

Cardoso, Miguel; Malloy, Brandon

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# The Impact of the First Wave of the COVID-19 Pandemic on Trade between Canada and the United States \*

Miguel Cardoso

Brandon Malloy

Brock University

St. Francis Xavier University

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## Abstract

We examine how the COVID-19 pandemic has impacted trade between Canada and the U.S., using a novel dataset on monthly bilateral trade flows between Canadian provinces and U.S. states, merged with COVID-19 health data. We find a statistically significant and robust negative relationship between the severity of COVID-19 and changes in Canadian exports and imports. Our results show that a one-standard deviation rise in COVID-19 severity in a Canadian province leads to a fall of 3.1-4.9% in exports and a 6.7-9.1% fall in imports. This result is robust to the measure of COVID-19 severity used: case levels, hospitalizations or deaths. We also investigate the role of COVID-19 policy responses and find that lockdown stringency measures did not significantly affect Canadian export or import flows. Decomposing our analysis by industry, we determine that trade in the relatively more labour-intensive manufacturing industry was most negatively affected by the pandemic, while the agriculture industry suffered the least disruption to trade flows. Collectively our results suggest that while trade was most adversely affected in industries and regions hardest hit by the pandemic, government-imposed lockdown restrictions do not appear to have caused significant additional decreases in Canadian exports or imports.

*Keywords:* COVID-19, Canadian trade, international trade, manufacturing, lockdown restrictions

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# 1 Introduction

The COVID-19 global pandemic has resulted in unprecedented disruptions to the Canadian economy, at the local, regional and national levels. In response, policy makers have urgently explored options to minimize its economic and public health repercussions and support Canadian consumers and businesses through the crisis.<sup>1</sup> The economic uncertainty created by this crisis can be particularly harmful for Canadian businesses that engage in international trade and depend on the global value chain as part of their business model.<sup>2</sup> Understanding the ramifications of the pandemic and the associated policy responses is crucial in evaluating the long-term prospects for Canadian trade and the Canadian economy in general.

While we are still in the early stages of a potential multi-year economic slow down, examining the early impacts of the "first wave" of the COVID-19 pandemic can help policy makers understand how initial policy responses such as "lockdowns" have affected various sectors of the Canadian economy and direct resources more effectively to aid the recovery process. While most government policies relating to the COVID-19 pandemic are directed at protecting public health, a robust evaluation of these policies will also consider the secondary effects on various other sectors of the Canadian economy like international trade. If these policies lead to significant reductions in trade, quantifying these effects can provide valuable information for weighing these costs against the public health benefits of pandemic restrictions. Conversely, if trade is not significantly impacted by these restrictions, this result can provide equally valuable insight to policymakers

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<sup>1</sup>Total government spending over the course of Canada's COVID-19 Economic Response Plan is projected to reach \$490 billion by 2026 ([Department of Finance Canada, 2020](#)). For comparison, during the 2008-2009 recession the government provided \$40 billion in the support of the Canadian economy ([Department of Finance Canada, 2009](#)).

<sup>2</sup>See the Trade Commissioner's overview on COVID-19 and Canada's international trade for details <https://www.tradecommissioner.gc.ca/campaign-campagne/commerce-international-covid-19-international-trade.aspx?lang=eng>.

deliberating the appropriate levels of policy response. With this motivation in mind, this paper utilizes new data on monthly bilateral trade flows between Canadian provinces and their corresponding trading partners at the United States (U.S.) state level to analyze the impact of the COVID-19 pandemic's first wave on Canada's international trade patterns.

This paper comprises four main research objectives contributing to the current sparse, but growing literature on the relationship between the COVID-19 pandemic and trade. First, we assemble a novel dataset on monthly bilateral trade flows from the Government of Canada's *Trade Data Online* (TDO) database and combine it with data on COVID-19 statistics from Canadian provincial and U.S. state health reporting agencies to document the changes in trade patterns between January 2019 and September 2020 amid the emergence of the COVID-19 pandemic. Second, our analysis provides insight on the differences in origin-specific and destination-specific effects. For example, if trade is highly impacted by conditions in the destination location, we would expect provincial exports to U.S. states hardest hit by COVID-19 to be most adversely affected, irrespective of origin province. Conversely, if trade is highly impacted by conditions in the origin location, exports from provinces such as Ontario and Quebec, where COVID-19 metrics are consistently highest among provinces, might be expected to suffer more than those coming from the Maritime provinces, where the pandemic severity is consistently lowest, irrespective of destination state. Third, we decompose our analysis of the pandemic's effect on trade into two distinct channels: exposure to infection (such as the number of cases, deaths or hospitalizations attributed to COVID-19) versus the severity of policy responses (such as restrictions on work, travel or gatherings). This allows us to examine whether variation in COVID-19 policy measures instituted across provinces and states have resulted in differences in outcomes in trade flows. Finally, we segment our analysis using the more disaggregated 2-digit NAICS goods classification system to determine whether different types of industries (i.e. agriculture vs. manufacturing) experience differential effects of the pandemic's severity

on the resultant changes in trade within each industry.

From our descriptive trends analysis we find large and persistent falls in bilateral trade between Canada and the U.S., both at the national and provincial/state level, following the classification of COVID-19 as a global pandemic in March 2020. At the national level, year-over-year decreases in both exports and imports were close to 50% in the months following the initial outbreak of the pandemic. The manufacturing, and mining, oil, and gas sectors were the hardest hit, where decreases in trade flows in these sectors surpassed 60%. At the provincial level, we find a similar trend, with all provinces experiencing a minimum 25% decrease in exports, while some provinces experienced as much as a 75% decrease in exports in the wake of the pandemic. We find similar magnitudes for the changes in provincial import flows.

We also find strong evidence that the decline of exports and imports is correlated with the severity of the COVID-19 pandemic. We find a negative relationship between monthly COVID-19 cases levels and changes in trade flows, across both provinces and time. Provinces experiencing higher population-adjusted case counts exhibit larger decreases in trade flows, with the largest decreases typically occurring in the months with the most severe COVID-19 outbreaks. We also find evidence of a positive relationship between monthly COVID-19 case levels and the severity of lockdown restrictions imposed by provinces over time.

With our descriptive analysis having revealed the broad negative relationship between trade and COVID-19, we next turn to a regression model for a more rigorous assessment of this relationship. Using a variety of COVID-19 health metrics, such as cases, deaths and hospitalizations (all population-controlled, per million inhabitants), we find that most of these measures of pandemic severity predict significant decreases in year-over-year trade flows, for both Canadian exports and imports. Due to the fact that our COVID-19 health metrics exhibit substantial differences in their mean levels, we interpret our coefficient

estimates based on a one-standard deviation increase in each control variable, for ease of comparison.<sup>3</sup> Using this method, our regression results predict that a one-standard deviation rise in the severity of the pandemic in Canada leads to a reduction of 3.1-4.9% in Canadian provincial exports and 6.7-9.1% in Canadian provincial imports.<sup>4</sup> Similarly, we find that a one-standard deviation increase in the severity of the pandemic in the U.S. results in a 2.3-7.1% decrease in Canadian exports and an 1.5-8.5% decrease in Canadian imports.<sup>5</sup> If we exclude our estimates for U.S. cases as they are not statistically significant at a 90% confidence level for Canadian exports or imports, the impact narrows to 6.3-7.1% and 5.1-8.5% for exports and imports, respectively. However, we find no statistically significant impact of the degree of lockdown stringency, either across Canadian provinces or U.S. states, on changes in Canadian export or import flows.

Building on the works of [Baldwin and Freeman \(2020\)](#) and [Blit \(2020\)](#), who find evidence of significant differences in the impacts of COVID-19 across industries, we further decompose our analysis at the NAICS 2-digit industry level, across the agriculture, mining, oil and gas, and manufacturing industries. We find significant differences in the impact of pandemic severity on trade across industries. While trade in the agriculture industry was largely unaffected by our COVID-19 health metrics, we find that higher COVID-19 case counts in Canadian provinces and U.S. states both negatively affect Canadian exports in the mining, oil and gas industry. We find the largest impact in the relatively more labour-intensive manufacturing industry, where increases in any of our Canadian health metrics (cases, deaths and hospitalization rates) lead to decreases in both Canadian exports

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<sup>3</sup>For example, our mean value for provincial monthly cases in Canada in 2020 was 264 per million, while the mean value of monthly hospitalizations and deaths per million were 10 and 12, respectively. See Table 1.

<sup>4</sup>Specifically, depending on whether we use cases, deaths or hospitalizations as our pandemic severity metric, we predict a decrease of 4.9%, 3.1% or 3.8% in Canadian exports, and a decrease of 7.3%, 6.7% or 9.1% in Canadian imports, respectively.

<sup>5</sup>Specifically, depending on whether we use cases, deaths or hospitalizations as our pandemic severity metric, we predict a decrease of 2.3%, 7.1% or 6.3% in Canadian exports, and a decrease of 1.5%, 8.5% or 5.1% in Canadian imports, respectively.

and imports, and increases in American deaths and hospitalizations also predict decreases in Canadian exports and imports.

Similar to our pooled results, we find that lockdown policies did not significantly affect Canadian export or import flows across any of these three industries. Taken together, these results suggest that measures imposed to protect public health did not have additional negative effects on year-over-year trade growth, above and beyond any direct effects of the pandemic's severity for a given province-state pair.

This paper contributes to the growing literature on understanding the economic and public health effects of the COVID-19 pandemic in Canada. Important analyses of the pandemic's effects in other areas of the Canadian economy by [Lemieux et al. \(2020\)](#), [Gallacher and Hossian \(2020\)](#), and [Beland et al. \(2020\)](#) have documented large drops in employment and worsening mental health stemming from COVID-19, especially for Canadians employed in industries where the possibility of remote work is less likely. More recently, [Frenette et al. \(2021\)](#) predict the long-term negative ramifications to youths' earnings prospects from entering the labour market during a COVID-19 fueled slowdown of the economy.

Work specific to international trade has been more limited; however, reports by intergovernmental organizations such as the World Trade Organization (WTO) and the Organisation for Economic Co-operation and Development (OECD) have highlighted the potential risk to global trade from COVID-19. For example, [OECD \(2020\)](#) finds the threat of re-nationalizing supply chains to ease the immediate burden of satisfying medical supply needs may make countries worse off in the long-run if countries retaliate by severing productive cross-border supply chains for intermediate goods in other industries. Alternatively, trade may expedite economic recovery in countries struggling to overcome COVID-19 outbreaks. Using a general equilibrium model of world production and trade, [Bonadio et al. \(2020\)](#) find that increased import flows during times of stringent national or

regional lockdowns can mitigate the economic losses caused by disruptions to domestic production capabilities. However, these same supply linkages may also prolong the negative impact from COVID-19 on trade, even after COVID-19 is under control domestically. [Baldwin and Freeman \(2020\)](#) warn that differences in the timing and severity of COVID-19 across countries create multiple waves of ‘supply-chain contagion’ where supply shocks in one country lead to the reductions of foreign intermediary goods in another. Studies by [Meier and Pinto \(2020\)](#) and [Friedt and Zhang \(2020\)](#) have highlighted the role that global value chains (GVC) have in magnifying the negative trade impact from COVID-19, focusing on the China and the U.S., respectively. A similar study conducted by [Hayakawa and Mukunoki \(2021a\)](#) expands to a larger set of countries but narrows the focus to the role of the COVID-19 pandemic in disrupting the GVC in the machinery-products industry.

