# Air Freight in the Pandemic: How Covid-related Policies Impact Air Freight Price Index

Wenqian Zhang*
The University of Chicago

June 3, 2022

**Abstract**

Air freight covers a wide spectrum of products from electronics to food. It plays a significant role in the supply chain transportation, especially the global supply chain transportation. However, the whole supply chain industry has been consistently challenged since Covid-19 hit the world in early 2020. The whole industry is faced with labor shortage, travel controls, lack of raw material and increasing demand for essential products. Air freight is inevitably disrupted in the Covid pandemic. The disruption does not only come from the pandemic itself, but also can be attributed to Covid-related policies such as international travel controls and grounded flights. Therefore, an opportunity is provided by the recent policies against the Covid-19 pandemic in different regions in the world. In this paper, I offer the first quantitative longitudinal analysis of the impact of Covid-related policies on air freight price index, capturing country-level and category-level heterogeneity of effects of those policies. I find that the issuance of Covid-related containment and closure policies decrease the air freight price index on average. The effect of decreasing mitigates the effect of the Covid-19 pandemic on air freight price. Significant policy types include public event cancellations, gathering restrictions, stay-at-home requirements, and international travel controls. After including country random effects, I find air freight between the US and distant Asian countries is more heavily impacted by Covid-related policies compared to North American countries. Furthermore, I focus on the inbound air freight price between the US and Canada, which fluctuates the most compared to other four trading partners. I find air freight for categories with more shipping options is more heavily impacted.

*MACSS, Division of Social Science, The University of Chicago, Email: wenqian@uchicago.edu
Word count: 7100

# 1 Introduction

Supply chain disruption has been a burgeoning topic, especially since Covid-19 prevails globally. Upstream suppliers have to pause their manufacturing catering to lockdown mandates. Downstream customers are faced with supply shortage and increasing demand for essential products. Both upstream customers and downstream suppliers suffer from labor shortage when their employees are infected by Covid. Besides from the dilemma of suppliers and customers, supply chain is also disrupted from the dilemma of the transportation part. Suppliers and customers serve as nodes in a supply chain. And the transportation part serves as a bridge to knit these nodes together. In the Covid pandemic, transportation industry is faced with travel controls adding on aforementioned labor shortage. A critical part of supply chain transportation is air freight, which uses cargo flights to transport freight from one airport to another. Air freight covers a wide spectrum of products from petroleum products, coal and chemical products, electrical components to agricultural products and food. Even though the volume of air freight is not comparable to sea freight with large containers and ground shipping, the high velocity and efficiency of air freight still makes it a top choice for many time-sensitive industries such as groceries and medicines. It's also a crucial way of freight transportation for trading between distant countries like the US and China.

Even though, the air freight makes it possible to transport freight efficiently and distantly. In the pandemic, the air freight industry inevitably has to undertake multiple shocks from Covid-related policies including grounded flights and travel controls. Airlines also suffer from labor shortage due to community outbreaks among crew members. In December 2021, a large proportion of Delta Airline employees contracted the more infectious Omicron variant of Covid-19. Delta Airline had to cancel a plethora of flights both domestically and internationally in the Christmas season. The same situation happened to other major airlines such as United Airline, American Airline and Southwest Airline as well, though not as severe as the Delta Airline case. The wide ranged cancellation caused sizable loss of both civil aviation and freight transportation. Moreover, airlines have to bear additional operational cost by just parking their fleets in the airports. As airlines take measures against the pandemic and try to reduce the impact of Covid-related restrict policies, the crisis in air freight industry also offers us an opportunity to observe how health policies against the pandemic impact this industry. Moreover, as different countries issue different policies, we can observe heterogeneity of effects of policies among different countries. We can also observe heterogeneity of effects of policies among different categories with the comprehensive coverage of air freight.

## 1.1 Disruptions from COVID-19

COVID-19 has been affecting the world for more than two years, since it hit in the very beginning of 2020. We have experienced three major waves of COVID-19 variants i.e. alpha, delta and omicron. To control the outbreak of Covid-19, governments around the world have issued a bulk of policies and guidelines. Air freight related policies such as lockdown and cancellation of flights have also evolved across multiple cycles. As a matter of course, researchers from multiple disciplines are now dedicated to exploring the numerous facets of the impact of COVID-19 on the world. In the context of supply chain, this burgeoning topic spawns discussions about supply chain credit risks (Agca et al., 2020), labor demand in supply chain (Fang et al., 2020), corporate resilience to the pandemic (Ding et al., 2021), omnichannel retailing in the pandemic (Hwang et al., 2020), etc. They all found when one region was exposed to the Covid-19 outbreak, the effect on the local supply chain would spill over even to the global supply chain. Specifically, Hwang et al. (2020) found the pandemic expedited the transition to online for omnichannel retailers. And the online channel can help both retailers and customers adjust to the disruption of Covid-19.

Past research mainly focuses on how supply chain as a whole is disrupted by the shock of the pandemic. However, there is currently no research paying attention to how the air freight industry, the very significant part of supply chain, is disrupted by the COVID-related policies. Nonetheless, air freight is closely related to the daily life of the public, especially in the special period of the pandemic. Since the outburst of the pandemic in 2020, the air freight industry has been constantly challenged by surging demand and plummeting number of available flights. The availability of flights is limited due to the community outbreak among flight crews. Moreover, international flights to some countries are tentatively canceled due to international travel controls and escalating Covid risks. For instance, in late December 2020, the Dutch government announced to ban all the flights from UK. This travel ban was adopted by some other European Union countries. And there's no doubt that this travel ban damaged the previously frequent air freight transportation between UK and EU. Therefore, it's necessary to assess how risks propagate through supply chain network to disrupt the air freight industry. Ideally, this research can shed light on how the air freight industry should make operational decisions to cope with disruptions from COVID-related policies.

