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L'IMPACT DES PERTURBATIONS DES CHAÎNES DE VALEUR MONDIALES SUR L'ACTIVITÉ ÉCONOMIQUE ET L'INFLATION : LE CAS DU CANADA

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RÉSUMÉ

Nous menons une évaluation approfondie de l'impact de la chaîne de valeur mondiale sur l'activité économique du Canada. Notre étude examine la dépendance de 32 secteurs industriels canadiens aux chaînes d'approvisionnement mondiales et analyse l'évolution de la production et de l'inflation au Canada de 1998 à 2022. En combinant les perturbations des chaînes d'approvisionnement mondiales et l'exposition des industries aux goulets d'étranglement étrangers, nous utilisons le modèle "Two-Way fixed effects" pour analyser l'impact des activités liées à la chaîne de valeur mondiale sur les taux de croissance du PIB et l'inflation des prix à la production au Canada au niveau de l'industrie, en tenant compte à la fois des industries manufacturières et non manufacturières. Nos principales conclusions indiquent que les secteurs industriels candiennes dependent massivement des chaines dapprovisionememnt mondiales ce qui la rend vulnérable aux perturbations qui affectent ces derniers, contrairment a à la Chine et aux États-Unis. De plus, notre analyse met en évidence l'importance à la fois des facteurs de demande et des facteurs d'offre en tant que déterminants des goulets d'étranglement de l'approvisionnement. Pendant la pandémie, les perturbations des chaînes d'approvisionnement est associée à une baisse du taux de croissance du PIB et à une augmentation de l'inflation, principalement en raison des facteurs d'offre dominants. Alors qu'avant la pandémie, nous observons une corrélation positive entre la pression de la chaîne de valeur mondiale, l'inflation et l'activité économique, lorsque le rôle des facteurs de demande est plus prononcé.

Mots-clés : Perturbations des chaînes d'approvisionnement mondiales, Croissance du PIB, Inflation des PPI, Industries manufacturières canadiennes, Chaîne de valeur mondiale, Analyse au niveau de l'industrie

ABSTRACT

We conduct a comprehensive assessment of the global value chain's impact on Canada's economic activity. Our study examines the reliance of 32 industries in Canada on global supply chains and investigates the evolution of Canada's output and inflation from 1998 to 2022. By combining global supply chain disruptions and industries' exposure to foreign bottlenecks, we employ the Two-way fixed effects model to analyze the impact of GVC-related activities on GDP growth rates and Producer Price Index (PPI) inflation in Canada at the industry level, considering both manufacturing and non-manufacturing industries.One of our key findings suggests that Canadian industrial sectors are more dependent on global supply chains compared to China and the United States, making them vulnerable to supply chain disruptions. Moreover, our analysis highlights the significance of both demand and supply factors as determinants of supply bottlenecks. During the pandemic, global supply chain pressure led to a decline in GDP growth and an increase in inflation driven by dominant supply factors. Before the pandemic, we observed a positive correlation between the global value chain pressure with both inflation and economic activity when the demand factor plays a more significant role.

Keywords: Global supply chain disruption, GDP growth, PPI inflation, Canadian manufacturing industries, Global value chain, Industry-level analysis.

INTRODUCTION

While international trade has been present for centuries, the past three decades have witnessed a significant increase in the complexity of the production process, resulting in the growth of global value chains (GVCs). Finished goods now incorporate value added from multiple countries, with value-added activities crossing borders before reaching consumers. This arrangement, known as global value chains (GVCs), has played a crucial role in boosting output, income, and job opportunities (Antràs et Chor, 2021). The expansion of GVCs has been remarkable, accounting for 52% of global trade since 2008, leading to the label "Age of Global Value Chains" (World Bank, 2020). However, there have been two turning points in the growth of GVCs. The first was a decrease following the 2008 financial crisis (World Bank, 2020). The second was the COVID-19 pandemic, which caused substantial disruptions to global supply chains, resulting in lockdowns, factory closures, and job losses (Freeman et Baldwin, 2020).

It is important to note that all countries participate in GVCs in various ways, with East Asia, North America, and Western Europe housing innovative and advanced manufacturing and service industries. In contrast, many countries in South America, Central Asia, and Africa focus on producing less complex goods (World Bank, 2020). Moreover, the exposure to bottlenecks varies across industry sectors (OECD Statistics, 2021).

This thesis aims at measuring the dependence on global value chains for several Canadian industries and quantifying the impact of supply chain disruptions on Canada's economy at the industry level. In particular, we will explore the role of GVCs in economic activity (measured as GDP growth). We will also study separately two types of industries: manufacturing and non-manufacturing industries. Moreover, we will consider the exposure to bottlenecks of different industries from the perspective of the share of foreign value added and use a new measure of supply chain disruption- the global supply chain pressure Index (GSCPI). Specifically, we aim to answer two key questions: how dependent are Canadian industries on GVCs and global supply chains (GSCs), and to what degree did the impact of supply chain disruptions influence the fluctuations in PPI inflation and GDP over the 1998-2022 period?

Canada's manufacturing and service industries exhibit differences in their exposure to foreign value, which are related to supply shocks over the past 20 years. Our finding shows that the volatility of the exposure to foreign trade in Canada's manufacturing industry is higher than that of non-manufacturing industries. The figures of Chapter 2 also presents that Canada's exposure to Global

value chains is higher than that of the US and China. As a small and open economy with advanced industries and technologies, this characteristic increases the risk of disruptions in the global supply chain while reducing the risk of domestic supply chain disruption compared to the other two countries.

One innovation in this study is to use industry-level panel data for Canada. This allows me to use the two-way fixed-effect (TWFE) model and employs the time-fixed effect and industry-fixed effect. Furthermore, the data for this study is a combination of exposure data from the OECD dataset (OECD Statistics, 2021) and global supply chain pressure data from the Federal Reserve Bank of New York (2022). Additionally, data on Canada's economy (output and PPI inflation) serve as the dependent variables (Statistics Canada, 2022b).

The contribution of this study is to analyze the effects of GVC disruptions on Canada's output and inflation using a two-way fixed-effect estimator. After controlling for the industry-fixed effect and time-fixed effect, the study finds a weak negative correlation between Canada's GDP growth rate and the fluctuations of GVCs for the overall sample period. Interestingly, once splitting the sample into pre-pandemic and pandemic subsamples, we find a strong negative correlation between global value chain disruptions and GDP in the pandemic period, and a positive and significant correlation before the pandemic, especially in the manufacturing sector. The study also finds that the PPI inflation of Canada's manufacturing industries is positively correlated with GVC disruptions from 1998-2022. The study's findings are consistent with the idea that GVC disruptions may be influenced by both supply and demand factors. Supply factors could explain the negative correlation between GVC disruptions and GDP and the positive correlation between GVC disruptions and PPI inflation during the pandemic. Demand factors could explain the positive correlation between supply chain disruptions and both GDP and PPI inflation before the pandemic. This also suggests the possibility that the new index computed by the Federal Reserve Bank of New York (2022) may not fully account for demand factors.

The thesis is organized as follows. In Chapter 1, we present the related literature. In Chapter 2, we conduct a comprehensive overview of Canada's Global Value Chains (GVC) and GVC-related economic activities. We categorize Canada's 28 industries into manufacturing and non-manufacturing sectors and assess their reliance on international trade flows from 1998 to 2022. We find that compared to the United States and China, Canada's manufacturing sector exhibits a higher level of reliance on the international supply chain. Furthermore, we introduce a new index created by the Federal Bank of New York (GSCPI) and briefly explain how it reflects the level of pressure on the

international supply chain. In Chapter 3, we employ the two-way fixed effects model to further investigate the relationship between GVC, Global Supply Chain (GSC), and inflation. Our findings indicate that global supply chain pressure leads to an increase in GDP growth rate before the pandemic, and a significant GDP decline during the post-pandemic period. On the other hand, PPI inflation is consistently influenced by supply expenditure imbalances resulting from disruptions in the global supply chain. These chapters provide an extensive analysis of Canada's GVC-related economic activities, explore the interconnections between GVC, GDP, and inflation, and develop deeper into the relationship through the application of the TWFE model, with a particular focus on the impact of global supply chain pressures on the economy.

CHAPTER 1
LITERATURE REVIEW

Global value chains and supply chains play a significant role in economic growth globally and in Canada. The rise of global value chains (GVCs) was a driving force behind the significant increase in international trade since 1990, accounting for nearly half of all trade. By implementing reforms to encourage GVC participation, developing countries can harness the potential of GVCs to drive growth, create better job opportunities, and alleviate poverty. Similarly, industrialized nations must pursue transparent and open policies, while all countries should work towards revitalizing multilateral cooperation (World Bank, 2020). The speed of GVC expansion leveled off after the 2008-09 financial crisis, recovering fast during 2010-2011. However, growth was slow from 2012 to 2017 before reaching a sustained period of growth after 2017 (World Trade Organization, 2019)

Numerous works have investigated GVCs' impact on international trade. Antràs et Chor (2021) review the recent literature on how GVCs shape international trade while evaluating several country- and industry-level datasets. They summarize two 'macro' approaches to estimating GVC, including calculating the share of value added in final goods and gross exports, and point out the limitations of these methods: in bilateral research, such as between industries or country-industry exports, the same value-added can be counted twice. In addition to quantifying the volume and the share of GVC-related trade flows, several types of research show profound interest in positioning countries and industries in global production networks. Borin et Mancini (2015) argue GVC-related trade comprises two types of linkages: forward and backward. Forward linkages involve the production and export of inputs that are subsequently re-exported, while backward linkages involve using imported inputs to produce goods for export. Borin *et al.* (2021) show that GVC participation is linked to both backward and forward linkages. Antràs et Chor (2019) employ "upstreamness" and "downstreamness" to classify the producing stage. The "upstreamness" of a country-industry assesses its proximity to sources of final demand across various production chains. The "downstreamness" considers its average positioning concerning sources of value added.

Researchers also seek micro methods to evaluate GVC-related activities. These studies have played a crucial role in enhancing our understanding of the factors influencing firms' involvement in global value chains (GVCs), particularly in terms of forward participation (exporting) and backward participation (importing). They are also interested in buyer-supplier relations in export and import

activities. Micro-level studies benefit from richer data environments, enabling detailed investigations of mechanisms and greater potential for achieving causal identification. B.Bernard *et al.* (2007) demonstrate that only a small fraction of firms can become exporters because only the most productive firms can overcome the cost of entering export markets. Extensive documentation of empirical evidence regarding exporters has been conducted in both developed economies (B.Bernard et Jensen, 1999) and developing countries (Clerides *et al.*, 1998). However, most firm-level studies are restricted to data from a single country due to challenges in merging administrative datasets from different countries (Antràs et Chor, 2021).