Perhaps most closely related to our work is [Hayakawa and Mukunoki \(2021c\)](#), who demonstrate the negative impact of COVID-19 on bilateral trade across a wide variety of countries in the first quarter of 2020. However, while they also examine year-over-year changes in trade flows, their pandemic severity metrics are limited to COVID-19 cases and deaths at the national level, do not address the impact that government policies (e.g. lockdown measures) have on trade flows, and focus solely on the first quarter of 2020, after which time much larger and wide-ranging changes in trade flows have been observed.<sup>6</sup>

Our work builds on this burgeoning literature with multiple contributions. First, to our knowledge, this is the first paper to describe the changes to monthly province-state trade flows between Canada and the U.S. in the wake of the COVID-19 pandemic. The Canada-U.S. relationship provides an ideal case study for the early effects of the pandemic on bilateral trade, as it is one of the most well-established and widely researched trade relationships in the world. The stability of Canada-U.S. trade prior to the pandemic

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<sup>6</sup>In a companion paper the authors do quantify the effect of lockdown policies on trade flows. See ([Hayakawa and Mukunoki, 2021b](#)) for details.



provides an opportunity to more accurately isolate the impact of the COVID-19 pandemic on trade flows.<sup>7</sup> Second, our work is unique in examining these changes at a more disaggregated level, to contrast the impacts on trade felt across various industries. Finally, this paper is among the first to jointly produce a quantitative analysis relating COVID-19 cases and policy data, such as lockdown severity, to trade data throughout the course of the “first wave” of the pandemic. This approach provides valuable insight for researchers and policymakers in designing and understanding the role of policy in response to the changing dynamics of the COVID-19 pandemic.

The remainder of the paper is structured as follows: Section 2 presents the data and descriptive analysis; Section 3 details our regression specifications and empirical results; Section 4 concludes.

## 2 Data

In this section, we describe the data sources and document the data patterns on the relationship between COVID-19 and bilateral trade between Canada and the U.S.

### 2.1 Data Sources

Our trade data, covering the 21-month period from January 2019 to September 2020, are compiled from the Government of Canada’s *Trade Data Online* (TDO) database, providing data on monthly bilateral trade flows between Canada and the U.S., at the province-state level, for select industries at the North American Industry Classification System (NAICS) 2-digit classification level. Four industries are recorded in the TDO: Agriculture, Forestry,

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<sup>7</sup>Bilateral trade in the 10 years leading up to the pandemic was consistent both in levels and as a fraction of total Canadian trade. This stability reduces concerns that our regression results are incorrectly attributing the fall in trade due to COVID-19 to a pre-pandemic trend (see Statistics Canada Table: 12-10-0011-01 (formerly CANSIM 228-0069) for details).

Fishing and Hunting (NAICS code 11), Mining and Oil and Gas Extraction (NAICS code 21), Utilities (NAICS code 22), and Manufacturing (NAICS codes 31-33). Collectively, these industries accounted for an average of 93% of total exports between Canada and the U.S. and 69% of the total Canadian worldwide exports during this time period. We have similarly high levels of coverage for imports, an average of 94% of total Canadian imports from the U.S. and 47% of total worldwide imports during this time period. The underlying data used in the TDO are sourced from Statistics Canada and the U.S. Census Bureau and updated monthly with only a three to four month lag which enables us to study the contemporaneous effects of COVID-19 on bilateral trade.<sup>8</sup>

Our COVID-19 data are assembled from a variety of sources. The Canadian data come from the “COVID-19 Canada” website hosted by ESRI Canada, which collects province-level COVID-19 metrics using ArcGIS software to compile data directly from each province’s official health reporting services.<sup>9</sup> The U.S. data are obtained from “The COVID Tracking Project”, which similarly amasses data directly from each state’s public health authority.<sup>10</sup> This provides us daily counts of positive cases and deaths, as well as supplementary metrics such as the number of tests administered and the number of hospitalizations.<sup>11</sup> For each province or state, we then aggregate daily counts to monthly totals to match to our monthly trade flow data, according to the source or destination location of each trade flow.

One particular challenge facing the Canadian and American economies due to the

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<sup>8</sup>See <https://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/home> for details.

<sup>9</sup>See <https://resources-covid19canada.hub.arcgis.com/> for details

<sup>10</sup>See <https://covidtracking.com/> for details

<sup>11</sup>The hospitalization data present a unique challenge: some U.S. states only report the daily change in hospitalizations as the number of new admissions, while other states report the change in total hospital census from the previous day. In these cases, it is therefore impossible to discern whether a “daily change of +3” represents 3 new infected patients to be cared for, or 5 new infected patients to be cared for with 2 previous patients being released. To address this discrepancy, we therefore use the monthly average for the number of “currently hospitalized” in the daily reports, as a measure of the resources employed in caring for patients, regardless of whether they are new admissions or previously admitted patients.

COVID-19 pandemic has been the introduction of “lockdowns”- restrictions on economic and social activity imposed by federal and provincial/state governments. In order to quantitatively assess the impact of these policy responses on trade, we use data from “The Oxford COVID-19 Government Response Tracker”, a unique index created by a panel of researchers and experts affiliated with the University of Oxford and the Blavatnik School of Government, to measure the degree of severity of these restrictions across a wide range of countries and regions over the course of the pandemic.<sup>12</sup> We use the generalized Lockdown Stringency Index, a weighted index of indicators such as school and workplace closures, restrictions on travel, movement or gatherings, or stay-at-home orders, ranging in value from 0 to 100. This index value is reported for each province and state on a daily basis, which we similarly aggregate into a monthly average to match to each monthly trade flow.

## 2.2 Trade Data Patterns

To visualize the impact of the COVID-19 pandemic on trade flows between 2019 and 2020, in Figure 1 we plot the year-over-year percentage change in total exports and total imports between Canada and the U.S.<sup>13</sup> Beginning in March 2020, coinciding with the declaration of COVID-19 as a global pandemic causing countries to begin taking policy actions such as lockdowns, we observe a substantial drop in both exports and imports compared to the same month in the previous year. These percentage decreases in trade are substantially larger than those observed for Canadian GDP, often by a factor of 2 to 3.<sup>14</sup>

We further investigate whether these trade patterns occur across the three 2-digit

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<sup>12</sup>See <https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker> for details.

<sup>13</sup>Year-over-year changes are calculated as  $\frac{X_{m,2020} - X_{m,2019}}{X_{m,2019}} \times 100\%$  where  $X_m$  denotes total exports or imports between Canada and the U.S. in month  $m$ .

<sup>14</sup>Refer to Table A.1.

NAICS goods categories in our data: (1) agriculture, (2) mining, oil and gas, and (3) manufacturing.<sup>15</sup> For example, due to the vital role that temporary foreign workers play in the agriculture sector in Canada, the imposition of travel restrictions and quarantine measures to combat COVID-19 may have a more pronounced effect in the production capacity in the agriculture sector, compared to the goods-producing sectors where temporary foreign worker employment is small (Lu, 2020). Alternatively, whereas demand for agricultural goods has remained high throughout the pandemic, demand in the mining, oil and gas sector may have fallen dramatically due to work from home orders reducing the need to travel. In Figure 2, we observe significant heterogeneity in the response and persistence of the shock to trade flows across industry categories, which presumably reflects the differences in the impact of COVID-19 on the demand or supply for the goods in these industries. There was a sharp and persistent decline in the mining, oil and gas, and manufacturing trade flows but only a modest decline in the agricultural sector, followed by a quick recovery.

The previous trade figures clearly show a notable decline in trade beginning in March 2020, which coincides with the arrival of significant numbers of COVID-19 cases, and the resultant policy responses, in North America. To first explore the relationship between trade flows and COVID-19 cases at the national level, in Figure 3 we plot changes in total exports and total imports against the national COVID-19 case totals over time. We find compelling evidence that the decline of exports and imports is strongly correlated with the severity in COVID-19 cases. For example, during our sample period, April and May report the highest number of COVID-19 cases, as well as the largest decreases in exports and imports relative to the same month in the previous year.

Given differences across provinces in their exposure to COVID-19, proximity to key U.S.

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<sup>15</sup>Due to a change in reporting procedures for the Utilities industry (NAICS-22) during the time-frame of our data, we omit this category from our analysis.

border crossings, and industry composition, a natural concern is that the trade patterns shown in Figure 1 and Figure 3 are driven by a selected sample of provinces. However, as we see in Figure 4, across almost all provinces, the severity of year-over-year decreases in exports and imports is correlated with higher COVID-19 case numbers.

Figure 5 further decomposes year-over-year changes in trade against COVID-19 cases per million at the provincial level, for each of our 2-digit NAICS industries. We find similarly negative relationships across all industries; however this negative correlation is stronger in some industries (manufacturing and mining/oil/gas) than others (agriculture). These differences can manifest for a variety of reasons. Safety measures aimed at slowing the spread of COVID-19 affecting the supply-side of the economy may arguably have a more pronounced impact on labour-intensive industries that require significant in-person presence for production.<sup>16</sup> Furthermore, the well documented fall in earnings for consumers from COVID-19 has also resulted in decreased aggregate demand; however, these shocks are not symmetric across all industries. Eaton et al. (2016) study the effect of the 2008-2009 recession on trade and show the large drop in trade that followed was largely caused by a shift away from durable product spending, e.g. manufactured goods products, towards non-traded sectors, e.g. housing. The heterogeneity in the transmission of these shocks across industries in the economy contributes to the differences observed in these figures.

Finding evidence of the relationship between changes in trade flows and COVID-19 cases, we next look at the link between COVID-19 cases and the resultant policy decisions regarding lockdowns. Figure 6 plots the lockdown stringency index for each Canadian province over the course of the pandemic, with all provinces exhibiting similarly strong (yet not identical) escalations of lockdown measures in the early months of the pandemic,

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<sup>16</sup>For example, the close proximity required in meat product manufacturing (NAICS code 3116) has led to larger outbreaks and temporary closures in that industry versus others, <https://www.bbc.com/news/53137613>.

followed by varying degrees of relaxation over the summer months and early fall of 2020.<sup>17</sup>

Figure 7 plots the relationship between the number of monthly COVID-19 cases (per million inhabitants) in each province and the severity of the lockdown measures implemented by each province during that month. As expected, we find a positive relationship between cases and lockdown policy response in 2020.<sup>18</sup> This finding lends credence to potential supply side effects, with provinces hardest hit by COVID-19 cases reacting with the most stringent lockdown policies, and therefore potentially experiencing larger effects on their trade flows.

Taken together, these findings suggest that there is a strong negative relationship between changes in trade flows between Canadian provinces and U.S. states and the severity of COVID-19 pandemic, both in case statistics and in policy responses such as lockdowns in those regions. This negative relationship holds across multiple industry categories, across provinces, and for both exports and imports. In the next section we outline a framework to empirically investigate this relationship.

