

## Supplementary Information

### *SI-1.1 Data on Internet Access Flexibility*

The FCCs Census Tract Internet Services database (Federal Communications Commission 2020a) provides data on ISPs offering fixed-connection services to at least one establishment (e.g., a residence or business) in a given census tract. Although the data provide a good measure of availability, they do not provide insights into the accessibility of services. As such, a ZIP-code-based fixed-connections dataset with accessibility data was also used (Pease 2020). Although many of the data collected between both of these sources encompass similar fields, any effects from duplicate attributes were removed within the exploratory factor analysis (EFA), as described in the main body of the manuscript. For a study of mobile (cellular) internet services, data on the percent coverage per census tract by different carriers were downloaded from the FCC (Federal Communications Commission 2020b). To assess internet accessibility, data on public internet access by county were downloaded from the FCC (Federal Communications Commission 2020c). As a further assessment of accessibility, data on complaints filed with the FCC were incorporated. These ZIP-code-based complaints are organized by category. For the purposes of this study, complaints relating to “Speed”, “Equipment”, and “Availability” were reclassified as complaints on lack of access; this grouping accounted for nearly 46% of complaints to the FCC.

### *SI-1.2 Data on Disruption Risk*

County-based data from FEMA on National Flood Insurance Program payouts were downloaded (FEMA 2019). FEMA databases on disaster declarations in Texas between 1953 and 2020 were also included (FEMA 2020); this dataset was categorized by the county-based number of disaster declarations per disaster type for each county in Texas. The data source that provided the majority of the sudden-onset disaster (SOD) data for this project was the NOAA NCEI’s Storm Events Database (NOAA National Centers for Environmental Information 2020). This dataset records all storm events between 1950 and 2020, categorized by 49 different storm types, and has associated data for damages, deaths, and injuries. This dataset was summarized by aggregating all storms of a particular type per county, along with their corresponding injuries, deaths, and damages.

### *SI-1.3 Data on Disruption Vulnerability*

Telemedicine requires interactive audiovisual communications between providers and patients, which is usually fulfilled through the internet, making the industry and the patients vulnerable to internet outages. Similarly, a majority of students rely on online resources to complete their in-classroom activities (National Center for Education Statistics 2019). Moreover, throughout the COVID-19 pandemic, a significant number of students continue to attend school virtually (Roche 2020). Finally, advanced industries encompass wide-ranging economic sectors that spend relatively high amounts of their budget on research and development, for which the internet is a critical tool.

For variable reduction to be effective, the variables being studied must have underlying common factors. This is not the case for disruption vulnerability. Disruption vulnerability examines broad categories (e.g., disruptions to healthcare, education, and advanced industries) that are not necessarily directly related to one another. As such, each of these was identified as a sub-contributor to disruption vulnerability. These were analyzed separately, and an overall disruption vulnerability rank was calculated as the mean of the sub-contributor rankings. Sections 2.4.1 through 2.4.3 provide a brief description of the datasets used for each of the sub-contributors to disruption vulnerability.

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#### *SI-1.3.1 Telemedicine Disruption Vulnerability*

To identify the counties that would be the most impacted by a disruption in telemedicine, healthcare infrastructure data were used. Department of Homeland Security (DHS) data on hospital locations (Department of Homeland Security 2020) were obtained and merged with Texas Department of Health and Human Services data on hospital beds per hospital (Texas Department of Health and Human Services 2016). Moreover, a series of resources from the US Health Resources and Services Administration comprising medically underserved areas and healthcare facility information were collected (Health Resources and Services Administration 2020). The data allowed for an assessment of the specific locations that may be more dependent on telemedicine, as areas with onsite facilities are not exclusively reliant on offsite virtual care.

#### *SI-1.3.2 Education Disruption Vulnerability*

County-based data on K–12 student enrollment were obtained from the TEA (Texas Education Agency 2020). Higher education enrollment data were also obtained from THED (Texas Higher Education Data 2020) and merged with a Homeland Infrastructure Foundation-Level Data (HFILD) vector on university locations (Department of Homeland Security 2019). The enrollment and university data were spatially joined with the counties where they belonged. The data were statistically summarized by aggregating total student credit hours (SCHs) by type and total universities by county. It should be noted that internet use was studied relative to the education delivery location (school/university), and not relative to the residences of the students, since the latter presents a significant challenge due to the disperse nature of the geographies from which student attendance at a specific university is derived.