The ongoing COVID-19 pandemic has disrupted GVCs worldwide since its beginning. The stickiness of GVCs is one of the determinants of GVC participation, making them particularly vulnerable to supply chain disruptions (Antràs et Chor, 2021). Previous research has shown that a supplier country affected by COVID-19 experiences a drop in the production of inputs, leading to a decrease in exported inputs and increased costs for importers. This, in turn, reduces the exports of final goods (Hayakawa et Mukunoki, 2021). Industries relying heavily on intermediate inputs from countries experiencing more bottlenecks will be more exposed to foreign supply chain disruptions. This exposure to bottlenecks can cause temporary or permanent inflation (Santacreu et LaBelle, 2022). The highly exposed sectors suffer larger declines in production, employment, imports, and exports. For example, American industry sectors with high China exposure to intermediate goods imports from China contracted significantly and robustly more than other sectors (Meier et Pinto, 2020). GVCs' heterogeneity across industries in cross-country sourcing patterns and their interaction with exogenous cross-country variation in containment policies have also been exploited (Santacreu *et al.*, 2022). Additionally, discussions have taken place regarding the international fragmentation of production, the OECD global trade report shows that the "localized" economy regime would contribute to more and further losses to the recession caused by the pandemic than the "interconnected" regime (OECD, 2021).

In our investigation of the relationships between inflation, output, and global value chains, recent studies have found a positive relationship between increased global supply chain pressure and economic growth. For instance, a study conducted by Chen et Novy (2021) shows that an increase in trade friction leads to a decline in global output and welfare, while the opening of global value chains has a positive effect on economic growth.

As for inflation, the recent inflationary pressures in Canada have also been linked to global supply chain disruptions. Research by Gravelle (2022) shows that supply chain disruptions caused by the

COVID-19 pandemic have contributed to higher input costs for businesses, which have led to upward pressure on consumer prices. Similarly, a study by Kabaca et Tuzcuoglu (2023) finds that supply chain disruptions, oil price, price mark-up, and wage mark-up shocks have contributed to the recent inflationary pressures in Canada.

The development of this thesis is based on the research of di Giovanni *et al.* (2022) and Santacreu et LaBelle (2022) on the global supply chain, further extending and applying their perspectives. di Giovanni argues that supply chain disruptions arise from imbalances between supply and demand, where changes in domestic demand for final goods lead to variations in imports and exports of foreign intermediate and final goods, explaining how changes in global conditions affect each country. Santacreu's research demonstrates the effects of exposure to global supply chain disruptions on the cross-industry Producer Price Index (PPI) in the United States.

Canada's exposure to Global Value Chains (GVCs) has been a subject of increasing research interest in recent years. A notable study by Martin et Mayneris (2022) highlights Canada's significant reliance on the United States for imports, with 77% of Canadian imports directly or indirectly connected to the U.S. Such a high level of import dependency underscores the need for a comprehensive understanding of Canada's position within GVCs and the associated risks and opportunities. Moreover, supply chain logistics vulnerabilities in Canada have garnered attention, especially concerning road and water transportation, which play a crucial role in trade (Jiang et Scarffe, 2021). The COVID-19 pandemic has further accentuated the importance of evaluating Canada's exposure to GVCs, as disruptions in global supply chains have raised questions about adaptability and resilience. The report of Statistics Canada (2022a) demonstrates sensitivity to disruptions in GVCs caused by the COVID-19 pandemic; the ratio of imported intermediate goods from food, energy, and transport industries has declined to a lower extent after the pandemic broke out. In this thesis, we utilize weighted monthly data on global supply chain pressure(GSCPINEW) to further validate the significance of exposure to foreign bottlenecks and demonstrate its impact on PPI inflation at the industry level. By introducing the interaction term between the pandemic dummy and GSCPINEW , we find that inflation is not directly related to the pandemic but is instead driven by supply-demand imbalances.

Furthermore, we investigate the relationship between GDP and weighted monthly global supply chain pressure. Our findings reveal a weak negative correlation between supply chain disruptions and domestic GDP growth. When examining the pre-pandemic and pandemic periods separately, we observe that global supply chain pressure positively impacts GDP growth. However, during the

COVID-19 period, this positive effect is counteracted by the detrimental effects of the pandemic.

CHAPTER 2
GLOBAL VALUE CHAINS AND CANADA'S ECONOMIC ACTIVITY

The COVID-19 pandemic has had a profound impact on international supply chains, leading to disruptions caused by the shutdown of factories and lockdown measures. When compared to the US and China, Canada exhibits a greater degree of dependence on the international supply chain compared to China and the United States, making it more susceptible to supply chain disruptions. Canadian Industries highly involved in the global supply chain, like manufacturing, are proved more vulnerable due to their reliance on international markets for materials and sales. Conversely, non-manufacturing sectors, including retail, real estate, and some service industries, have a higher proportion of domestic value-added and experience comparatively less impact. To measure this, we employ the Global Supply Chain Pressure Index (GSCPI) to assess the effect of supply chain bottlenecks on Canada's GDP and inflation (Federal Reserve Bank of New York, 2022). Besides, we also observe that during the peak of the global supply chain disruption, most industries experienced a significant decline in GDP growth rates, while the retail industry displayed a rapid recovery starting in May 2020. Additionally, supply chain bottlenecks contribute to inflation growth both before and after the pandemic.

We will begin our investigation by examining how global value chains (GVCs) have changed across various industries in Canada over a 20-year period. We follow the same methodology used by Santacreu *et al.* (2022). Our macroeconomic approach focuses on how the share of foreign value added in Canadian exports has changed over time. More precisely, we calculated a measure of GVC participation in the share of gross exports (GE) that are produced using foreign value-added (FVA) for each industry. Our data is derived from the OECD TIVA dataset, which provides information on gross exports and foreign trade in value-added from 1998 to 2018. This data allows us to decompose the value added of Canadian industries into 70 different sources, including (i) Canada, (ii) 63 other countries, and (iii) "the rest of the world," which encompasses all remaining countries and areas.

The equation is:

$\text{Exposure}_{jt} = \frac{FVA_{jt}}{Gross\ export_{jt}}$

Here we employ the share of foreign value added in gross export to calculate the industry j's exposure to foreign bottleneck in year t.

One significant disadvantage of this method is that there is a discrepancy between the industrial

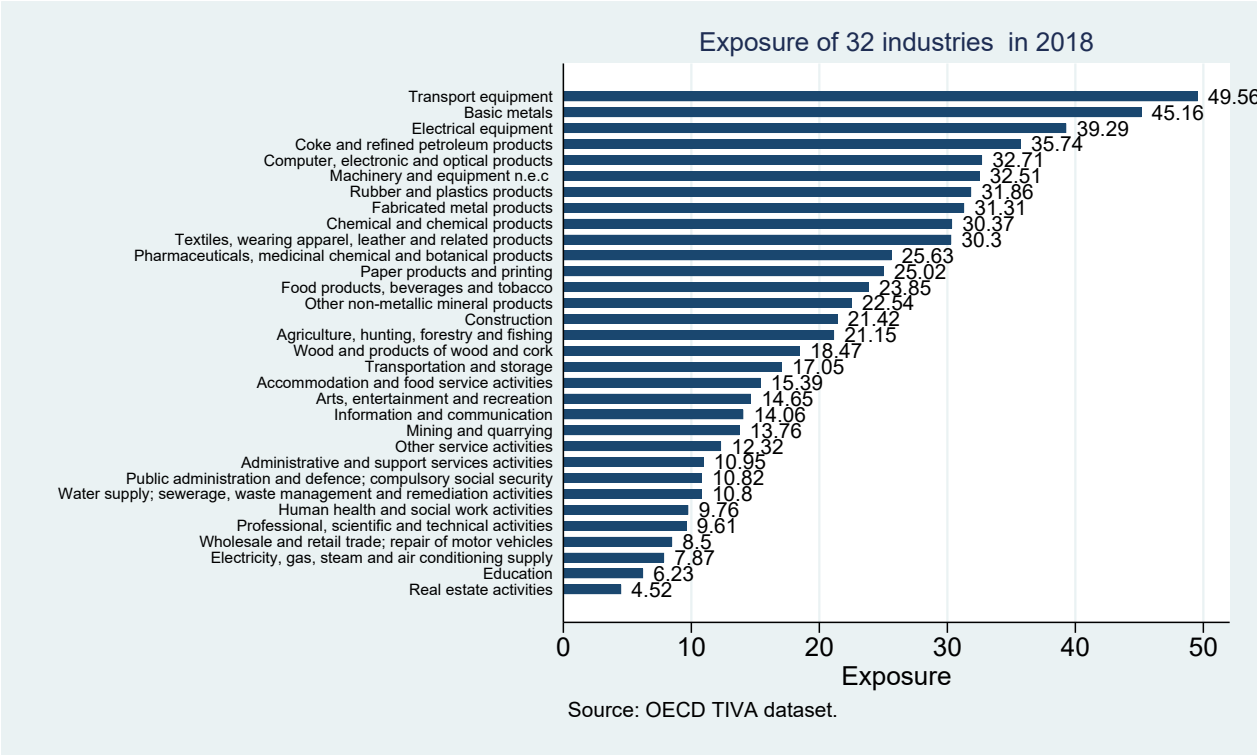


Figure 2.1: Exposure of 32 industries in 2018

classifications used by the OECD dataset and Statistics Canada. When we explore how foreign exposure bottlenecks impact inflation and input in various industries, we observe that the OECD dataset employs the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 4), whereas Canada uses the North American Industry Classification System (NAICS) to classify industries. There are differences in the names and classification methods of certain industries, and some industries, such as the textiles industry, lack GDP data prior to 2000. To ensure data accuracy, we have made an effort to select industries for our study that have names closely aligned between NAICS and ISIC classifications. As a result, we chose to analyze 32 industries present in both databases and utilize the industry name and ISIC REV.4 code to establish classification criteria.

2.1 Characteristics of foreign Value Added in Canada's industries

2.1.1 Characterizing Canada's industry groups with their exposure

Figure 2.1 displays the exposure of the 32 chosen industries in 2018. It is worth noting that all industries with high exposure fall under the category of manufacturing industries. Based on this observation, we can divide the 32 industries into two groups: (i) 15 manufacturing industries with an exposure range of 21.42≤exposure≤49.56 and (ii) 17 non-manufacturing industries with an exposure of <21.42. To further analyze the evolution of the share of value in these 32 industries in Canada, we plot the variation in their exposure from 1998 to 2018 using the OECD TIVA database.

