

# ***MANAGING SUPPLY CHAIN DISRUPTION RISK FOR CORONAVIRUS OUTBREAK***

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# Background

## COVID-19 Pandemic

- Threatening human beings and the world economy
- 30.2 million confirmed cases and 548 thousand deaths in the United States
- Dramatically increasing demand for PPE and ventilators



## Medical Supply Chain

- Personal protective equipment & ventilators
- Media: perceive that there was a severe disruption of the PPE supply chain; accuse the U.S. manufacturers of relying too much on offshoring
- Government: seeks to reconstruct the U.S. medical supply chain

**T** TIME

Coronavirus Is Causing a Huge PPE Shortage in the US | Time

Executive Order on America's Supply Chains

On February 24, 2021, President Joe Biden signed an executive order with the policy goal of strengthening and diversifying supply chains in ...

2 weeks ago



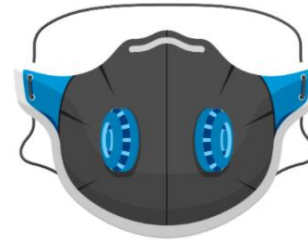
# Medical Equipment



Ventilators  
(HS 901920)



surgical masks, PPE  
(HS 630790)



Respirators, PPE  
(HS 392690)



surgical gowns, PPE  
(HS 621010)



protective suits, PPE  
(HS 392620)



protective goggles, PPE  
(HS 900490)

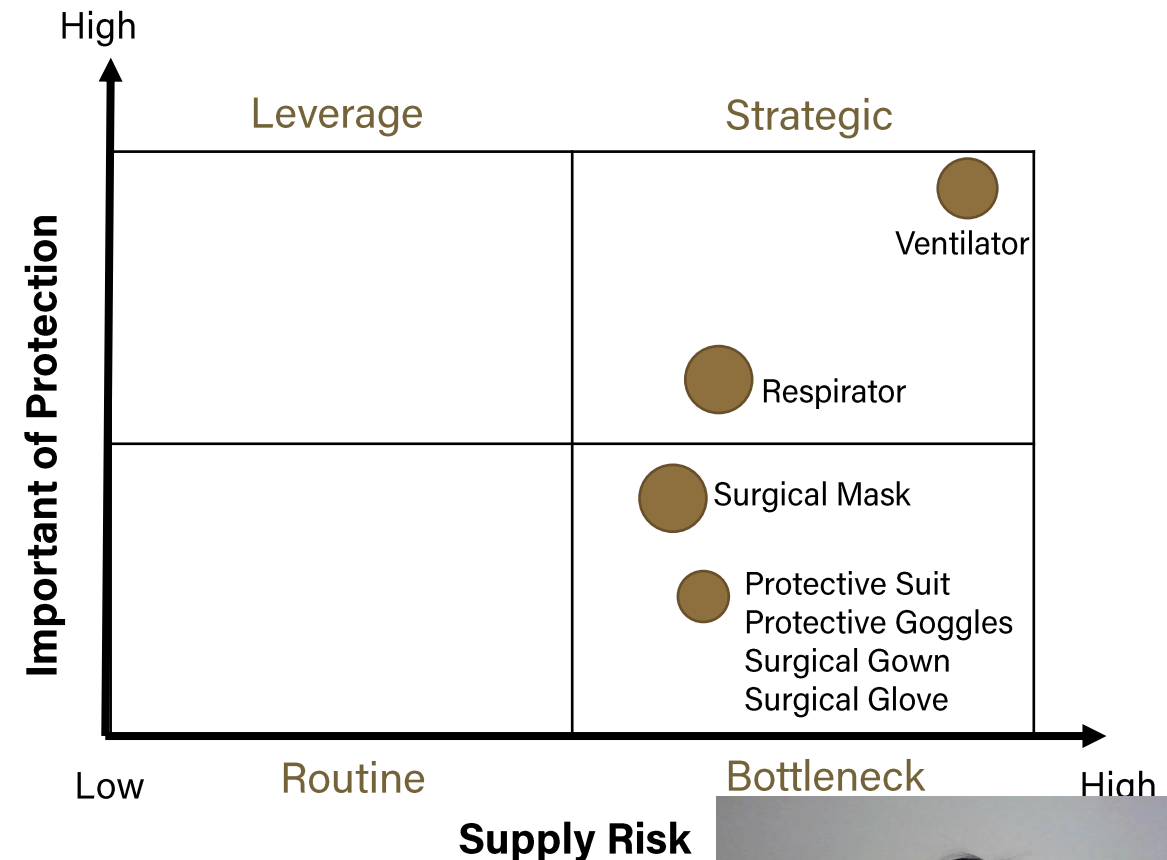
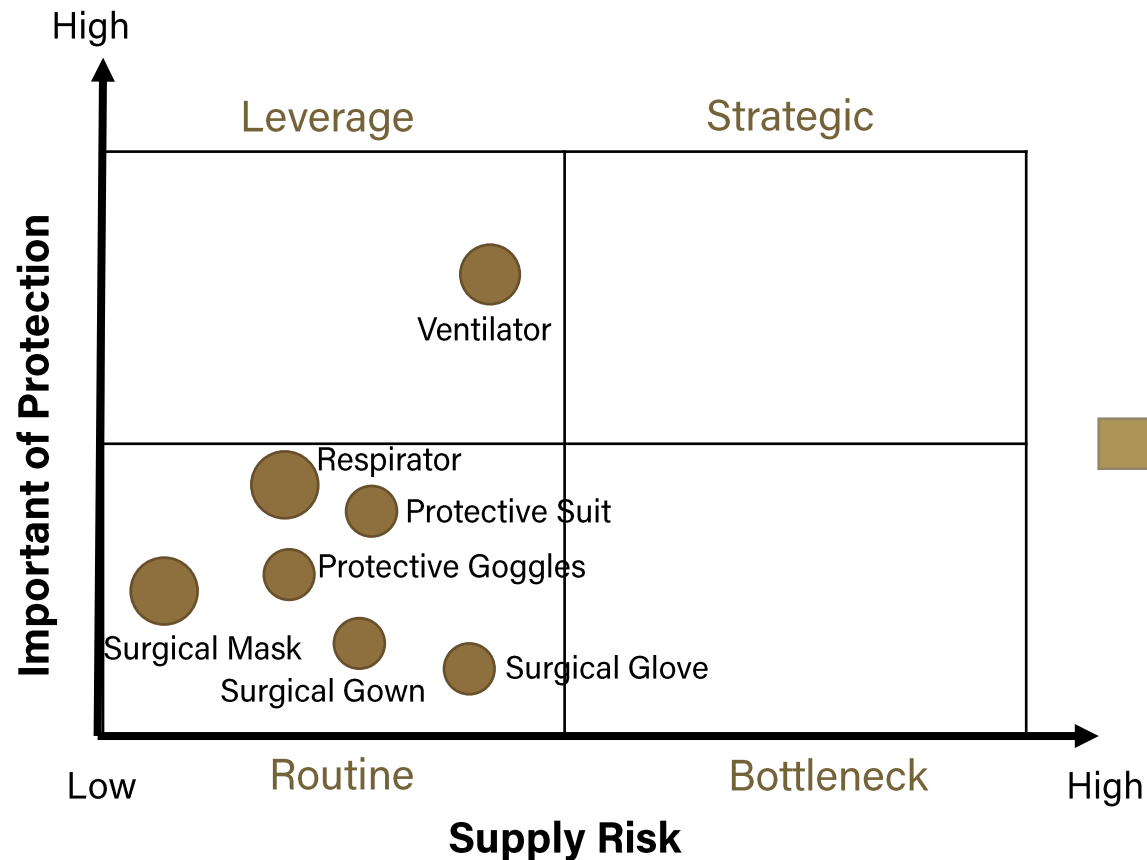