Even though there is no research focusing on air freight disruptions in the pandemic, there are several research evaluating COVID-related risks to supply chain as a whole empirically. (Agca et al., 2020; Hwang et al., 2020; Ding et al., 2021) These empirical methodologies can also be applied to air freight industry analysis. For instance, Agca et al. (2020) used CDS spread as the proxy for supply chain risks to examine the risk propagation process. CDS of a company stands for the risk of default by the company. Higher CDS indicates higher risk of default. Agca et al. (2020) found local household demand shock would propagate through global supply chain and generate a spillover effect in other regions. Hwang et al. (2020) used transaction data and DID analysis to demonstrate how COVID-relate policies drive omnichannel retailers online. They found omnichannel (i.e. including both offline and online selling channels) could help retailers survive in the pandemic. Furthermore, it is appealing for offline-leaning customers to shop online if retailers add essential products such as masks and hand sanitizers to their assortment. Ding et al. (2021) used stock market data and corporate financial data to illustrate how different corporate financial attributes including supply chain relationship impact the resilience to COVID disruptions. They found companies are more severely disrupted in the stock market if they have more suppliers and customers in countries with more Covid-19 exposure.

## 1.2 Air freight and COVID-19

Air freight transportation is the core of supply chain, especially global supply chain. Air freight provides an efficient solution to freight transportation between distant places. Moreover, the high velocity of air freight perfectly meets the need of many time-sensitive industries such as groceries and medicine. Hence, air freight has boomed and covered a wide spectrum of products in the past decades. Based on the data from Department of Transportation, 6.7 million air freight tons were shipped to the US in 2019 (Department of Transportation, 2020). Even though the number is not comparable to the volume of sea freight with large containers or ground shipping with more dense networks, the diverse coverage and efficiency of air freight still makes it a critical part of supply chain transportation. For distant shipping such as from the US to China, the only ways are air freight and sea freight. Therefore, the stabilization of air freight market is crucial to supply chain and even economic development. But after the outbreak of the pandemic, the inbound air freight price of the US has experienced dramatic fluctuation. The Bureau of Labor Statistics uses air freight price index to measure this fluctuation. This index is a normalized value (baseline is set as 100) weighted by real air freight prices and freight values. The price indexes went sky high in April and May 2020. However, it declined significantly afterwards. Swegal and Wiesner (2021) attribute the increase to grounded planes with surging demand after the US issued its first lockdown polices against COVID-19. And they attribute the decline to a new normal that the industry are adjusting to the changes brought by COVID-19. Besides, Suau-Sanchez et al. (2020) evaluate the long-term and short-term impact of COVID-19 on air transportation as a whole. They point out that the shock at airports and hubs may consistently impact this industry even after the pandemic. The marketplace may become more competitive and aggressive.

More specifically, some scholars focus on the policy impact on air transportation and the recovery of air freight after the pandemic. Meng et al. (2021) examine how control policies from different countries have different impacts on air transportation in the perspective of effectiveness and prompt. They find out more stringent policies such as those in China have the mildest impact because they help effectively control the outbreak of the pandemic and bring the public back to normal. Similarly, Gudmundsson et al. (2021) concludes that air freight in Asia Pacific area is expected to recover fastest compared to the industry in Europe or North America. The difference is mainly due to heterogeneous policies in these countries against COVID-19.

Even though there are some researches touching on the air freight in the pandemic and policy impacts, there is no research to quantify the impact of control policies on air freight. My work addressed this gap, and captures the heterogeneous effects of policies in different countries or categories. My study focuses on the inbound air freight price between the US and its trading partners including Canada, Mexico, China and Japan. I use a panel of monthly inbound air freight price index of the US with monthly Covid-related policy counts in all aforementioned five countries. In robustness, I control for Covid cases and Covid death cases to account for the effect of the pandemic itself. I first examine the average effect of Covid-related containment and closure policies. I find these policies decrease air freight price index, which means mitigating the impact of the pandemic itself. Then, I further examine the heterogeneous effect of policies among different countries. I find distant Asian countries are more heavily impacted by these policies. Besides from that, I investigate the heterogeneous effect of the policies among different categories as well. I focus on the inbound air freight price between the US and Canada, which fluctuates the most compared to other four trading partners. I find air freight for categories with more shipping options is more heavily impacted.

The rest of the paper is as follows. Section 2 is on data and empirical methods. Section 3 is on results and discussion. Section 4 concludes. Section 5 is on data and code availability.

# 2 Data and Methods

A major difficulty in investigating freight transportation is the ability to observe the transportation network. For tractability, I focus on air freight between the US and its four major trading partners – Canada, Mexico, China and Japan. There are several reasons for focusing on the US. First, the US is a major consumption center of the world with the most large companies such as Boeing and Apple. These companies import components, materials and subsystems around the world. Second, the US has experienced multiple waves of Covid-19 variants from Alpha to Omicron. The US government has also issued different levels of policies against the Covid pandemic. Furthermore, the US has the most diverse trading partners including its neighboring countries like Canada and Mexico, UK and the EU countries, Asian countries, African countries and etc. This wide trading network provides an opportunity to observe the differential impact of different Covid-related policies issued by different countries. My study draws on three sources of data – inbound air freight price index of the US, Covid policy data and Covid infection and deaths data. I discuss each in turn below.

## 2.1 Air freight price rate

I use air freight price index dataset provided by US Bureau of Labor Statistics (Bureau of Labor Statistics, 2022). Air freight is an essential part of supply chain, especially global supply chain. It's also consistently challenged and even disrupted in the past two years of pandemic. The disruptions are mainly concentrated in the limited/declining supply leading to the imbalanced supply-demand relationship. More specifically, air freight may be capped or even canceled between two countries due to factors such as International travel control and outbreaks among air crews. But demand for commodities, medicines, PPEs are increasing during the course of the pandemic. A straightforward proxy for the supply-demand relationship would be the price, as it is the results of supply-demand equilibrium. Higher air freight prices stand for the incapability of air freight industry under the disruptions of the pandemic. In this project, I include the sample from December 2019 to March 2022 to cover the whole period of Covid-191 so far. The sample is a panel data at country-industry-month level. Countries include the major trading partners of the US such as Canada, China and Mexico. Industry is based on North American Industry Classification System (NAICS) containing food manufacturing, agriculture and etc. A summary table of this dataset is in Table 1.