Manufacturing Industries Group

According to the World Bank's 2020 report (World Bank, 2020), Canada's participation in Global Value Chains (GVCs) is characterized by a complex and intricate nature. The growth of GVCs in Canada has been primarily driven by the machinery, transportation, and electronics industries. Consequently, Canada's transportation equipment, electrical equipment, computer, and machinery sectors are heavily reliant on international supply chains, resulting in high exposure levels for these industries.

Specifically, Canada's transportation equipment industry reached a high exposure level of 49.56 in 2018. This underscores the critical role of international trade flows in the manufacturing processes of the country's transportation sector. Moreover, Canada's high-latitude location makes its rubber and plastics industries particularly dependent on global supply chains.

Furthermore, despite Canada's position as the fourth largest oil producer, its refined oil inputs are heavily dependent on global supply chains, with 46% of oil relying on imports according to Canada Energy Regulaor (2019). In particular, the import of refined gasoline amounted to 7.9 billion liters in 2018. An analysis of changes in the exposure of 15 industries over the past two decades indicates that the coke and refined petroleum products industry has experienced significant fluctuations. In 2000, the industry's exposure peaked at 47.72 before declining steadily. This finding suggests that Canada's refined petroleum products industries have a high exposure to global supply and demand energy shocks.

When examining the overall trend of the share of foreign value added (FVA) in the manufacturing

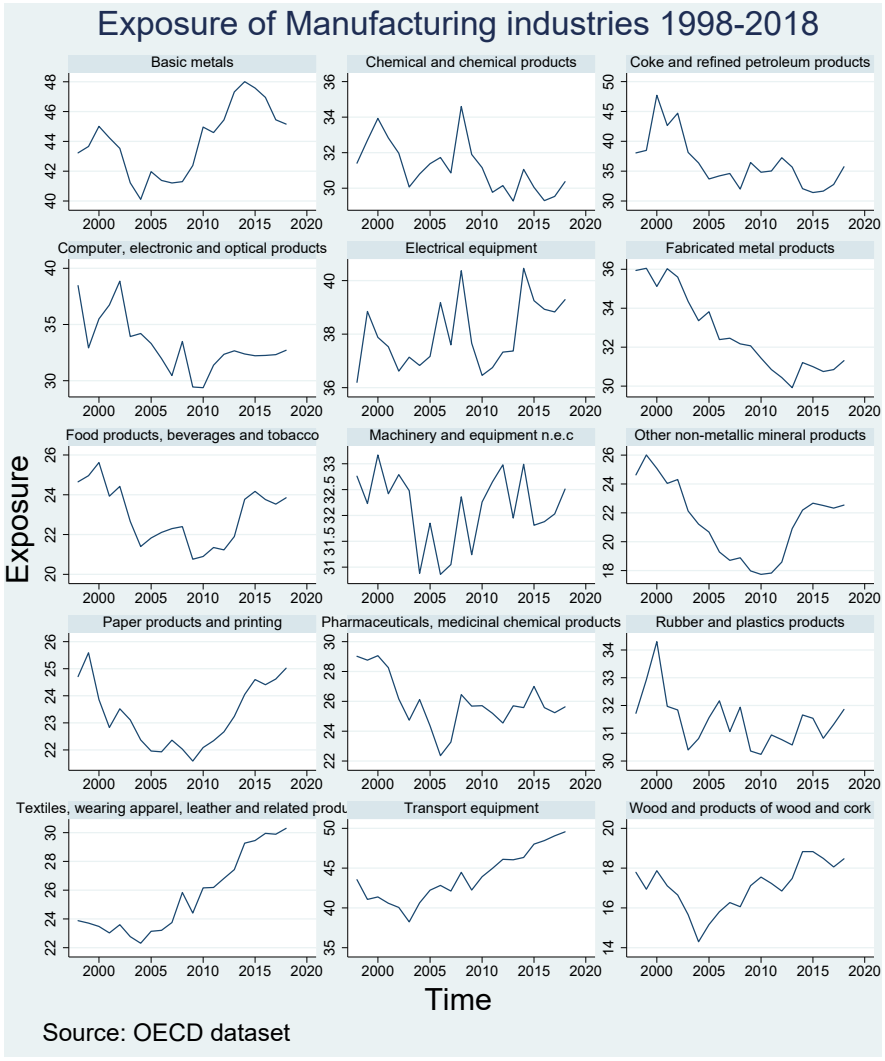


Figure 2.2: Exposure of Manufacturing industries 1998-2018

industry, various types of trends in exposure can be observed. For the electrical equipment industry, exposure displayed a positive trend during 2002-2008, followed by negative growth in 2008-2010, and a slow increase during 2010-2015. Overall, from 2002 to 2020, there was a consistent upward trend. The machinery and equipment industry exhibited significant fluctuations in exposure from 2005 to 2020 but demonstrated a positive trend overall. The coke and refined petroleum industries experienced substantial volatility, with a general decline compared to their levels in the early 2000s. The computer, electronic, and optical products industries, paper products industries, wood industries, and other non-metallic products industries all experienced a downturn around 2008-2010, followed by a rapid increase. The basic metal industry, transport equipment industry, textiles, wearing apparel, leather, and related products industries reached their lowest point around 2005, followed by a positive trend from 2005 to 2018.

Nonmanufacturing Industries Group

Figure 2.3 shows that except for the mining, construction, and agriculture industries, all the remaining 14 industries belong to the service sector. Over the past 20 years, the exposure fluctuations of these industries have remained relatively stable. This suggests that Canada's service sector exports rely more on domestic services rather than international trade. However, the utility industry, which comprises of the electricity and gas, steam, water supply, and waste management industries, is the most volatile among the service industries.

The mining industry is the most volatile among all 17 sectors studied in this research. Interestingly, around 2008, the share of foreign value for the mining industry was lower than 13%. Despite Canada's status as one of the leading exporters of mineral products, the price and export volume of these products are significantly affected by the relationship between supply and demand.

Additionally, the real estate activities sector has the lowest exposure of all the industries, with a share of 4.52% in 2018. This indicates that the real estate activities sector is highly reliant on domestic supply chains.

The overall trend in the nonmanufacturing industry's share of foreign value added (FVA) remained relatively stable from 1998 to 2018, with minimal fluctuations. Currently, the industry maintains a consistent level of FVA without significant changes during this period. The mining and quarry industry, as well as the agriculture industry, exhibit larger fluctuations compared to the service sector. Both the mining and quarry industry and the agriculture industry experienced a downturn,

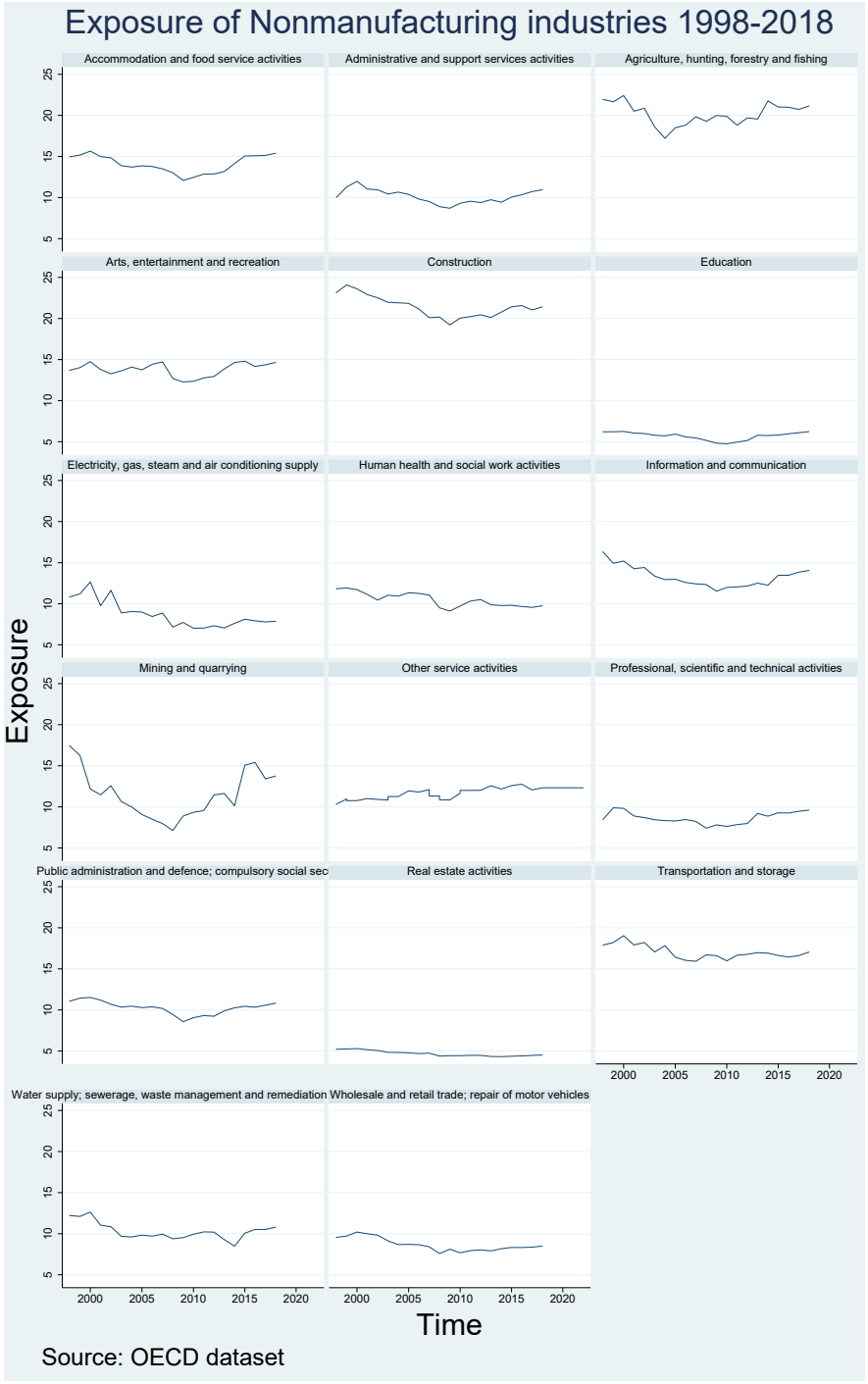


Figure 2.3: Exposure of Nonmanufacturing industries 1998-2018

reaching their lowest exposure levels around 2008. However, they have since shown a slow and steady recovery, displaying a positive trend.