surgical gloves, PPE  
(HS 401511)



# Product Categories

## Krajlic Matrix: Shift of Product Positioning in the Pandemic

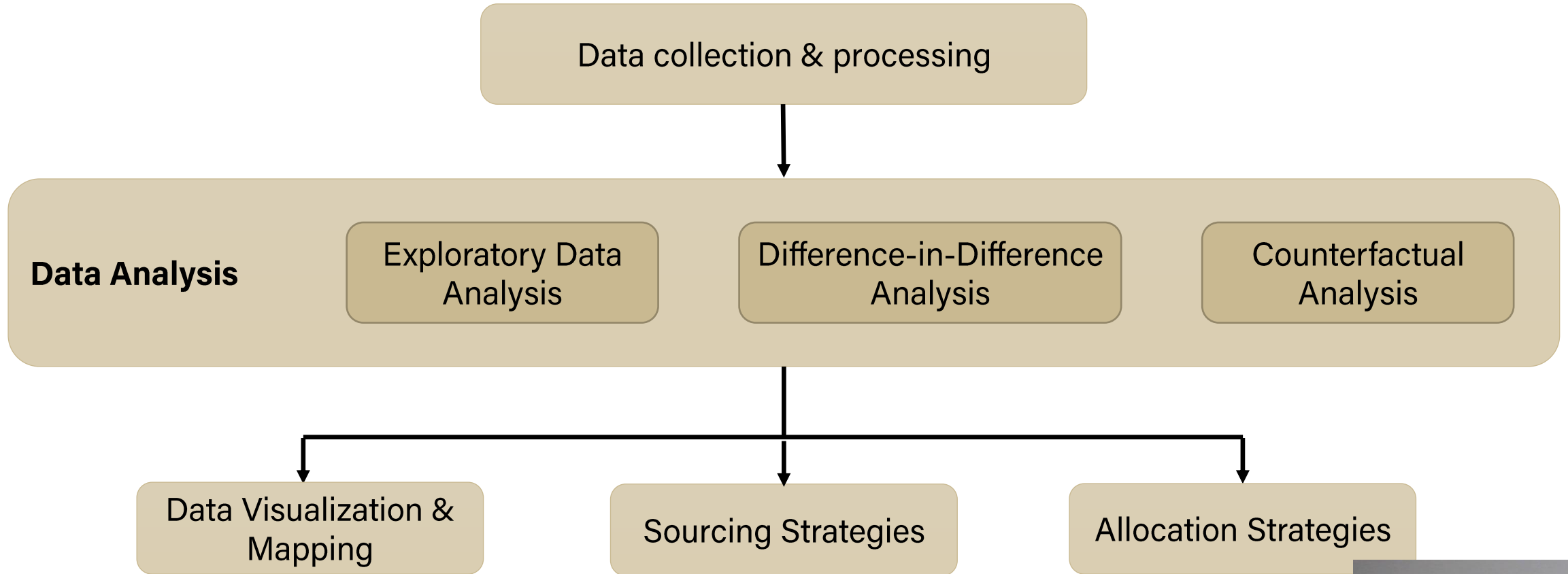


# Research Questions

- What happened to the medical supply chain and how resilient is the medical supply chain?
- How to enhance the strategic sourcing and procurement for the medical supply chain for each medical supply in different product categories?
- How should the distribution system respond to the pandemic and supply chain disruption caused by the pandemic?



