, Niger, North Macedonia, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Togo, Zambia and Zimbabwe. The sample period is May 2020–January 2021. We cluster standard errors at the country level. The outcome variable is average change in monthly sales compared to 1 year ago (2019), SALESGR1. The key independent variable is the measure of epidemiological susceptibility risk, ESRC, for the year 2019. Appendix A provides the definition of variables.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

reducing perceived risk by consumers and producers. These deliberations mean that the covariance term COV (ESR_{it}, ε_{it}) in Eq. (1) is non-zero, because even if it is conditional on the fixed effects, ESR may be endogenous to sales growth. For this reason, we use instrumental variable (IV) estimates to check the robustness of our estimates. For comparison, we apply an OLS estimation with random effects (RE), an IV method that deploys the 2SLS estimator and an IV method that deploys the two-step generalized method of moments (GMM) estimator. The latter uses the first difference transformation, treating the lag values of the outcome variables as internal instruments for the lagged outcome variable, thereby producing more consistent and unbiased estimates. We use the degree of religiosity (RELIG) in a country as the excluded instrument in the IV analysis. Appendix A describes the variable. The degree of religiosity correlates highly with the ESR (−0.7289) and little with SALESGR (−0.0423). The social anthropology research documents a strong connection between religiosity and epidemiological risk. For example, Ransome (2020) reviews the evidence and argues that religion is an important social determinant of public health practice. Traditional mechanisms (e.g. social values and support) and spatial configurations (e.g. distribution of denominations, membership and adherence rates) of religious groups can explain the association between religion and social attitudes towards epidemics. Weinberger–Litman *et al.* (2020) document that different religious groups put under Covid-19 quarantine in the USA exhibited different behaviour towards compliance with the rules, engagement in social support and containment of anxiety. Table 9 presents the results from using the IV estimation methods. The results document that in the new models the ESR remains a positive and significant predictor of real sales growth of firms, but its effect is smaller. The effect of managerial experience remains negative and significant. The

Table 9. Instrumental variable models

	(1)	(2)	(3)	(4)
ESR	1.587**	1.574**	1.587**	1.573**
	(0.796)	(0.786)	(0.796)	(0.788)
MANAGEXP		−0.675*		−0.675*
		(0.409)		(0.402)
SIZE		1.450***		1.450***
		(0.373)		(0.373)
SECTOR		−0.089		−0.089
		(0.318)		(0.318)
OWNPRV		−0.067*		−0.067*
		(0.037)		(0.037)
OWNFOR		−0.058		−0.058
		(0.036)		(0.036)
OWNGOV		−0.103**		−0.103**
		(0.040)		(0.040)
EXPORTER		1.120		1.120
		(0.695)		(0.695)
GDPCAP	0.001	0.001*	0.001	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	−0.058	−0.057	−0.056	−0.055
	(0.149)	(0.147)	(0.149)	(0.147)
First stage				
Religiosity	−2.669***	−2.653***	−2.668***	−2.652***
	(0.397)	(0.394)	(0.397)	(0.394)
Sanderson–Windmeijer F-stat (pv)	45.136 (0.000)	45.248 (0.000)	45.136 (0.000)	45.248 (0.000)
IV analysis				
Stock–Wright LM stat (pv)	3.995 (0.046)	4.703 (0.030)	3.995 (0.046)	4.703 (0.030)
Kleibergen–Paap LM stat (pv)	13.493 (0.000)	14.123 (0.000)	13.493 (0.000)	14.123 (0.000)
N	102,240	99,680	102,240	99,680

Notes: The table reports the baseline results after applying instrumental variable (IV) methods for estimation. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The independent variable is the value of the epidemiological susceptibility index, ESR. Control variables include the firm-specific characteristics and the macro controls. Models (1) and (2) present the results of an IV method that uses the 2SLS estimator. Models (3) and (4) presents the results of an IV method that uses the two-step GMM estimator with robust standard errors. The external instrument used in the IV methods is the degree of religiosity in the country (RELIG). The Sanderson–Windmeijer F-statistic is larger than 10 and shows that the endogenous variable object of testing is not weakly identified. The Stock–Wright LM statistic suggests that the overidentifying restrictions are valid. The Kleibergen–Paap LM statistic suggests that the null hypothesis of underidentification is rejected and our (excluded) instrument is correlated with the endogenous regressor.

*$p < 0.1$;

**$p < 0.05$;

***$p < 0.01$.

Sanderson–Windmeijer F-statistic suggests that the endogenous variable object of testing is not weakly identified. The Stock–Wright LM statistic suggests that the overidentifying restrictions are valid. The Kleibergen–Paap LM statistic suggests that our model is not underidentified.

Further robustness checks

The link between ESR and firm performance is multifaceted. Different countries are subject to different institutional influences. These differences may influence the ESR effect on firm performance. We apply additional robustness assessments to control for the impact of diverse country-level conditions. We use different groups of new controls to contain measurement error and potential collinearity bias – we applied correlation checks before including the new controls in each group. We also use a lagged value of the new time-varying controls to contain concurrent causality bias. We estimate again Eq. (1) to include the separate impact of a country's cultural and social conditions, global risk conditions, health conditions and environmental conditions.