2.1.2 Comparisons of exposure with China and the US.

Figures 2.4 and 2.5 provide a comparative analysis of the exposure of the three industry groups in Canada, China, and the United States over the period of 1998-2018. The findings indicate that Canada's manufacturing industries have a higher share of foreign value than the United States, except for the coke and refined products industry. This observation is consistent with the characteristics of Canada's small and open economy, where manufacturing is highly integrated with the United States (Martin et Mayneris, 2022). Moreover, Canada's manufacturing sector is more dependent on international supply chains than China, which is known as the "world's factory." However, this is not the case for some industries such as coke and refined petroleum products, computers, electronics, and optical products. These industries show high exposure levels in all three countries, implying a dependence on imports of crude oil and primary products from other countries. Furthermore, the exposure of the service sectors in the non-manufacturing group is relatively stable and close in all three countries since they mainly rely on the domestic market.

Regarding the coke and refined petroleum products industry, the exposure level has been highly volatile in all three countries, indicating a dependence on crude oil imports, which is subject to price fluctuations in international crude oil markets. In the case of computers, electronics, and optical products industry, the exposure levels are very high in both Canada and China, but for different reasons. Canada has imported a significant number of primary products from the United States and China, whereas China is now known as the "hub of the regional supply chain network" and has shifted its role from low-value-added activities to more high-value-added activities, leading to a decline in its exposure to computers and electronic industry over the past two decades.

Furthermore, all three countries are major exporters of minerals, and the exposure level of the mining industry is relatively low. This implies that the mining sector is less affected by international supply chain disruptions. Finally, the service sectors in the non-manufacturing group are relatively stable and close in all three countries, indicating their dependence on the domestic market and the limited impact of international supply chain disruptions on these sectors.

