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Abstract

Small businesses have suffered disproportionately from the COVID-19 pandemic. We use near-real-time weekly data from the Small Business Pulse Survey (April 26, 2020 - June 17, 2021) to examine the constantly changing impact of COVID-19 on small businesses across the United States. A set of multilevel models for change are adopted to model the trajectories of the various kinds of impact as perceived by business owners (subjective) and those recorded for business operations (objective), providing insights into regional resilience from a small business perspective. The findings reveal spatially uneven and varied trajectories in both the subjectively and the objectively assessed impact of COVID-19 across the U.S., and the different responses to the pandemic shock can be explained by evolving health situations and public policies, as well as by the economic structure and degree of socioeconomic vulnerability in different areas. This study contributes to scholarship on small businesses and regional resilience, as well as identifying policies and practices that build economic resilience and regional development under conditions of global pandemic disruption.

Keywords

small business resilience, COVID-19, public policy, multilevel model for change

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Introduction

The arrival of coronavirus (COVID-19) had an unprecedented impact on the health and economic well-being of people across the world. In the U.S, the first half of 2020 was marked by a net loss of over 15 million jobs. This net loss was equivalent to the previous 7 years of job gains for all firms (Small Business Association (SBA 2021). Although businesses of all sizes were braced for record losses, small businesses were impacted disproportionately, because larger firms were more likely to have the resources, legal structure, and returns to scale to be able to respond to social-distancing regulations for operating and reopening during the pandemic (Fairlie 2020). However, the health of the U.S. economy is tied to the fate of small businesses. From 2000 to 2019, small businesses created 10.5 million net new jobs, accounting for 65.1% of net new job creation. Currently, small businesses comprise 99.9% of all firms, employing 61 million, or 47.1%, of private-sector workers (SBA 2020). Given these statistics, understanding the experiences of small businesses during pandemic disruptions is vital if the U.S. economy is to rebound and reinvent itself.

Research has established that regional environments, such as state business climates and entrepreneurship ecosystems, human capital, social capital, and business networks are fundamental to the formation of new firms and the development of existing ones (Kang et al. 2021; Qian 2018). Furthermore, income inequality and varying industrial structures, regional attractiveness, dynamic adaptation abilities, and institutional environments are all important factors for regional resilience (Christopherson et al. 2010; Geelhoedt et al. 2021; Martin et al. 2016; Pontarollo and Serpieri 2021). Whereas these studies have indicated a linkage between small business resilience and regional socioeconomic characteristics, most studies on regional resilience have focused on macroeconomic performance (e.g. regional GDP, employment) in the face of economic crisis. Very few studies have examined small business resilience from a regional perspective.

The economic struggles that have resulted from COVID-19 differ from those of previous disasters in nature and extent. Studies on COVID-19 based on data from the early stages of the pandemic have tracked the number of businesses that shut down, or experienced disrupted operation or financial constraints, to determine the most impacted industries (Bartik et al. 2020; Fairlie 2020). Other studies have revealed significant temporal and spatial variations in impact (Kim, 2021; Wang and Kang, 2021; Zhai et al. 2021a, 2021b). Building upon earlier findings, this study is based on analyses of data that span over 1 year to examine the impact of the pandemic at various points in time and in various geographical locations. Specifically, it examines the impact of COVID-19 on U.S. small businesses from a multidimensional, longitudinal, and regional perspective by addressing the following questions:

- What has been the impact of COVID-19 on small businesses in the U.S. and how has this impact varied across time and place?
- What are the regional factors associated with temporal and spatial variations?

Drawing on the Small Business Pulse Survey (SBPS) for the 48 contiguous states[1] in the U.S. from the week April 26-May 2, 2020 to the week June 7-13, 2021, we investigate how the impact of COVID-19 varied across the states over that period. Degrees of impact are measured both by small business owners' subjective assessments of perceived impact and by objective measures of business operational disruption and financial status. We employ a set of multilevel models for change to examine the trajectories of the multi-dimensional impact over time and to evaluate their relationship with the constantly changing and volatile health situation and with various public policies, while taking account of the local context of long-term economic structure and socioeconomic vulnerability existing pre-COVID-19. The results demonstrate significant variations in pandemic-related disruption of small businesses over time and across states and significant differences between people's perception of, and the market response to, policies designed to help cope with a situation of disastrous shock.

This study represents one of the first attempts to assess the regional resilience of small businesses by systematically examining multiple indicators from a longitudinal perspective; and it contributes to the design of policies and practices for building economic resilience and regional development during global pandemic disruptions. For example, government-imposed restrictions or lockdowns, including regulations governing which businesses could operate, forced millions of small businesses throughout the U.S. to temporarily shut down (Balla-Elliott et al. 2020). At the time of writing, different coronavirus variants are changing the calculations of governments around the world, raising doubts about how quickly they can recover from the pandemic (WSJ 2021). Evaluating COVID-19 experiences over a year from a longitudinal and spatial perspective provides evidence as to how policy frameworks should evolve to improve the effectiveness of programs and help small businesses combat the negative effects, and navigate the uncertainty and risks, of today's pandemic-filled business environment.

Small Business Resilience and Regional Socioeconomic Factors

Small businesses are, in many ways, more vulnerable to disasters than large businesses, because they tend to have less access to physical and financial capital and lack geographic diversity; and they are less likely to have contingency plans (Marshall and Schrank 2014; Sauser et al. 2018). Previous research has identified a number of attributes that are most important in building resilience, such as business size, industrial sector, age of business, amount of emergency planning, financial situation, market range, and previous disaster experience (Adekola and Clelland 2020; Haynes et al. 2019; Orhan 2016; Webb et al. 2000). However, beyond individual and organizational preparedness for turbulence and discontinuities, the survival of small businesses also depends on regional capabilities to resist recessionary shocks.

Regional Economic Structure

Researchers have linked regional resilience with socioeconomic and institutional factors (Martin & Sunley, 2015). Some industries are more sensitive than others, and regional sensitivity is the result of a combination of these sectoral sensitivities (Brown and Greenbaum 2017; Martin et al. 2016). For example, based on regional employment data for Canada from 1987 to 2012, research has found that employment loss in each recession was closely associated with industry mix in the preceding growth period. During each recession, manufacturing had much bigger employment losses and a much weaker recovery than the service sector (Ray et al. 2017). Similarly, during COVID-19, some industries, such as accommodation and food services, the arts, entertainment, recreation, and educational services, have been more vulnerable than others (SBA 2020). Wang and Kang (2021) find that metropolitan areas that have higher densities of vulnerable industries are associated with more business losses and more negative impact as perceived by small business owners.

The degree of sectoral specialization also impacts overall regional sensitivity. On the one hand, diversification, the opposite of specialization, reduces the concentration of risk (Groot et al. 2011). On the other, specialization can benefit regional growth by increasing competitiveness and externalities, which consequently increases regional resilience in the long run (Kitsos and Bishop 2018). In particular, regional human capital and innovation efforts can capture internal capabilities simultaneously, reacting 'innovatively' to adverse external conditions (Crescenzi et al. 2016). For example, regions endowed with technologically coherent knowledge bases are better prepared to face unforeseen downturns and display adaptive resilience. Local economies tend to be more adaptable if they innovate in those of their industrial and service sectors that have the strongest growth opportunities (Rocchetta and Mina 2019).

Drawing on these studies, we ***hypothesize*** that the impact of COVID-19 on small businesses in a region is associated with the region's economic structure. A region's economic structure includes several dimensions: its industrial specialization or diversification, its competitiveness (e.g. the proportion of high technology and the extent to which the labor force is highly skilled), and its vulnerability to disastrous events (e.g. the proportion of industries vulnerable to pandemic disruption).

Health Situation and Socioeconomic Vulnerability

Previous research studies have offered ample evidence that resilience in the face of disaster is affected by the degree to which social vulnerability is spread across multiple dimensions: race/ethnicity, gender, income, poverty, education, and social isolation. Social vulnerability exacerbates not only the damage caused by disasters, but also affects people's access to social and economic resources, and therefore their overall ability to cope with and recover from the impact of disasters (Marshall and Schrank 2014; Peacock et al. 2014; van de Lindt et al. 2018). For example, when natural disasters occur, socioeconomically and physically vulnerable groups experience later

evacuation, sustain a greater degree of damage, can access fewer private and public resources for recovery, and demonstrate slower and lower volumes of repair and rebuilding activity (Van Zandt et al. 2012). However, community resilience is highly dependent on the equity of resource distribution, access to financial resources, and the ability of local institutions to adapt to external shocks (Matarrita-Cascante and Trejos 2013).