Table 10. Country-level controls and further robustness checks

	(1)	(2)	(3)	(4)
ESR	4.429**	6.133***	6.290**	3.879*
	(2.201)	(2.299)	(2.506)	(1.998)
MANAGEXP	−1.348***	−1.297***	−1.220***	−1.302***
	(0.212)	(0.212)	(0.229)	(0.223)
SIZE	1.043***	1.021***	1.065***	1.076***
	(0.230)	(0.227)	(0.253)	(0.245)
OWNPRV	−0.019*	−0.048*	−0.047	−0.047
	(0.010)	(0.028)	(0.029)	(0.030)
OWNFOR	−0.018*	−0.046*	−0.046	−0.044
	(0.010)	(0.027)	(0.028)	(0.029)
OWNGOV	−0.039*	−0.066**	−0.058*	−0.054
	(0.020)	(0.032)	(0.034)	(0.036)
EXPORTER	0.891	0.894	0.795	0.947
	(0.679)	(0.674)	(0.768)	(0.716)
GDPCAP	−0.001**	−0.001	−0.001	−0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
GDPG	0.820***	0.503*	0.405	0.053
	(0.268)	(0.425)	(0.465)	(0.495)
CULTGLB	0.275*			
	(0.185)			
FAMTIES	−43.810***			
	(10.660)			
BCRISIS		−0.022*		
		(0.069)		
GEOPOL		5.552		
		(3.853)		
MALARIA			−0.418	
			(0.981)	
TUBERCULS			8.381*	
			(0.339)	
TEMP				−6.936**
				(3.163)
RAINFALL				−0.076*
				(0.042)
Country effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Sector effects	Yes	Yes	Yes	Yes
adj. R^2	0.086	0.084	0.090	0.091
N	98,222	99,680	88,975	92,486

Notes: The table reports the baseline OLS results after controlling for additional country-level factors. We cluster standard errors at the country level. The outcome variable is real sales growth, SALESGR. The independent variable is the value of the epidemiological susceptibility index, ESR. The sample period is 2006–2019. Appendix A defines the variables. The additional new control variables include cultural conditions (model 1), global risk conditions (model 2), diseases (model 3) and weather conditions (model 4).

*$p < 0.1$;

**$p < 0.05$;

***$p < 0.01$.

First, we consider cultural conditions. Kagawa-Singer (2011) argues that cultural assimilation influences health outcomes by affecting shared behaviour and the provision of care to people. Umberson and Thomeer (2020) ague that family structure and transition affect health outcomes and document that family ties have wide-ranging consequences for health. We check the importance of these suggestions by including in the newly estimated model (1) the index of cultural globalization (CULTGLB) from Gygli *et al.* (2019) and the index of the strength of family ties (FAMTIES) from Alesina and Guliano (2010). Second, we consider global risk conditions. Wiengarten *et al.* (2016) argue that, given the extent of globalization, geopolitical and other risks have increased the complexity of supply chains and their effect on firm performance. Forbes (2004) argues that epidemic and financial crises affect firm performance through their impact on export competition and direct sales exposure to countries in crisis. We check the importance of these suggestions by including in the newly estimated model (2) whether a country is facing a financial crisis (BCRISIS) and the degree of geopolitical risk (GPR). The World Development Indicators and Caldara and Iacoviello (2019), respectively, provide the data. Third, we consider health conditions. Jung *et al.* (2016) argue that epidemic outbreaks cause consumers to alter their spending behaviour, causing considerable disruption in aggregate consumption expenditure with large heterogeneity across sectors. We check the importance of these suggestions by including in the newly estimated model (3) the incidence of malaria (MALARIA) and tuberculosis (TUBERCULOSIS) per country. The World Development Indicators provide the data. Fourth, we consider environmental conditions. Huang *et al.* (2018) argue that climate conditions affect firm performance directly through extreme weather events and indirectly through their effects on other global risk factors. We check the importance of these suggestions by including in the newly estimated model (4) the average temperature (TEMP) and the average degree of precipitation (RAINFALL) per country. The World Development Indicators provide the data. Table 10 presents the results of the new estimation models (1) to (4) separately, inclusive of the new controls. The new estimates document that the coefficient of ESR remains positive and significant under all new controls. The effect is stronger when we control for the influence of diseases and weather conditions. Managerial experience remains a significant negative predictor of sales growth. Cultural globalization exerts a positive effect, whilst family ties exert a strong negative effect on sales. Banking crises, epidemiological and weather conditions are also significant predictors. These findings are in line with the baseline results and broadly corroborate those of previous studies.