## 3 Quantitative Analysis

### 3.1 Empirical Approach

To quantify the impact of COVID-19 on trade, we construct a set of regression specifications to examine year-over-year changes in trade flows across province-state pairs, controlling for COVID-19 health metrics and government policy response measures. Our health metrics include COVID-19 cases, average hospitalizations and deaths, while the policy

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<sup>17</sup>By comparison, the U.S. exhibits a similar initial spike in lockdown stringency in the initial months of the pandemic in the U.S., with a slightly larger degree of variation in their lockdown stringency through the summer and fall months, as shown in Figure A.1.

<sup>18</sup>This relationship is likely even more strongly positive when accounting for the fact that a number of provinces (particularly the small Maritime provinces) have  $\approx 0$  cases in a given month.

response is measured by our lockdown stringency index.

Across all regressions, our dependent variable is the year-over-year difference in monthly directional trade flows for each province-state pair in a given NAICS 2-digit industry. Due to potential heteroskedasticity issues arising from the large variation in trade values between larger and smaller province-state pairs, we log-transform our dependent variable. Further, due to the relative frequency of zero-values in our trade data, we use the following transformation:

$$\log \Delta X_{psit} \equiv \log(1 + X_{psit}) - \log(1 + X_{psi(t-12)}) \quad (1)$$

where  $\log \Delta X_{psit}$  represents the change in logged trade flows (exports or imports) between province  $p$  and state  $s$  in month  $t$  between years 2019 and 2020.

Our regression specification in equation (2) takes the form:

$$\begin{aligned} \log \Delta X_{psit} = & \beta_1 \Delta \text{COVID-19}_{pt} + \beta_2 \Delta \text{Lockdown}_{pt} \\ & + \beta_3 \Delta \text{COVID-19}_{st} + \beta_4 \Delta \text{Lockdown}_{st} \\ & + \Delta \delta_{psi} + \Delta \epsilon_{psit} \end{aligned} \quad (2)$$

where  $\text{COVID-19}_{pt}$  and  $\text{COVID-19}_{st}$  represents one of our COVID-19 health metrics,<sup>19</sup> such as Cases, Deaths, and Hospitalizations in each province  $p$  and state  $s$ , respectively, and  $\text{Lockdown}_{pt}$  and  $\text{Lockdown}_{st}$  represent our lockdown stringency index values.<sup>20</sup> We also include a province-state-industry fixed effect,  $\delta_{psi}$ . These fixed effects control for

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<sup>19</sup>In comparison to Hayakawa and Mukunoki (2021c) we do not add a value of one to our measures of COVID severity measures. Instead, we leave our COVID severity variables of interest, cases, hospitalizations, and deaths as non-logged per-million counts to account for population differences across provinces and states while still keeping a straightforward interpretation of our estimates.

<sup>20</sup>For consistency in representing the relationship of year-over-year changes in our dependent and independent variables, we represent the change ( $\Delta$ ) between observed values for monthly values in 2019 and 2020. However, since there were no observed cases, hospitalizations or deaths due to COVID-19 prior to 2020, this can be equivalently interpreted as simply the 2020 value of each variable.

any unobserved heterogeneity across province-state-industry observations that may be correlated with both trade flows and COVID-19 severity, and might otherwise bias our estimates.

We run separate regressions using each of our COVID-19 health metrics, due to the fact that the incredibly high level of correlation between these three measures, as shown in Table 2, presents issues with multicollinearity.<sup>21</sup>

### 3.2 Regression Results

The estimation results for equation (2) using our pooled sample for Canadian exports and Canadian imports are presented in Tables 4 and 5, respectively. Columns (1) through (3) show the anticipated negative coefficient estimates when using cases, deaths and hospitalizations as our various metrics for measuring the severity of the pandemic across provinces and states. However, our estimates for cases in U.S. states are not statistically significant in explaining export growth, and cases and hospitalizations in U.S. states are not statistically significant in explaining import growth.

Interpreting these coefficient estimates, we predict that each additional COVID-19 case per million in a Canadian province reduces Canadian exports by 0.01% from its previous year's value in a given month. While this effect may appear small, it is perhaps better understood in the context that, as shown in Table 1, mean values of provincial cases are 264 per million over this time span, with a standard deviation of 476 per million. Thus a one-standard deviation increase in provincial cases results in a 4.9% decrease in Canadian export flows and a 7.3% decrease in Canadian import flows.<sup>22</sup> Similarly, a

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<sup>21</sup>The mean VIF values for provincial cases, deaths and hospitalizations is 18.34, while for states it is 7.17, both of which suggest a strong likelihood of multicollinearity causing significant instability in our estimates if we were to include them all simultaneously.

<sup>22</sup>Due to the substantial differences in the mean values and standard deviations of our various COVID-19 metrics, we proceed with this approach to interpreting our coefficient estimates, for ease of comparison. Specifically, we simply multiply the coefficient estimates by the standard deviation of the appropriate statistic



one-standard deviation increase in provincial deaths or hospitalizations result in a 3.1% and 3.8% reduction in Canadian exports, respectively, and a 6.7% and 9.1% decrease in Canadian imports. Alternatively, a one-standard deviation increase in U.S. deaths results in a 7.3% decrease in Canadian exports and a 8.5% decrease in Canadian imports.<sup>23</sup>

In column (4), using our lockdown indices, we find the expected negative signs, but our coefficient estimates are not statistically significantly different from zero. However, unlike our health metrics, we note that the lack of statistical power for our lockdown measures may be a reflection of the relative lack of variation in lockdown policies across provinces in each month (regardless of variation in COVID-19 incidence) leading to larger standard errors in our regression analysis when using lockdown stringency as our explanatory variable.<sup>24</sup> Using the point estimates, we would predict a one-standard deviation increase in provincial lockdown stringency would decrease Canadian exports by 3.73% and Canadian imports by 5.25%, while a one-standard deviation increase in state lockdown stringency would decrease Canadian exports by 0.67% and Canadian imports by 11.1%. These estimates would be consistent with the idea that Canadian lockdown policies adversely affect both exports and imports to an economically significant degree, while U.S. lockdown policy is more likely to impact Canadian imports, but not Canadian exports. However, while these point estimates suggest there may potentially be an economically significant effect of lockdowns on trade flows, due to the large standard errors in this case, we are unable to confidently assert that these values are statistically significantly different from zero.

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in Table 1 to derive our interpretations.

<sup>23</sup>We also consider adding time fixed effects to our regression, in addition to our province-state-industry fixed effects. However, this results in most of our coefficient estimates becoming statistically insignificant, as shown in Tables A.2 and A.3. We suspect this is due to the high correlation between this time component and the COVID-19 health and lockdown metrics, leaving relatively little statistical power for the remaining variation in case/death/hospitalization statistics.

<sup>24</sup>This can be seen in Figure 6, as well as in Table 3, which demonstrates the much lower values in the coefficient of variation by month for lockdown stringency (0.06-0.13) than for cases (0.61-2.07) or deaths (0.89-2.14).

In columns (5) through (7), we combine each of our COVID-19 health metrics with the lockdown policy measure. We find similar coefficient estimates, however likely due to the relatively high correlation between the pandemic severity and lockdown measures, some of our estimates like provincial cases and deaths lose their statistical significance.

One issue to address with our pooled results is the influence of potential outliers- specifically, the disproportionately high population-adjusted COVID-19 case counts in Quebec, particularly in April and May 2020, relative to all other Canadian provinces.<sup>25</sup> To test the robustness of our pooled results, we omit Quebec from our regression analysis, and find similar results to those from our full sample. In most instances, our coefficient estimates are similar, but larger in magnitude, when omitting Quebec- for example, a one-standard deviation increase in provincial deaths (outside of Quebec) now results in an 18% decrease in Canadian export flows and a 17.4% decrease in Canadian import flows, compared to 3.1% and 6.7%, respectively with our full sample estimates. Similarly, a one-standard deviation increase in provincial hospitalizations predicts a 14.1% decrease in Canadian exports and a 20.1% decrease in Canadian imports when excluding Quebec, compared to 3.8% and 9.1%, respectively, in our full sample.<sup>26</sup> These results are not unexpected- due to the fact that Quebec experienced such disproportionately large case and death counts compared to other Canadian provinces in many months, but continued to produce and trade at less disproportionately suppressed levels, including Quebec in our pooled sample serves to slightly dampen the relationship between adverse COVID-19 outcomes and trade disruptions.

Another issue potentially complicating our estimation is the prevalence of zero-values in our trade data. There are a substantial number of province-state-industry observations that have zero trade flows in each corresponding month of both 2019 and 2020. However,

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<sup>25</sup>In addition to the outliers representing Quebec in Figure 5, this can be easily seen in Figure A.2, with Quebec's case counts being notably higher than the rest of Canada in most months.

<sup>26</sup>Refer to Tables A.4 and A.5

we cannot be sure whether these zero-value observations arise from lack of domestic production in a given industry, or from barriers to trade or prohibitive transportation costs. As a result, these zero-value cases do not add explanatory power to the relationship between pandemic severity and changes in trade flows in our analysis. To check the robustness of our results, we repeat our analysis on the subset of observations with non-zero values in corresponding months of both 2019 and 2020. This reduces our sample size from 13,770 to 9,550 observations of year-over-year changes in monthly trade flows at the province-state-industry level. We find this approach produces similar results for our COVID-19 and lockdown measures from the full sample.<sup>27</sup>

Collectively, these results generally support an economically significant effect of COVID-19 on Canadian trade with the U.S.; however, some of our estimates, including those for provincial case numbers are only statistically significant at a 90% confidence level. Given the heterogeneity in trade flow changes across industries observed in Figure 2, and the correlation between the severity of COVID-19 and trade flows changes across industries observed in Figure 5, these pooled results may be obscuring heterogeneous industry-specific impacts. We therefore run versions of equation (2) separately for the agriculture (Table 6), mining, oil and gas (Table 7), and manufacturing (Table 8) industries.

Consistent with the results found by Hayakawa and Mukunoki (2021c), we find no strong evidence that the severity of COVID-19, as measured by our health metrics, had any statistically significant effect on Canadian agriculture trade flows. Unlike the more volatile demand for durable goods, agricultural goods are composed of many necessities that are required for daily living, which are more likely to maintain stable levels over time. Similarly, stricter lockdown measures had no significant negative impact on agriculture trade flows, which in part reflects the nature of agricultural production in Canada and the

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<sup>27</sup>These results can be found in Tables A.6 and A.7, but are omitted here for brevity. We conclude that a PPML estimation of our specification is not of first-order importance given the similarity of our results from our pooled sample and non-zero sample when using the  $\log(1+x)$  transformation.

U.S. being relatively capital-intensive (by a factor of three) compared to manufacturing (Baldwin et al., 2008), where these lockdown measures would presumably affect labour-intensive industries more acutely.

In our results for the mining, oil and gas industry, we find some evidence that U.S. deaths and hospitalizations each negatively affect Canadian export flows, with a one-standard deviation increase in deaths or hospitalizations resulting in a 5.6% and 10.1% reduction in mining, oil and gas exports, respectively. Both Canadian and U.S. cases decrease Canadian exports, although the former is only significant at a 90% confidence level. These results would be in keeping with theories of decreased demand for fuel products stemming from work-from-home orders and the introduction of mandatory quarantine requirements for international travel. Similar to our results for the agriculture industry, we also find that the severity of lockdown measures across Canadian provinces and U.S. states did not have a significant impact on trade flows in the mining, oil and gas industry.