#### *SI-1.3.3 Labor Disruption Vulnerability*

While it is likely that most industrial sectors rely on the internet in some way, for the purposes of this study, the advanced industries (as enumerated by Rothwell and Kulkarni, 2015) were defined as those that would be significantly disrupted in case of an internet outage (Rothwell and Kulkarni 2015). These are listed in Table S2 of the SI. County-based data from the Bureau of Labor Statistics (BLS) for each of these industries were downloaded and summarized. Five-point summaries and means were obtained for each county's location quotient (LQ) distribution, and the quarterly wage and employment per capita were summarized per county. LQs compare the distribution of an industry in a county with respect to the entire US by dividing the concentration of the county's jobs in that industry by the concentration of nationwide jobs in that industry (US Bureau of Labor Statistics 2020).

#### *SI-2.0 Digital Divides*

Disparities in availability and accessibility are addressed through the concept of digital divides. A digital divide is caused by the differences in access and quality of technological resources, including the internet. The first-level digital divide considers whether a particular population has access to technological resources, while a second-level digital divide (SLDD) refers to the quality of such access. Given that there are important geospatial differences in the SLDD (Swain and Pearson 2003; Cruz-Jesus et al. 2016; Hohlfeld et al. 2017; Hamburg and Lütgen 2019), this paper characterizes digital divides as a measure of the flexibility of internet access.

**Table S1.** Description of datasets used for geospatial analysis; note that the summary of attributes is not all-inclusive.

	Source	Dataset Name	Data Date	Basis	Summary Attributes in Dataset
Internet Access	FCC	Census Tract ISP Offerings	June 2019	Census Tract	Maximum Upload/Download Speed Technology Number of Residential/Business Providers Total Number of Providers Maximum Upload/Download Speed by Technology Total Providers by Technology
	High Speed Internet	ZIP Code ISP Offerings	June 2020	Zip Code	Maximum Upload/Download Speed Technology Maximum Availability Number of Residential/Business Providers Maximum Upload/Download Speed by Technology Providers by Technology Availability by Technology
	FCC	Internet Access Data	June 2017 and Dec. 2017	Census Tract	Households with Broadband Access (10 mb Up, 1 mb Down) in Census Tract (Rounded to the Nearest 20%) Households with Internet in Census Tract (Rounded to Nearest 20%)
	FCC	Public Complaint Data	2015–2020	Zip Code	Amount of Complaints (by Type of Complaint)
	FCC	Public Internet Access Data	Dec. 2018	County	Rural Percent Access to Broadband Rural Percent Access to Cellular Rural Percent Access to Both Urban Percent Access to Broadband Urban Percent Access to Cellular Urban Percent Access to Both
	FCC	Operator Coverage Maps	June 2019	Census Tract	% Max Coverage of Census Tract Number of Carriers in Census Tract
	FEMA	Disaster Declarations	1950–2020	County	Type of Disaster Declaration Date of Disaster Declaration
Dis. Risk	FEMA	NFIP Claims	TBD	County	Flood Insurance Paid on Building Damage Flood Insurance Paid on Building Contents Flood Insurance Paid on Compliance Total Flood Insurance Paid
	NCEI	Storm Events	2019	County	Injuries by Storm Type (42 Types) Deaths by Storm Type (42 Types) Damage to Property by Storm (42 Types) Damage to Crops by Storm Type (42 Types) Total Damage by Storm Type (42 Types)
	BLS	Labor Statistics	2019	County	Total Wages (Q1–Q4 and Yearly Average) Total Employed (Q1–Q4 Yearly Average) Relative Concentration of Wages (5-Point Summary and Average) Relative Concentration of Employers (5-Point Summary and Average)
Disruption Vulnerability	TEA	K–12 Enrollment	2019	County	1–8 Enrollment 9–12 Enrollment