Like previous disasters, COVID-19 has disproportionately impacted vulnerable communities: those which have a significant number of racial minority members, older adults, homeless, and low-income households (Bambra et al. 2021; Dokhov and Topnikov 2021). Both international and national crises often call attention to the inequalities in the labor market that disproportionately affect individuals from marginalized backgrounds (Cook and Grimshaw 2021; Kantamneni 2020). In the case of COVID-19, preliminary analyses have revealed that its spread and impact on businesses have indeed been unevenly distributed across space (Bartik et al. 2020; Kim 2021; Zhai et al. 2021a). For example, Zhai et al. (2021) show that in the U.S, densely populated areas, such as Los Angeles (CA), Denver (CO), New York City (NY), and Miami (FL), are likely to have more business closures than areas with a lower population density. In addition, permanent closures of entertainment and recreation businesses are significantly fewer than those of retail and trade businesses and food services. Wang and Kang (2021) also find that metropolitan areas with higher densities of vulnerable industries are associated with more business losses and higher negative impacts as perceived by small business owners.

Drawing on these studies, we ***hypothesize*** that the impact of COVID-19 on small businesses is highly dependent on the evolving health situation, such as the pandemic's incidence rate, death rate, and vaccination rate. Furthermore, the proportion of the population that is socioeconomically vulnerable correlates negatively with regional recovery and resilience.

Role of States and Public Policy

Public policies are instrumental in providing precautionary planning against crises, mitigating the worst effects once a crisis has arrived, and transforming and reorientating regions towards recovery. Governments worldwide responded to COVID-19 with a variety of laws, regulations, and assistance programs at different levels (Bourdin et al. 2021). Throughout the U.S, laws that required officials to implement physical distancing resulted in stay-at-home orders, restricted travel, closed schools and nonessential businesses, banned large gatherings, imposed curfews and the use of sanitary cordons, and the mask wearing requirement (Gostin and Wiley 2020). Balla-Elliott et al. (2020) argue that these regulations have been a constraint on firms' operating decisions, and they suggest that firms would not have remained shut down several months into the pandemic without government-imposed orders.

There are also significant differences in government financial support programs and their implementation. In March of 2020, the U.S. passed the Coronavirus Aid, Relief,

and Economic Security (CARES) Act, which provided the largest federal government program for assisting small businesses (e.g. the Payroll Protection Program (PPP)) to blunt the quick and devastating toll caused by the pandemic. Barik et al. (2020) report that 70% of respondents anticipated taking advantage of aid programs like the PPP. However, aid programs are far from perfect, and many respondents anticipated they would have problems accessing the aid. Based on the data of 120,000 firms in 60 countries, Cirera et al. (2021) find that although governments around the world have implemented a wide range of policy support measures, their reach has been limited, especially for more vulnerable firms and countries.

Drawing on these studies, we ***hypothesize*** that government policies and programs influence how small businesses cope with the impact of COVID-19. Indeed, Zhai et al. (2021b) find that the temporal and spatial patterns of business closure are closely related to the differing scales of the stay-at-home orders imposed. Likewise, Kim (2021) shows that the arrival of COVID-19 in Korea has been accompanied by a decrease in sales of small businesses there. The emergence of pandemic management strategies, including the repeated lifting and reinforcing of lockdowns, has weakened the effectiveness of policies for controlling the spread of infectious diseases. Therefore, it is critical to detangle different policy factors across time and space. For example, on the one hand, social distancing measures and regulations that restrict economic reopening constrain business operations; on the other hand, financial assistance packages improve business owners' morale and put them in a position to continue trading.

Data and Variables

Data

The main source of data on the pandemic's impact on small businesses at the state level is the SBPS, which is an experimental data product designed and published by the U.S. Census Bureau. The SBPS is a weekly survey soliciting responses from small business owners (all non-farm, single-location businesses that have between one and 499 employees and receipts of $1000 or more) giving their assessment of the impact of COVID-19, the challenges (e.g. to operations and finances) that businesses are facing, and details of the assistance they have applied for and received. The SBPS is conducted in phases, with each phase comprising 9 weeks. Phase 1 was initiated on April 26, 2020 and concluded on June 27, 2020. The most recent data at the time of our data analysis covered the week of June 7, 2021 - June 13, 2021, the fourth week of Phase 5. Our data set thus covered full data from the first 4 phases of the SBPS and partial data from Phase 5 (the first 4 weeks), thus giving us figures for 40 weeks[2] Our analyses of the data focused on the 48 contiguous states.

To address our research questions, we examined four categories of variables that we hypothesized were associated with the regional resilience of small businesses in the face of COVID-19: (1) economic structure, (2) socioeconomic vulnerability, (3) health

situation, and (4) public policy. We obtained these variables from multiple sources, as indicated in Table 1.

Dependent Variables: Impacts on Small Businesses at the State Level

We investigated both subjective assessments of the impact of the pandemic, as perceived by small business owners, and objective measurements, such as businesses' financial status and the details given of operational disruptions they had suffered. The Overall Sentiment Index (OSI) and the Expected Recovery Index (ERI) are subjective assessments, each of which is derived from one survey question. The former assesses the overall effect of the pandemic on businesses, while the latter summarizes the length of time recovery is expected to take. The other two indexes, the Operational Challenges Index (OCI) and the Financial Stress Index (FSI), assess the overall effect of the pandemic on business operations and the financial difficulties experienced by businesses, respectively. The OCI incorporates responses from multiple survey questions about changes in revenue; paid employment and hours; times during which businesses were closed; and supply chain disruptions. The FSI presents a picture of cash on hand, loans, regular payments missed, and any applications made for financial assistance from various sources to cope with financial stress[3]. All four indexes have a range of [-1,1], with negative values indicating a negative effect, zero indicating little or no effect, and positive values indicating a positive effect. Supplementary File 1 (SF1) provides descriptive statistics for the four impact indexes at the state level. The impact of the pandemic on small businesses in the 48 U.S. states was negative throughout the study period. As indicated by the smallest absolute value of the mean for the OCI, small businesses seemed to be the least negatively impacted in terms of operational challenges. We also observed a value very close to 0, -0.02, in South Dakota in the week of June 7, 2021-June 13, 2021, the last week of our study period. Supplementary File 2 (SF2) shows the pairwise Pearson's correlation coefficients among the four indexes. All of them are statistically significant at the 1% level. The OSI is relatively highly correlated with the other three indexes; and the objective indicators, the OCI and FSI, have a high correlation of 0.7. In contrast, they have lower correlations with the subjective indicator, the ERI, and these are 0.51 and 0.49 respectively. Their relationships are further demonstrated by Figure 1(a) and (b), which visualize the statistical distributions of each index and pairwise relationships among the four indexes in the "initial" and "final" week of each Phase, respectively.

Figure 2 displays the trajectories of the four indexes averaged across the states. In producing the figure, we coded the first week of Phase 1 as Week 1, and gaps between consecutive phases were taken into account (Phase 1: Week 1-9, Phase 2: Week 15-23, Phase32: Week 27-35, Phase 4: Week 41-49, Phase 5: Week 54-57). All four indexes show sharp increases over the study period, suggesting the negative impact of the COVID-19 pandemic on small businesses became less severe during that time. However, the trajectories do not show anything like a steady linear progression: all indicate a sudden rebound around Phase 3 (November 9, 2020 - January 10, 2021),

Table 1. Descriptions and Sources of Variables for the U.S. States.

Variable	Description	Source
Dependent variables		
OSI	Overall sentiment index: Overall impact of the pandemic on small businesses.	SBPS Phases 1-5.
OCI	Operational challenges index: Overall impact of the pandemic on business operations, including revenue, closure, employment, and supply chain.	SBPS Phases 1-5.
FSI	Financial stress index: Overall financial difficulties experienced by small businesses, including cash on hand, loan and other payments miss, and the requests for financial assistance from sources like federal programs (e.g., Paycheck Protection Program (PPP), Economic Injury Disaster Loans (EIDL), small Business Administration (SBA) Loan Forgiveness), state or local government programs, banks, self, and family or friends.	SBPS Phases 1-5.
ERI	Expected recovery index: The length of time needed for the small business to recover as assessed by owners.	SBPS Phases 1-5.
Independent variables		
Cross-sectional variables		
HHI	Regional industrial concentration measured by the Herfindahl–Hirschman index (HHI).	BEA regional economic accounts 2019.
Essential	% of workers in essential industries	2015-2019 ACS microdata (IPUMS).
HSI	% of jobs labeled as "high-status" in the NAICS sectors of Information (51), FIRE (Finance, insurance, and real estate) (52-53), and Professional, scientific, and technical services (54).	BEA regional economic accounts 2019.
EssMinority	% of minority (non-Hispanic White) workers in essential industries.	2015-2019 ACS microdata (IPUMS).
VI	% of jobs in the top 3 NAICS sectors (Accommodation and Food services (72), Educational services (61), and Arts, Entertainment, and recreation (71)) identified to be most vulnerable to the COVID-19 pandemic.	SBPS and BEA regional economic accounts 2019.