# Research Flow



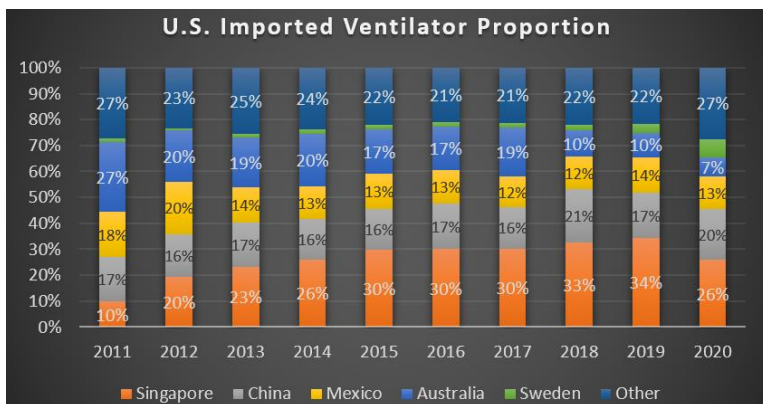
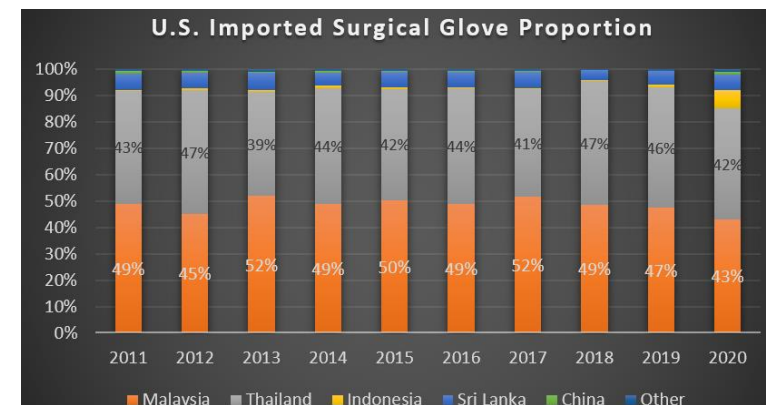
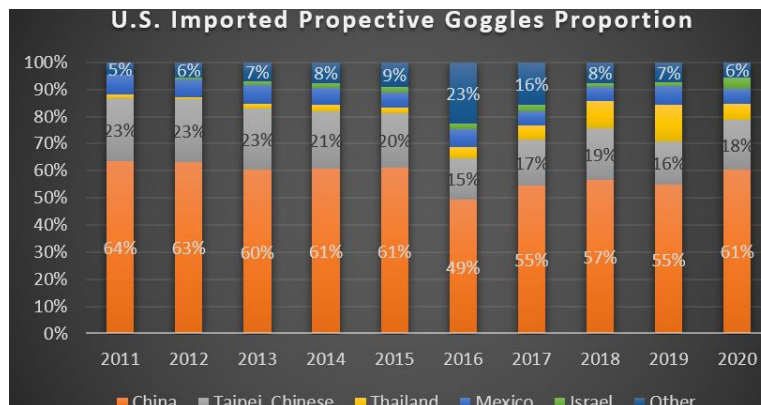
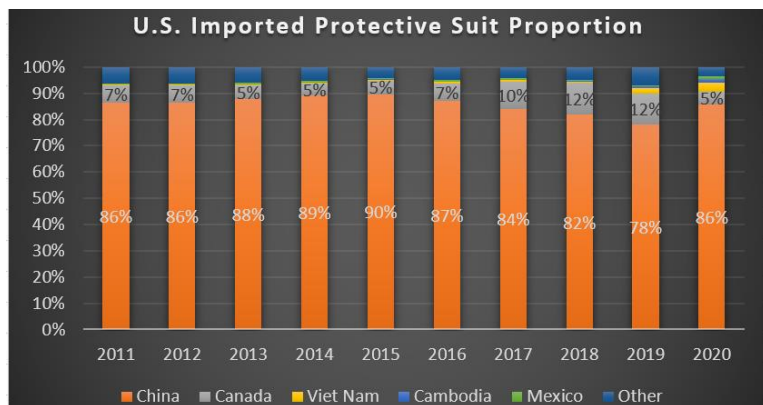
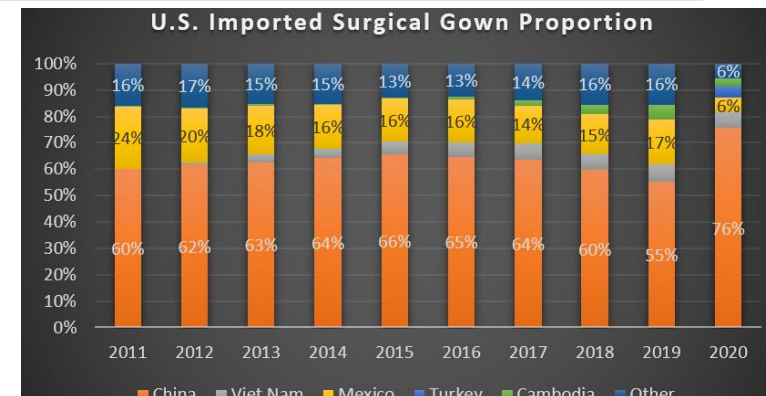
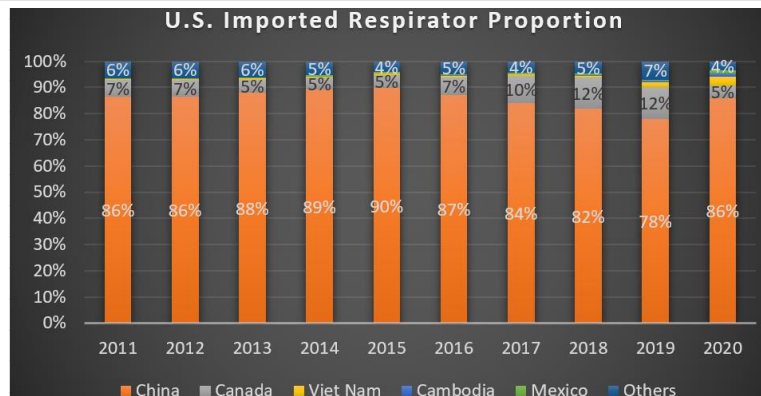
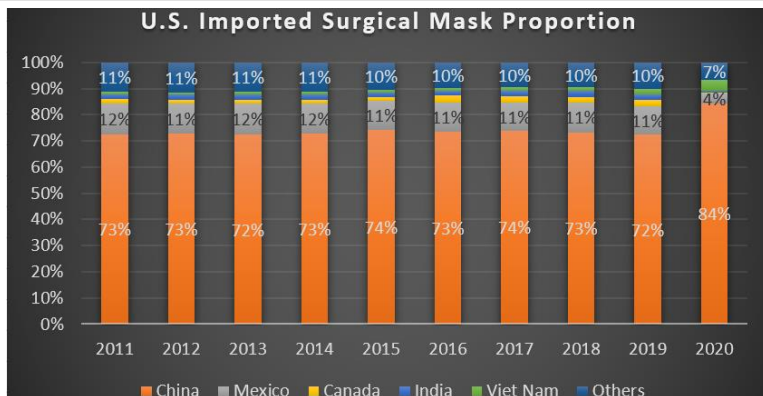
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# Exploratory Data Analysis