I choose four major trading partners in my sample, which are Canada, Mexico, China and Japan. While European countries are one of the largest trading partners as well. But BLS only reports incomplete France, Germany and UK data. Though it does report complete data of EU as a whole, I don't think it's appropriate to treat all EU countries as a whole. Different countries inside EU have their own Covid-related policies. It would be messy to aggregate policies of all EU countries. Hence, I decide to remove EU countries and UK in my sample. The complete time range for the four trading partners of this sample contains 28 months. But price indexes of some industries only start to be reported in December 2020. So these indexes only span 16 months. This table shows heterogeneous average price index levels among different countries and different industries. It also shows heterogeneous volatility levels (standard deviation) among different countries and different industries. I will use mixed-effects regression models (MRM) to capture the heterogeneity. MRM models are compatible with missing data mentioned earlier. In this study, I only focus on inbound air freight price index. There are two reasons for excluding outbound air freight price index in this study. First, BLS only differentiates export categories into non-manufacturing and manufacturing. While import categories are divided by more detailed types. The granularity of export categories is not enough to capture category-level heterogeneity. Second, in my initial analysis, outbound air freight price index is not significantly impacted by Covid-related containment and closure policies from either the US or the destination countries.

**Table 1:** Summary statistics of air freight price index data

| Country | Direction | NAICS Industry | Number of Observations | Mean | Std. Dev. | 25% percentile | Median | 75% percentile |
|---|---|---|---|---|---|---|---|---|
| Canada | Import | All | 28 | 151.400 | 25.938 | 133.000 | 148.400 | 173.125 |
| | | Food manufacturing | 28 | 118.600 | 14.403 | 105.500 | 113.500 | 134.300 |
| | | Petroleum and coal products manufacturing | 28 | 105.193 | 31.180 | 80.075 | 106.750 | 120.800 |
| | | Mining | 28 | 97.011 | 36.075 | 70.525 | 93.300 | 121.625 |
| | | Primary metal manufactoring | 28 | 119.036 | 20.704 | 96.850 | 118.550 | 136.575 |
| | Export | All | 28 | 104.144 | 47.320 | 80.075 | 113.500 | 134.300 |
| | | Non manufacturing | 16 | 99.035 | 44.167 | 72.913 | 106.125 | 130.156 |
| | | Manufacturing | 16 | 108.300 | 5.033 | 104.075 | 108.700 | 111.150 |
| Mexico | Import | All | 28 | 91.679 | 34.504 | 72.913 | 100.577 | 118.914 |
| | | Agriculture, forestry, fishing and hunting | 16 | 122.300 | 13.085 | 111.725 | 125.000 | 135.350 |
| | | Beverage and tobacco product manufacturing | 28 | 124.100 | 3.155 | 123.425 | 124.300 | 125.700 |
| | | Primary metal manufacturing | 28 | 89.379 | 33.908 | 72.913 | 102.326 | 110.538 |
| | | Computer and electronic product manufacturing | 28 | 75.800 | 1.511 | 74.550 | 75.300 | 76.800 |
| | | Electrical equipment, appliance, and component manufacturing | 28 | 93.199 | 43.318 | 77.604 | 109.925 | 123.931 |
| | | Household appliance manufacturing | 28 | 91.790 | 40.560 | 72.913 | 106.432 | 123.931 |
| | Export | All | 28 | 109.400 | 13.498 | 97.400 | 103.800 | 121.950 |
| | | Non manufacturing | 28 | 129.100 | 35.564 | 94.725 | 126.600 | 158.725 |
| | | Manufacturing | 28 | 108.000 | 12.111 | 97.125 | 102.100 | 119.575 |
| China | Import | All | 28 | 100.100 | 2.237 | 98.200 | 99.300 | 102.150 |
| | | Computer and electronic product manufacturing | 28 | 93.718 | 36.884 | 74.085 | 100.600 | 123.436 |
| | | Electrical equipment, appliance, and component manufacturing | 28 | 93.265 | 39.392 | 77.632 | 102.950 | 121.356 |
| | Export | All | 28 | 103.600 | 7.980 | 96.875 | 101.500 | 110.000 |
| | | Non manufacturing | 28 | 99.900 | 23.340 | 80.300 | 103.900 | 116.650 |
| | | Manufacturing | 28 | 85.211 | 35.022 | 74.972 | 98.750 | 102.750 |
| Japan | Import | All | 28 | 84.263 | 34.894 | 74.972 | 98.750 | 102.750 |
| | | Computer and electronic product manufacturing | 28 | 85.368 | 33.084 | 74.972 | 98.388 | 103.825 |
| | Export | All | 28 | 106.182 | 8.833 | 99.300 | 105.050 | 112.550 |
| | | Non manufacturing | 28 | 109.896 | 29.841 | 83.625 | 109.100 | 132.475 |
| | | Manufacturing | 28 | 103.729 | 3.078 | 101.700 | 102.450 | 106.875 |

## 2.2 Covid policy data

Covid policy data is from Oxford Covid-19 Government Response Tracker (OxCGRT) project (Hale et al., 2021). The dataset summarized more than 50 Covid policy index such as "school closing", "workplace closing", "cancel public events" and "mandatory vaccination". I plan to focus on travel and workplace related policy from both origin countries and destination countries indexes like "restrictions on internal movement" and "international travel controls". The data is at country-state-date level. I aggregate it to country-month level to align it with air freight price rate data. Figure 1 below summarizes the stringency of different policies issued since January 2020. Because the original dataset is at the state/region level. There may be duplicates in one country. Therefore, I code policy variables of one country in one month as 1 as long as this kind of policy is in place this month in some parts of this country. And I code policy variables of one country in one month as 0 if this kind of policy is not in place this month in any part of this country. For example, the Illinois government and California government may both issue International travel restrictions after the federal government issued the same restriction. In this case, it counts as 3 policies in this dataset. Therefore, I plan to use dummy variables, which equals to 1 if a country has policies issued in a specific month and equals to 0 otherwise. This helps to account for the substantial gap and duplicates incurred by number of states/provinces of different countries. In this example, if Illinois issued “stay at home requirements” in March 2021, then I code “stay at home requirements” of the US in March 2021 as 1 even though other states like Wyoming might not issue this policy in March 2021.

Figure 1 shows the stringency of policies issued by each country across time. Hale et al. (2021) calculated the stringency by analyzing all policies issued at a daily level. I aggregate it to the monthly level by taking the average. This figure indicates that at the early stage of the Covid pandemic, all countries starting from China adopted very stringent policies to control the Covid outbreak. After China successfully controlled the spread of Covid at a very low level in May 2020, the Chinese government reduced the stringency. While countries like Canada and Mexico still kept their policies at a more strict level and Japan increased its policy stringency. The second shadow and the third shadow cover the emergence of the Alpha variant and the Omicron variant respectively. In these two phases of new variants, Canada, China and Mexico all increased their policy stringency level. But Japan and the US still kept their policy at previous level. Moreover, the US kept lowering its policy stringency level after April 2020, one month after the lockdown.