(continued)

Table 1. (continued)

Variable	Description	Source
CRE3	% of individuals with 3 plus risk factors out of 11 risk factors.	2018 census Bureau community resilience Estimates (CREs).
AREAPCT_URBAN	Urbanization (% of urban areas)	U.S. 2010 census Urban and Rural Classification and Urban Area Criteria
Party	Political party of the governor.	—
Longitudinal variables		
IR	Infection rate, also referred to as "R-effective", quantifies the disease's "virality" by epidemiology models.	COVID Act now.
ICI	Infected case incidence: New daily infected cases for every 100,000,000 people (weekly average).	COVID Act now.
DCI	Death case incidence: New daily death cases for every 100,000 people (weekly average).	COVID Act now.
VCR	Vaccinations completed ratio.	COVID Act now.
Assis	% of small businesses that have received any federal financial assistance since Mar 13, 2020 (for Phases 1-3) and since December 27, 2020 (for Phases 4-5).	SBPS Phases 1-5.
SCI	School closing index measuring the extent of requiring or recommending closing schools and universities	Oxford COVID-19 government response Tracker (OxCGRT) U.S. State-level Covid-19 Policy responses
WCI	Workplace closing index measuring the extent of requiring or recommending closing workplaces or working from home	OxCGRT U.S. State-level Covid-19 Policy responses
SHRI	Stay at home requirements index which records orders to "shelter-in-place"	OxCGRT U.S. State-level Covid-19 Policy responses
FCI	Face covering index recording policies on the use of facial coverings outside the home	OxCGRT U.S. State-level Covid-19 Policy responses

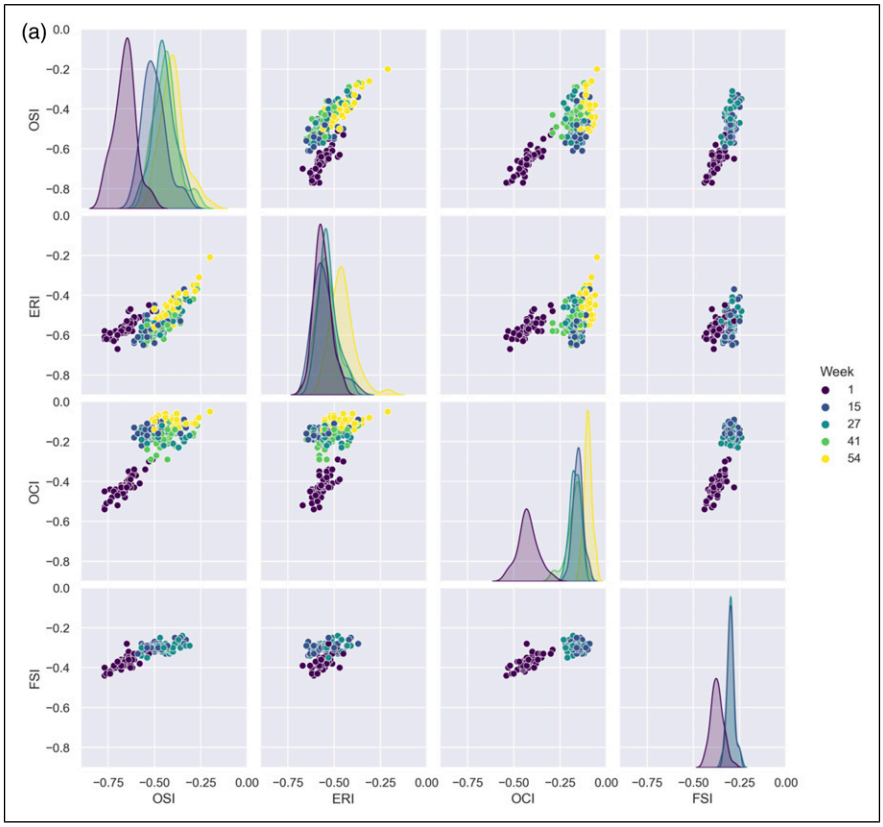

Figure 1. (a) Distributions of and pairwise relationships among four impact indexes at the "initial" week of each Phase. (b) Distributions of and pairwise relationships among four impact indexes at the "last" week of each Phase.

although the rebounds are less obvious for the OSI and FSI; and all, except for the ERI, show a sharp increase in Phase 1, with the OSI continuing to increase during Phase 2, although not as sharply as during Phase 1. During Phase 3 the OSI is shown to have stabilized and started to decrease. Then, we see the OSI increasing at a moderate pace during Phase 4 and the first 4 weeks of Phase 5.

In contrast, the ERI, which measures small business owners' expectations of business recovery, shows a quite different trajectory. The average expectation does not show a sharp increase in Phase 1 – on the contrary, it even decreases significantly before, like the OSI, increasing during Phase 2. Then, in Phase 3, it recovers and stabilizes to levels similar to those found at the beginning of Phase 2, suggesting that in that period small business owners were not optimistic about recovery despite a short

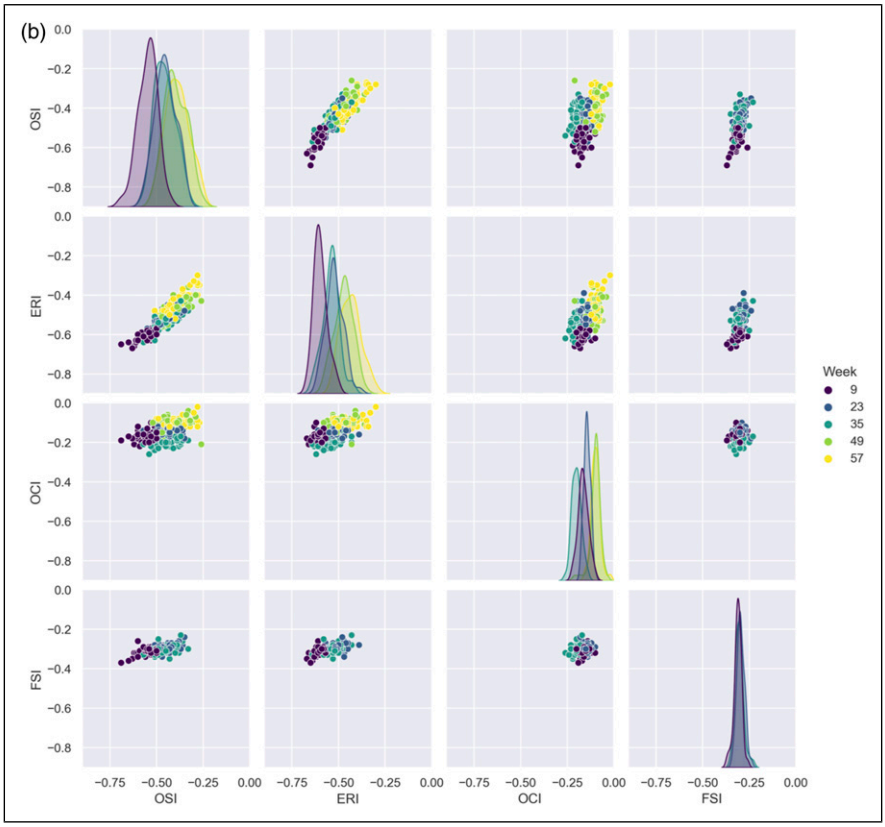

Figure 1. Continued.

period of regaining confidence from August to October 2020. Finally, we see the ERI climbing quickly and consistently in Phases 4 and 5.