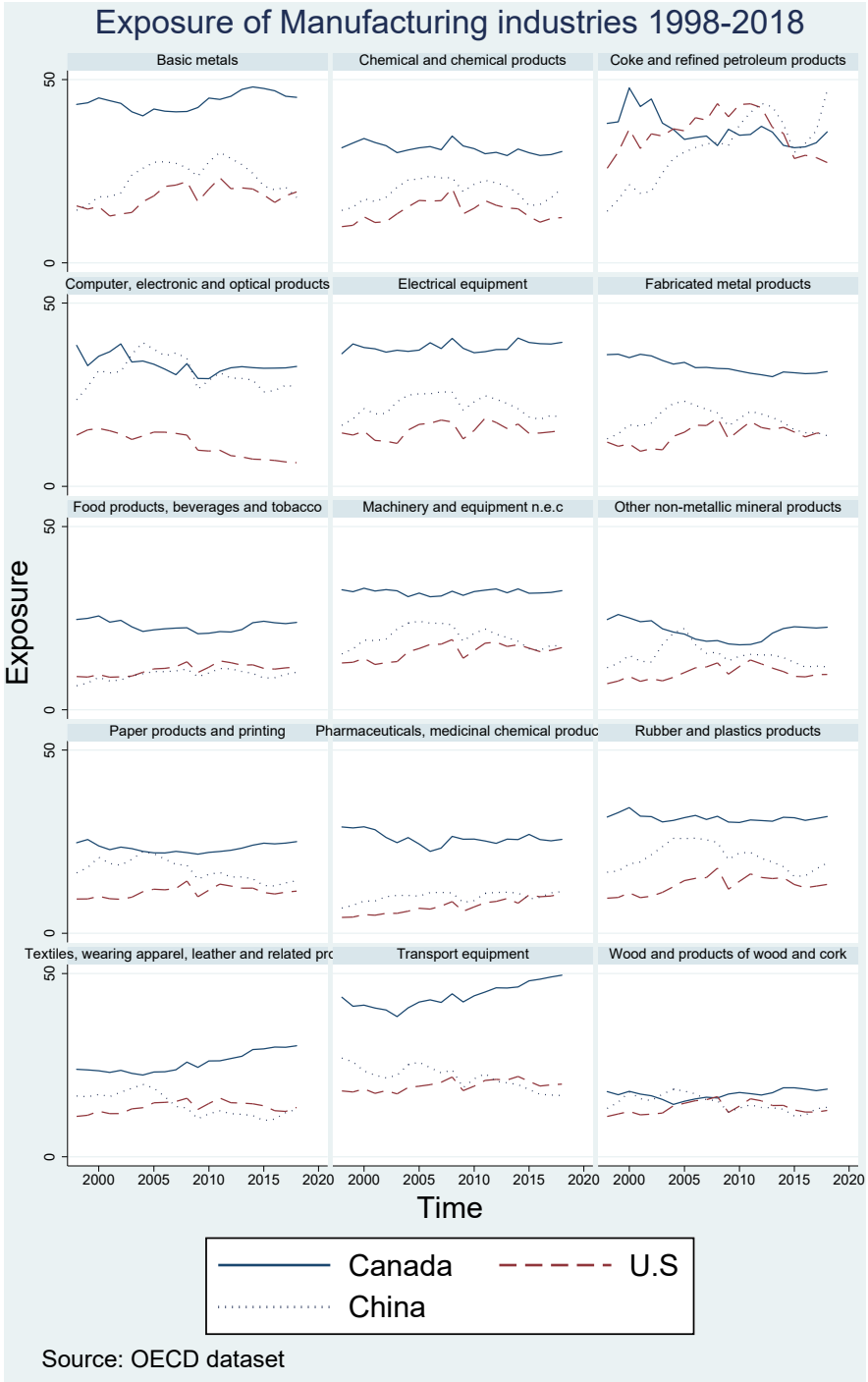


Figure 2.4: Exposure of Manufacturing industries 1998-2018

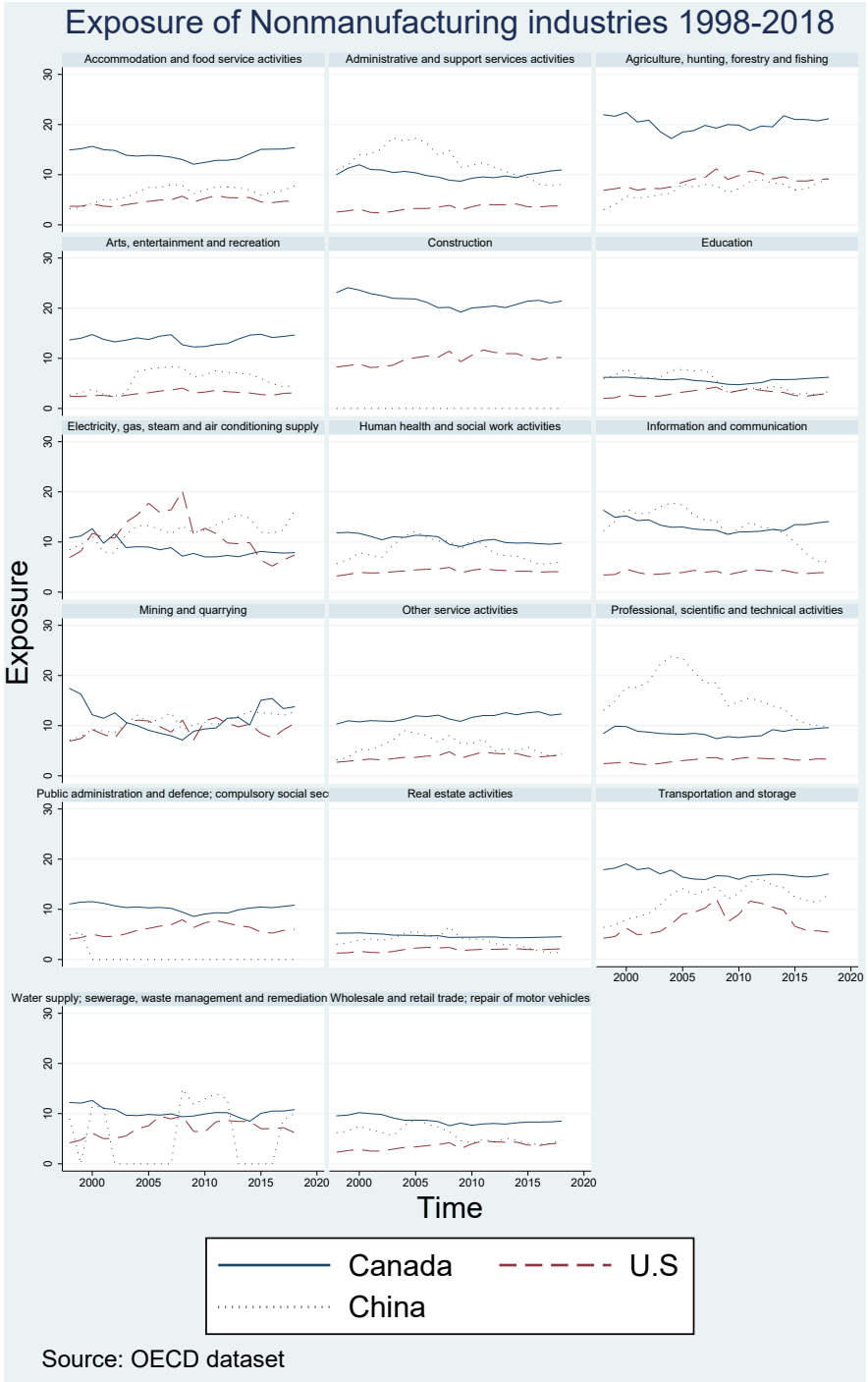


Figure 2.5: Exposure of Nonmanufacturing industries 1998-2018

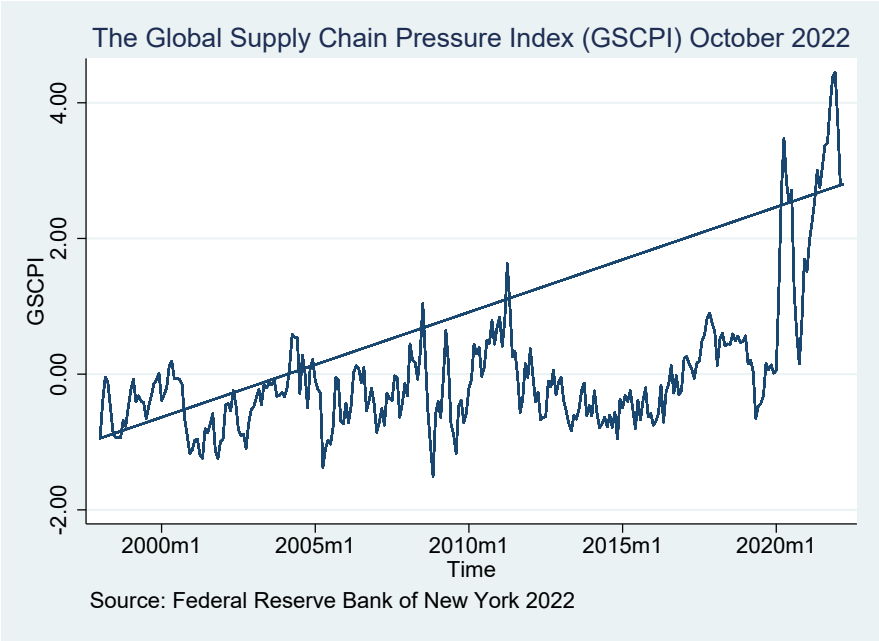


Figure 2.6: The global supply chain pressure index(GSCPI) October 2022

2.2 The global supply chain pressure index.

The Federal Reserve Bank of New York created the Global Supply Chain Pressure Index to assess supply chains. It seeks to assist those affected by disruptions in the world supply chain in academia, commercial organizations, governments, and consumers. This indicator shows the correlation between the evolution of global supply variables and the persistence of inflationary pressures, particularly in PPI and to a lesser extent in CPI, is significant (di Giovanni *et al.*, 2022). The index is standardized in a way that a zero signifies it's at the mean value, with positive values indicating the number of standard deviations above this mean value, and negative values indicating the opposite.

GSCPI is based on supply chain and transportation-related data from manufacturing companies. Data from three sources are combined to calculate the transportation cost data: (i) The Baltic Dry Index, which measures the average cost of shipping major raw materials by sea. (ii) the Harpex index, which calculates the cost of cargo ships globally. A cost index for freight flights between Asia, Europe, and the United States is provided by the (iii) BLS(di Giovanni *et al.*, 2022).

Additionally, they make use of the Purchase Manager Index (PMI) polls, which offer economic analysis from top private sector executives. They use a GDP-weighted average of the previously mentioned "New Orders" PMI subcomponents as well as a similarly weighted average of the "Quan-

tities Purchased" PMI subcomponents for seven markets: the Euro area, China, Japan, South Korea, Taiwan, the UK, and the US. The following PMI subsets are notably utilized by the GSCPI: Delivery times, "which captures the extent to which supply chain delays in the economy impact producers," according to the New York Fed; Backlogs, taking into account the volume of orders that businesses have received but haven't yet been able to fulfill; and acquired stocks, a measure of inventories. (di Giovanni *et al.*, 2022)

In April, the deterioration of global supply chain pressures was mainly caused by the Chinese "delivery times" factor, the rise in airfreight costs from the United States to Asia, and the euro area's "delivery times" factor. At the same time, the "backlog" factor worsened, while the "purchased stocks" factor showed some improvement throughout the month.

According to the paper of Federal Reserve Bank of New York (2022),the GSCPI fluctuates over time, with notable episodes such as the rebound during the Global Financial Crisis (GFC). Although efforts are made to remove demand factors, the GSCPI still captures some demand components during the GFC. The index's variation is smaller than in later periods, which may reflect stronger supply-side factors. In 2011, the index rose due to natural disasters in Japan and flooding in Thailand, impacting automobile and electronics production globally (di Giovanni *et al.*, 2022). The index also increased during the 2017-2018 China-U.S. trade disputes as firms adjusted global sourcing strategies. The rise between 2015-2017 was influenced by substantial global economic growth, contributing to supply chain pressure for different reasons.

In the empirical analysis proposed in the next chapter, we will interact this measure of GVC disruption with the time-varying exposure of each industry to GVCs. This will provide us with industry-level time-varying measures of GVC disruptions (see Appendix A).

2.3 Canada's macroeconomic dynamics

In this section, we will divide the industrial sector into manufacturing and non-manufacturing sectors, as in part 2.1, and study the changes in Canada's macroeconomic data, including GDP growth rate and industrial price index growth rate between 1998-2022. It is important to note that even though both the output table and the Industrial Price Index table on the Statistics Canada website employ the NAICS classification (Statistics Canada, 2022b), there are differences in industries listed in the PPI table and the output table. First, only manufacturing industries are

listed in the Industrial Producer Price Index (PPI) table. Second, textiles, wearing apparel, leather, and related products are removed from the GDP table due to a lack of data before 2000. Besides, the paper and wood industries are combined into one industry –the wood and paper products industry in the GDP tables. We also use the chemicals and pharmaceuticals products industry instead of its branch Chemical and chemicals products industry in Canada's output table.

2.3.1 Canada's GDP

We can now survey the characteristics of the GDP growth rate in 2 groups simultaneously. Generally, there are several periods of GDP fluctuations : (1) the financial crisis in 2008 caused a decline in many industries' GDP growth rates, (2) the economic recovery, and the adjustment of supply and demand after the 2008 global financial crisis, (3) since the 2020 pandemic, the GDP growth rate has hit rock bottom and quickly recovered. However, the volatility of the GDP growth rate in the three exposure groups varies.

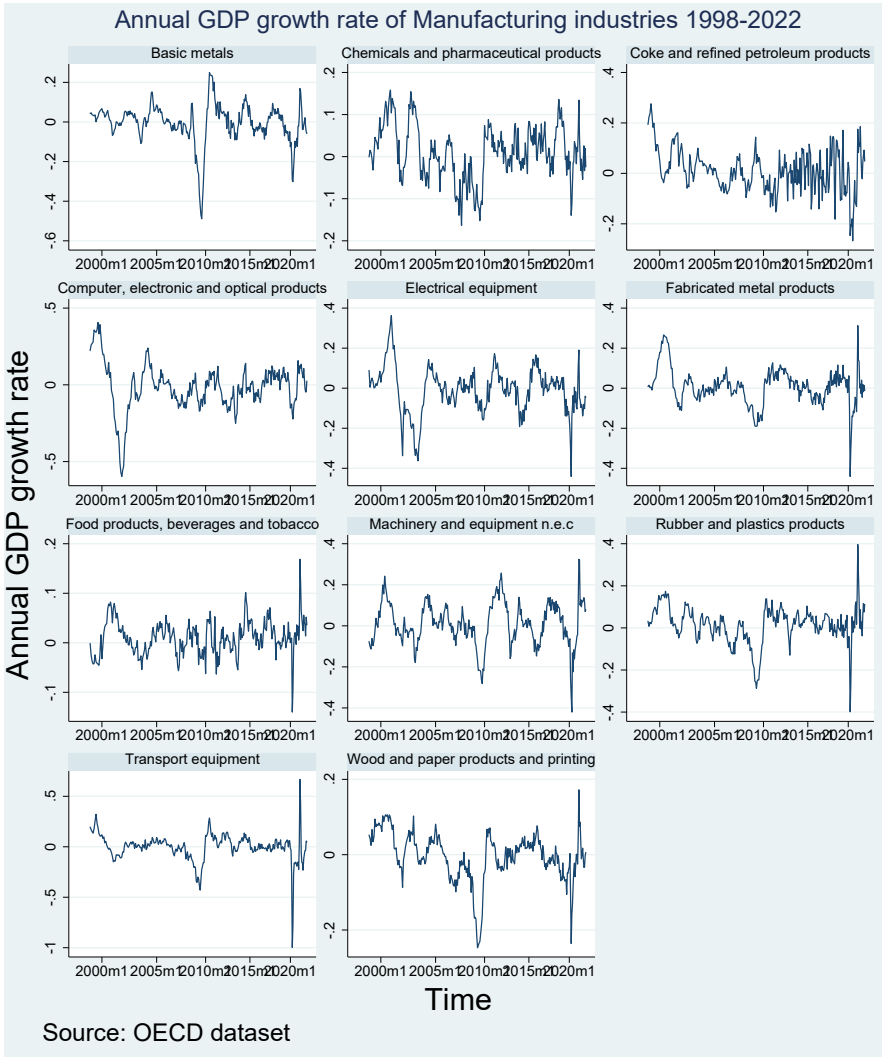


Figure 2.7: Annual GDP growth rate of Manufacturing industries in October 2022

Figure 2.7 and Figure 2.8 illustrate the annual GDP growth rates from 1998 to 2022 for the manufacturing and non-manufacturing groups. We find that the GDP growth rates of industries with a high share of foreign value added are relatively more volatile, while the GDP growth rate of industries with a lower share of foreign value is less volatile before 2020. However, this does not precisely match the characteristics of the transport equipment industry, which has the highest exposure and the GDP growth rate remained relatively stable between -20% and 20% per year until 2020 when the COVID epidemic caused significant fluctuations in the GDP growth rate of the transport equipment industry.

Since the COVID-19 pandemic outbreak in 2020, there has been a significant shift in the fluctuation of GDP growth rates. Most industries in both exposure groups experienced significant declines and rebounds in their growth rates. For instance, the wholesale and retail trade industry, which had been extremely stable before 2020, reached a low point of -4% at the beginning of 2020 and then rebounded to a peak of 4%, which is different from its pre-2020 behavior.

2.3.2 Canada's inflation

In this section, we will analyze the evolution of PPI inflation in Canada's manufacturing industry sectors. Producer prices refer to the prices at which businesses sell their products or services to others, and the PPI tracks the average change in prices received or paid by Canadian producers over time. However, we can only obtain PPI inflation data for the manufacturing sector, not for the services, mining, and agriculture sectors. Also, there are some differences in the industrial classification methods used in the GDP and PPI tables, limiting our analysis to only 14 manufacturing industries.

Two global recessions have occurred since 1998, one in 2008 and another in 2020, causing a months-long decline in inflation until the economy recovered. The drivers of disinflation were different in the two recessions, with demand and oil price shocks driving the global disinflation in 2009 in broadly equal measures, while the 2020 inflation collapse was predominantly driven by demand shocks.