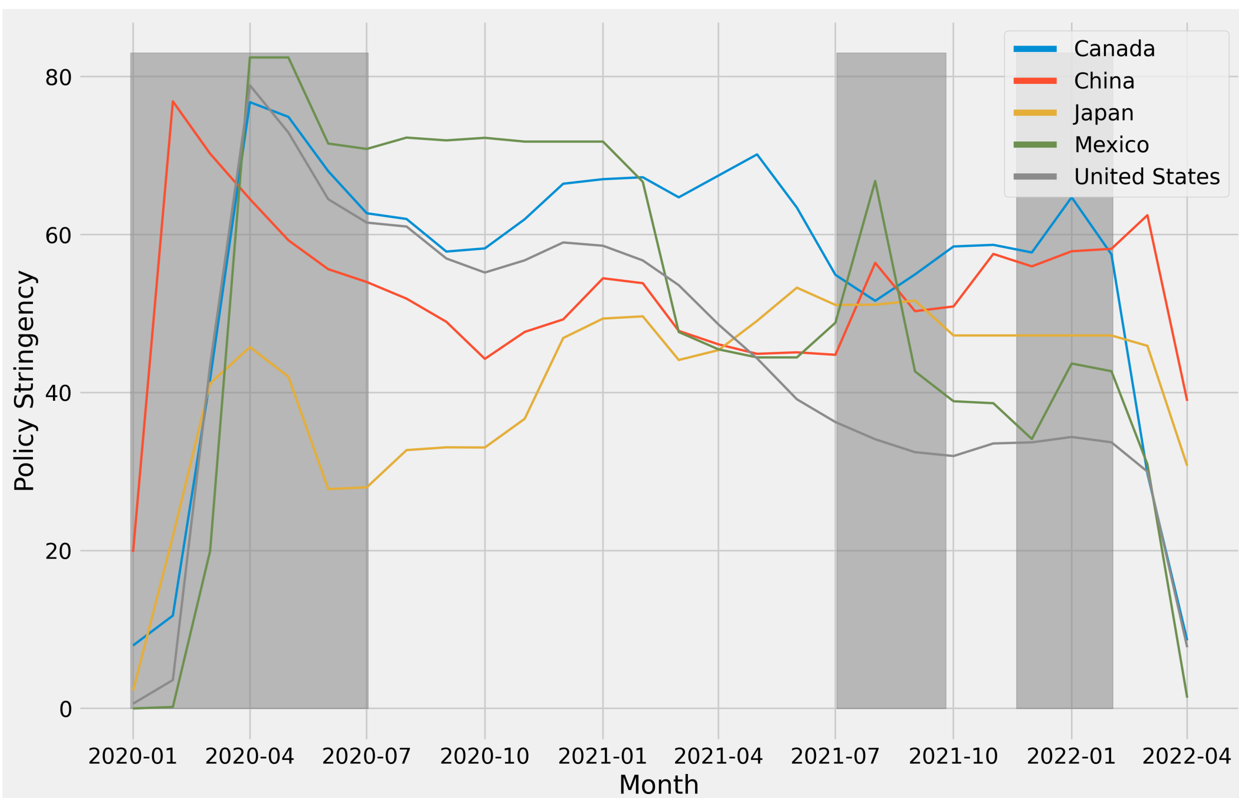



**Figure 1:** Policy stringency summary

## 2.3 Mixed-effects Regression Models

I examine the impact of Covid-related containment and closure policies on import air freight price index among four major trading partners of US, i.e. Canada, Mexico, China and Japan. I applied mixed-effects regression models (MRM) to capture heterogeneous effects among different countries. MRM allows each countries to have random coefficients of policy covariates, which deviate from the average effects. The detailed implementation can be described as the equation below. $PI_{i,t}$ is the price index of country $i$ in month $t$. $b_{0,i}$ is the intercept or the starting level given data is in the time order here. $b_{0,i}$ is composed of the average intercept of the four countries $\beta_0$ and the individual random intercepts $v_{0,i}$. Similarly, $b_{1,i}$ is the coefficient of covariates $R.E._{\cdot i,t}$ with random effects. It's also composed of the average effect $\beta_1$ and the individual random coefficients $v_{1,i}$. This setting makes it possible for different countries to have different reactions to the same type of policies. $b_2$ are the coefficients of fixed effect covariates $F.E._{\cdot i,t}$. $C_{i,t}$ are control variables including Covid cases and Covid death cases in each country. I use the logarithm transformation of the case numbers to account for the substantial gaps among different countries. $\varepsilon_{i,t}$ is the error term following normal distribution.

$$
\begin{aligned}
&PI_{i,t} = b_{0,i} + b_{1,i} \times R.E._{\cdot i,t} + b_2 \times F.E._{\cdot i,t} + C_{i,t} + \varepsilon_{i,t} \\
&b_{0,i} = \beta_0 + v_{0,i} \\
&b_{1,i} = \beta_1 + v_{1,i}
\end{aligned}
$$

# 3 Results and Discussion

## 3.1 Impact of Covid-related policies among countries

As presented in Table 2, Covid-related containment and closure policies from origin countries such as "cancel public events", "restrictions on gatherings", "stay at home requirements" and "International travel controls" have offsetting effects on air freight price index relative to time trends and Covid case effects. Because all the policy covariates here are binary indicators. The results indicate that if country $i$ has international travel controls in effect in month $t$, the air freight price index would drop 23.64, which is 19.7% of the average air freight price index given its average value is 120. The explanation can be applied to other policy covariates. These findings hold when controlling for Covid case number and death number from both the origin countries and the destination country. The offsetting effects can be due to less demand for product shipping. The demand for product shipping comes from both suppliers and customers. The Covid-related containment and closure policies restrict the public to a smaller area leading the pause of production on the supplier's side. When the productivity of suppliers declines, they will naturally have less need to transport freight from their countries to the US, even though they want to. Therefore, these policies mitigate the effect of the Covid pandemic itself on air freight price index.