Turning to the two objective measures of the impact of COVID-19, we can see that the average OCI starts at −0.4, increases dramatically during Phase 1, stabilizes during Phase 2, and decreases during Phase 3. This indicates that although the operational challenges faced by small businesses weakened to a significant extent from April to June 2020, they seem to have made a comeback during the period November 2020 - January 2021. In Phase 4, the average OCI increases to a level not seen before and stabilizes at around −0.1 in the first 4 weeks of Phase 5. This level represents a 76.8% increase from −0.4 at the beginning of the survey in April 2020 and comes the closest amongst all four indices to the baseline of 0, representing little or no effect on small businesses. The average FSI increases in Phase 1, stabilizes in Phase 2, and decreases slightly in Phase 3. Since the SBPS had, by Phase 4, stopped asking questions necessary

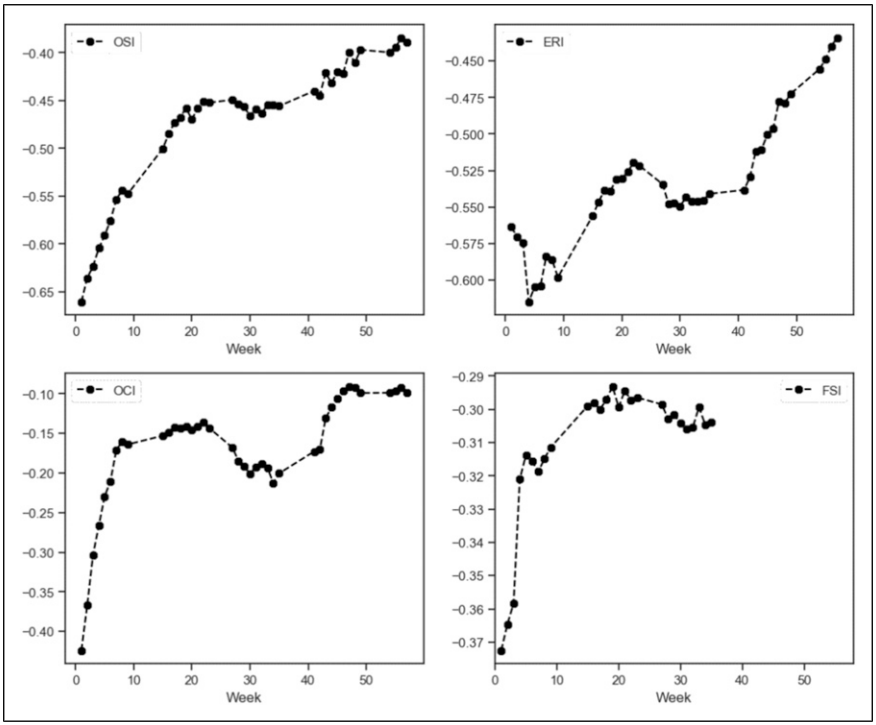

Figure 2. Average Trajectories of Four Indexes across the 48 Contiguous U.S. States (Week 1 started on April 26, 2020, and Week 57 ended on June 13, 2021).

for the construction of the FSI, there is no way of knowing how the small businesses fared in facing up to financial stress in the last part of the research period.

The evolution of the four impact indexes was not uniform across the 48 U.S. states. Figure 3 shows significant differences in the spatial distribution of each index over the study period. For instance, while the states on the northeastern coast initially fared the worst in handling business operational challenges, they improved so much that they escaped out of the first quintile. However, small business owners in these states fared the worst according to their assessments of the pandemic's impact at the beginning and the end of the study period.

Independent Variables: Longitudinal Variables in Health Statistics and Public Policies

The ever-changing public health situation for each state is measured by the COVID-19 infection rate (IR), the infection case incidence (ICI), the death case incidence (DCI), and the vaccination completion rate (VCR). The average trends for these measurements

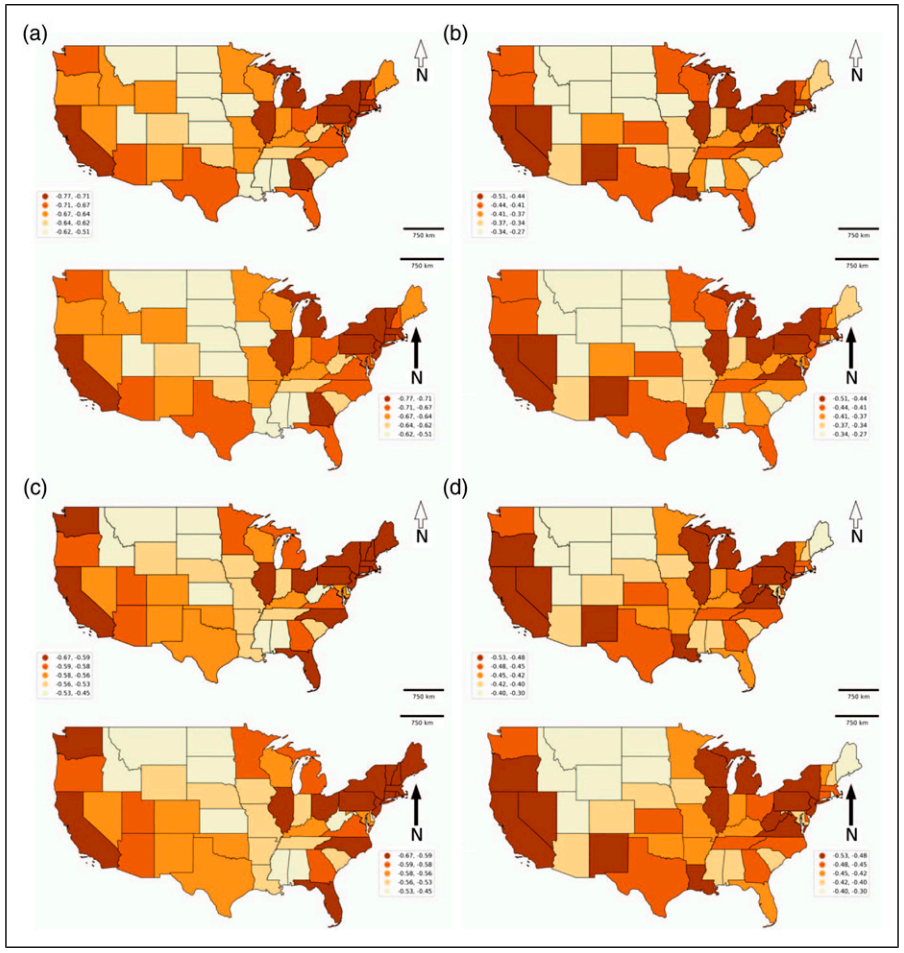

Figure 3. Spatial distribution (quintile choropleth map) of each index for the 48 contiguous U.S. States. (a) OSI - Week 1: 2020/04/26-2020/05/02, (b) OSI - Week 57: 2021/06/07-2021/06/13, (c) ERI - Week 1: 2020/04/26-2020/05/02, (d) ERI - Week 57: 2021/06/07-2021/06/13, (e) OCI - Week 1: 2020/04/26-2020/05/02, (f) OCI - Week 57: 2021/06/07-2021/06/13, (g) FSI - Week 1: 2020/04/26-2020/05/02, (h) FSI - Week 35: 2021/01/04-2021/01/10.

across the U.S. States are presented in Figure 4. A rebound can be seen for the ICI and the DCI from Week 30 to Week 41, which corresponds to that observed for the four indexes. The low levels of the ICI and DCI, and the fast-growing VCR, also match the lower levels of the negative impact indexes in the last two phases. As expected, the VCR is negatively correlated with the IR, ICI, and DCI, while the DCI is positively correlated with the ICI, with Pearson's Correlation Coefficient being 0.56, as shown in Supplementary File 3 (SF3).