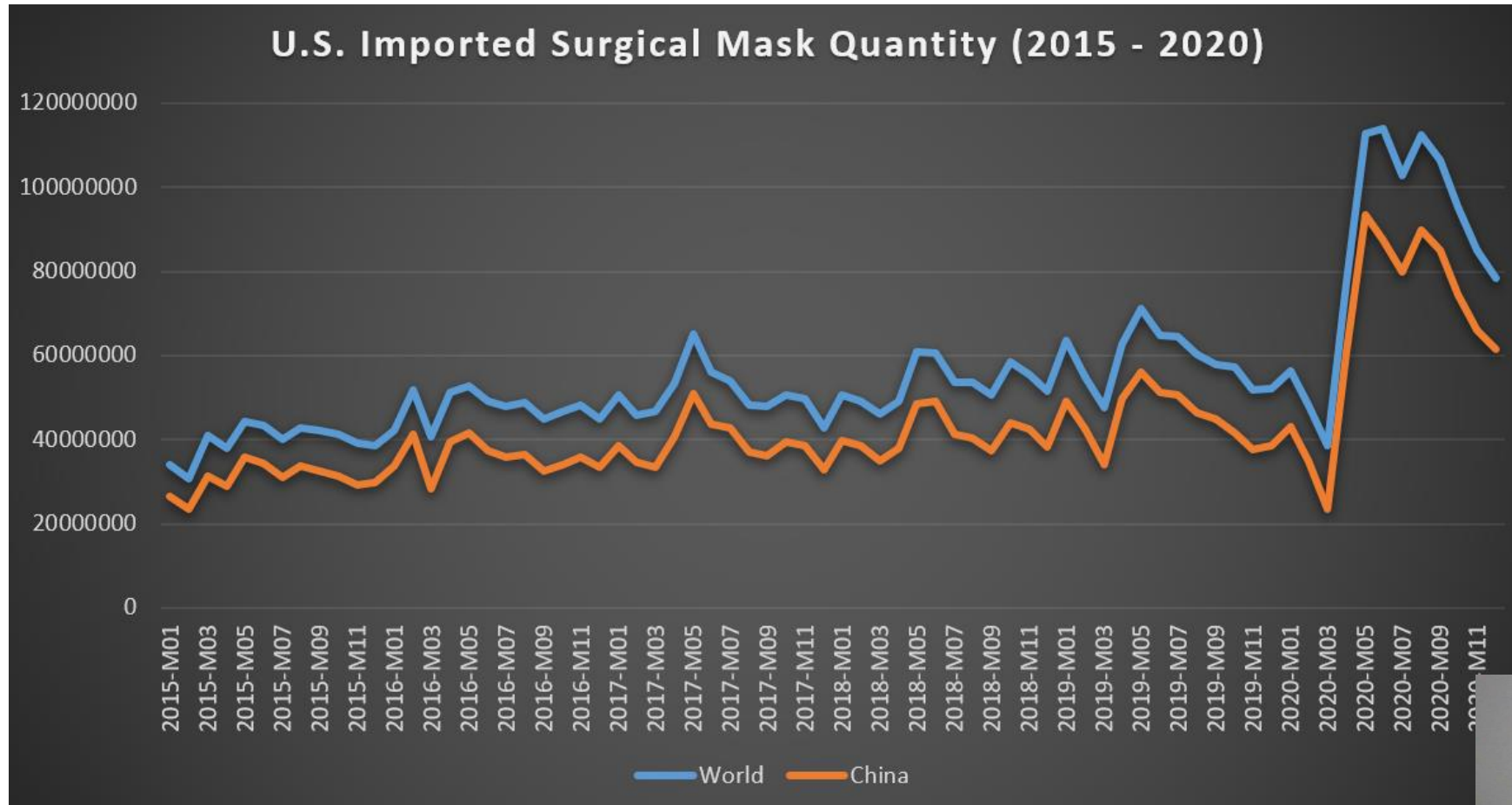


## Observation:

- Stable proportion



# Exploratory Data Analysis

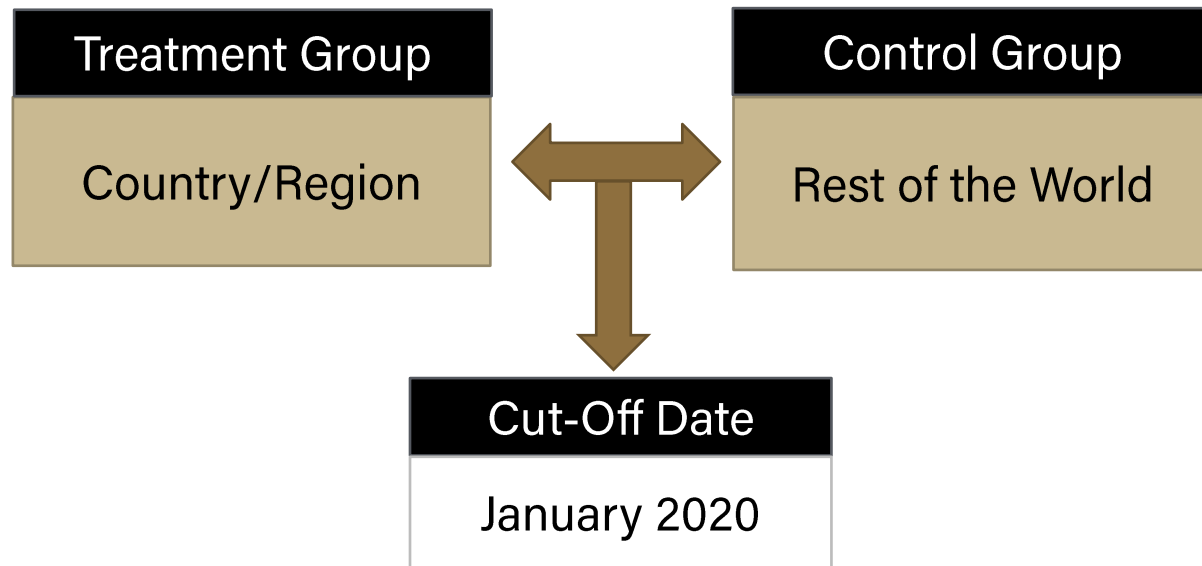




# Change of Import Quantity by Region

## Difference-in-Difference Analysis Method

- Statistical technique used in econometric to analyze the effect of an event or policy change
- Measure the effect of COVID-19 pandemic on the import trade



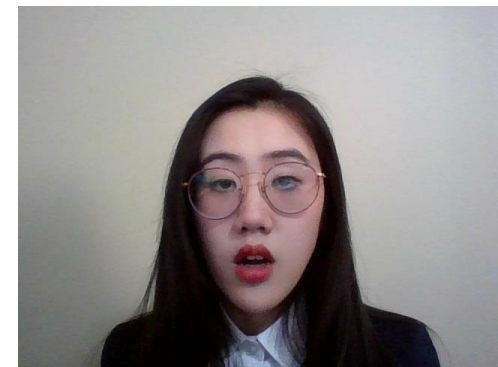
$$y = \beta_0 + \beta_1 T + \beta_2 S + \beta_3 (T \cdot S) + \varepsilon$$