Overall, the annual PPI inflation in the Canadian manufacturing sector has remained relatively stable, except for the periods of recession and recovery in 2008 and 2020, due to the influence of the flexible exchange rate and stable macroeconomic policies. Figure 2.9 shows that the coke and refined petroleum industry, with exposure as high as 35.74 in 2018, is particularly susceptible to

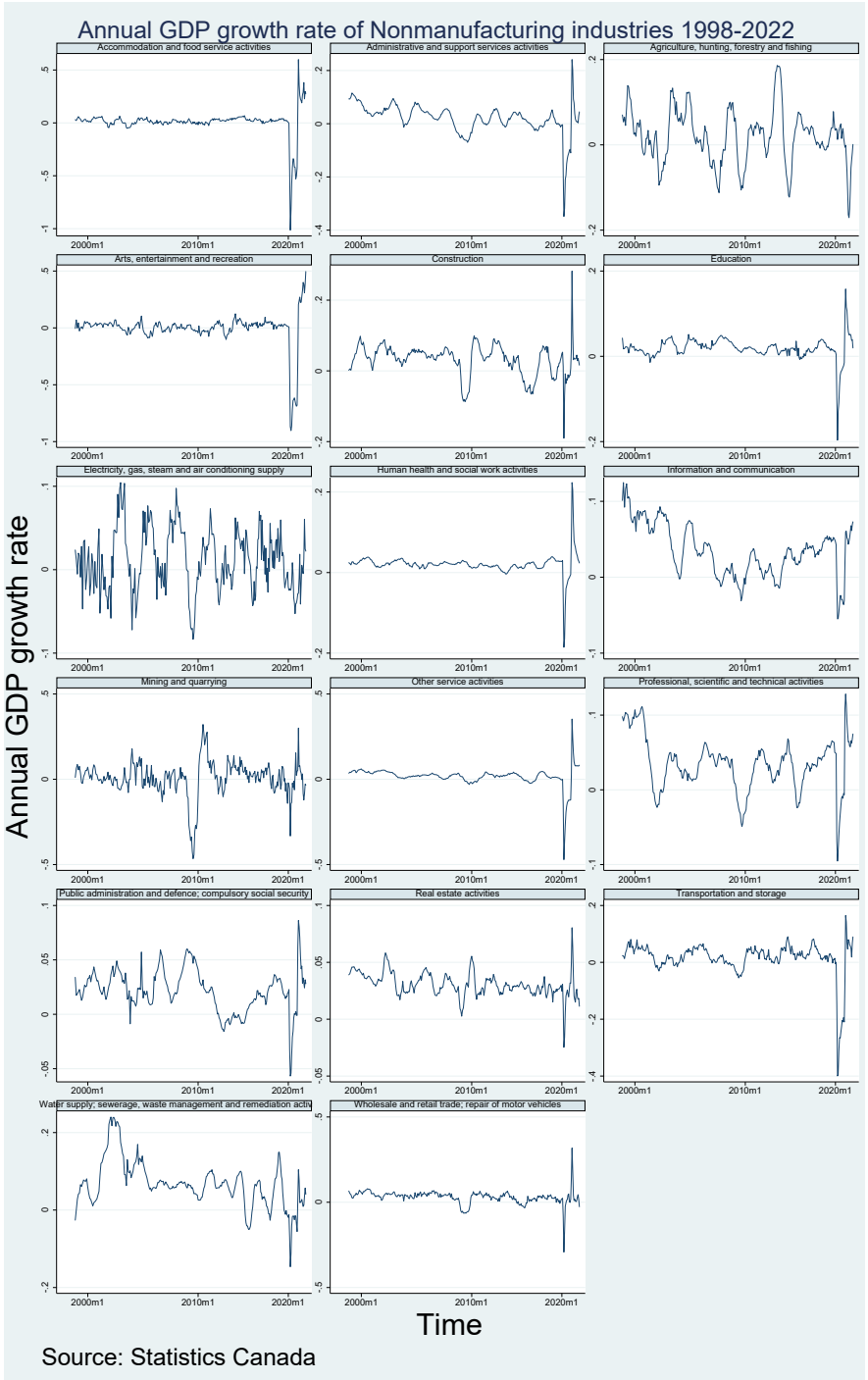


Figure 2.8: Annual GDP growth rate of Non Manufacturing industries in October 2022

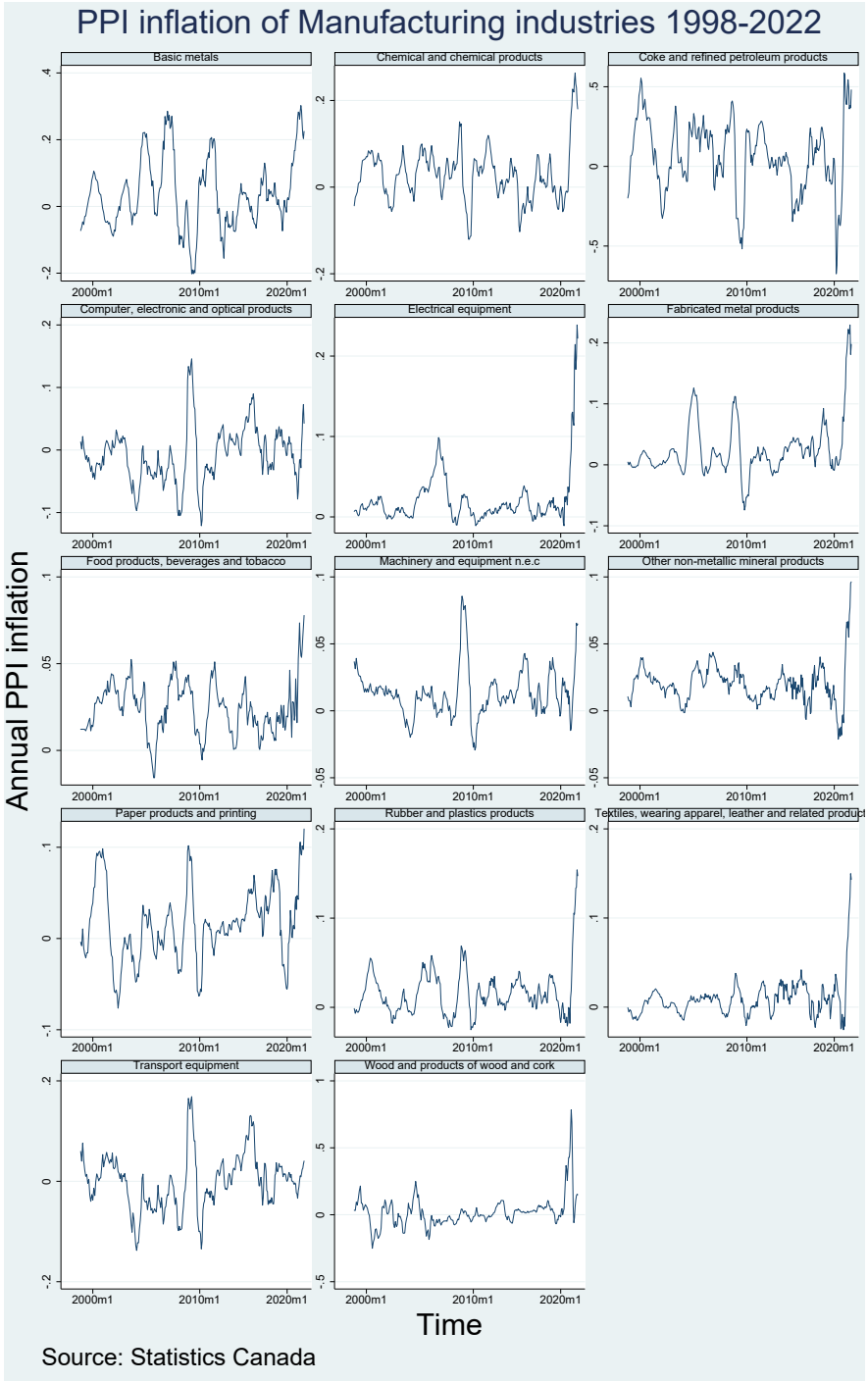


Figure 2.9: PPI inflation of Manufacturing industries in October 2022

price fluctuations due to demand and supply shocks, as well as political and military reasons such as the Iraq War, OPEC fights for market shares, and Iran sanctions. Although the 2020 recession was shorter than the one in 2008, it had a more significant impact, and the decline of inflation in most industries was not as severe as in 2008. During the 2008 financial crisis, the transport equipment industries experienced a peak in inflation rates, whereas during the COVID-19 period, the growth in PPI inflation was not as pronounced. In contrast, industries such as rubber and plastic products, wood and products of wood and cork, textiles and wearing apparel, leather and related products, and electrical equipment, which rely heavily on imported raw materials, witnessed much higher increases in PPI inflation during the COVID-19 pandemic compared to the magnitude seen during the 2008 financial crisis.

CHAPTER 3
EMPIRICAL ANALYSIS

In this chapter, we will utilize two-way fixed effect models (TWFE) to examine the relationship between global supply chain disruption, Canadian GDP, and inflation. Our analysis is built upon previous research investigating the connection between GVC, inflation, and GDP growth rate (Santacreu et al,2019; Giovanni et al,2022). However, our model is unique in that it incorporates both time and industry variations into one model and assesses how this relationship varies across manufacturing and non-manufacturing industries.

Furthermore, we will create a new variable by multiplying the stress level of the global supply chain $GSCPI_t$ (Federal Reserve Bank of New York, 2022) and the exposure to foreign bottlenecks $EXPOSURE_t^i$ (OECD Statistics, 2021). Since we can only get annual data for exposure from the OECD, to get the monthly data, we assume that the exposure is the same for each month of the same year. and has not changed since 2018, since only annual data of exposure from 1998-2020 is available in the OECD dataset. Therefore, we can obtain the following equation:

$$GSCPINEW_t^i = EXPOSURE_t^i * GSCPI_t$$

Here, $EXPOSURE_t^i$ represents the industry's exposure in a particular month t, while $GSCPI_t$ refers to the monthly global supply chain pressure index. The GSCPINEW denotes the global supply chain pressure for a particular industry as it is the result of GSCPI weighted by the industry's exposure.