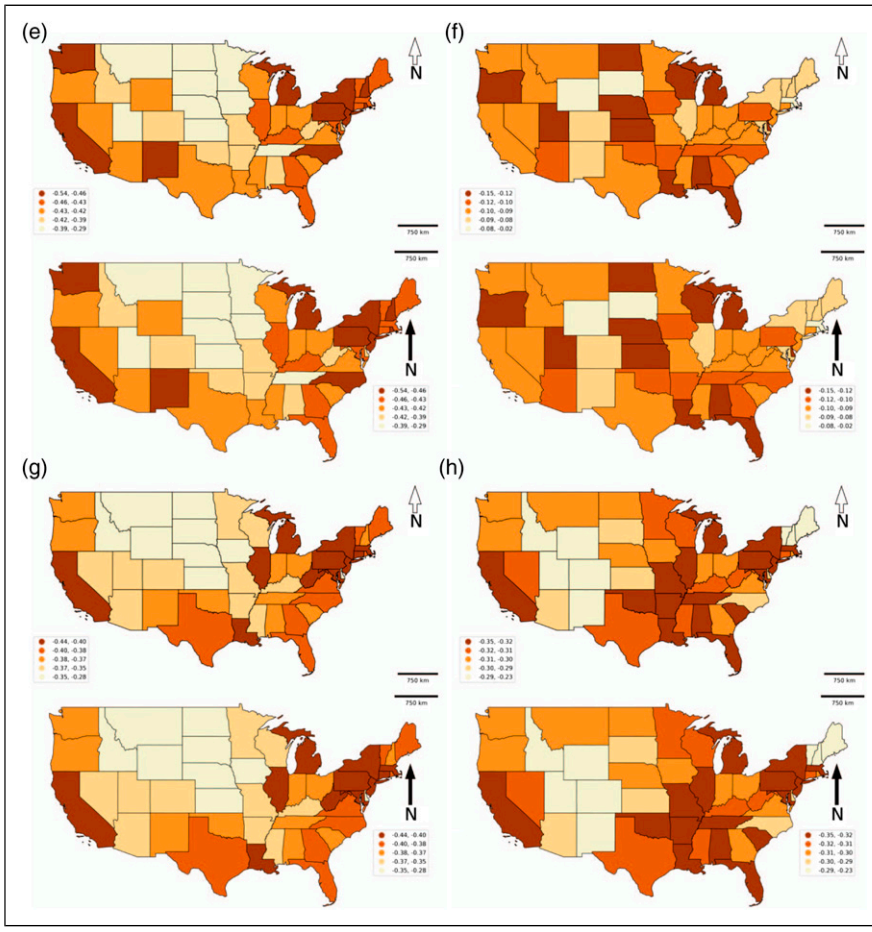

Figure 3. Continued.

Public policies and their implementation have varied widely across the States and have been frequently changed to deal with the fast-spreading pandemic, as well as to mitigate the economic downturn associated with it. Many of these policies have directly or indirectly influenced small businesses. For instance, a stay-at-home order, which required residents to stay at home and avoid non-essential trips, was enacted in most of the states before Week 1. This would negatively impact many businesses, especially those requiring face-to-face engagement with customers, such as restaurants and hotels. The Stay-at-Home Requirements Index (SHRI) captures the stringency of this order at the state level. As Figure 4 shows, it was at its maximum at the beginning of the study period, quickly declined during Phase 1 (April 2020-June 2020), stabilized in Phase 2 (August 2020-October 2020), increased slightly in Phase 3 (November 2020 - January

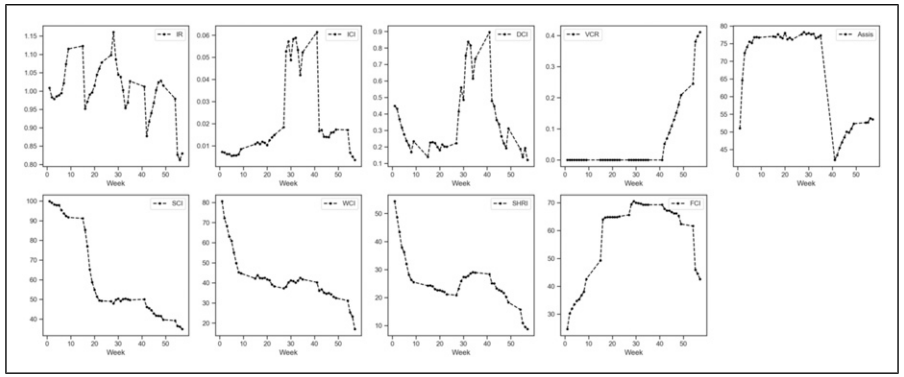

Figure 4. Average trends of COVID-19 severity, federal assistance, and state policies across 48 contiguous U.S. states.

2021), and then decreased dramatically to a very low level in Phases 4 and 5 (February 2021-June 2021). The upward trend observed in Phase 3 coincides with worsening health statistics and the reappearance of severe negative impacts on small businesses.

The Workplace Closing Index (WCI), which measures the extent of requiring or recommending the closing of workplaces or working from home, is also included in our analysis, since it directly impacts business operations. Its average trend reflects that of the SHRI. The School Closing Index (SCI), which measures the extent of requiring or recommending the closing of schools and universities, is considered, since it is likely to indirectly impact small businesses through employees having to take time off or even quit jobs to take care of children at home. We see that this index follows a similar pattern to those of the SHRI and the WCI.

Finally, the Face Covering Index (FCI) records the effect of policies requiring the use of facial coverings outside the home, policies that can impact small businesses if these requirements prevent some customers from enjoying their services. The FCI's average trend during the early phases is distinctive from those of the other three policy indexes: we see it at its lowest in the beginning, and it climbs quickly in Phase 1; by the second week of Phase 2 (August 16-22, 2020), it has peaked and stabilized; but at the beginning of Phase 3 it climbs again to reach its highest level, and remains there for the rest of Phase 3. Face covering restrictions were loosened in Phases 4 and 5, so here the FCI reflects the other three policy indexes, partially due to increased vaccination rates.

Figure 4 also indicates the degree of federal financial assistance received by small businesses in each state. Two rounds of coronavirus pandemic relief from the federal government were available to small businesses during the study period. The CARES Act (2020) was enacted on March 27, 2020 and provided the first round of financial assistance. The second round was provided by the Consolidated Appropriations Act (2021), which was enacted on December 27, 2020. Phases 1 to 3 of

the SBPS included questions about assistance received from the first round, while Phase 4 and beyond replaced these with questions regarding the second round of assistance. Figure 4 shows that the percentage of small businesses receiving federal financial assistance after March 13, 2020, during Phases 1-3, quickly climbed to around 78%, whereas by June 2021 only 55% of small businesses had benefitted from the second round of assistance.

The correlation shown amongst these public policies and public assistance variables is mostly moderate. If we look at SF3, we see that the highest correlation is between the WCI and the SCI, with Pearson's Correlation Coefficient being 0.48. In addition, none of these variables is highly correlated with the public health statistics, and the majority are not significantly correlated with the public health variables at the 5% level. These variations could help explain inter-state differences in the trajectories of the pandemic's impact on small businesses.

Time-Invariant Independent Variables

A set of state-level cross-sectional variables measuring economic structure, socio-economic vulnerability, and other demographic and political features were hypothesized to be associated with COVID-19's impact on small businesses. Table 2 lists some descriptive statistics for these variables.

We considered three variables concerning the economic structure of a state. The first was the degree of industrial concentration, or the opposite of that, industrial diversification. We adopted the Herfindahl–Hirschman Index (HHI), a commonly used index for regional industrial concentration. The HHIs for U.S. states in 2019 ranged from 693 to 875, with states on the western coast, Texas, and Florida occupying the lower end of the spectrum, indicating relatively low levels of industrial concentration. Supplementary File 4 (SF4) presents the spatial patterns for HHIs across the states. The second variable, the HSI, measures the percentage of industries that employ high-wage and high-skilled workers in each state. As shown in Supplementary File 5 (SF5), states on the western coast and northeastern coast have the highest percentages of high-status industries. The third variable, the Essential Index, measures the percentage of jobs in a state's industries that are deemed essential during the pandemic (mapped in Supplementary File 6 (SF6)).

Socioeconomic vulnerability was measured by three variables: the percentage of vulnerable industries (VI), the percentage of individuals having 3 or more out of 11 risk factors (CRE3), and the percentage of minority employees in essential industries (EssMinority). Supplementary File 7 (SF7) shows the spatial distributions of these variables across the states. For the VI, the average score for the four impact indexes (the OSI, OCI, FSI, and ERI) for each NAICS sector was used to identify the three sectors that were hit hardest by the pandemic. The weekly averages for accommodation and food services (72), educational services (61), and arts, entertainment, and recreation (71) were the lowest, and these sectors were therefore determined to be the most

Table 2. Descriptive Statistics for Contextual Variables at the State Level.

	HHI	Essential	HSI	EssMinority	VI	CRE3	AREAPCT_URBAN
Mean	763.81	57.67	17.75	29.54	12.16	25.11	7.59
Std	41.76	2.59	3.12	14.88	1.99	2.94	10.55
Min	693	53.66	11.84	6.31	9.3	19.25	0.2
25%	735.5	55.79	15.54	18.66	11.09	22.99	1.4
50%	757.5	57.4	17.21	26.62	11.88	24.91	3.52
75%	788.75	59.68	19.87	39.82	12.66	27.35	8.02
Max	875	62.79	23.76	64.23	21.79	31.41	39.7
Obs.	48	48	48	48	48	48	48

vulnerable to the pandemic. The percentage of jobs in these sectors for all 48 states was calculated and visualized in the choropleth map.