$y$  → target variable indicating import amount

$T$  → dummy variable for period

$S$  → dummy variable for treatment

$\beta_3$  → difference-in-difference estimator



# Change of Import Quantity by Region

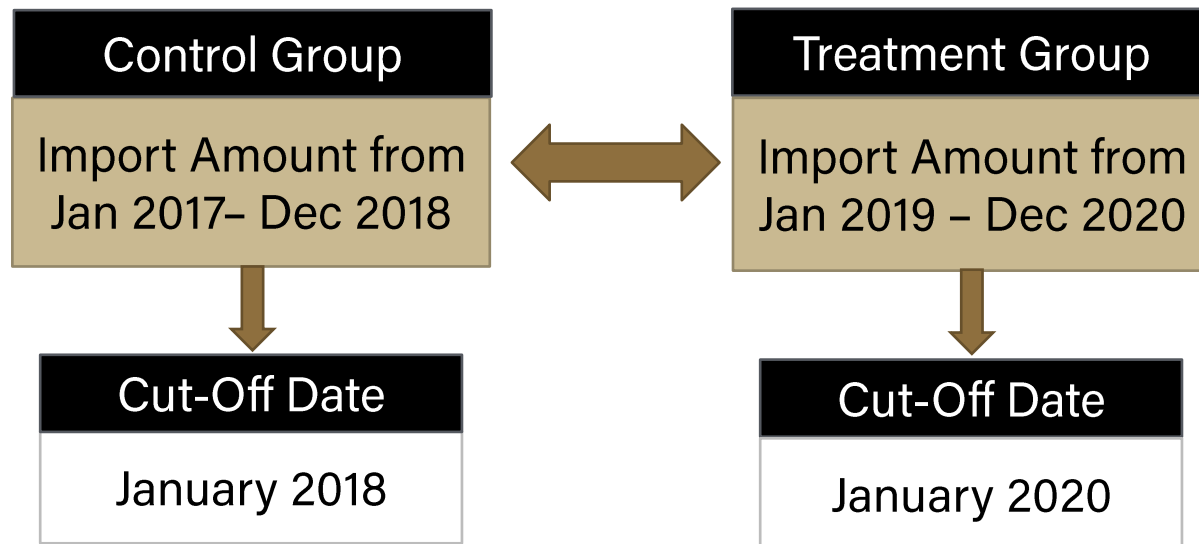
	Surgical Masks DiD Estimate	Respirators DiD Estimate	Surgical Gowns DiD Estimate	Protective Goggles DiD Estimate	Protective Suits DiD Estimate	Surgical Gloves DiD Estimate	Ventilators DiD Estimate
China	20948655 ( <b>&lt; 2e-16 ***</b> )	20463974 ( <b>&lt; 2e-16 ***</b> )	9397345 ( <b>&lt; 2e-16 ***</b> )	674037 ( <b>6.59e-6 ***</b> )	12562350 ( <b>2e-16 ***</b> )	154563 (0.7266)	84592 (0.43212)
Singapore	/	/	/	/	/	/	<b>-230982</b> ( <b>0.00298 **</b> )
Mexico	612937 (0.2973)	3705087 ( <b>0.00867</b> )	/	32128 (0.782)	/	/	-24649 (0.827)
Viet Nam	2191426 ( <b>0.00238 **</b> )	/	661712 ( <b>0.03112 *</b> )	-11114 (0.923)	482588 ( <b>0.0109 *</b> )	/	/
Canada	<b>-1244903</b> ( <b>0.083515 *</b> )	1338850 (0.425)	/	/	-69156 (0.65150)	/	/
Taipei, China	/	/	/	120872 ( <b>5.94e-08 ***</b> )	/	/	/
Malaysia	/	/	/	-35600 (0.759)	-22162 (0.9080)	236370 (0.471)	/
Rest of Asia	1064327 (0.1321)	4211610 ( <b>0.005045</b> )	35071 (0.91285)	-15251 (0.896)	-37931 (0.842212)	195906 (0.669)	3485 (0.9749)
Rest of America	327947 (0.6571)	-1845948 (0.2611)	400918 ( <b>0.09736</b> )	-18257 (0.874)	88308 (0.6470)	-280122 (0.50498)	-10390 (0.92472)
EU	-670711 (0.34506)	1739564 (0.297)	-450814 (0.1434)	-19195 (0.868)	-155148 (0.4158)	-258207 (0.54173)	227811 ( <b>0.0418</b> )
Rest of Europe	-518456 (0.46232)	-1556923 (0.35)	-455639 (0.1391)	-18111 (0.875)	-145265 (0.443)	NA	17735 (0.87236)
Oceania	-568407 (0.41716)	<b>-2625396</b> ( <b>0.09859 *</b> )	-454657 (0.1399)	-17657 (0.878)	-145442 (0.4423)	NA	21060 (0.8501)
Africa	-555272 (0.42846)	<b>-2706901</b> ( <b>0.087211 *</b> )	-426102 (0.167)	-17817 (0.877)	-151129 (0.425)	NA	-9294 (0.929932)
Unit	Kilograms	Kilograms	Kilograms	Dozens	Kilograms	Dozens Pairs	Kilogram

## Observations:

- The pandemic increases the U.S. imported PPE amount from China and Viet Nam significantly compared to the rest of the world.
- The COVID-19 pandemic decreases PPE for regions such as Europe, Oceania, and Africa, but the decrease is not significant; only a few regions result in a significant negative impacts from COVID-19 compared to the rest of the world.
- For U.S. ventilator imports, Singapore has a significant decrease and European Union has a significant increase.



# Change of Import Quantity over Time



$$y = \beta_0 + \beta_1 T + \beta_2 S + \beta_3 (T \cdot S) + \varepsilon$$

$y$  → target variable indicating import amount

$T$  → dummy variable for period

$S$  → dummy variable for treatment

$\beta_3$  → difference-in-difference estimator



# Change of Import Quantity over Time

	Surgical Masks DiD Estimate	Respirators DiD Estimate	Surgical Gowns DiD Estimate	Protective Goggles DiD Estimate	Protective Suits DiD Estimate	Surgical Gloves DiD Estimate	Ventilators DiD Estimate
treat*post	24235414 (0.00475 **)	31338950 (3.11e-05 ***)	12304312 (0.00133 **)	841554 (0.0314 *)	13889936 (0.000602 ***)	1639692 (0.000614 ***)	204887 (0.268)

## Observations:

- COVID-19 pandemic significantly increases the imported amount of PPE products
- The imported quantity of ventilators also increases, but not significantly



# Data Visualization and Mapping Tool



## Goal and Indicators

- Goal:
  - Establish the top medical suppliers' profile for US
  - Estimate medical supply production capacity and potential
  - Construct data transparency for decision makers and supply chain professionals
- Indicators Included:
  - Trade flow: US import value from 7 supplying regions
  - Import growth rate: US average import growth rate over last 5 years
  - Average distance of trading countries: the average distance between the selected country and all its importing countries weighted by the trade values
  - HHI index: measurement of the market concentration of PPE and ventilator

$$HHI = \sum_{i=1}^n s_i^2 \quad \text{where } s_i \text{ is the share of the country } i \text{ in the world market, } n \text{ is the number of countries.}$$





# What If the Import Proportion Changed...

## Counterfactual/ What-If Analysis

- If the distribution of the medical supply has been changed since 2019, what could be the expected supply quantities for 2020? Will the change of distribution increase or decrease the quantities?
- Goal: find out the scenario that returns highest quantity