The results for the manufacturing industry show the largest and most consistent negative impact of COVID-19 on trade flows. In particular, we find that the severity of cases, deaths and hospitalizations in Canadian provinces have significant negative impacts on both Canadian exports and Canadian imports. Additionally, deaths in U.S. states have a significant negative impact on Canadian imports. Alternatively, we find no support for lockdown measures significantly impacting Canadian exports or imports in the manufacturing industry. The in-person presence requirement and relatively labour-intensive nature of the manufacturing industry corresponds to larger negative impacts of the pandemic's severity on trade flows, as compared to other industries. Interpreting these coefficient estimates, we predict a one-standard deviation increase in provincial cases results in a 5.2% decrease in Canadian exports and a 12.3% decrease in Canadian imports in the manufacturing industry. A similar one-standard deviation increase in provincial

deaths results in 4.8% less Canadian exports and 10.2% less Canadian imports in this category. The comparable values for U.S. state deaths are a 4.0% reduction in Canadian exports and an 8.8% reduction in Canadian imports. Finally, we estimate that a one-standard deviation increase in provincial hospitalizations decreases Canadian exports by 6.3% and decreases Canadian imports by 12.2%, while a comparable increase in U.S. state hospitalizations results in a 2.5% fall in Canadian exports and a 6.4% drop in Canadian imports of manufactured goods.

Taken together, our industry-specific results provide support for a demand-driven mechanism as a central explanation of the results depicted in Tables 6, 7, and 8. During highly volatile times, consumers typically consume fewer durable goods, but continue to consume necessities, consistent with our findings of a drop in manufacturing trade, and stable agricultural and oil and gas trade. Furthermore, we find that Canadian case counts affect Canadian imports more severely than Canadian exports, which further supports this explanation. However, without stronger data to identify a causal relationship, this theory is still speculative.

In each industry, we find no statistically significant impact of provincial or state lockdown stringency on Canadian export or import flows. However, as with our pooled sample, this result may be due at least in part to the fact that, despite significant differences in levels of COVID-19 severity (as measured by cases, deaths and hospitalizations) across provinces and states, there is much less variation in the severity of the lockdown measures imposed (shown in Figure 6), particularly at the outset of the pandemic in March and April 2020. This lack of variation in our lockdown index may hamper our ability to estimate the true impacts of the lockdown restrictions during the first wave of the COVID-19 pandemic, but may become more effectual as provinces and states pursue more varied policy responses over time.

## 4 Conclusion

In this paper we contribute to the small but growing literature on the economic fallout from the COVID-19 pandemic, using timely data on bilateral trade flows between Canadian provinces and U.S. states. We find that all Canadian provinces experienced a minimum 25% year-over-year decrease in monthly exports, with some provinces experiencing as much as a 75% decrease in exports in the months following the classification of COVID-19 as a global pandemic. Our descriptive results identify a strong negative relationship between the severity of COVID-19 in a province or state and export and import flows. We also demonstrate a positive relationship between the severity of our COVID-19 health statistics, represented by cases, hospitalizations and deaths, and our quantitative measure of lockdown stringency across provinces.

We follow our descriptive results with a series of regressions to further evaluate the negative relationship between COVID-19 health metrics and government policy responses to trade. Across a variety of specifications we find our COVID-19 health metrics, such as cases, deaths and hospitalizations, produce the expected negative effect on Canadian exports and imports observed during our sample period. Repeating our quantitative analysis at the more disaggregated 2-digit NAICS level, we find a large degree of heterogeneity that is obscured in the aggregated trade data. We find the severity of our COVID-19 metrics across provinces to be a much stronger and statistically significant predictor of decreasing trade flows within the manufacturing (and to a lesser extent the mining, oil and gas) industry than in the agriculture industry, where trade flows experienced the least disruption during the course of the pandemic.

One possible factor contributing to the lack of statistical significance of our lockdown estimates is the fact that, particularly in the first few months of the pandemic's emergence in Canada, most provinces followed very similar public health responses and imposed

similar restrictions, regardless of their provincial COVID-19 case loads at the time. As a result, our lockdown stringency metric exhibits a low coefficient of variation across provinces over the time frame of our data, remaining between 0.06 and 0.13 in every month. This lack of variation in policy responses may contribute to the lack of statistical power of our lockdown measures to explain the variation in trade flows observed in our data. While this paper focuses on the impacts of the first wave of the COVID-19 pandemic, future studies may be better equipped to analyze this channel, particularly as early indications suggest increasing variation in lockdown policies across provinces as the pandemic progresses into its second and third waves.

As the course of the pandemic evolves, and more data becomes available, these relationships can be reevaluated, and further insight into the effects of COVID-19 health metrics and policy measures on trade can be ascertained. Unfortunately, traditional control variables like GDP that are typically employed in gravity-models of international trade will never be available on a monthly basis at the provincial and state level; however, with enough time to collect more data and amass sufficient observations on annual or quarterly GDP figures, these estimates may be improved. Additionally, while data is typically not available at the more disaggregated regional level, similar analyses can be performed at the national level for other Canadian trading partners.

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# Figures

Figure 1: Canadian Trade to the United States, National Level

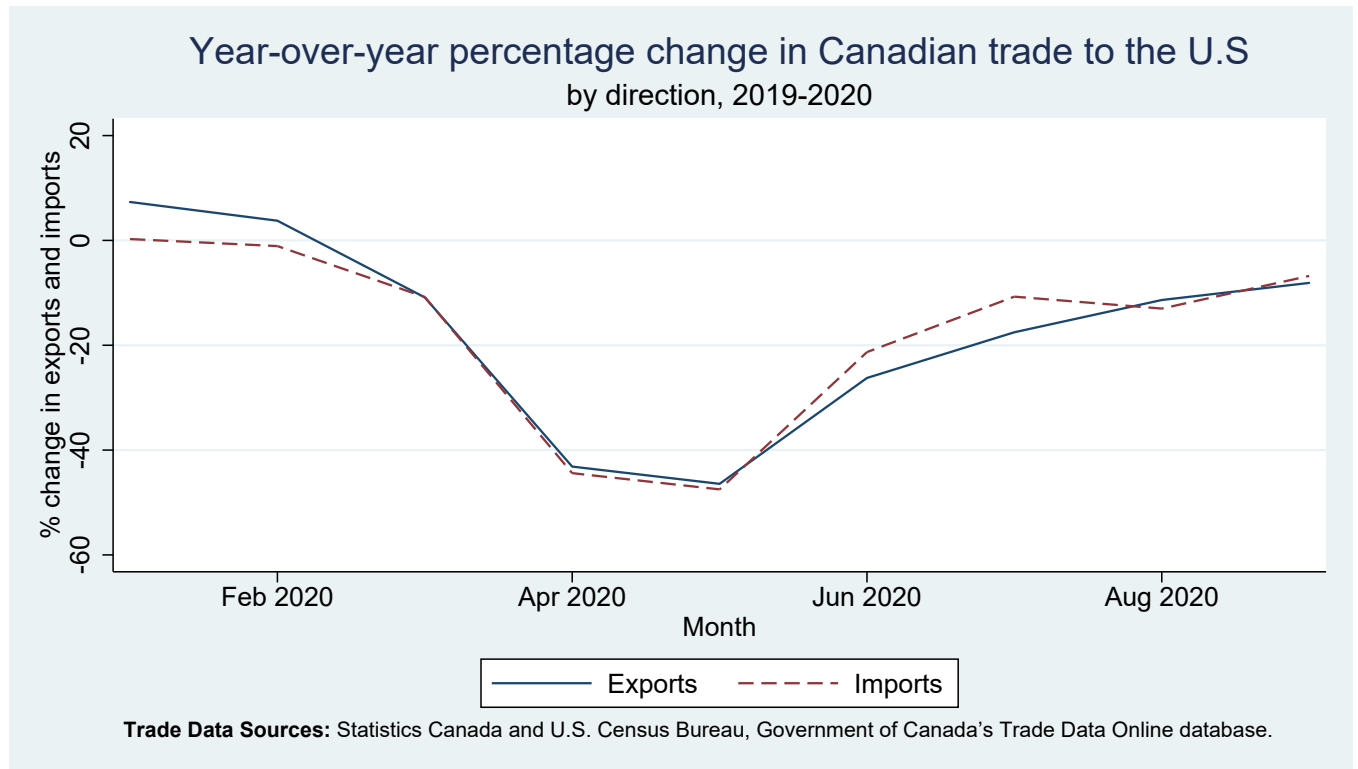
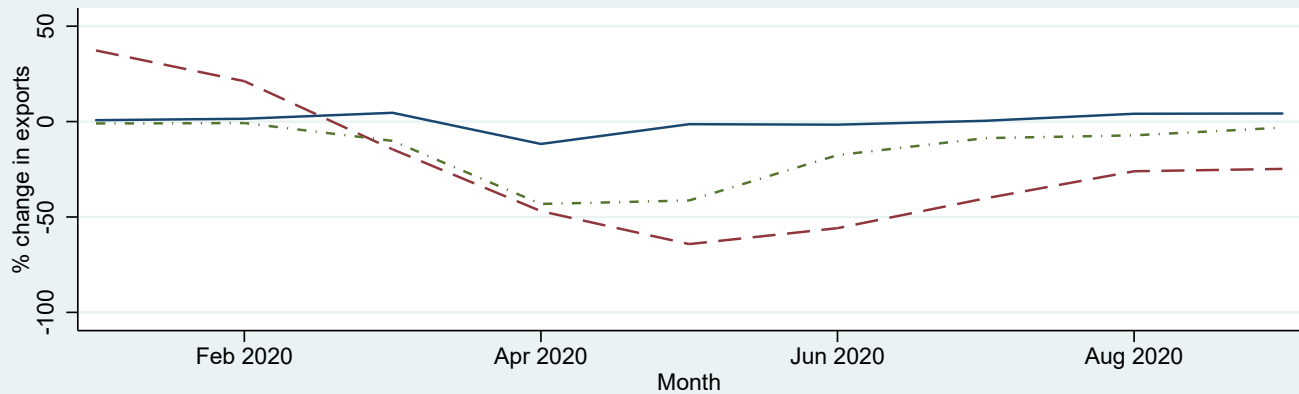
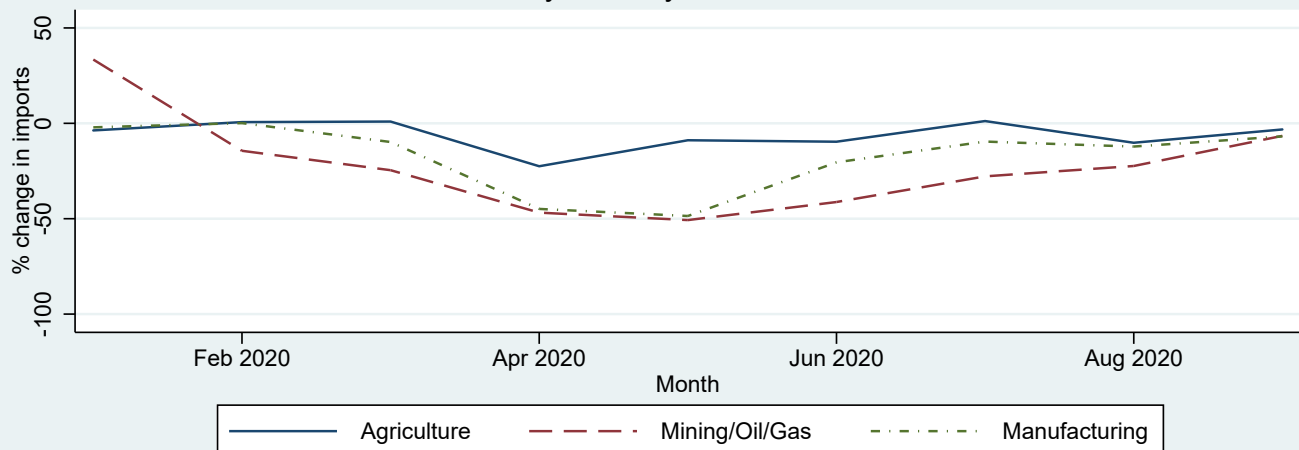