The CRE3 is a measure of community vulnerability, which is also known as the inverse of community resilience. This variable was drawn from the Community Resilience Estimates (CREs), which had recently been developed by the U.S. Census Bureau. The CREs incorporate 11 risk factors (RFs), ranging from socioeconomic characteristics such as income-to-poverty ratio, absence of household caregivers, communication barriers, unemployment, elderly, and lack of health insurance, to housing issues such as overcrowding. These RFs are known to have exacerbated the pandemic's toll. We used one of the published variables, CRE3, which represented the percentage of individuals with three or more RFs, as a proxy for community vulnerability.[4] The map indicates that the sunbelt states generally have higher levels of community vulnerability, meaning that households in these states are more vulnerable to the pandemic.

We further looked at the racial composition of essential workers in each state using the index EssMinority. On average, minority workers accounted for 29.54% of all essential workers in an average state. However, the percentage of minority workers covered a wide range (from 6.31% to 64.23%). Sunbelt states generally had values that were at the high end of the spectrum, and states in the northern plain region had values near the lower end.

Other Control Variables

We used the percentage of urban areas, as defined by the U.S. Census Bureau after the 2010 census, as a proxy for urbanization; and we further incorporated the political party of the state governor. Supplementary File 8 (SF8) shows the spatial distributions of these two variables across states. We then tested the bivariate relationships between independent variables. As shown in Supplementary File 9 (SF9), the CRE3 has a strong positive relationship with the EssMinority variable, indicating that those states, where

households are vulnerable to disasters, are also likely to have more minority workers in essential industries, which could further exacerbate their vulnerability to the pandemic.

Multilevel Model for Change

How small businesses have fared during the pandemic has been changing over time, as indicated by the average trajectories of the four impact indexes in Figure 2. In addition, there have been significant differences in the changes across the 48 contiguous U.S. states, as indicated by the maps in Figure 4. Using a multilevel model for change allowed us to address both aspects: within-state changes over time and inter-state differences in change. This model is formalized as a two-level model, as shown in equation (1), where Level 1 models how each state changes over time while Level 2 describes how the trajectories differ across states. In the model, y_{ti}, the pandemic impact on small businesses in State i at time t, is a function of time (the survey week as represented by $Week_{ti}$), public health and policy factors that change over time $(X1_{ti}, \ldots, XK_{ti})$ [5], and contextual factors $(Z1_{ti}, \ldots, ZM_{ti})$ that set up an environment to combat the pandemic.[6] As noted earlier, the trajectories of the four impact indexes do not present a horizontal line but rather rise and fall at different stages. The coefficients of the time variables ($Week_{ti}$ and its exponentiation) shed light on the shape of the trajectory when the longitudinal explanatory variables are held constant, allowing us to predict the impact status for the future in a controlled framework. We refined the model by testing different polynomials (such as quadratic, cubic, and even higher orders of $Week_{ti}$) to determine the equation that best described the observed trajectories. The cubic polynomial turned out to be the most appropriate, based on comparisons of measures of goodness of fit like AIC, BIC, and Log Likelihood and the significance of estimated coefficients.

The intercept in Level 1, submodel π_{0i}, is modeled as random effects associated with socioeconomic/demographic cross-sectional variables before the onset of the pandemic. The other coefficients in the Level 1 model are treated as fixed effects.[7] Maximum likelihood techniques are used for estimating the multilevel model and this was done using the R package lme4 (Bates, 2015).[8]

Level 1

$$y_{ti} = \pi_{0i} + \pi_{w1i} Week_{ti} + \pi_{w2i} Week_{ti}^2 + \pi_{w3i} Week_{ti}^3 + \pi_{1i} X1_{ti} + \cdots + \pi_{Ki} XK_{ti} + \varepsilon_{ti} \quad (1)$$

Level 2

$$\pi_{0i} = \beta_{00} + \beta_{01} Z1_i + \cdots + \beta_{0M} ZM_i + \zeta_{0i}$$
$$\pi_{w1i} = \beta_{w10}$$
$$\pi_{w2i} = \beta_{w20}$$
$$\pi_{w3i} = \beta_{w30}$$
$$\pi_{1i} = \beta_{10}$$
$$\pi_{2i} = \beta_{20}$$
$$\cdots$$
$$\pi_{Ki} = \beta_{K0}$$
$$\varepsilon_{ti} \sim N\left(0, \sigma_{\varepsilon}^2\right) \text{ and } \zeta_{0i} \sim N\left(0, \sigma_0^2\right)$$

The time variable, $Week_{ti}$, was set to start at 0 instead of 1 to facilitate the interpretation of the intercept as the initial status (in the first week of the SBPS). We ensured that all independent variables were presented at a similar scale by first dividing the HHI by 10,000 and then dividing the percentage variables and the time variable $Week_{ti}$ by 100. Then all independent variables except for Week and Party were further mean-centered (grand mean centering for longitudinal independent variables). These re-scaling efforts facilitated a model interpretation that meant that the fixed effect β_{00} was the average initial status of the pandemic impact for a state.[9]

Model Results

The trajectory for each dimension of the pandemic's impact on small businesses at the state level over the whole study period (April 26, 2020- June 13, 2021) was modeled as a cubic function with a set of longitudinal and cross-sectional variables (Table 3). The cubic function was selected based on comparisons of measures of goodness of fit like AIC, BIC, and Log Likelihood and the significance of estimated coefficients. The cross-sectional variables helped to explain the difference in the initial status of the trajectories across states. Because all the other coefficients in the Level 1 submodule were treated as fixed effects, the impacts of the contextual variables on the initial status of the trajectories could carry over to their future status. Community vulnerability and urbanization levels were negatively associated with the initial status of all the indexes except for that representing operational challenges (the OCI). The OCI was more sensitive to policies, as three out of four policy variables were significant.

For the first subjective index, the overall sentiment index (OSI), the fitted cubic function had one real root of 0.864. The only significant time-varying variables were infection rate and new infection cases. This suggested that if the infection rate and the ICI were at their historical means (which are 1 and 0.02) by around Week 87 (January 3-9, 2022), the OSI would be close to 0, as shown in Figure 5, indicating zero or little negative impact perceived by the small business owners. However, since the ICI was negatively associated with the OSI, a larger number of infection cases predicted a delay in the recovery. Furthermore, the IR was found to be positively associated with the OSI.

Table 3. Modeling the Temporal Trajectories of COVID-19's impact on Small businesses across 48 Contiguous U.S. States.

	Parameter		Overall Sentiment Index (OSI)	Expected Recovery Index (ERI)	Operational Challenges Index (OCI)	Financial Stress Index (FSI)
Initial status, π_{0i}	Intercept	β_{00}	−0.6615 (0.0088) ***	−0.5915 (0.0078) ***	−0.3757 (0.0070) ***	−0.3675 (0.0037) ***
	HHI	β_{01}	0.1201 (1.2761)	0.0760 (1.0863)	−0.3866 (0.5032)	0.0896 (0.4443)
	Essential	β_{02}	0.3980 (0.2539)	0.3425 (0.2162)	0.0982 (0.1003)	0.2052 (0.0887) *
	EssMinority	β_{03}	−0.0084 (0.0554)	0.0016 (0.0471)	−0.0006 (0.0218)	0.0059 (0.0193)
	HSI	β_{04}	0.0005 (0.2283)	−0.0275 (0.1944)	0.0704 (0.0897)	0.1461 (0.0795)
	VI	β_{05}	0.0696 (0.2729)	−0.1064 (0.2323)	0.0609 (0.1075)	0.1602 (0.0950)
	CRE3	β_{06}	−0.0073 (0.0026) **	−0.0043 (0.0022) *	−0.0002 (0.0010)	−0.0023 (0.0009) *
	AREAPCT_URBAN	β_{08}	−0.1315 (0.0509) **	−0.1372 (0.0433) **	0.0043 (0.0204)	−0.0676 (0.0179) ***
	Party (Republican)	β_{09}	0.0268 (0.0095) **	0.0302 (0.0081) ***	0.0089 (0.0038) *	0.0037 (0.0033)
Rate of change,	Week	β_{w10}	1.6100 (0.0617) ***	0.3679 (0.0568) ***	2.1085 (0.0700) ***	1.1506 (0.0504) ***
	$Week^2$	β_{w20}	−4.1442 (0.2561) ***	−0.9770 (0.2357) ***	−6.2075 (0.2918) ***	−5.8355 (0.3510) ***
	$Week^3$	β_{w30}	3.6655 (0.3630) ***	0.9976 (0.3341) **	6.0820 (0.4142) ***	8.9644 (0.6643) ***
Time-varying variable	IR	β_{20}	0.0274 (0.0081) ***	0.0141 (0.0074)	0.0448 (0.0092) ***	−0.0029 (0.0046)
	ICI	β_{30}	−0.3849 (0.0539) ***	−0.4346 (0.0496) ***	−1.1112 (0.0616) ***	−0.0168 (0.0354)
	DCI	β_{40}	−0.0026 (0.0029)	0.0045 (0.0027)	−0.0091 (0.0034) **	−0.0056 (0.0019) **
	VCR	β_{50}	0.0532 (0.0310)	0.1676 (0.0285) ***	−0.0068 (0.0353)	
	SCI	β_{60}	−0.0081 (0.0075)	−0.0488 (0.0069) ***	0.0799 (0.0084) ***	−0.0115 (0.0045) *
	WCI	β_{70}	0.0036 (0.0057)	0.0162 (0.0052) **	−0.0372 (0.0061) ***	0.0066 (0.0032) *
	SHRI	β_{80}	−0.0106 (0.0062)	0.0051 (0.0057)	−0.0409 (0.0067) ***	−0.0069 (0.0038)
	FCI	β_{90}	0.0015 (0.0063)	0.0111 (0.0058)	−0.0085 (0.0069)	−0.0068 (0.0035)