Exporter	2019 Actual	2020 Actual	2019 Percentage	2019 True Percentage	2020 Percentage	Change	Percentage Change	2019 Base	2020 Counterfactual		
China	542872477	800439937	70.00%	76.69%	77.92%	1.474453	47%	495527501	730631996.4		
Mexico	50250368	63053695	9.14%	7.10%	6.14%	1.254791	25%	64701734	81187134.45		Total Quantity (kg)
Viet Nam	15145684	44996690	2.75%	2.14%	4.38%	2.970925	197%	19467152	57835446.44		1022562459
Canada	36548597	29287248	6.64%	5.16%	2.85%	0.801323	-20%	47004323	37665666.44		
India	17567117	16850737	3.19%	2.48%	1.64%	0.95922	-4%	22581896	21661015.43		Change compared to Original
Rest of Asia	28273098	45951433	5.14%	3.99%	4.47%	1.625271	63%	36385877	59136892.82		0%
Rest of America	12515382	22240811	2.28%	1.77%	2.16%	1.777078	78%	16140039	28682108.79		
EU	3336361	2276284	0.61%	0.47%	0.22%	0.682265	-32%	4318168.2	2946137.194		
Rest of Europe	1053902	1638187	0.19%	0.15%	0.16%	1.554402	55%	1345003.2	2090675.21		
Oceania	120193	165000	0.02%	0.02%	0.02%	1.372792	37%	141579.29	194358.9243		
Africa	213251	399924	0.04%	0.03%	0.04%	1.875368	88%	283158.57	531026.3903		
Total	707896430	1.027E+09	100.00%	100.00%	100.00%	1.451201	45%	707896430	1022562459		



# Counterfactual Analysis

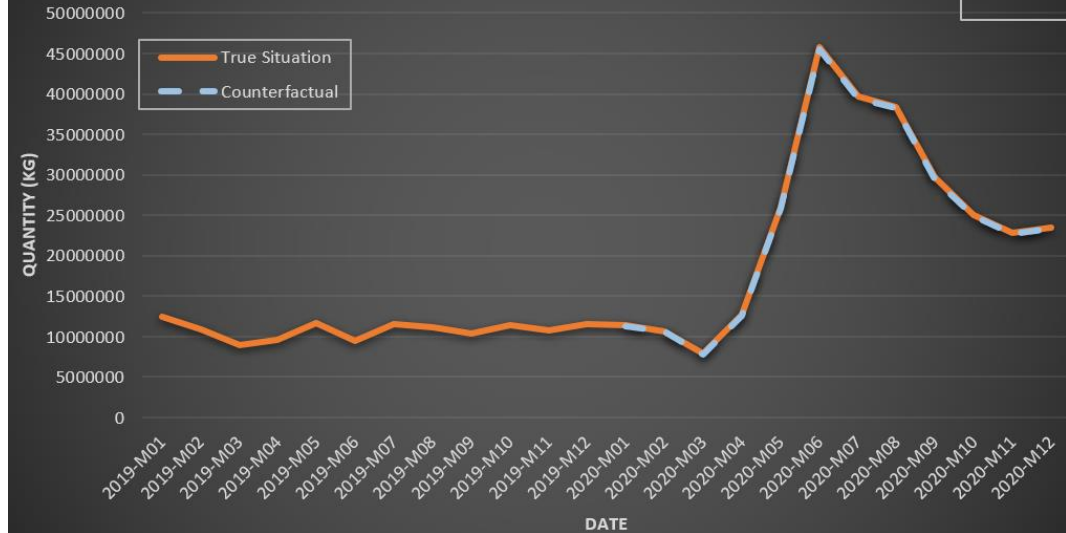
## U.S. Imported Respirator Counterfactual Analysis

-1%



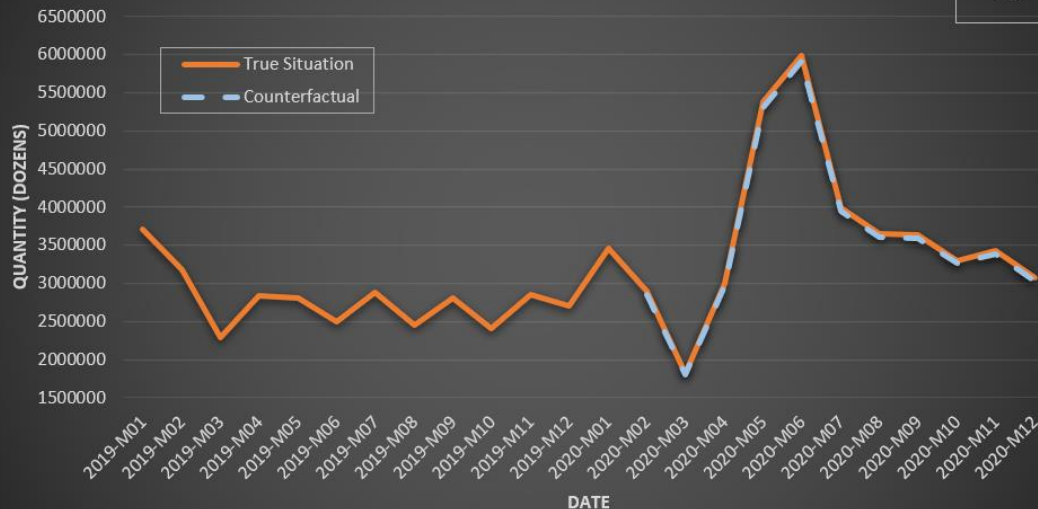
## U.S. Imported Surgical Gown Counterfactual Analysis

-1%



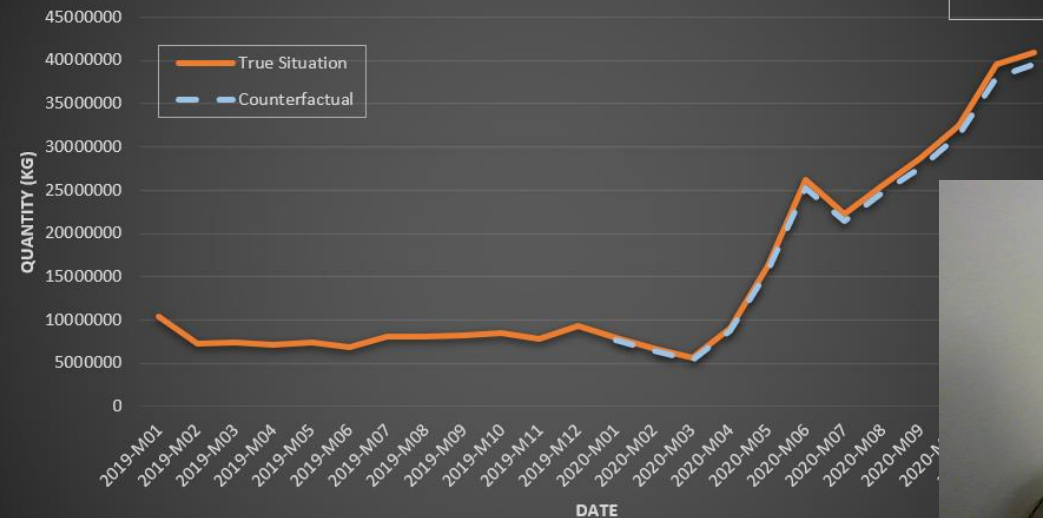
## U.S. Imported Protective Goggles Counterfactual Analysis