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TCES	University Enrollment	2019	N/A (Shapefile)	SCH Attempted Total Enrollment
HRSA	Medically Underserved Areas	N/A	N/A (Shapefile)	Polygons of Medically Underserved Areas
HRSA	Primary Healthcare Facilities	N/S	N/A (Shapefile)	Locations of Primary Care Facilities
HRSA	Health Professional Shortage Areas	N/A	N/A (Shapefile)	Polygons of Dental, Mental, and Physician Shortage Areas.
DHS/TDSHS	Hospitals	N/A	N/A (Shapefile)	Total Hospital Beds Total Employees

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**Table S2.** Notable cluster characteristics for internet access EFA; the median is presented unless otherwise indicated.

Cluster (Rank)	Number of Census Tracts	Total Fiber Availability (%)	Mean Non-Satellite Availability (%)	Mean Non-Satellite Speeds (bps)	ISPs per Tract	% Rural Access to Broadband and Cellular	% Urban Access to Broadband and Cellular
Outliers (4)	237	194*	95.22	925,843.88	6	88.2	99.8
1 (5)	708	100	100.00	1,000,000.00	5	88.2	94.5
2 (3)	1425	100	99.70	996,042.11	5	84.6	99.7
3 (6)	1177	100	100.00	994,494.48	5	99.9	100
4 (1)	955	0	86.07	88,072.25	3	84.6	99.9
5 (2)	751	0	97.62	992,596.54	4	75	99.7

\*Over 100% signifies more than one type of fiber available.

**Table S3.** Notable cluster characteristics for disruption risk EFA; the median is presented unless otherwise indicated.

Cluster (Rank)	# of Counties	Hurricane Disaster Declarations	Total Disaster Declarations	Property Damage PC	Total Crop Damage PC	Total Damage PC	Flood Insurance Paid PC (NFIP)
Outliers (1)	19	4	16	19,845.64	263.55	21,132.54	18.12
1 (6)	153	4	17	497.46	7.77	574.20	23.85
2 (3)	9	4	19	687.15	12,565.32	13,516.70	97.59
3 (2)	10	7.5	24	9472.35	178.74	9762.39	117.15
4 (5)	60	3	15	2827.25	526.76	3843.30	8.42
5 (4)	3	6	14	38,767.59	2730.91	40,626.22	6.01

PC = per capita.

**Table S4.** Notable cluster characteristics for labor disruption vulnerability EFA; the mean is presented unless otherwise indicated.

Cluster (Rank)	# of Counties	Yearly Advanced Industries Employment PC	Yearly Wage PC	LQ for Establishments - Median	LQ for Establishments - Max
Outliers (1)	7	0.34	10,660.85	38.84	27.32
1 (5)	50	0.03	535.44	1.80	5.10
2 (3)	16	0.12	3054.13	3.59	3.20
3 (6)	144	0.00	78.01	0.62	2.48
4 (4)	30	0.06	1370.21	3.78	6.97
5 (2)	7	0.21	5689.68	20.61	27.60

PC = per capita, LQ = location quotient.

**Table S5.** Notable cluster characteristics for education disruption vulnerability EFA; the mean is presented unless otherwise indicated.

Cluster (Rank)	# of Counties	Universities per 100,000	SCH At-tempted PC	SCH Face to Face At-tempted PC	K-8 Enrollment PC	9-12 Enrollment PC
Outliers (1)	10	2.75	2.61	1.68	0.13	0.07
1 (3)	15	1.92	0.64	0.35	0.11	0.05
2 (6)	7	0.30	0.00	0.00	0.01	0.00
3 (4)	125	0.86	0.01	0.00	0.10	0.05
4 (5)	87	0.67	0.00	0.00	0.13	0.06
5 (2)	2	2.30	2.10	0.91	0.10	0.06

PC = per capita.

**Table S6.** Notable cluster characteristics for medical disruption vulnerability EFA; the mean is presented unless otherwise indicated.