Figure 2: Canadian Bilateral Trade to the United States, by Industry

### Year-over-year percentage change in Canadian exports to the U.S. by industry, 2019-2020

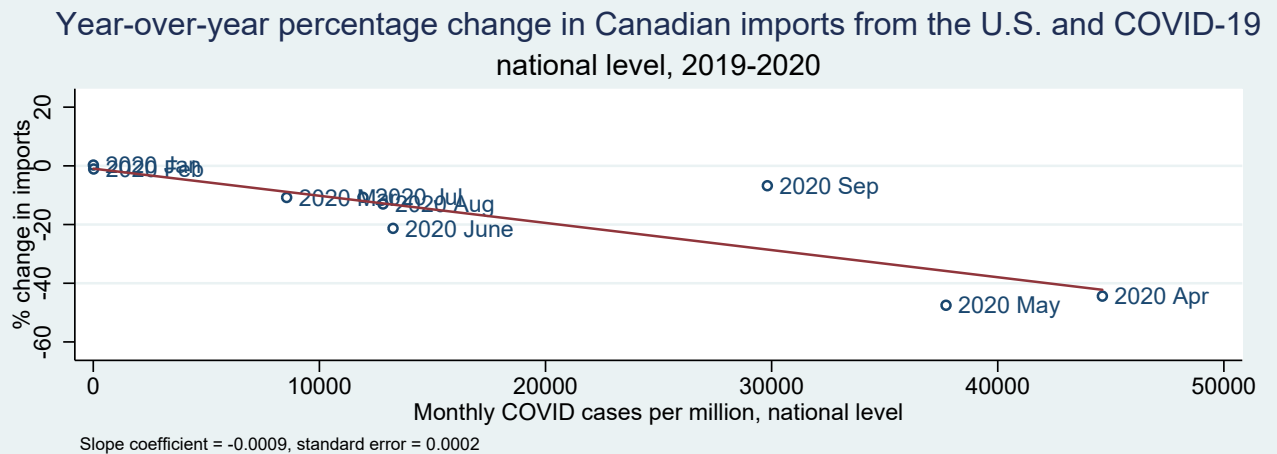
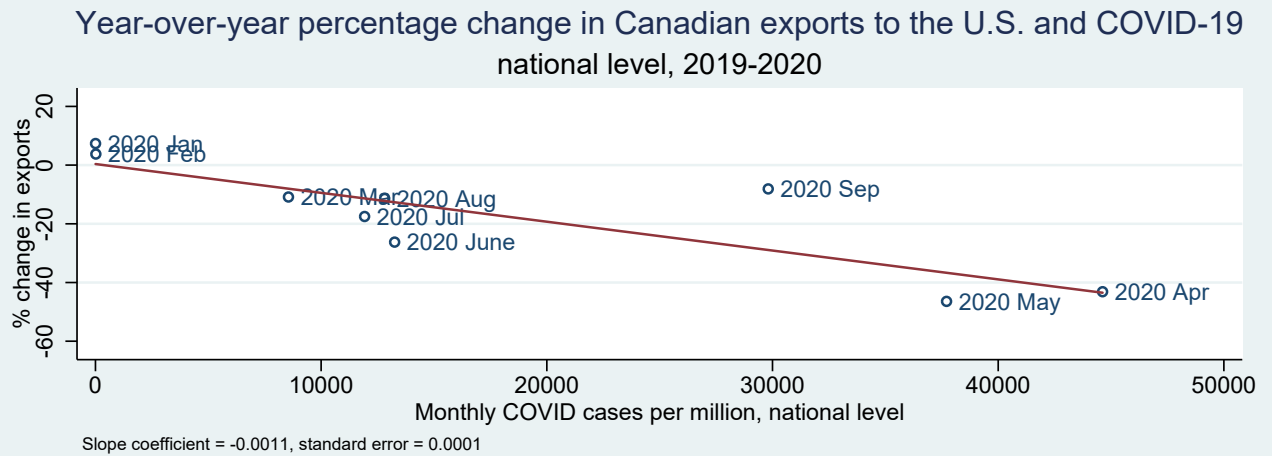


### Year-over-year percentage change in Canadian imports from the U.S. by industry, 2019-2020



**Trade Data Sources:** Statistics Canada and U.S. Census Bureau, Government of Canada's Trade Data Online database.

Figure 3: Canadian Trade vs. Canadian Monthly COVID-19 Cases



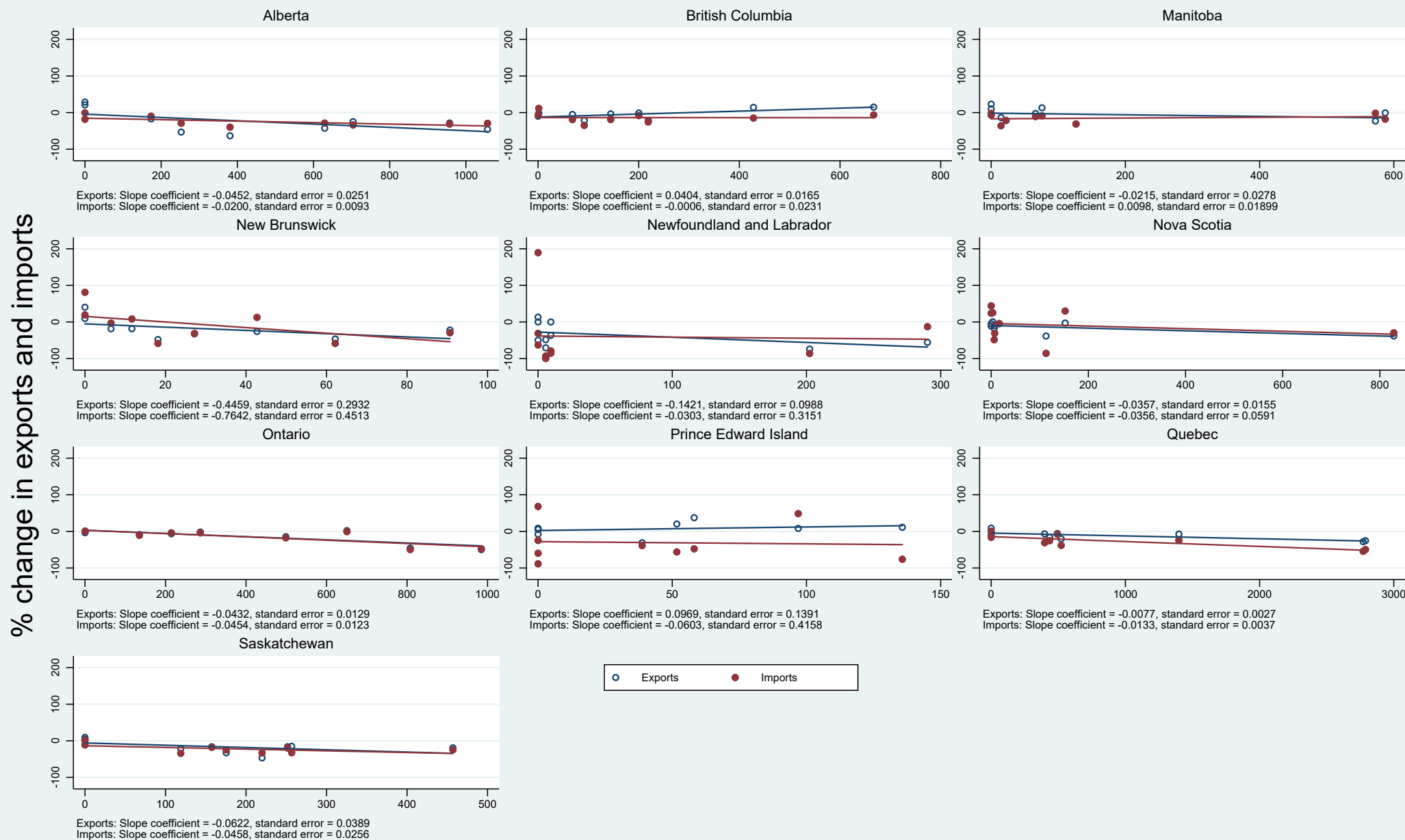
The rightmost observations in both graphs represent Quebec for April and May 2020.

**Trade Data Sources:** Statistics Canada and U.S. Census Bureau, Government of Canada's Trade Data Online database.  
**COVID-19 Data Sources:** ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the U.S.