-1%

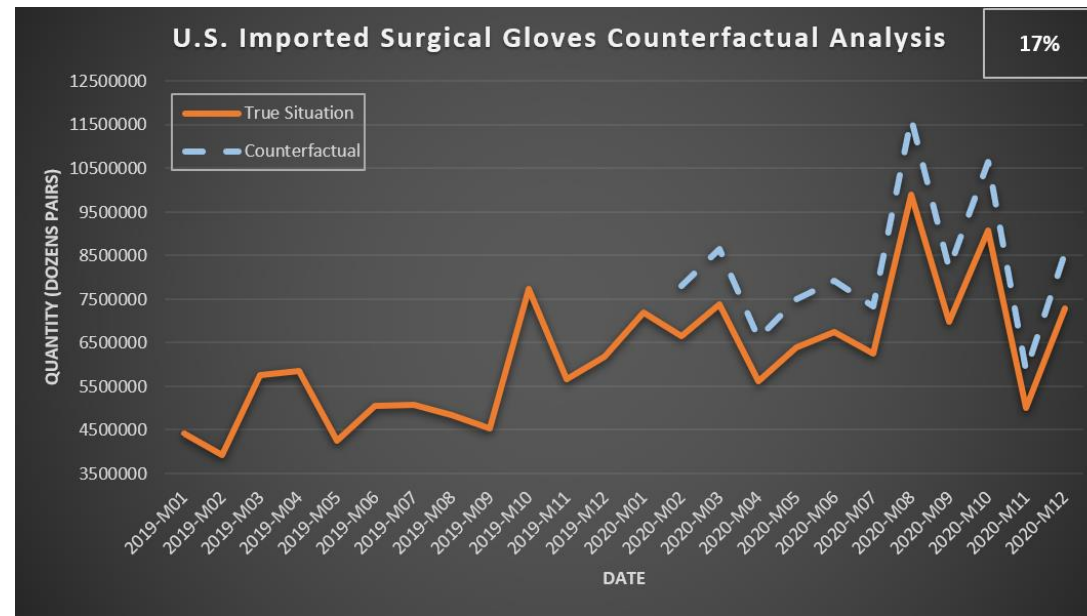
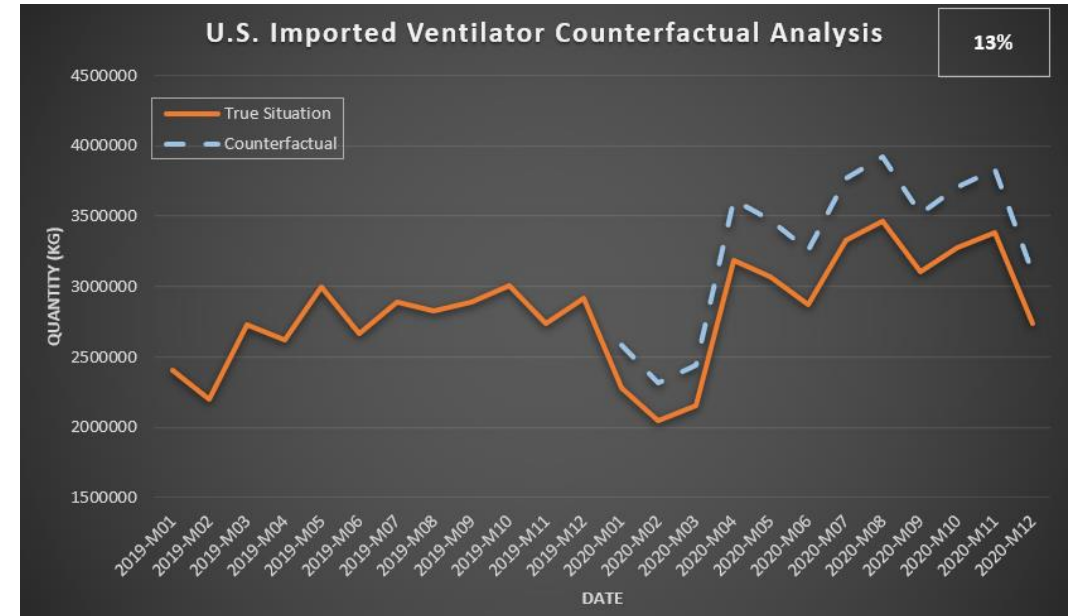
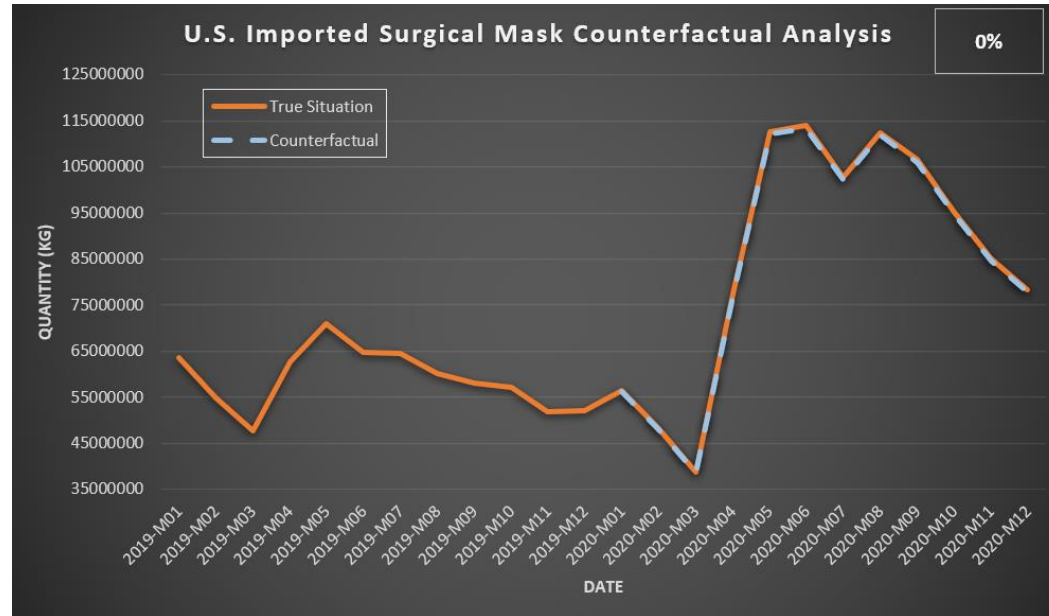


## U.S. Imported Protective Suit Counterfactual Analysis

-4%



# Counterfactual Analysis



# Sourcing Strategies

## Result from Counterfactual Analysis:

- Current supply proportion returns almost the largest quantities of surgical masks, respirators, protective goggles, surgical gowns, and protective suits.
- For surgical gloves, diversifying the supply source to Asian countries (China, Sri Lanka, Indonesia) increases imported quantity
- For ventilators, increasing percentage of supply distribution from China and European Union may increase the possible supply quantity.
- Backshore or nearshore is likely to decrease the quantity of medical supply.