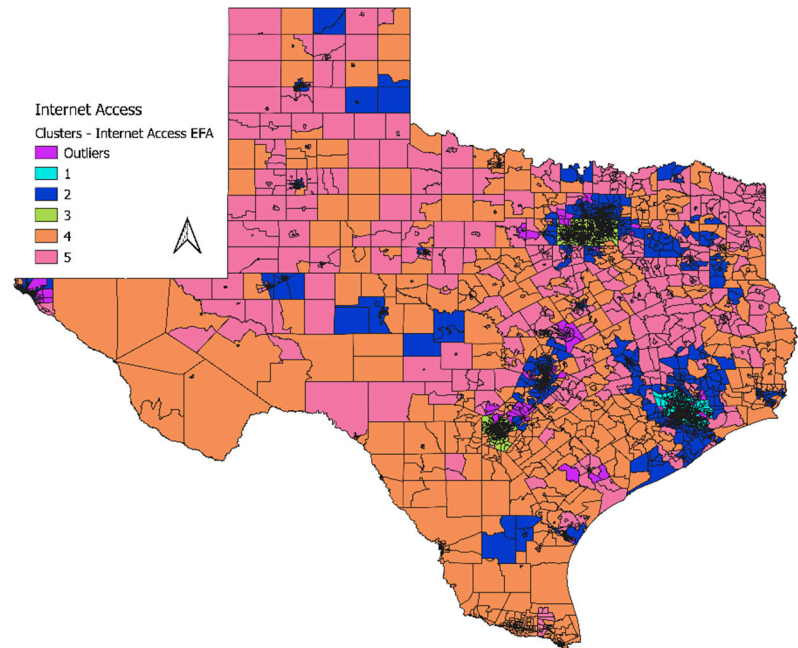
Cluster Group (Rank)	# of Counties	Average Hospital Beds per 100,000	Medically Underserved Area Percent (%)	Primary Care Shortage (%)	Mental Health Shortage (%)	Dental Health Shortage (%)	ICU Beds PC
1 (2)	50	224.8	96.795	100.000	98.000	2.000	198.69
2 (1)	82	173.0	100.000	99.311	100.000	100.000	1661.05
3 (3)	41	409.8	9.571	92.683	100.000	100.000	28.67
4 (5)	16	275.4	31.014	7.022	44.034	0.627	16.95
5 (4)	65	317.6	9.214	86.888	98.461	4.616	12.21

PC = per capita.

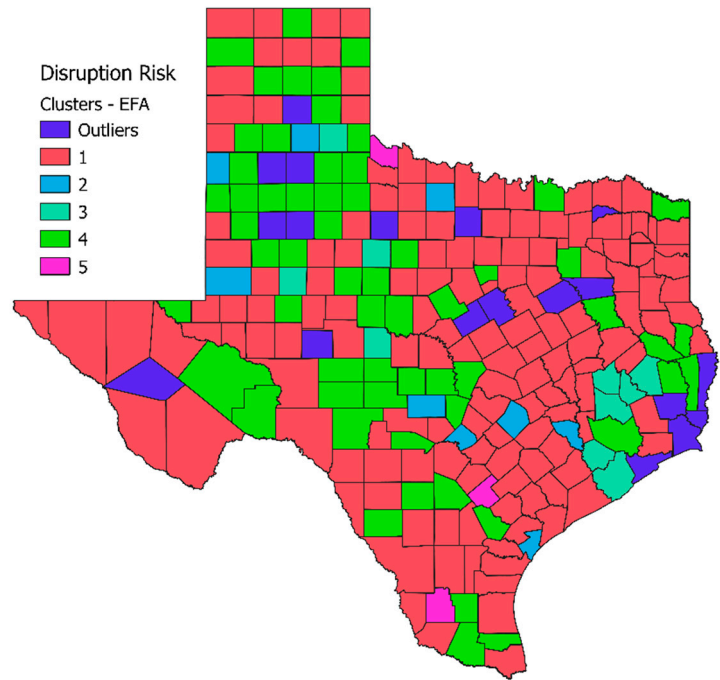
**Table S7.** Advanced industries (Rothwell and Kulkarni, 2015)—in the top 50% of STEM employers as well as in the top 21% for research and development spending per employee.