**Table 2: Changes in Policy Variables to Import Air Freight Price Index**

The table reports the estimates of regressing Covid-related containment and closure policies on air freight price index. The dependent variable is the import air freight price index. *date* is the time variable encoding in the format 0 to 27 from December 2019 to March 2022. Variables $C\_1$ to $C\_8$ are different types of containment and closure policies in origin countries. *log_case_org* and *log_death_org* are the Covid case number and death number of origin countries in logarithm. Similarly, *log_case_dst* and *log_death_dst* are the counterparts in the destination country, i.e. the US. $Country\ Var$ is the estimated variance of country-level random intercepts. $date\ Var$ is the estimated variance of date-level random effects. The dataset is organized at the country-month level. ***, **, and * indicate the 1%, 5%, and 10% levels of significance, respectively.

| | *Dependent variable:air freight price index* | | | | | |
|---|---|---|---|---|---|---|
| | Coef. | Std.Err. | $z$ | $P > \|z\|$ | [0.025 | 0.075] |
| Intercept | 115.604 | 14.409 | 8.023 | 0.000 | 87.363 | 143.845 |
| date | $0.758^{***}$ | 0.277 | 2.737 | 0.006 | 0.215 | 1.301 |
| C1_School_closing_org | -1.027 | 13.220 | -0.078 | 0.938 | -26.938 | 24.884 |
| C2_Workplace_closing_org | 0.805 | 8.178 | 0.098 | 0.922 | -15.224 | 16.833 |
| C3_Cancel_public_events_org | $-35.935^{**}$ | 16.905 | -2.126 | 0.034 | -69.067 | -2.802 |
| C4_Restrictions_on_gatherings_org | $-6.954^{**}$ | 3.084 | -2.255 | 0.024 | -12.999 | -0.910 |
| C5_Close_public_transport_org | 6.277 | 4.756 | 1.320 | 0.187 | -3.046 | 15.599 |
| C6_Stay_at_home_requirements_org | $-21.311^{**}$ | 8.770 | -2.430 | 0.015 | -38.499 | -4.123 |
| C7_Restrictions_on_internal_movement_org | 26.158 | 13.708 | 1.908 | 0.056 | -0.709 | 53.026 |
| C8_International_travel_controls_org | -23.644** | 11.508 | -2.054 | 0.040 | -46.199 | -1.088 |
| log_cases_org | $13.562^{***}$ | 2.788 | 4.865 | 0.000 | 8.098 | 19.026 |
| log_death_org | $-11.962^{***}$ | 2.664 | -4.489 | 0.000 | -17.184 | -6.739 |
| log_cases_dst | $-6.199^{*}$ | 3.267 | -1.897 | 0.058 | -12.602 | 0.204 |
| log_death_dst | $6.617^{*}$ | 3.570 | 1.854 | 0.064 | -0.380 | 13.614 |
| Country Var | 752.789 | | | | | |
| date Var | 0.754 | | | | | |

Besides from the average effects, I also examine the random effects among all four trading partners presented in Figure 2. This figure displays the random effects of "international travel controls" policy among all four countries. I focus on "international travel controls" because it's the most related to international freight transportation. Besides, its average estimated coefficient is larger than other significant policies except for "cancel public events". The average estimated coefficient of "international travel controls" is -23.644. And the random effects displayed in the figure indicates how the impact of this policy in different countries deviates from the average effect. Hence, positive random effects indicate less total effects given that total effects equals to average effects (negative) plus individual random effects. North American countries like Canada and Mexico have positive random effects, which would decrease the policy effects given they're negative. While Asian countries like China and Japan have negative random effects, which would deepen the policy effects. The heterogeneity can be mostly attributed to different distance between the US and these countries and different stringency of these policies in these countries. Asian countries, especially East Asian countries like China and Japan, have more stringent containment and closure policies against Covid-19. For instance, China government has been restricting the number of international flights since the outbreak of the pandemic. Furthermore, only flights of authorized airlines from authorized foreign airports can land at authorized Chinese airports. Adding on this, Asian countries can only rely on air freight and sea freight for trading with the US. These containment and closure policies drive the demand for Asian products in the two countries to shift to substitutes within the countries or from closer neighboring countries.

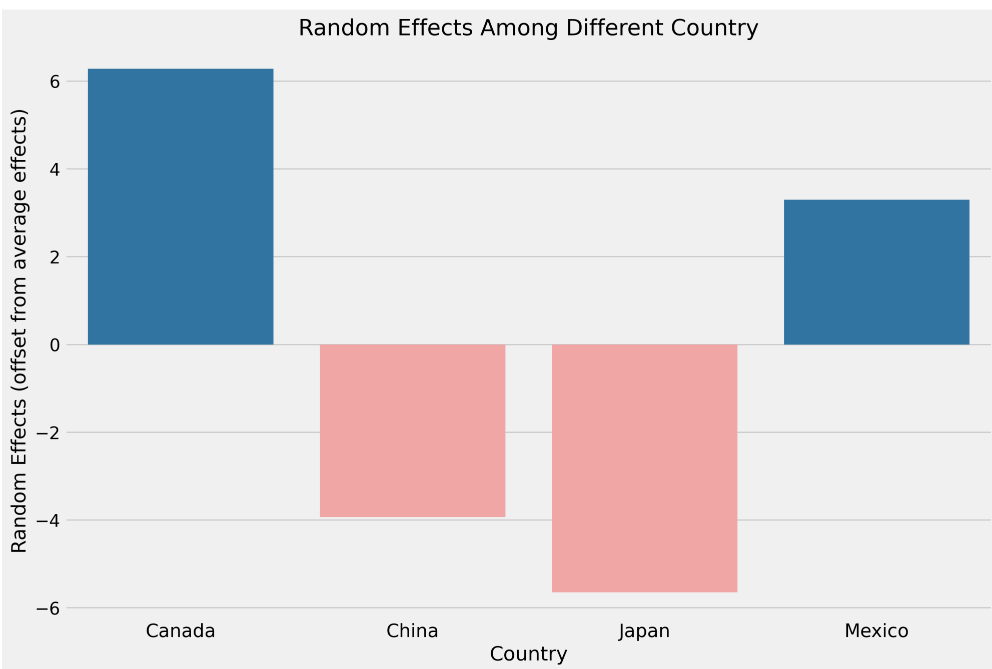
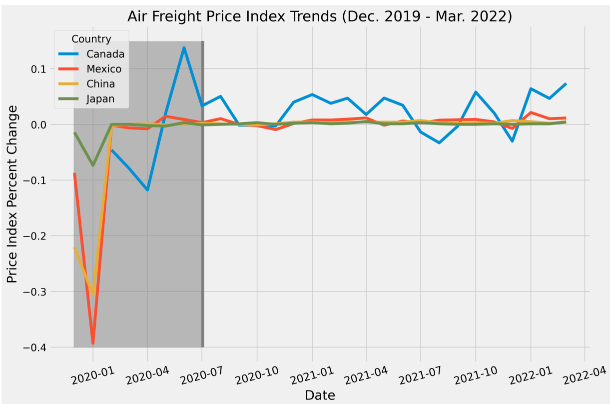