Figure 4: Canadian Trade to the United States and COVID-19 Cases, by Province

# Year-over-year percentage changes in Canadian trade with the U.S. and COVID-19

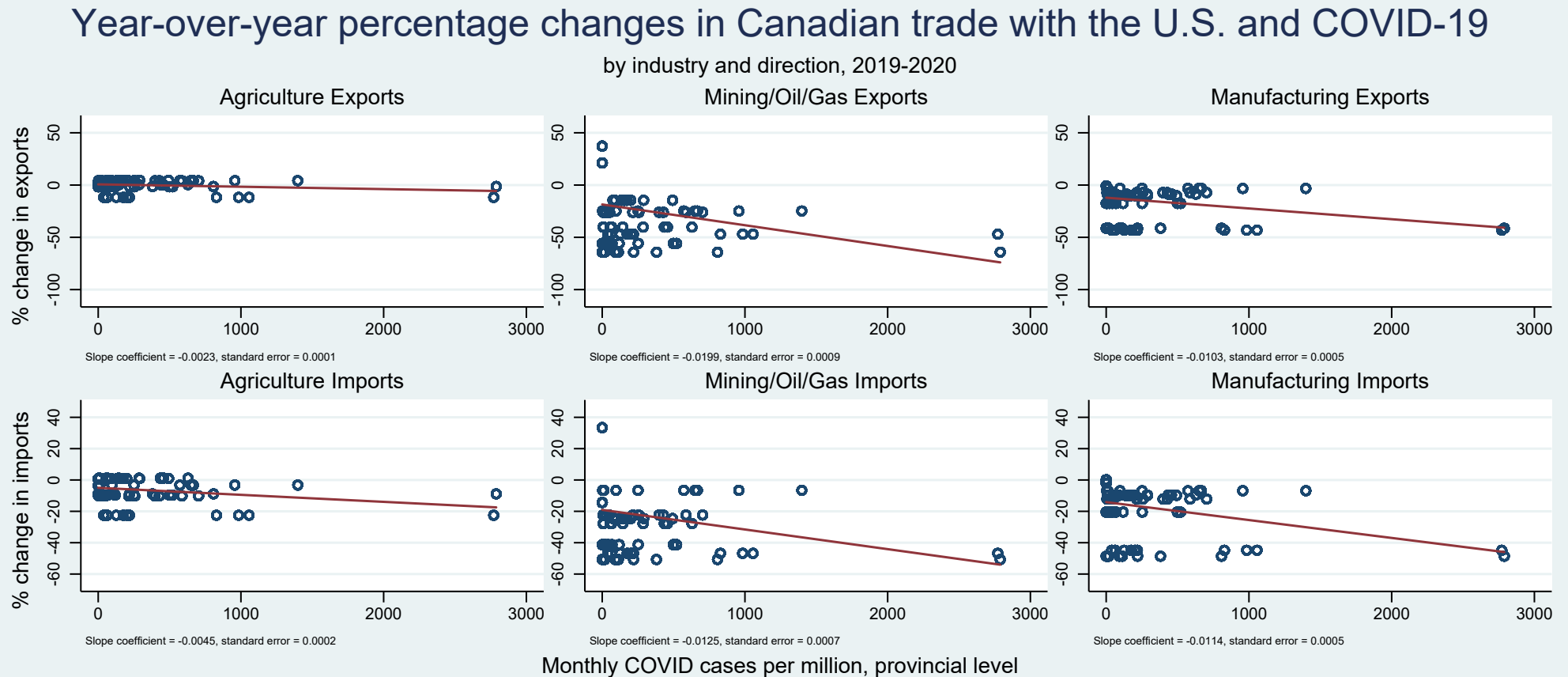
by province and direction, 2019-2020



Monthly COVID cases per million

**Trade Data Sources:** Statistics Canada and U.S. Census Bureau, Government of Canada's Trade Data Online database.  
**COVID-19 Cases Data Sources:** ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the U.S.

Figure 5: Canadian Trade and Monthly COVID-19 Cases, by Industry



The rightmost observations in the graphs represent Quebec for April and May 2020. Each point represents a different province in a given month, between January 2020 and September 2020.

**Trade Data Sources:** Statistics Canada and U.S. Census Bureau, Government of Canada's Trade Data Online database.

**COVID-19 Cases Data Sources:** ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the U.S.

Figure 6: Canadian Lockdown Stringency

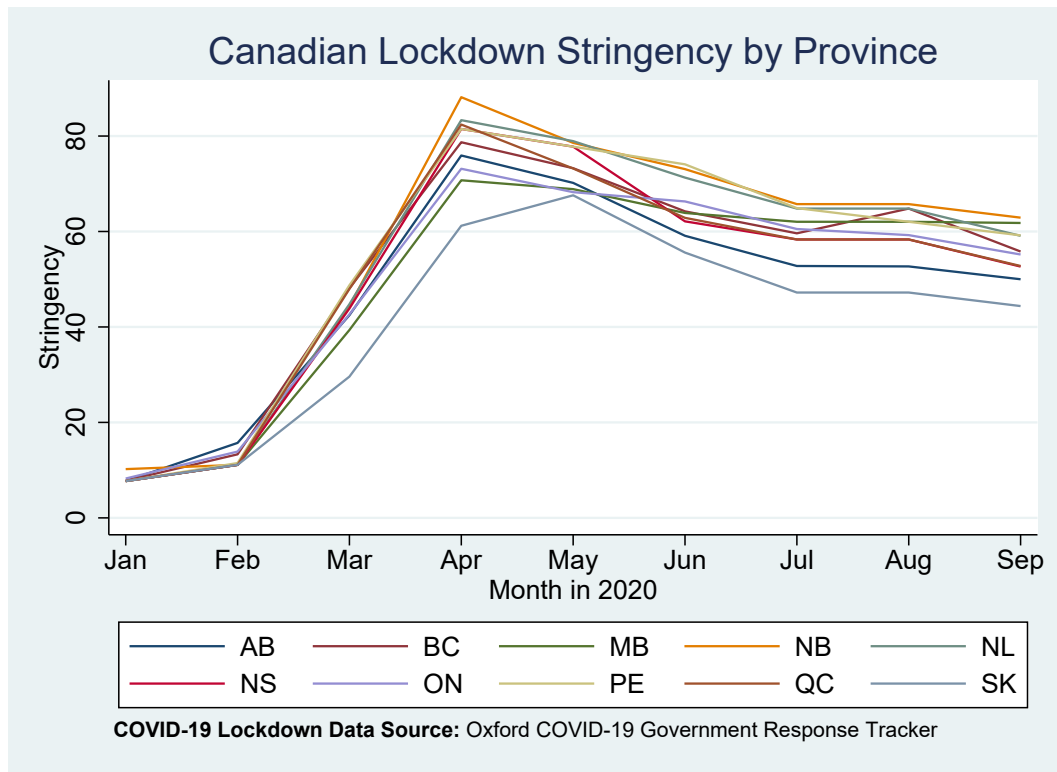
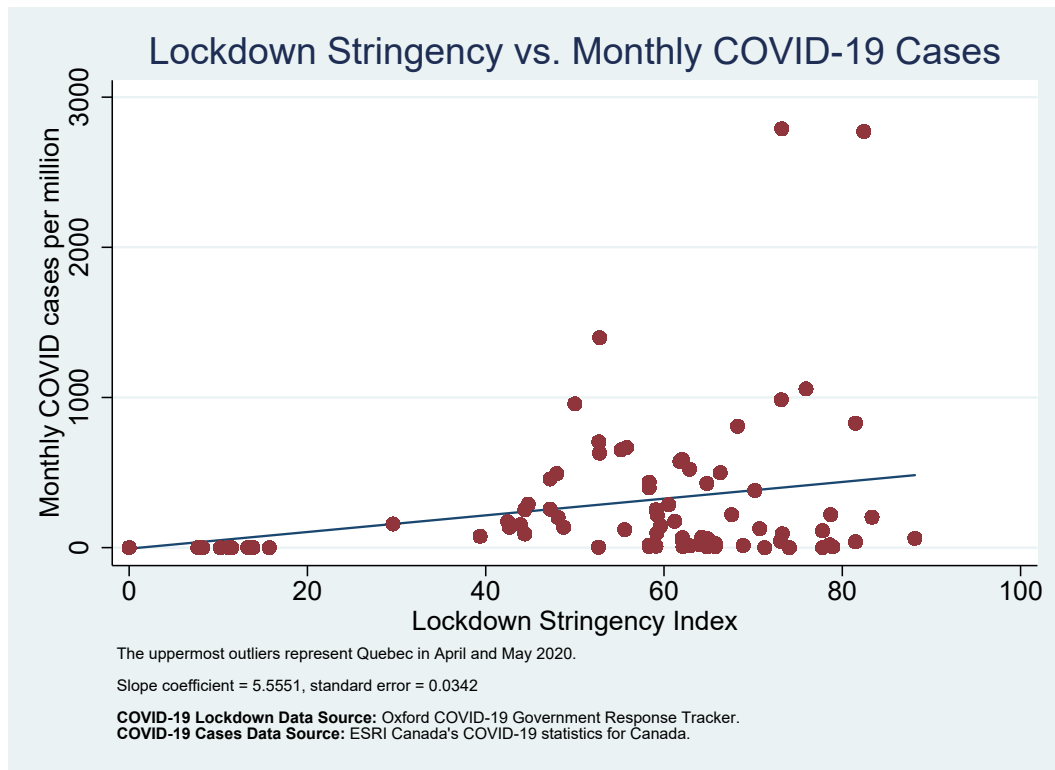




Figure 7: Canadian Lockdown Stringency vs COVID-19 Cases



## Tables

Table 1: Summary Statistics: COVID-19 Statistics  
(per Million)

Variable	Mean	Std. Dev.	Min	Max	Obs
Cases, province	263.95	476.36	0	2789.06	27,540
Deaths, province	12.31	43.39	0	329.88	27,540
Hospitalizations, province	10.15	27.9	0	194.5	27,540
Lockdown, province	50.45	24.09	7.71	88.15	27,540
Cases, state	2223.53	2620.43	0	14755.39	27,540
Deaths, state	56.96	98.39	0	934.05	27,540
Hospitalizations, state	71.92	100.27	0	812.77	27,540
Lockdown, state	49.66	26.81	0	92.93	27,540

Notes: This table contains the summary statistics for the COVID-19 health and lockdown measures across the 10 Canadian provinces and 50 U.S. state (plus D.C.) from Jan-Sept 2020. COVID-19 Cases Data Sources: ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the United States. COVID-19 Lockdown Data Source: Oxford COVID-19 Government Response Tracker.

Table 2: Correlations: COVID-19 Statistics  
(per Million)

	Lockdown	Cases	Avg. Hosp.	Deaths
Lockdown	1			
Cases	0.49	1		
Avg. Hosp.	0.37	0.86	1	
Deaths	0.31	0.84	0.98	1

Notes: COVID-19 Cases Data Sources: ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the United States. COVID-19 Lockdown Data Source: Oxford COVID-19 Government Response Tracker.

Table 3: Summary Statistics by Month

	Lockdown Stringency			Cases (per Million)			Deaths (per Million)		
	Mean	Std Dev	CoV	Mean	Std Dev	CoV	Mean	Std Dev	CoV
January	8.02	0.75	0.09	0.04	0.08	2.00	0	0	N/A
February	12.11	1.55	0.13	0.21	0.43	2.07	0	0	N/A
March	43.20	5.32	0.12	190.44	115.70	0.61	1.72	1.53	0.89
April	77.66	7.33	0.09	646.60	801.14	1.24	36.50	63.61	1.74
May	73.44	4.32	0.06	444.11	817.11	1.84	47.30	97.25	2.06
June	65.25	5.71	0.09	153.16	192.78	1.26	14.23	30.41	2.14
July	59.43	5.50	0.09	210.07	215.54	1.03	4.73	6.08	1.28
August	59.53	5.55	0.09	269.03	239.70	0.89	3.58	3.66	1.02
September	55.38	5.39	0.10	461.91	448.21	0.97	2.74	3.11	1.13

Notes: This table contains the mean and standard deviation values, as well as the coefficient of variation, for the Lockdown Stringency index, Cases and Deaths per million inhabitants across the 10 Canadian provinces during each month of 2020. COVID-19 Cases Data Sources: ESRI Canada's COVID-19 statistics for Canada and the COVID Tracking Project for the United States. COVID-19 Lockdown Data Source: Oxford COVID-19 Government Response Tracker.