NAICS Code	NAICS Title
2111	Oil and Gas Extraction
2122	Metal Ore Mining
2211	Electric Power Generation, Transmission, and Distribution
3241	Petroleum and Coal Products Manufacturing
3251	Basic Chemical Manufacturing
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing
3254	Pharmaceutical and Medicine Manufacturing
3259	Other Chemical Product and Preparation Manufacturing
3271	Clay Product and Refractory Manufacturing
3279	Other Nonmetallic Mineral Product Manufacturing
3311	Iron and Steel Mills and Ferroalloy Manufacturing
3313	Alumina and Aluminum Production and Processing
3315	Foundries
3331	Agriculture, Construction, and Mining Machinery Manufacturing
3332	Industrial Machinery Manufacturing
3333	Commercial and Service Industry Machinery Manufacturing
3336	Engine Turbine and Power Transmission Equipment Manufacturing
3339	Other General Purpose Machinery Manufacturing
3341	Computer and Peripheral Equipment Manufacturing
3342	Communications Equipment Manufacturing
3343	Audio and Video Equipment Manufacturing
3344	Semiconductor and Other Electronic Component Manufacturing
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing
3346	Manufacturing and Reproducing Magnetic and Optical Media
3351	Electric Lighting Equipment Manufacturing
3352	Household Appliance Manufacturing
3353	Electrical Equipment Manufacturing
3359	Other Electrical Equipment and Component Manufacturing
3361	Motor Vehicle Manufacturing
3362	Motor Vehicle Body and Trailer Manufacturing
3363	Motor Vehicle Parts Manufacturing
3364	Aerospace Product and Parts Manufacturing
3365	Railroad Rolling Stock Manufacturing
3366	Ship and Boat Building
3369	Other Transportation Equipment Manufacturing
3391	Medical Equipment and Supplies Manufacturing
3399	Other Miscellaneous Manufacturing
5112	Software Publishers
5152	Cable and Other Subscription Programming
5172	Wireless Telecommunications Carriers (except Satellite)
5174	Satellite Telecommunications
5179	Other Telecommunications
5182	Data Processing, Hosting, and Related Services
5191	Other Information Services
5413	Architectural Engineering and Related Services

5415	Computer Systems Design and Related Services
5416	Management, Scientific, and Technical Consulting Services
5417	Scientific Research and Development Services
6215	Medical and Diagnostic Laboratories