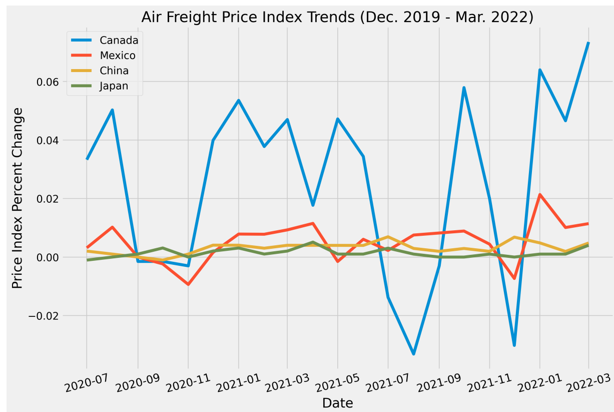

**Figure 2:** Random effects of international travel controls among countries

## 3.2 Impact of Covid-related policies among categories: example of Canada

Figure 3a shows the different time trends of air freight price index in the four countries since December 2019. To better display the details of all four-time trends, I present the time trends after July 2020 in Figure 3b. It's obvious that import air freight price index from Canada volatilizes the most. Even after January 2020 when air freight price index went back to normal, Canada still has substantial volatility. Therefore, I focus on Canada and its categories of air freight products following the main analysis in the last subsection.




(a) Since December 2019




(b) Since July 2020

**Figure 3:** Change in air freight price index among countries

I also employ MRM to gauge the impact of policies and capture category-level heterogeneity. In contrast to the regression in Table 2, I use percent change in air freight price index for smooth series among categories. I use percentage change here for a smooth time series to fit the regression model. In Table 2, because I try to capture country-level heterogeneity, using percentage change might cancel out the substantial difference among countries, especially among Mexico, China and Japan. Hence, the starting month is changed from December 2019 to January 2020. Furthermore, I removed destination country case number and death number, which are only marginally significant in main analysis to reduce noise. Covid-related policies and statistics of origin countries are proven to be more significant than those of destination countries from previous analyses. I also use stringency level from 0 to 4 (I only focus on travel only policies in this case.) as policy covariates instead of binary indicators. Because policy stringency change across time is more comparable within one country. It's hard to interpret or measure the stringency level of policies from different countries across time. As presented in Table 2, international travel controls have the strongest effect. The negative sign is consistent with the main analysis. When the Canada government escalates international travel controls by one level, the percent change in air freight price index would drop by 0.187, which is close to 1039% of the average percent change. However, it's important to note that the stringency level of International travel controls is kept at a high level steadily by the Canada government since April 2020. The average level of the whole period is 3.6 with the standard deviation of 1.04. And if we limit the time scope to the period after Canada and the US announced to close their shared borders on March 18, 2020. The standard deviation is only 0.23, which means changes in international travel controls have substantial impact on air freight price index but wouldn't yield the impact as large as 1039%.

**Table 3: Changes in Policy Variables to Import Air Freight Price Index from Canada**
The table reports the estimates of regressing Covid-related containment and closure policies on air freight price index of Canada. The dependent variable is the import air freight price index percent change. *date* is the time variable encoding in the format 0 to 26 from January 2020 to March 2022. Variables $C\_1$ to $C\_8$ are different types of containment and closure policies in origin countries. *log_case* and *log_death* are the Covid case number and death number of origin countries in logarithm. $Category\ Var$ is the estimated variance of category-level random intercepts. $Category \times C8\_International\_travel\_controls\ Cov$ is the estimated covariance between category-level random intercepts and random effects of C8 policies. $C8\_International\_travel\_controls\ Var$ is the estimated variance of category-level random effects. The dataset is organized at the category-month level. ***, **, and * indicate the 1%, 5%, and 10% levels of significance, respectively.

| | *Dependent variable:air freight price index change* | | | | | |
|---|---|---|---|---|---|---|
| | Coef. | Std.Err. | $z$ | $P > \|z\|$ | [0.025 | 0.075] |
| Intercept | -0.155 | 0.127 | -1.228 | 0.220 | -0.403 | 0.093 |
| date | -0.007 | 0.007 | -0.906 | 0.365 | -0.021 | 0.008 |
| C1_School_closing | $0.075^{*}$ | 0.040 | 1.881 | 0.060 | -0.003 | 0.154 |
| C2_Workplace_closing | $-0.112^{*}$ | 0.064 | -1.746 | 0.081 | -0.238 | 0.014 |
| C3_Cancel_public_events | 0.156 | 0.129 | 1.209 | 0.227 | -0.097 | 0.409 |
| C4_Restrictions_on_gatherings | 0.090 | 0.067 | 1.348 | 0.178 | -0.041 | 0.221 |
| C5_Close_public_transport | -0.367 | 0.259 | -1.419 | 0.156 | -0.874 | 0.140 |
| C6_Stay_at_home_requirements | -0.093 | 0.077 | -1.198 | 0.231 | -0.244 | 0.059 |
| C7_Restrictions_on_internal_movement | -0.001 | 0.128 | -0.007 | 0.995 | -0.253 | 0.251 |
| C8_International_travel_controls | $-0.187^{***}$ | 0.069 | -2.699 | 0.007 | -0.323 | -0.051 |
| log_cases | 0.043 | 0.027 | 1.604 | 0.109 | -0.009 | 0.095 |
| log_death | 0.031 | 0.028 | 1.085 | 0.278 | -0.025 | 0.086 |
| Category Var | 0.000 | 0.041 | | | | |
| Category × C8_International_travel_controls Cov | -0.000 | | | | | |
| C8_International_travel_controls Var | 0.005 | | | | | |