## Sourcing Strategies according to Kraljic Matrix:

- PPE products are bottleneck items ➡ **Secure Supply or Supply Diversification**
- Ventilator is a strategic/critical item ➡ **Performance-based partnership**





# Ventilator Allocation Strategy

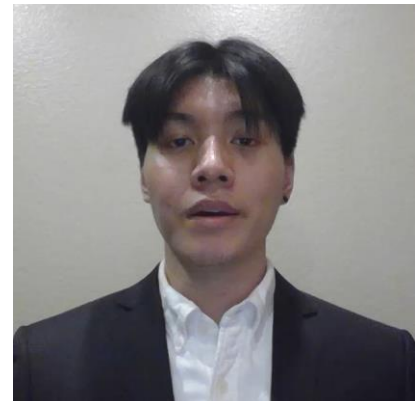
State	Publication date	Scoring systems	Death rate (2 mon before publication date)	Death rate (2 mon after publication date)
Washington	3/29/2020	mSOFA	4.27%	7.56%
Connecticut	3/24/2020	No	1.94%	9.27%
Illinois	3/1/2020	No	0.00%	4.40%
Nevada	4/2/2020	Other	2.61%	5.68%
Oregon	8/14/2020	Other	1.25%	1.42%
Alaska	4/15/2020	SOFA	2.41%	0.67%
Arizona	6/26/2020	SOFA	2.09%	2.53%
California	6/1/2020	SOFA	3.85%	1.29%
Indiana	4/3/2020	SOFA	3.42%	6.66%
Iowa	4/1/2020	SOFA	1.64%	2.90%
Kansas	2/28/2020	SOFA	0.00%	3.53%
Massachusetts	4/7/2020	SOFA	2.34%	8.29%
Michigan	4/8/2020	SOFA	4.74%	13.24%
Minnesota	3/1/2020	SOFA	0.00%	6.47%
New York	4/22/2020	SOFA	7.51%	23.49%
Oklahoma	4/7/2020	SOFA	4.56%	6.13%
Pennsylvania	3/22/2020	SOFA	0.60%	7.21%
Tennessee	6/10/2020	SOFA	24.20%	1.33%
Vermont	5/18/2020	SOFA	5.86%	14.07%

\***SOFA**(Sequential Organ Failure Assessment)

\***mSOFA** (modified Sequential Organ Failure Assessment)

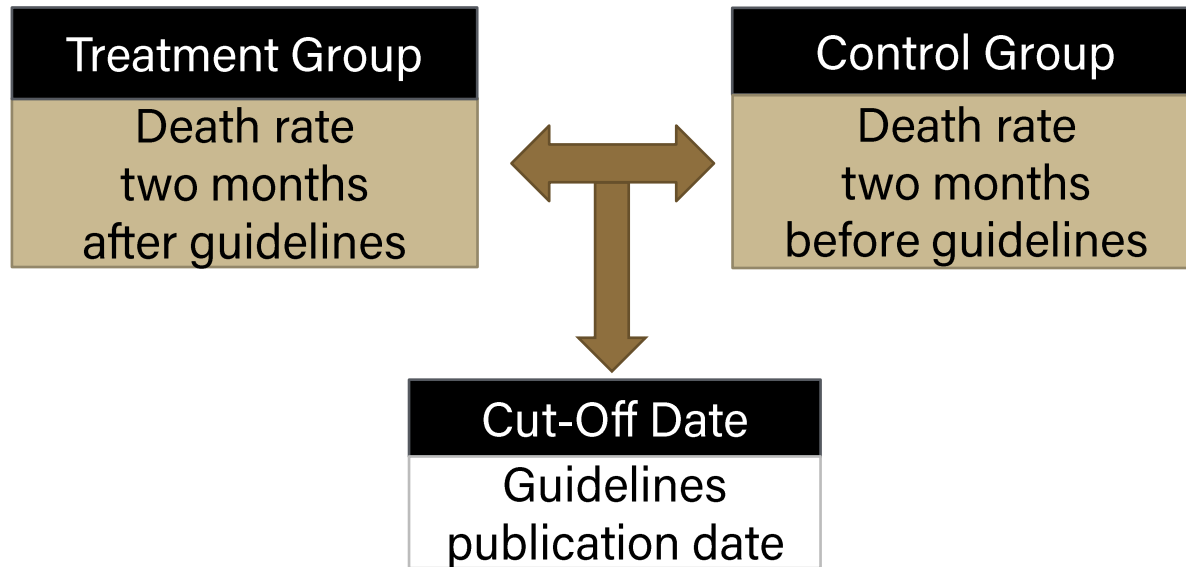
\***Other**(Other scoring system)

\***No**(No scoring system specified)



# Ventilator Allocation Strategy Analysis

- To find the most effective scoring system applied by during the pandemic



$$y = \beta_0 + \beta_1 T + \beta_2 S + \beta_3 (T \cdot S) + \varepsilon$$

$y$  → target variable indicating death rate

$T$  → dummy variable for period

$S$  → dummy variable for treatment

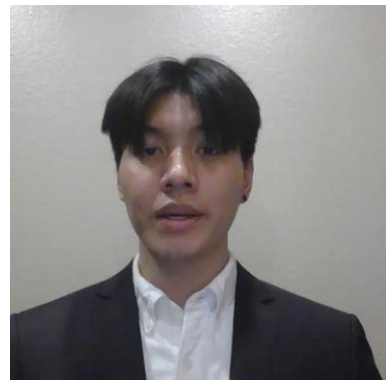
$\beta_3$  → difference-in-difference estimator

\***SOFA**(Sequential Organ Failure Assessment)

\***mSOFA** (modified Sequential Organ Failure Assessment)

\***Other**(Other scoring system)

\***No**(No scoring system specified)



# Ventilator Allocation Strategy Analysis

	SOFM DiD Estimate	mSOFA DiD Estimate	Other DiD Estimate
Treat*Post	-0.08628*	0.012285	0.044488

- SOFA might be the most appropriate strategy to reduce deathrate.
- But there are still many factors could affect deathrate.



# Conclusion

Research Questions	Answer
What are the facts of the current medical supply chain?	Counter to the general perception, there was no significant disruption in the U.S. medical supply chain including PPE products and ventilators; it is rather flexible and resilient.
How to enhance the sourcing strategies for the medical supply chain?	Government can build secure supply for PPE products and develop performance-based partnership with ventilator suppliers to prepare for the next pandemic.
How should the distribution system respond to the pandemic?	Comparing three different allocation strategies, SOFA policy can effectively decrease death rate.

## Implications:

- The interactive map provides a tool to make medical supply chain transparent for decision makers and supply chain professionals.



# THANK YOU



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