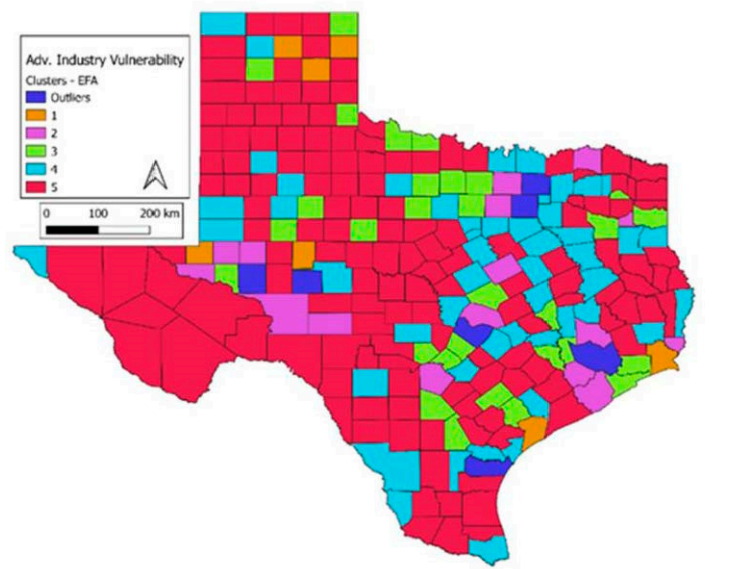


**Figure S1.** Clusters from k-means of internet access EFA.

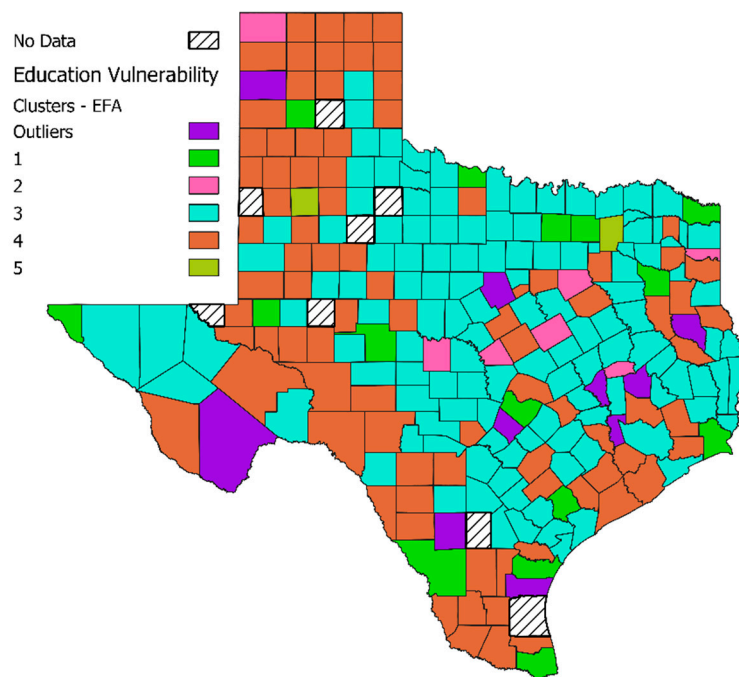


**Figure S2.** Clusters from k-means of sudden-onset disasters EFA.

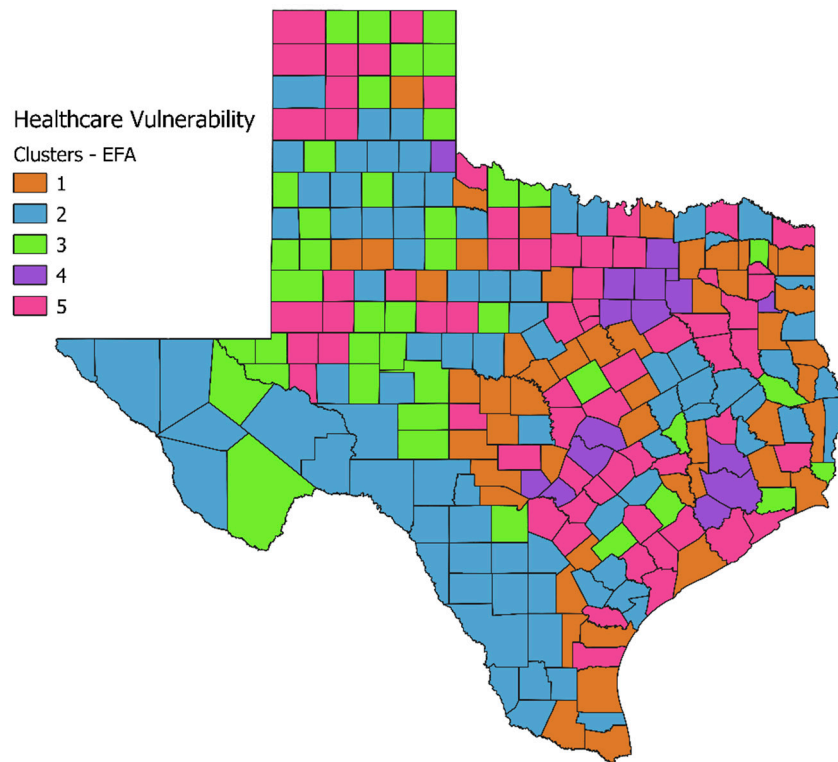




**Figure S3.** Clusters from k-means of advanced industries EFA.



**Figure S4.** Clusters from k-means of education EFA.



**Figure S5.** Clusters from k-means of healthcare/medical EFA.

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