Imported freight from Canada to the US is divide into four categories. Manufactory-1 contains food manufactory; Manufactory-2 contains paper, petroleum, coal products and chemical manufactory; Manufactory-3 contains primary metal and machinery manufactory; Nonmanufactory contains agriculture and mining. The agriculture of nonmanufactory is referring to raw products from agriculture. While manufactory-1 refers to processed food. For instance, apples, the fruit, fall into agriculture in nonmanufactory. But apple jam and apple pie fall into manufactory-1, food manufactory. For category-level random effects, both the estimated variance of random intercepts and the estimated covariance between random intercepts and random trends are zero. Yet, the estimated variance of random trends is non-zero. These findings indicate the starting levels of air freight price index in different categories have no significant correlation with the trends. Higher starting level doesn't suggest larger or smaller policy effects. But the non-zero estimated variance of International travel controls indicate the existence of heterogeneity among categories. Figure 4 displays this kind of heterogeneity. Manufactory-1 and manufactory-3 have negative random effects, which would deepen the negative average effects. Meanwhile, manufactory-2 and nonmanufactory have positive random effects, which would offset the average effects. Categories with negative random effects are the categories with more ways to ship. Food, primary metal and machinery can be shipped via trucks as well. Although petroleum, chemical and mining products can also be shipped by trucks, they require more sophisticated equipment like tank trucks. Therefore, international travel controls have larger impact on manufactory-1 and manufactory-3, because they can easily shift to another shipping methods leading to declining demands of air freight. Taking the aforementioned apple example again, if the Canadian government restricts their flight numbers to and from the US ("international travel controls"). Apple jams (manufactory-1) can still be transported into the US by trucks or ships. However, even though apples can also be transported by trucks. Apples will expire much faster than apple jams. Therefore, apples still need to rely heavily on air transportation leading to less impact of border closure on air freight demand.

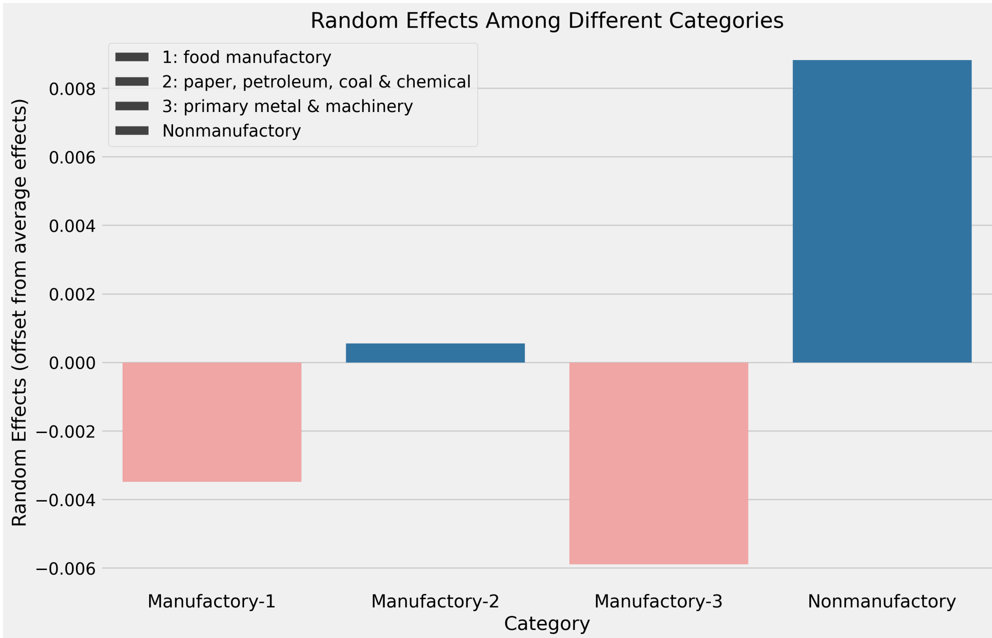



**Figure 4:** Random effects of International travel controls among countries in Canada

## 3.3 Discussion

This paper contributes to answer how Covid-related containment and closure policies impact air freight price index. My original hypothesis is this kind of policies increase air freight price index by limiting the number of available flights. However, after examining the effects with country-level and category-level data, I find the effects are actually opposite. The policies have a larger effect to decrease the demand side so that they will offset the increasing price due to the pandemic. To be more clear, the demand here is referring to the demand for air freight transportation. Both suppliers and customers have impact on the demand for air freight transportation. Because if suppliers pause their production, they don't need to ship their products out. And if customers have less demand for some specific products, they also don't need air freight to transport the products into the US. The findings are still consistent with previous research: 1) Covid-19 disrupt supply chain and the risks propagate through supply chain (Agca et al., 2020). The coefficients of Covid cases in my analyses are positive, which indicates the pandemic increases air freight price. 2) Hwang et al. (2020) demonstrates that online retailing or supply chain parts with more shipping options are less impacted under the shock of Covid-related policies. My category-level analysis shows that categories with more shipping options other than air freight would shift out of air freight with escalated International travel controls. International travel controls would decrease the demand for air freight in these categories leading to offset the Covid effects.

The strength of this paper focuses on capturing country-level and category-level heterogeneity. After checking the policy data, national-level policies align with state/province-level policies in the US, Canada, China and Japan. For Mexico, the dataset only tracks national level policies. MRM models used in this paper admit different countries and different categories to experience different impacts of Covid-related policies. And the results differentiate countries with more stringent policies and heavier reliance on air freight (China and Japan). The findings also differentiate categories with more shipping options other than air freight (manufactory-1 and manufactory-3).

The limit of this paper is the granularity of air freight data. Air freight price index is organized at country-month level. However, air freight, especially International air freight, requires large flights and large airports. Therefore, only specific hub city such as New York in the US and Shanghai in China have the capability for air freight. Even though state-level policies align with nation-level policies in the dataset, policies in large cities/municipalities will have larger impact on air freight price. The offsetting effects of policies may be underestimated by treating all states/provinces equally. However, the magnitude may be different. The sign (negative coefficients) of effects should still hold. This paper still provides insights about the impact of policies on air freight.