Table 4: OLS Estimates of Year-over-Year Export Growth Regressions  
All Observations

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-0.000103* (5.64e-05)				-8.11e-05 (6.21e-05)		
Cases, state	-8.85e-06 (1.23e-05)				-4.98e-06 (1.33e-05)		
Deaths, province		-0.000712* (0.000414)				-0.000664 (0.000439)	
Deaths, state		-0.000725*** (0.000268)				-0.000688** (0.000299)	
Hospitalizations, province			-0.00136* (0.000720)				-0.00129* (0.000779)
Hospitalizations, state			-0.000625** (0.000301)				-0.000601* (0.000335)
Lockdown, province				-0.00155 (0.00533)	-0.00101 (0.00540)	-0.000367 (0.00537)	-0.000496 (0.00538)
Lockdown, state				-0.000251 (0.00484)	2.45e-06 (0.00485)	2.27e-05 (0.00487)	0.000261 (0.00485)
Constant	0.0219 (0.0295)	0.0251* (0.0148)	0.0337 (0.0210)	0.0656 (0.0621)	0.0586 (0.0629)	0.0398 (0.0645)	0.0434 (0.0643)
Observations	13,770	13,770	13,770	13,770	13,770	13,770	13,770
Adjusted $R^2$	0.0719	0.0723	0.0722	0.0719	0.0718	0.0721	0.0721

Notes: The table contains estimates of versions of equation (2) for export trade flows between Canadian provinces and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table 5: OLS Estimates of Year-over-Year Import Growth Regressions  
All Observations

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-0.000154** (7.53e-05)				1.91e-05 (8.43e-05)		
Cases, state	-5.93e-06 (1.30e-05)				2.56e-05* (1.37e-05)		
Deaths, province		-0.00155* (0.000842)				-0.000751 (0.000862)	
Deaths, state		-0.000866** (0.000362)				-0.000197 (0.000400)	
Hospitalizations, province			-0.00326** (0.00134)				-0.00134 (0.00142)
Hospitalizations, state			-0.000513 (0.000346)				0.000296 (0.000381)
Lockdown, province				-0.00218 (0.00535)	-0.00264 (0.00530)	-0.00140 (0.00536)	-0.00185 (0.00533)
Lockdown, state				-0.00414 (0.00490)	-0.00497 (0.00494)	-0.00423 (0.00489)	-0.00452 (0.00492)
Constant	-0.118*** (0.0330)	-0.103*** (0.0206)	-0.102*** (0.0261)	0.144** (0.0637)	0.147** (0.0635)	0.129** (0.0648)	0.139** (0.0639)
Observations	13,770	13,770	13,770	13,770	13,770	13,770	13,770
Adjusted $R^2$	0.0997	0.101	0.100	0.102	0.102	0.102	0.102

Notes: The table contains estimates of versions of equation (2) for import trade flows between Canadian provinces and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table 6: OLS Estimates of Year-over-Year Export and Import Growth  
NAICS-11: Agriculture

VARIABLES	Year-over-year Export Growth				Year-over-year Import Growth			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cases, province	5.18e-05 (4.63e-05)				-0.000123 (0.000103)			
Cases, state	4.23e-06 (9.07e-06)				6.50e-06 (1.98e-05)			
Deaths, province		0.000843* (0.000500)				-0.000912 (0.00104)		
Deaths, state		-0.000143 (0.000201)				-0.000860* (0.000510)		
Hospitalizations, province			0.00124 (0.000768)				-0.00203 (0.00168)	
Hospitalizations, state			-0.000126 (0.000217)				-0.000503 (0.000540)	
Lockdown, province				-0.00187 (0.00370)				-0.00649 (0.00874)
Lockdown, state				0.00176 (0.00324)				0.00101 (0.00727)
Constant	0.00544 (0.0230)	0.0275** (0.0124)	0.0249 (0.0160)	0.0367 (0.0493)	-0.0645 (0.0532)	-0.0277 (0.0282)	-0.0273 (0.0388)	0.180 (0.114)
Observations	3,019	3,019	3,019	3,019	2,323	2,323	2,323	2,323
Adjusted $R^2$	0.183	0.184	0.184	0.183	0.256	0.257	0.257	0.259

Notes: The table contains estimates of versions of equation (2) for export and import flows between Canadian provinces and U.S. states between January 2020 and September 2020, for all non-zero observations. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table 7: OLS Estimates of Year-over-Year Export and Import Growth  
NAICS-21: Mining, Oil and Gas

VARIABLES	Year-over-year Export Growth				Year-over-year Import Growth			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cases, province	-9.14e-05*				-2.13e-05			
	(4.79e-05)				(0.000139)			
Cases, state	-3.18e-05**				-2.60e-05			
	(1.37e-05)				(2.35e-05)			
Deaths, province		-0.000570				-0.000608		
		(0.000548)				(0.00131)		
Deaths, state		-0.000886***				-0.000597		
		(0.000341)				(0.000839)		
Hospitalizations, province			-0.00112				-0.00163	
			(0.000967)				(0.00210)	
Hospitalizations, state			-0.00101***				-0.000419	
			(0.000388)				(0.000733)	
Lockdown, province				-0.00751				-0.0136
				(0.00548)				(0.0118)
Lockdown, state				0.00228				0.0102
				(0.00480)				(0.0106)
Constant	0.0999***	0.0578***	0.0870***	0.252***	0.0635	0.0412	0.0515	0.167
	(0.0373)	(0.0207)	(0.0310)	(0.0756)	(0.0662)	(0.0455)	(0.0530)	(0.149)
Observations	2,278	2,278	2,278	2,278	1,918	1,918	1,918	1,918
Adjusted R <sup>2</sup>	0.186	0.185	0.187	0.188	0.168	0.168	0.168	0.168

Notes: The table contains estimates of versions of equation (2) for export and import flows between Canadian provinces and U.S. states between January 2020 and September 2020, for all non-zero observations. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table 8: OLS Estimates of Year-over-Year Export and Import Growth  
NAICS-31: Manufacturing

VARIABLES	Year-over-year Export Growth				Year-over-year Import Growth			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cases, province	-0.000109*** (2.70e-05)				-0.000258*** (4.52e-05)			
Cases, state	1.54e-08 (5.84e-06)				-2.87e-06 (7.86e-06)			
Deaths, province		-0.00110*** (0.000295)				-0.00234*** (0.000651)		
Deaths, state		-0.000406** (0.000163)				-0.000899*** (0.000256)		
Hospitalizations, province			-0.00225*** (0.000436)				-0.00439*** (0.000969)	
Hospitalizations, state			-0.000245* (0.000145)				-0.000634** (0.000253)	
Lockdown, province				-0.00269 (0.00343)				-0.00648 (0.00427)
Lockdown, state				-0.000995 (0.00308)				0.000377 (0.00372)
Constant	-0.0747*** (0.0127)	-0.0670*** (0.00898)	-0.0630*** (0.0101)	0.0796** (0.0380)	-0.113*** (0.0173)	-0.112*** (0.0154)	-0.0985*** (0.0187)	0.104* (0.0535)
Observations	4,253	4,253	4,253	4,253	3,598	3,598	3,598	3,598
Adjusted R <sup>2</sup>	0.176	0.178	0.178	0.183	0.122	0.127	0.126	0.127

Notes: The table contains estimates of versions of equation (2) for export and import flows between Canadian provinces and U.S. states between January 2020 and September 2020, for all non-zero observations. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%