(continued)

Table 3. (continued)

Parameter	Overall Sentiment Index (OSI)	Expected Recovery Index (ERI)	Operational Challenges Index (OCI)	Financial Stress Index (FSI)
Goodness-of-fit (stochastic parts)				
AIC	−7253.4443	−7579.1663	−6823.4783	−6950.7593
BIC	−7131.1684	−7456.8904	−6701.2024	−6842.2515
Log Likelihood	3648.7221	3811.5831	3433.7392	3496.3796
Num. Obs.	1916	1916	1916	1296
Num. Groups: State	48	48	48	48

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; inside the parentheses are standard errors.

None of the policy measures was significant, suggesting an insensitivity of perceived negative impacts to the public policy instruments. At the same time, the initial value (Week 1) of the OSI for an average state (all the contextual variables were at their mean) with a Democratic governor was estimated to be −0.66. In contrast, for a similar average state with a Republican governor, the initial value (Week 1) of the OSI was −0.63, indicating fewer negative impacts on small business owners' overall sentiment. The difference in the initial status could also have been explained by

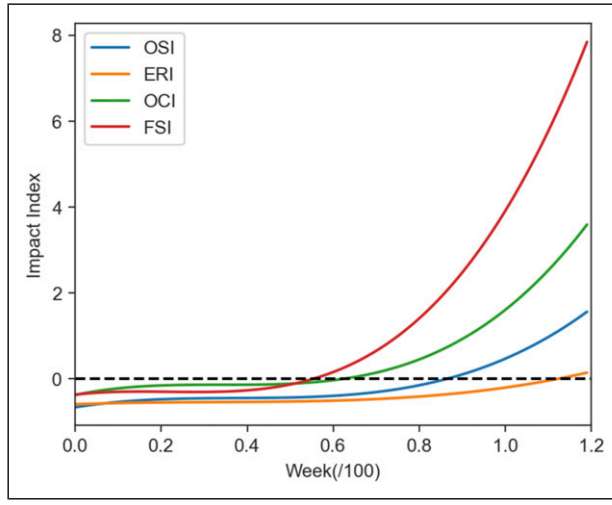

Figure 5. Predicted trajectories of the four impact indexes. Note: The range of the four indexes is [-1,1]. This plot is to illustrate when each index is expected to reach 0, the level of little or no impact, for an average state based on our model.

community vulnerability and urbanization levels, as the estimated coefficients for both covariates (CRE3 and AREAPCT_URBAN) were statistically significant at the 1% level. These negative coefficients indicated that a state that had a higher level of community vulnerability or a higher urbanization level tended to have a lower initial level of OSI, meaning that small business owners in those states were less optimistic about the pandemic.

For the other subjective index, the expected recovery index (ERI), the average trajectory of this was expected to reach 0, indicating zero or little negative impact, by Week 113, as suggested by the fitted cubic function, which had one real root of 1.122 (Figure 5). Like the OSI, the ERI was negatively associated with the ICI. However, the ERI was positively related to the VCR. A potential explanation was that vaccination boosted business owners' confidence in the recovery. The ERI was also negatively associated with the index of school closure (SCI) and positively associated with that of workplace closure (WCI). Additionally, like the OSI, the initial value (Week 1) of the ERI for an average state with a Democratic governor was estimated to be −0.59, but it would have been −0.56, slightly less severe, for a similar state with a Republican governor. Furthermore, both community vulnerability and urbanization levels were negatively associated with the initial status of the expected recovery of businesses.

In contrast to the subjective indexes, the two objective indexes were expected to reach 0 from negative impacts much more quickly. For the OCI, the only root of the fitted cubic function was 0.624, which translated to around Week 63 (July 19-25, 2021) if the net effect of the health and policy variables was 0 (Figure 5). It was even sooner for the FSI, which was expected to reach zero around Week 56 (May 31-June 6, 2021) (Figure 5). Again, the precondition for this prediction was that the net effect of the health and policy variables was zero or almost zero. It should also be noted that the sample size for the FSI was smaller, as we lacked data for Phases 4 and 5, and therefore the prediction error was expected to be greater. Nevertheless, the strong contrast between the subjective and objective indexes of the impact of the pandemic on small businesses pointed to the differences in people's perceptions and the response of the market in the face of a disaster.

In addition to potentially taking less time to recover for business operations (OCI), this operational challenge was positively associated with the infection rate and infection cases, as was the OSI. And the OSI was also negatively associated with the death case incidence. In contrast to the ERI, the OCI was not significantly associated with the VCR when other variables were controlled for. Furthermore, all the policy indexes except for the FCI were significant, indicating a high sensitivity of business operations to public policies. And, the initial status of the OCI was related to the political party of the governor, as was the case with the two subjective indexes – it was −0.38 for an average state with a Democratic governor and −0.37 if the governor was a Republican. Except for the governor's political party, the other contextual variables were insignificant.

The financial stress index (FSI) was negatively associated with the death case incidence, like the OCI; but unlike the OCI, the FSI was negatively associated with the stringency of school closing (SCI) and positively associated with the stringency of

workplace closing (WCI). Interestingly, the initial status of the FSI was not related to the governor's political party, but it was negatively associated with community vulnerability and urbanization, like the two subjective indexes. Unlike all the other three indexes, the initial status of the FSI was positively associated with the proportion of essential jobs.

Based on the models with a cubic function, we created overall predicted trajectories for the four impact indexes for an average state over time (Figure 5). This clearly shows that the business operation indexes are predicted to recover sooner than the perception-based indexes.

Discussion and Conclusion

This study examined the evolution of pandemic disruption of small businesses across the United States for over a year. Our research built upon previous investigations and demonstrated that the impact felt by small businesses varied significantly across time periods and geographical locations (Kim 2021; Wang and Kang 2021; Zhai et al. 2021a, 2021b). These temporal-spatial variances reflected significant disparities in the health situation, degree of government intervention, economic structure, socioeconomic vulnerability, and other institutional environments across the 48 states studied.

First, individual perceptions of the impact of COVID-19 vs. market responses. The OSI, which has been negative throughout the study period, would approach 0 around Week 87, indicating zero or little negative impact perceived by small business owners. The expected threshold weeks for the other indexes are: Week 113 for the ERI, Week 63 for the OCI, and Week 56 for the FSI, leaving aside public health and policy effects. So, it can be expected that a recovery point indicated by the two objective measures will occur sooner than a recovery point indicated by the subjective measures. Furthermore, the OSI is highly sensitive to health situations, but we observed virtually no association with policy measures. This suggests a lack of sensitivity, as regards overall sentiment, to public policy instruments, especially in the early stages of the pandemic, as indicated by the two-stage models (SF1). However, as time progresses, business owners' perceptions of the overall negative impact of the pandemic become sensitive to mitigation policies, such as workplace closure and face-covering policies. In contrast to what is suggested by the objective indexes, small businesses seem likely to recover much sooner if outcomes are measured by the subjective indexes, since these are heavily influenced by public policy intervention, especially in the early stages of pandemic disruption. The strong contrast between the subjective and objective indexes points to the differences between people's perception of, and market response to, policies created in response to a shocking disaster.