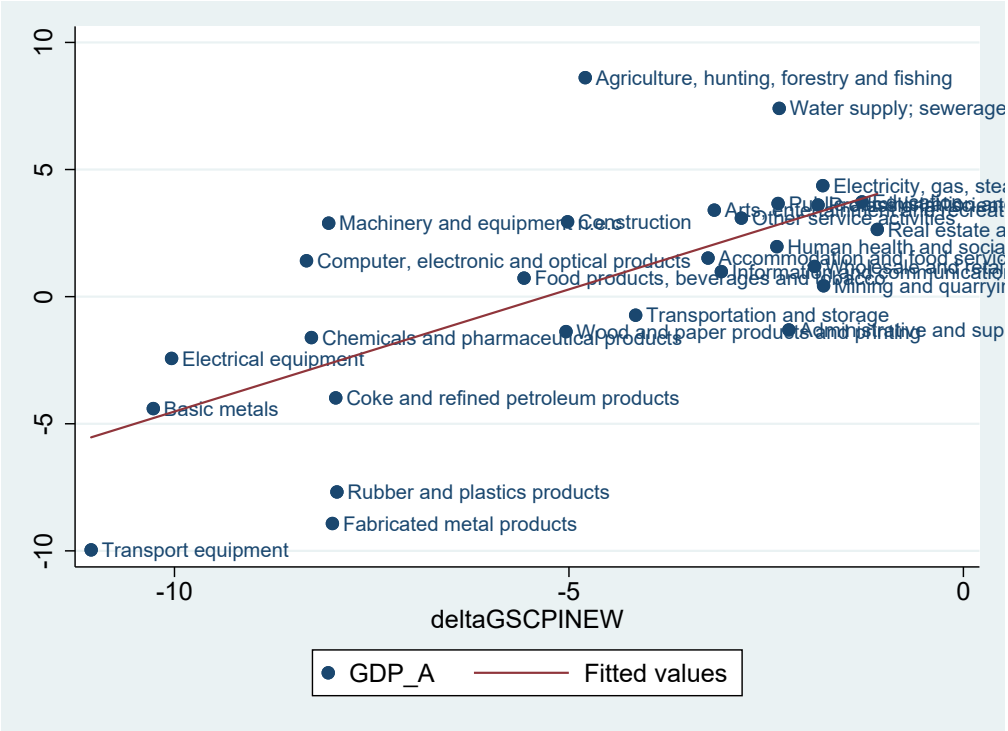
When calculating the growth rate of PPI inflation and GDP for each month, we compare those growth rates to those from the same month of the previous year. As a result, we could employ the PPI and GDP growth rate at a monthly frequency. This is required to improve the accuracy of our studies and minimise any concerns with collinearity, which can occur when we have the same exposure for every 12 month of a year. By calculating annual growth rate for GDP inflation at a monthly frequency, we can minimize any potential issues with collinearity and ensure the validity of our analyses.

3.1 Discussion about the GVC, GSC, output, and inflation.

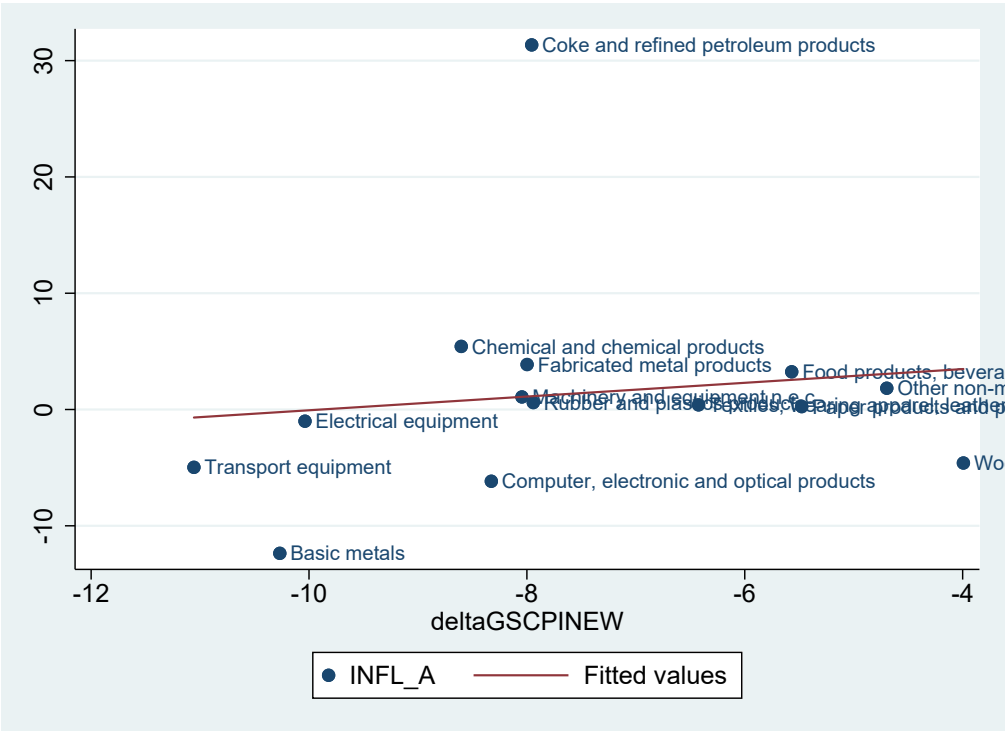
Our research aims at exploring the relationship between exposure to foreign value added bottlenecks and two key macroeconomic variables: output and inflation. We will first present some unconditional correlations at a specific points in time. Specifically, we will focus on the time when fluctuations in GDP and PPI (producer price index) were at their highest and lowest points, respectively, during 2008 financial cris and the second peak of the global supply chain pressure -December 2021.

Figure 3.1 and 3.2 suggest that the growth of GDP and inflation is positively correlated with the growth of GSCPINEW in May 2008 except for the nonmanufacturing industries. Figures 3.3 and 3.4 show that there is a negative relation between the deltaGSCPINEW and GDP in December 2021 which is the highest point of the global supply chain pressure. Besides, it becomes stronger for the manufacturing industries. It also indicates a positive correlation between inflation and GSCPINEW. Notably, while output in the non-manufacturing sector is also negatively correlated with GSCPINEW, this relationship is less pronounced and almost parallel.

Based on these findings, we hypothesize that over the past 20 years, there is a negative correlation between the independent variable GSCPINEW and dependent variable GDP growth rates, and the supply chain pressure is also an essential factor for inflation. Previous research suggests that disruptions in the supply chain leads to increased inflation((Santacreu et LaBelle, 2022), but why there is a negative correlation between output and GSCPINEW remains a question. Besides, it is essential to note that the findings presented in this section only represent a specific point in time and cannot be generalized to the entire period under study. Moreover, the impact of economic recession and financial crisis on different industries can occur at different times, leading to a delayed or advanced response. This is why we have employed the use of a two-way fixed effect model (TWFE) in our analysis. By incorporating both time and industry variations, we can gain a more comprehensive understanding of how these factors interact and affect the overall relationship between global supply chain disruption, Canadian GDP, and inflation.