## A Appendix

Figure A.1: U.S. Lockdown Stringency

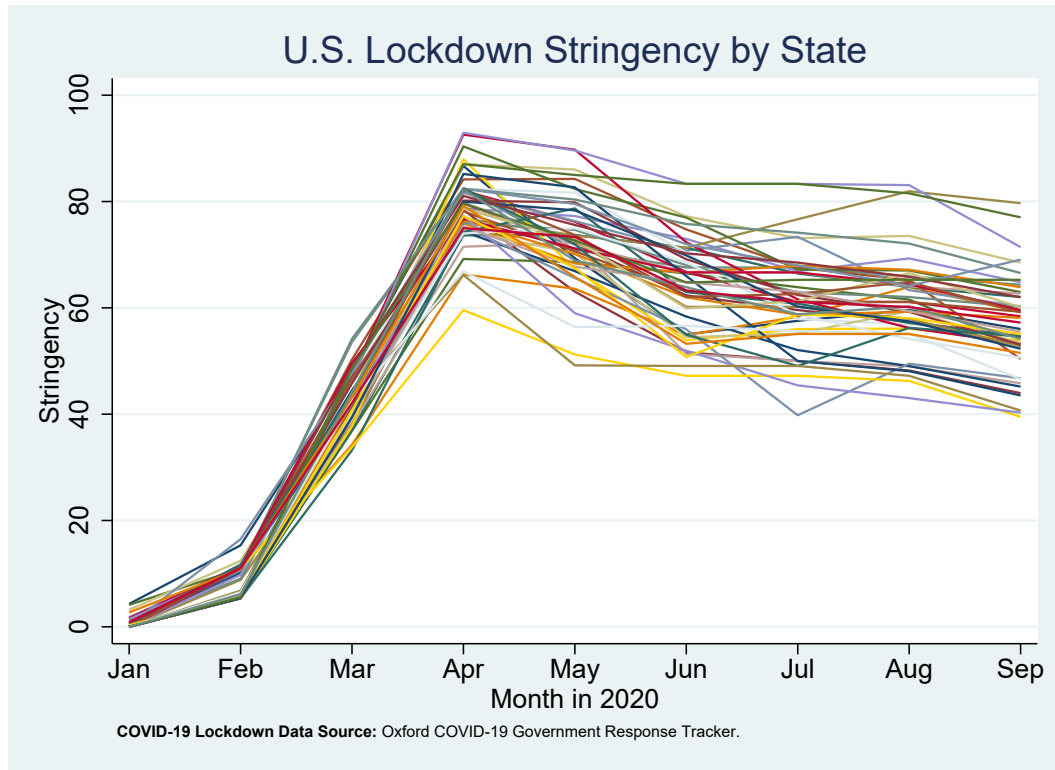


Figure A.2: Canadian Monthly COVID-19 Cases, by province

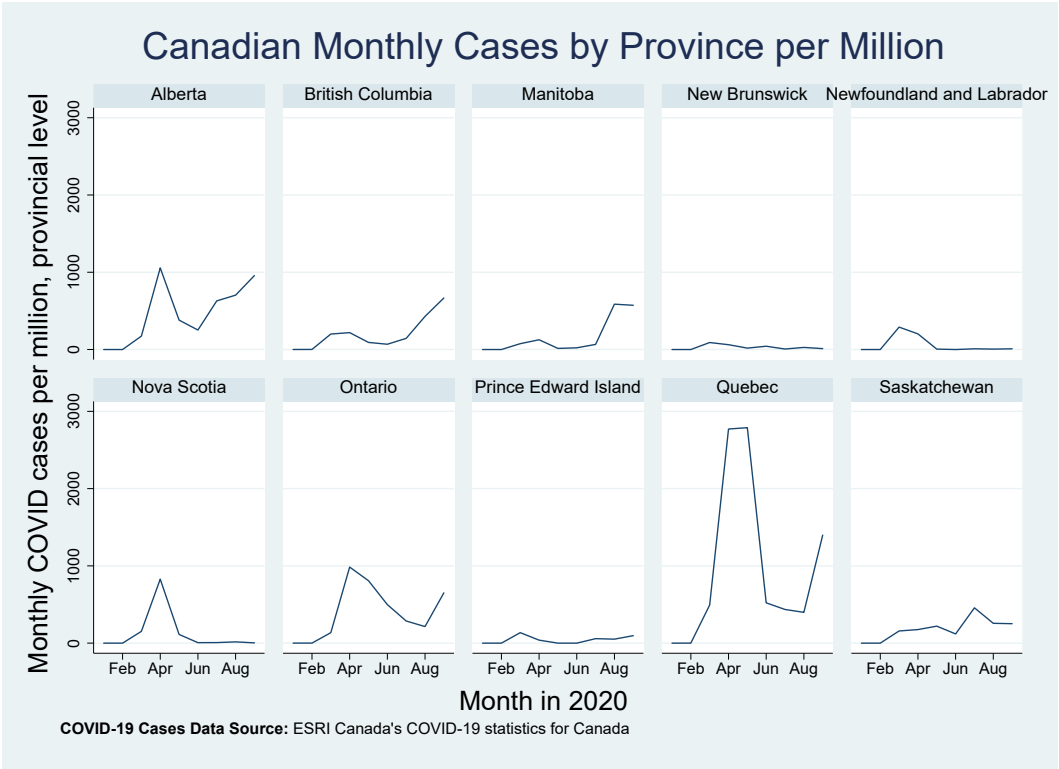


Table A.1: Year-over-Year Growth: Canadian Trade vs. GDP

Month	Canadian Exports	Canadian Imports	Canadian GDP
January	7.3%	.26%	1.9%
February	3.8%	-1.1%	2.4%
March	-10.9%	-10.8%	-5.5%
April	-43.14%	-44.4%	-16.7%
May	-46.43%	-47.5%	-13.2%
June	-26.23%	-21.3%	-8%
July	-17.51%	-10.7%	-5.8%
August	-11.36%	-13.1%	-4.9%
September	-8.10%	-6.8%	-4.2%

Notes: Canadian trade data from Government of Canada's Trade Data Online database. Canadian GDP data from Statistics Canada, Table 36-10-0434-02.

Table A.2: OLS Estimates of Year-over-Year Export Growth Regressions  
Including Time Dummies

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-7.05e-05 (6.53e-05)				-7.48e-05 (6.57e-05)		
Cases, state	-1.61e-05 (1.49e-05)				-1.56e-05 (1.49e-05)		
Deaths, province		-0.000417 (0.000520)				-0.000442 (0.000520)	
Deaths, state		-0.000658** (0.000316)				-0.000681** (0.000320)	
Hospitalizations, province			-0.000759 (0.000907)				-0.000680 (0.000899)
Hospitalizations, state			-0.000687** (0.000347)				-0.000703** (0.000350)
Lockdown, province				0.0127 (0.00793)	0.0130 (0.00797)	0.0128 (0.00795)	0.0125 (0.00791)
Lockdown, state				0.00485 (0.00635)	0.00459 (0.00638)	0.00553 (0.00639)	0.00537 (0.00636)
Constant	-0.0359 (0.0766)	-0.0359 (0.0766)	-0.0359 (0.0767)	-0.141 (0.106)	-0.143 (0.106)	-0.142 (0.106)	-0.140 (0.106)
Observations	13,770	13,770	13,770	13,770	13,770	13,770	13,770
Time Dummies	Y	Y	Y	Y	Y	Y	Y
Adjusted R <sup>2</sup>	0.0725	0.0727	0.0727	0.0726	0.0726	0.0728	0.0728

Notes: The table contains estimates of versions of equation (2) for export trade flows between Canadian provinces and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table A.3: OLS Estimates of Year-over-Year Import Growth Regressions  
Including Time Dummies

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	3.19e-05 (8.92e-05)				3.09e-05 (8.95e-05)		
Cases, state	7.26e-06 (1.69e-05)				6.37e-06 (1.70e-05)		
Deaths, province		0.000457 (0.000920)				0.000452 (0.000921)	
Deaths, state		5.22e-06 (0.000419)				3.45e-05 (0.000418)	
Hospitalizations, province			0.000693 (0.00153)				0.000713 (0.00153)
Hospitalizations, state			0.000270 (0.000413)				0.000293 (0.000414)
Lockdown, province				0.00292 (0.00954)	0.00281 (0.00956)	0.00282 (0.00954)	0.00309 (0.00955)
Lockdown, state				-0.00726 (0.00664)	-0.00715 (0.00665)	-0.00729 (0.00663)	-0.00747 (0.00665)
Constant	0.0927 (0.0814)	0.0927 (0.0814)	0.0927 (0.0814)	0.0739 (0.109)	0.0747 (0.109)	0.0747 (0.109)	0.0727 (0.109)
Observations	13,770	13,770	13,770	13,770	13,770	13,770	13,770
Time Dummies	Y	Y	Y	Y	Y	Y	Y
Adjusted $R^2$	0.104	0.104	0.104	0.104	0.104	0.104	0.104

Notes: The table contains estimates of versions of equation (2) for import trade flows between Canadian provinces and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table A.4: OLS Estimates of Year-over-Year Export Growth Regressions  
Excluding Quebec

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-0.000183 (0.000138)				-0.000150 (0.000153)		
Cases, state	-8.49e-06 (1.39e-05)				-5.11e-06 (1.47e-05)		
Deaths, province		-0.00413** (0.00182)				-0.00420** (0.00198)	
Deaths, state		-0.000696** (0.000297)				-0.000708** (0.000328)	
Hospitalizations, province			-0.00506** (0.00230)				-0.00525** (0.00250)
Hospitalizations, state			-0.000558* (0.000333)				-0.000578 (0.000368)
Lockdown, province				-0.00169 (0.00567)	-0.00170 (0.00568)	-0.000681 (0.00564)	-0.00100 (0.00566)
Lockdown, state				-0.000127 (0.00513)	0.000682 (0.00517)	0.000725 (0.00517)	0.00107 (0.00515)
Constant	0.0100 (0.0343)	0.0182 (0.0172)	0.0238 (0.0236)	0.0492 (0.0666)	0.0481 (0.0663)	0.0176 (0.0683)	0.0234 (0.0680)
Observations	12,393	12,393	12,393	12,393	12,393	12,393	12,393
Adjusted $R^2$	0.0716	0.0722	0.0720	0.0715	0.0715	0.0720	0.0718

Notes: The table contains estimates of versions of equation (2) for export trade flows between Canadian provinces (excluding Quebec) and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table A.5: OLS Estimates of Year-over-Year Import Growth Regressions  
Excluding Quebec

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-0.000107 (0.000130)				0.000251* (0.000147)		
Cases, state	-1.67e-06 (1.34e-05)				3.11e-05** (1.41e-05)		
Deaths, province		-0.00400** (0.00172)				-0.000509 (0.00181)	
Deaths, state		-0.000805** (0.000395)				-0.000160 (0.000434)	
Hospitalizations, province			-0.00721*** (0.00224)				-0.00120 (0.00240)
Hospitalizations, state			-0.000416 (0.000368)				0.000378 (0.000408)
Lockdown, province				-3.63e-05 (0.00551)	-0.000495 (0.00548)	0.000154 (0.00551)	-0.000365 (0.00549)
Lockdown, state				-0.00595 (0.00508)	-0.00789 (0.00515)	-0.00580 (0.00511)	-0.00613 (0.00516)
Constant	-0.161*** (0.0350)	-0.118*** (0.0212)	-0.117*** (0.0267)	0.113* (0.0662)	0.117* (0.0660)	0.108 (0.0682)	0.118* (0.0672)
Observations	12,393	12,393	12,393	12,393	12,393	12,393	12,393
Adjusted $R^2$	0.0901	0.0911	0.0909	0.0930	0.0937	0.0928	0.0929

Notes: The table contains estimates of versions of equation (2) for import trade flows between Canadian provinces (excluding Quebec) and U.S. states between January 2020 and September 2020. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state.\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table A.6: OLS Estimates of Year-over-Year Export Growth Regressions  
Non-Zero Observations

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-5.29e-05** (2.36e-05)				1.63e-05 (2.69e-05)		
Cases, state	-6.15e-06 (5.08e-06)				5.50e-06 (5.35e-06)		
Deaths, province		-0.000337 (0.000255)				3.16e-05 (0.000268)	
Deaths, state		-0.000417*** (0.000132)				-0.000166 (0.000132)	
Hospitalizations, province			-0.000813* (0.000419)				-5.79e-05 (0.000455)
Hospitalizations, state			-0.000380*** (0.000137)				-9.74e-05 (0.000141)
Lockdown, province				-0.00377 (0.00234)	-0.00405* (0.00238)	-0.00357 (0.00239)	-0.00360 (0.00240)
Lockdown, state				0.000832 (0.00208)	0.000698 (0.00209)	0.000911 (0.00208)	0.000876 (0.00208)
Constant	-0.00758 (0.0130)	-0.00813 (0.00784)	-3.37e-05 (0.0103)	0.108*** (0.0292)	0.111*** (0.0298)	0.103*** (0.0302)	0.105*** (0.0303)
Observations	9,550	9,550	9,550	9,550	9,550	9,550	9,550
Adjusted $R^2$	0.185	0.186	0.186	0.188	0.188	0.188	0.188

Notes: The table contains estimates of versions of equation (2) for export trade flows between Canadian provinces and U.S. states between January 2020 and September 2020, for all non-zero observations. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%



Table A.7: OLS Estimates of Year-over-Year Import Growth Regressions  
Non-Zero Observations

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cases, province	-0.000155*** (5.50e-05)				-4.70e-05 (5.88e-05)		
Cases, state	-5.52e-06 (9.32e-06)				1.15e-05 (1.00e-05)		
Deaths, province		-0.00141** (0.000574)				-0.000916 (0.000574)	
Deaths, state		-0.000815*** (0.000277)				-0.000478 (0.000293)	
Hospitalizations, province			-0.00288*** (0.000914)				-0.00180* (0.000939)
Hospitalizations, state			-0.000544** (0.000269)				-0.000158 (0.000293)
Lockdown, province				-0.00788* (0.00424)	-0.00760* (0.00418)	-0.00611 (0.00419)	-0.00630 (0.00420)
Lockdown, state				0.00262 (0.00364)	0.00226 (0.00364)	0.00237 (0.00360)	0.00233 (0.00362)
Constant	-0.0550** (0.0240)	-0.0493*** (0.0160)	-0.0406** (0.0198)	0.141** (0.0547)	0.135** (0.0541)	0.109** (0.0544)	0.114** (0.0547)
Observations	7,839	7,839	7,839	7,839	7,839	7,839	7,839
Adjusted $R^2$	0.195	0.197	0.197	0.198	0.198	0.199	0.198

Notes: The table contains estimates of versions of equation (2) for import trade flows between Canadian provinces and U.S. states between January 2020 and September 2020, for all non-zero observations. Cases, Deaths and Hospitalizations are per-million population. Includes province-state-industry fixed effects. Robust standard errors clustered by province-state. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%