Second, the health situation. Balla-Elliott et al. (2020) argue that economic needs, rather than health concerns, have compelled businesses to reopen. Our study finds that the infection rate (measuring the disease's "virality") is positively associated with

business owners' negative perceptions (the OSI) and business operation constraints (the OCI). The infection case incidence is negatively associated with the OSI, ERI, and OCI. The death case incidence is negatively associated with two operational indexes, the OCI and the FSI. And the vaccinations completed ratio is positively associated with the expected time of recovery (ERI), suggesting that vaccination boosts business owners' confidence in recovery. However, breaking the data into two stages reveals that health indicators have lost almost all their statistical significance by Stage 2 (Phases 4-5), except that the ICD and DCI are significant for business operation constraints. This indicates that none of the health variables is significant for subjective perceptions, although objective measures of business operations indicate much faster recovery. The findings suggest that small business operations are mainly impacted by non-health factors in the later stages of the pandemic.

Third, public policy factors. Mitigation and social distancing policies have no significant impact on overall negative perceptions (the OSI) but are significantly associated with the other three indices, especially that for operational challenges (the OCI). Among all four policy indices, that for face covering (the FCI) is not significantly correlated with any indicator of impact; and school closure (the SCI) and workplace closure (the WCI) have a broader impact than stay-at-home requirements (the SHRI) on small businesses. Upon closer investigation of the two stages, we found that all the virus-containing and social distancing policies at Stage 1 (April 26, 2020 - January 10, 2021) were significantly associated with the two objective measures, the OCI and FSI; and the effects were consistent between the two indicators. These findings are in contrast to those of Goolsbee et al. (2020) study, which did not find any significant impact from state shutdown orders on consumer visits to businesses. This inconsistency may indicate differences in behavior between consumers and businesses. It could also be because our study adopted a longitudinal approach and differentiated between various types of government constraining orders. Additionally, we do want to note that all the policy variables lost their significance in the model of the OCI at Stage 2 (February 15, 2021-June 13, 2021) in our study.

When it comes to federal financial assistance, the findings suggest that this is not sufficient to boost the confidence of small business owners. However, government assistance is a significant positive factor in reducing business operation constraints at Stage 1. This is consistent with Bartik et al.'s (2020) work that suggests the need for government assistance and its importance in helping small businesses. However, we found that the positive effects dwindled by Stage 2. These patterns indicate the difference in people's perception of, and market response to, a disruption and to ensuing policy instruments. The change in efficacy over time also suggests that providing government aid early is critical.

Fourth, economic structure. Results from modeling the full trajectories of the indices we investigated indicate that industrial specialization, economic diversification, and industrial composition are not significant factors associated with our four indications of COVID-19 impact, except that the initial status of the FSI is positively associated with the proportion of a

state's employees who hold essential jobs. When the model is analyzed in two stages, a higher percentage of essential jobs in a state is associated with a higher financial stress index at the start of Stage 1. However, by Stage 2, the relationship between the two weakens. At the same time, the percentage of "high-status" (HIS) industries and the percentage of vulnerable industries (VI) become positively associated at the beginning of Stage 2 (Week 41) for operational challenges (the OCI). The change from Stage 1 to Stage 2 in our study indicates that the regional economic structure may not matter during a short-term external shock; but, with the economic reopening, it may play a more significant role in the recovery. For instance, regional competitiveness, expressed by regional human capital and innovation advantages, can influence a region's response to external shocks in the longer term (Crescenzi et al. 2016; Martin et al. 2016; Ray et al. 2017). This warrants further tracking of the development of small businesses in relation to the evolving public health and socioeconomic environments.

Fifth, socioeconomic vulnerability. Community vulnerability (the CRE3) is significantly and negatively associated with the initial status of all the indexes except that for business operational challenges (the OCI). Vulnerability is negatively associated with the initial status of overall negative perception and business financial stress at Stage 1. By Stage 2, community vulnerability is significantly associated with both subjective indexes, overall sentimental impacts and expected recovery, but not with business operations. This suggests that social inequalities, racial disparities, poverty, and other socioeconomic disadvantages can be critical sources of vulnerability for small businesses (Bates and Peacock 2008; Zhang et al. 2009).

Furthermore, small business resilience and community resilience have never been more intertwined than in today's circumstances. The striking differences between the viewpoint of business owners and the operational/financial challenges facing their businesses also indicate the range of roles that small businesses (and owners) play in their communities. Small business owners simultaneously identify themselves as family members, business operators, and community members, and the pandemic's disruption has blurred the boundaries between work and home for many people. In order to create sensible policies, policymakers will need to understand and value the multiple roles that small business owners play in sustaining the economy, their homes, and their communities. To avoid unintended consequences, policymaking should take account of the fact that all these challenges must be met simultaneously.

These findings have several implications for policymaking. First, government assistance is vital for small business survival during disastrous events. It should kick in as early as possible and reach the businesses in most need. While most business relief programs are initiated at the federal level, implementation is at the local level. And it is critical to connect government agencies, community-based organizations, and small businesses to ensure smooth access to government business aid. Second, social distancing and virus containment policies play a highly significant role in business operations. Unlike many natural disasters in history, pandemic disruptions need coping strategies that deal with far beyond economic and health issues. How should health concerns be balanced with economic recovery plans? How should governments set

development goals? What powers do governments have at different levels? Small businesses should be brought to the table when policy decisions are being made. Third, socioeconomic vulnerabilities play a significant role during periods of economic renewal for small businesses and their communities. Difficulties in applying for financial support, distrust of government, and confusion about the rules make businesses in underserved communities less likely to take part in assistance programs than others. Therefore, in the short term, it is important to simplify the application process and give those applying for assistance effective guidance. In the longer term, social structures, economic inequality, and disparities that affect disadvantaged communities when they try to access resources should be explicitly taken into account to help improve their future resilience. Lastly, this crisis has increased the need to engage with technologies and adopt different forms of e-commerce in small business operations. It has shown the need for policies that promote education and facilitate the adoption of technology at the micro level, and for regional development strategies that will help diversify regional economies and promote innovation at the macro level.

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Notes

1. We understand that many COVID-19 studies have been conducted at the county or finer geographic scale. However, state-level analyses are meaningful for evaluating the effects of political processes on small businesses. U.S. states retain a significant degree of autonomy and differ in their institutional arrangements in ways that can affect pandemic policymaking to a greater extent than institutional differences across counties. Political and institutional processes designed either to limit the virus or to provide government aid operate primarily at state level. The state institutional context also plays a primary role in the formation of public health policies and government aid programs. For example, U.S. states vary significantly in policies relating to face-covering, business/school closing, and mandatory vaccination. Therefore, we use the state as our unit of analysis. In addition, no comprehensive, time-consistent data on the impact of COVID-19 over the time span at a scale below that of the state were publicly available for a national study in the U.S. when the project was conducted.

2. There are gaps between consecutive phases, and our temporal analyses and visualization took account of these gaps. More details are given in later sections.
3. It should be noted that since Phase 4 (February 15, 2021), the SBPS has undergone drastic changes with existing questions dropped and new questions added. And because of the dropping of several questions essential to the construction of the FSI, the SBPS has stopped releasing the FSI.
4. We looked at several other indicators of community resilience/vulnerability which were demonstrated to be highly correlated with the CRE3. The Pearson's correlation coefficient between the CRE3 and CDC's SVI is 0.79 and is significant at the 0.1% significance level. Besides, social capital has been argued to be an important determinant of community disaster survival and recovery, and a social capital index has been developed by the U.S. Congress Joint Economic Committee (Aldrich and Meyer 2015). The CRE3 is negatively correlated with this index (Pearson's Correlation Coefficient = −0.83, p-value = 0).
5. Our models assess the association between the ever-changing public health and policy factors and the negative impacts of the pandemic on small businesses at the state level. The estimated models should not be interpreted as causal relationships.
6. The weekly SBPS was conducted in phases, and there were some gaps between consecutive phases. For instance, Phase 1 and Phase 2 were separated by 6 weeks. The former concluded on June 27, 2020, while the latter started on August 9, 2020. Our model takes theses gaps into account.
7. Multicollinearity was checked with the variance inflation factor (VIF), which measures the degree to which the variance of a coefficient estimate is increased due to collinearity. Low/moderate levels of VIFs (<6) were observed for all the explanatory variables except for the VCR, which was highly correlated with the time variable (Person's correlation coefficient = 0.73). The VIFs on the time variables were also inflated, due to the incorporation of the polynomial terms.
8. Each impact index is organized at two levels. It is first organized by time, and then organized by state. The multilevel model for change takes this hierarchical structure into account and accounts for within-state correlations.
9. To further examine how the impacts changed over time and how they responded to stimuli, we divided the whole sample into two stages: the first stage was comprised of Phases 1 to 3 (April 26, 2020-January 10, 2021), and the second stage was comprised of Phase 4 and the first 4 weeks of Phase 5 (February 15, 2021-June 13, 2021). Due to limitations of space, we have provided the results in supplementary file 10 (SF10).

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