Future research can focus on two parts. The first is to expand air freight transportation to other transportation ways, especially sea freight transportation. Sea freight with large containers is more capable to transport non-emergent freight globally compared to air freight. But at the early stage of the pandemic, there were several community outbreaks among sailors. Following these outbreaks, many countries issued restrictions on foreign freighters. Even at this moment, there are still sporadic outbreaks among sailors. Studying how sea freight impacted by Covid related policies can provide insight for sea freight companies and major sea ports to adjust to the Covid pandemic.

The second field of future research is to use more granular data to investigate how Covid related containment and closure policies impact specific air freight routes such as Paris to New York or Shanghai to Los Angeles. As mentioned in the discussion of limitation, international air freight transportation needs large larger freighters, which require high-level airports to take off and land. Therefore, international air freight transportation concentrates in a small subset of cities including New York, London, Paris, Shanghai, Tokyo and etc. Policies in these cities naturally have more impact on air freight price compared to policies in other regions. Investigating the policy impact on specific routes can shed light on how to allocate limited flights in the Covid pandemic. For instance, the Chinese government is still restricting the number of foreign flights. Only flights from designated cities can fly into China. Hence, freight airlines need to think about how to shift flights to other cities if they cannot use direct flights from Chicago to Shanghai.

# 4 Conclusion

This paper contributes to the literature on supply chain disruption by focusing on inbound air freight price index and Covid related policies, and by capturing the country-level and category-level heterogeneity. I use the inbound air freight price index between the US and its major trading partners to examine the policy effects in amplifying or mitigating the Covid pandemic impact.

By exploring the average effect of Covid related containment and closure policies, I find that these policies mitigate the effect of the Covid pandemic itself on air freight price index. Because the policies restrict the productivity of suppliers so that suppliers have less demand to transport their product to the US. Further exploration of country-level analysis shows

Covid related policies more heavily impact distant Asian countries with higher stringency such as China and Japan. These countries have less options besides from air freight to transport their products to the US. And the policies in these countries drive customers in the US to shift to suppliers in other countries with more lax policies.

In terms of category-level heterogeneity, I focus on four categories of air freight from Canada to the US. The random-effects analysis indicates that Covid related policies more heavily impact categories with more shipping options. In contrast to the country-level analysis, categories with more shipping option can easily shift to other transportation leading to less demand for air freight transportation. And there's no substantial different impact pf the policies on the productivity of different suppliers in one country. Therefore, the decline in demand for air freight mainly comes from being substituted by other flexible transportation.

# 5 Data and Code Availability Statement

All datasets analyzed and generated during the current study are available in the GitHub repository: https://github.com/macs30200-s22/replication-materials-Sirius2713 with the identifiers: https://doi.org/10.5281/zenodo.6570841. To cite this repository, please use the format : Wenqian Zhang. "Macs30200-s22/replication-materials-sirius2713: Draft". Zenodo, May 22, 2022. https://doi.org/10.5281/zenodo.6570841.

# References


S. Agca, J. R. Birge, Z. Wang, and J. Wu. The Impact of COVID-19 on Supply Chain Credit Risk. *SSRN Electronic Journal*, 2020. ISSN 1556-5068. doi: 10.2139/ssrn.3639735. URL https://www.ssrn.com/abstract=3639735.

Bureau of Labor Statistics. Measuring price change for air freight in the u.s. import/export price indexes, 2022. URL https://www.bls.gov/mxp/publications/factsheets/air-freight-facts.htm.

Department of Transportation. Segmented 2019 inbound freight data, Sep 2020. URL https://www.transtats.bts.gov/DataIndex.asp.

W. Ding, R. Levine, C. Lin, and W. Xie. Corporate immunity to the covid-19 pandemic. *Journal of Financial Economics*, 141(2):802–830, 2021. ISSN 0304-405X. doi: https://doi.org/10.1016/j.jfineco.2021.03.005. URL https://www.sciencedirect.com/science/article/pii/S0304405X21000957.

H. Fang, C. Ge, H. Huang, and H. Li. Pandemics, Global Supply Chains, and Local Labor Demand: Evidence from 100 Million Posted Jobs in China. Working Paper 28072, National Bureau of Economic Research, Nov. 2020. URL http://www.nber.org/papers/w28072. Series: Working Paper Series.

S. Gudmundsson, M. Cattaneo, and R. Redondi. Forecasting temporal world recovery in air transport markets in the presence of large economic shocks: The case of covid-19. *Journal of Air Transport Management*, 91:102007, 2021. ISSN 0969-6997. doi: https://doi.org/10.1016/j.jairtraman.2020.102007. URL https://www.sciencedirect.com/science/article/pii/S0969699720305871.

T. Hale, N. Angrist, R. Goldszmidt, B. Kira, A. Petherick, T. Phillips, S. Webster, E. Cameron-Blake, L. Hallas, S. Majumdar, and H. Tatlow. A global panel database of pandemic policies (oxford covid-19 government response tracker). *Nature Human Behaviour*, 2021. doi: https://doi.org/10.1038/s41562-021-01079-8. URL https://doi.org/10.1038/s41562-021-01079-8.

E. H. Hwang, L. Nageswaran, and S.-H. Cho. Impact of COVID-19 on Omnichannel Retail: Drivers of Online Sales during Pandemic. *SSRN Electronic Journal*, 2020. ISSN 1556-5068. doi: 10.2139/ssrn.3657827. URL https://www.ssrn.com/abstract=3657827.

F. Meng, W. Gong, J. Liang, X. Li, Y. Zeng, and L. Yang. Impact of different control policies for covid-19 outbreak on the air transportation industry: A comparison between china, the u.s. and singapore. *PLOS ONE*, 16(3):1–19, 03 2021. doi: 10.1371/journal.pone.0248361. URL https://doi.org/10.1371/journal.pone.0248361.

P. Suau-Sanchez, A. Voltes-Dorta, and N. Cugueró-Escofet. An early assessment of the impact of covid-19 on air transport: Just another crisis or the end of aviation as we know it? *Journal of Transport Geography*, 86:102749, 2020.

H. Swegal and A. Wiesner. Inbound air freight prices go sky high in the midst of pandemic. *Beyond the Numbers: Prices and Spending*, 10:1–7, 2021.