Conclusions

Epidemics are extreme risk events that cause large social and economic costs for countries and firms. The impact of epidemics on business performance materializes mainly through consumer perception of risk and the resilience of the supply chain networks. It is therefore critical to assess whether countries are prepared to identify and manage these risks adequately in order to maintain consumer confidence and the integrity of the supply chain networks, thereby sustaining business continuity and survival. Many countries remain unprepared to respond and manage epidemic risks. We respond to the challenge of assessing country preparedness by constructing a country-level index of ESR. Subsequently, we use the ESR index to predict corporate performance around the world. We construct the ESR measure using objective and reproducible information with useful policy implications. We therefore account for the role of infrastructure, demographics, economic activity and governance. The ESR index proves a significant and positive predictor of corporate sales growth around the world. Its effect is stronger in smaller and non-manufacturing firms operating in less developed and larger countries. Moreover, its effect is stronger when we control for epidemiological episodes and weather conditions. It appears that the latter conditions exert a stronger mitigating effect than the economic or geopolitical factors. The specific characteristics of firms are mostly significant controls. However, long-serving incumbent management does not improve firm performance. The results remain robust to various sensitivity and endogeneity tests. It appears that our ESR measure captures diverse conditions of epidemiological risk contagion, thereby affecting firm performance. Therefore, it might potentially be a useful tool for predicting and managing epidemic outbreaks and assessing their implications for corporate sustainability. The ESR index uses time-varying variables that are objectively measured and available for a large range of countries. As a result, it can be reproduced annually and its predictive power in explaining economic behaviour can be regularly assessed. In this respect, it could enter the policy decision-making frameworks as an early warning variable.

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Appendix A: Definition of variables

Variable	Description and source
SALESGR	The real annual growth of sales (%) of the firm, from the World Bank Enterprise Surveys. The variable takes values in the [−100, +100] interval.
SALESGR1	The real monthly growth of sales (%) of the firm, from the Covid19 World Bank Enterprise Surveys 2020. The variable takes values in the [−100, +100] interval.
EMPLGR	Annualized growth (%) of permanent, full-time workers in the firm, from the World Bank Enterprise Surveys.
ESR	The composite index of epidemiological susceptibility risk. The index consists of 17 time-varying variables and takes values in the [−10, +10] interval. Higher values imply a lower degree of a country's susceptibility to epidemiological risk or, alternatively, higher preparedness to deal with epidemiological risk.
MANGEXP	Logarithm of the number of years in the firm of the top manager, from the World Bank Enterprise Surveys.
SIZE	Ordinal variable that takes the value 1 if the firm is small (5–19 employees), 2 if it is medium (20–99 employees) and 3 if it is large (over 99 employees), from the World Bank Enterprise Surveys.
SECTOR	Ordinal variable that takes the value 1 if the firm is in the manufacturing sector and 2 if it is in other sectors, from the World Bank Enterprise Surveys.
OWNPRV	Percentage of a firm's equity capital owned by domestic private owners, from the World Bank Enterprise Surveys.
OWNFOR	Percentage of a firm's equity capital owned by foreign owners, from the World Bank Enterprise Surveys.
OWNGOV	Percentage of a firm's equity capital owned directly by the state, from the World Bank Enterprise Surveys.
EXPORTER	Binary variable that takes the value 1 if the firm has more than 50% of its total sales exported and 0 otherwise, from the World Bank Enterprise Surveys.
GDPCAP	Logarithm of GDP per capita (current USD), from the World Development Indicators.
GDPG	The growth rate of a country's GDP, from the World Development Indicators
CULTGLB	The index of cultural globalization, from Gygli *et al*. (2019). It measures the extent of cultural globalization across countries.
FAMTIES	The index of the strength of family ties in a country, ranging from −1 to +1, from Alesina and Giuliano (2010).
BCRISIS	Dummy variable that takes the value 1 if the country experiences a financial crisis in a given year and 0 otherwise, from the World Development Indicators.
GEOPOL	Logarithm of the annual index of geopolitical risk, from Caldara and Iacoviello (2019). The index is based on public news covering geopolitical tensions around the world. Larger values indicate higher risk.
MALARIA	Logarithm of the annual incidence of malaria (number of infections per 1,000 people) in a country, from the World Development Indicators.
TUBERCULS	Logarithm of the annual incidence of tuberculosis (number of infections per 1,000 people) in a country, from the World Development Indicators.
TEMP	Logarithm of the average annual temperature (°C) of a country, from the World Bank's Climate database.
RAINFALL	Logarithm of the average annual rainfall (mm) of a country, from the World Bank's Climate database.
RELIG	The share of people who answer in the affirmative to the question: 'Is religion important in your life?' From the Gallup Poll 2010.

Charilaos Mertzanis is an Associate Professor of Finance at Abu Dhabi University, United Arab Emirates. Previously, he served for many years as senior financial regulator in Greece, academic faculty and international expert on financial regulation and policy. His research focuses on the impact of institutions and policy actions on corporate financial decision-making, governance and performance around the world.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supporting Information