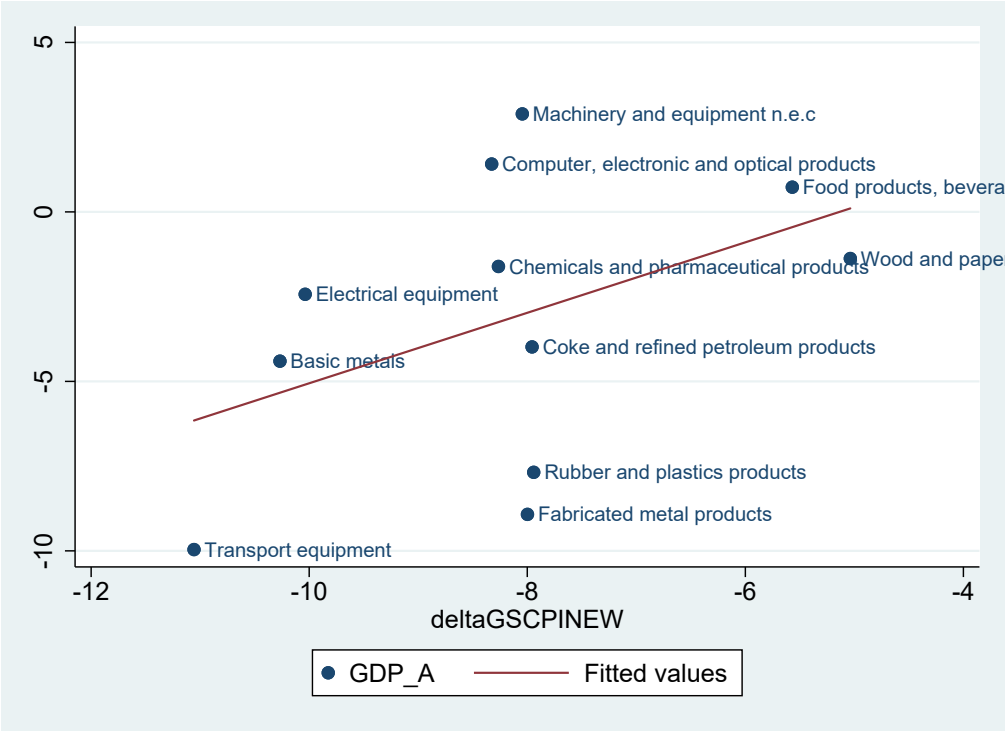


(a) Variation of GDP and GSCPINEW in May 2008| coefficient: 0.6773

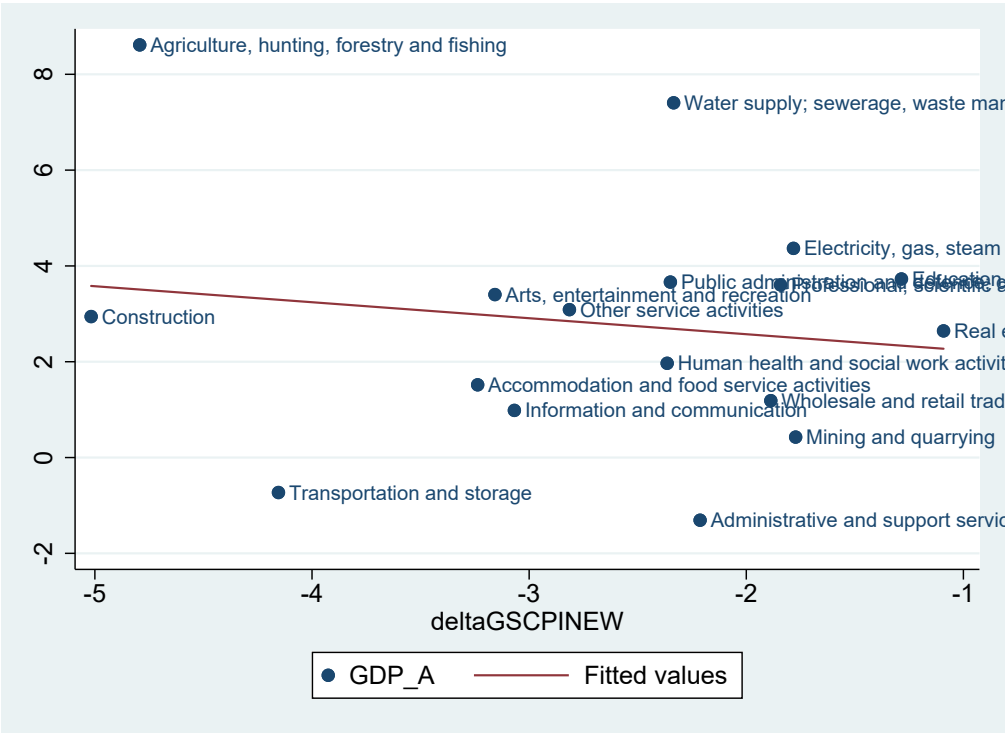


(b) Variation of inflation and GSCPINEW in May 2008| coefficient: 0.1275

Figure 3.1: Canada's economy activity in May 2008

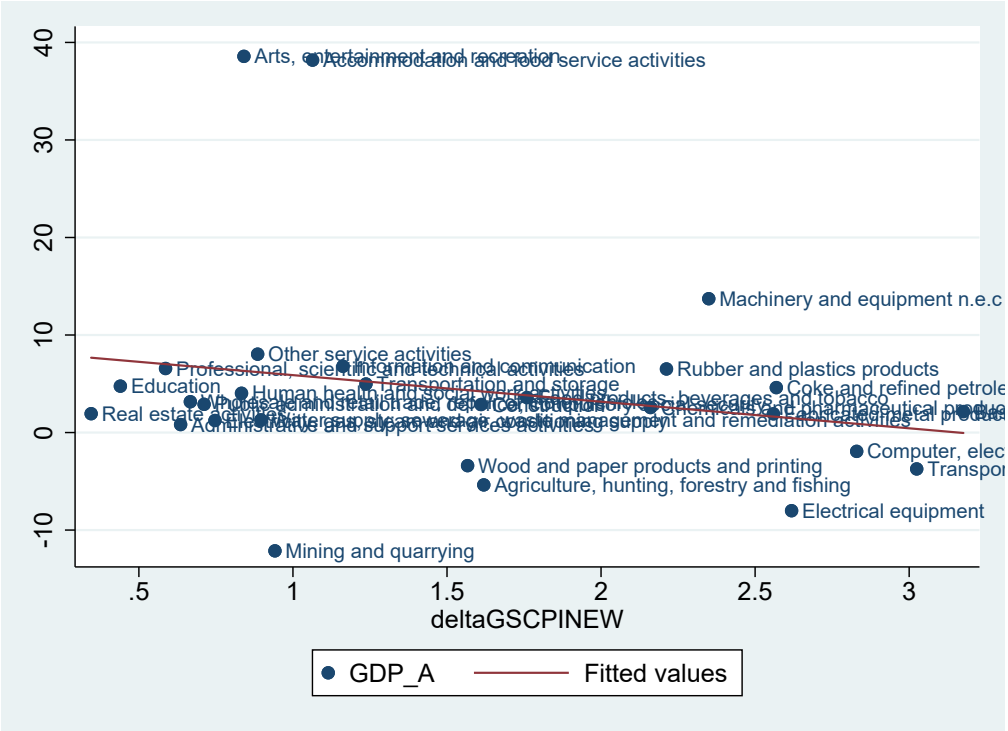


(a) manufacturing industries in May 2008 | coefficient: 0.4436

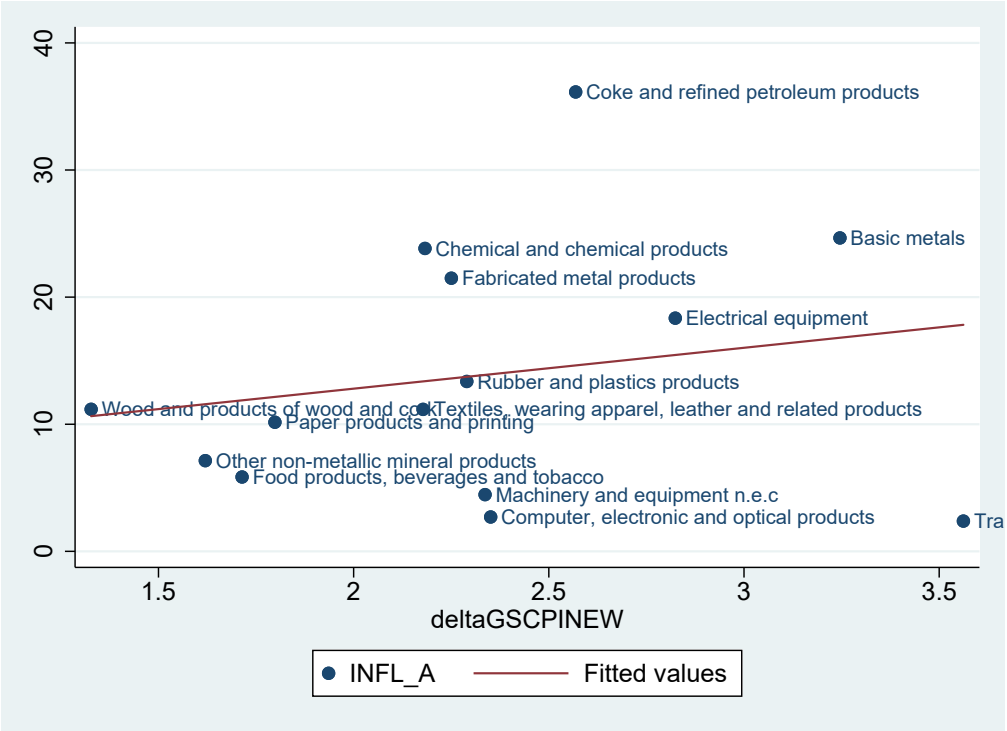


(b) Non manufacturing industries in May 2008| coefficient: -0.1497

Figure 3.2: Variation of GDP and GSCPINEW in May 2008

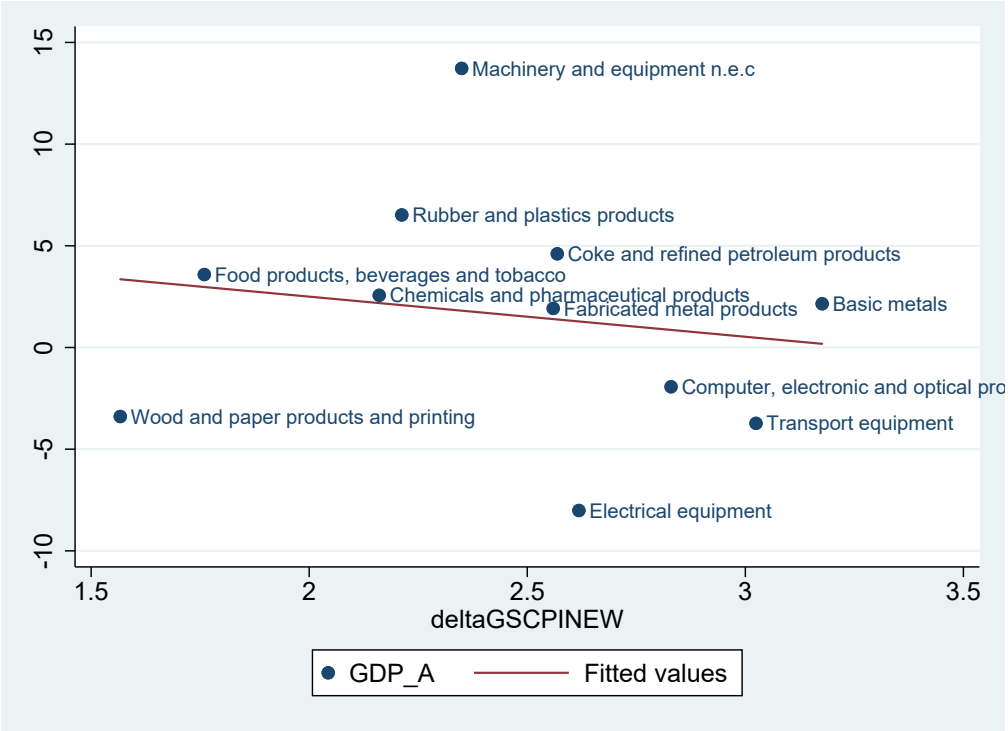


(a) Variation of GDP and GSCPINEW in December 2021| coefficient: 0.0377



(b) Variation of inflation and GSCPINEW in December 2021| coefficient: 0.1300

Figure 3.3: Canada's economy activity in December 2021



(a) manufacturing industries in December 2021| coefficient: 0.7285

(b) Non manufacturing industries in December 2021| coefficient: 0.0266

Figure 3.4: Variation of GDP and GSCPINEW in December 2021

3.2 Models

We consider the time-fixed effect, industry-fixed effect, and the pandemic dummies in our model to explore how they influence our model. We can now start estimating the industry-level panel data with two-way fixed effect models. The equation is following:

$$Y_{it} = \alpha + \beta_1 * GSCPINEW_{it} + \beta_2 * z_{it} + \gamma_i + \delta_t + \epsilon it$$

Here comes from the heterogeneous exposure of different industries to global value chains interacted with the time variation of the global value chain stress index,where Y_{it} is the growth rate of GDP or inflation of the industry i at month t, α is the constant, and GSCPINEW is the new variable, which is the combined data of GSCPI and exposure, β_1 is the coefficient of the GSCPINEW pre-pandemic. z is interaction term between the pandemic dummy and the GSCPINEW, and β_2 is coefficient of z. γ_i represents the industry fixed effects and the δ_t is the time fixed effects.

In addition, the equation of z is :

$$z_{it} = GSCPINEW_{it} * PANDEMIC_t$$

where $PANDEMIC_t$ is a dummy equals to one during the pandemic period.

3.2.1 GVC, GSC and GDP– two-way fixed effects models.

In this part, we initially regress GSCPINEW and the GDP growth rate, gradually incorporating new dummy variables. This approach allows us to investigate the impact when considering industry fixed effects, time fixed effects, and then pandemic dummies. We employ a similar method for both Table 3.1 and Table 3.2. However, in Table 3.2, exposure is categorized into five periods at five-year intervals: 1998-2002, 2003-2007, 2008-2012, 2013-2017, and 2018-2022. This stratification is intended to yield more significant correlation coefficients.

As Table 3.1 and Table 3.2 show, the unconditional correlation between The global supply chain pressure index and GDP growth is negative and weakly statistically significant. This result is robust to the inclusion of industry fixed effects (Second column). Once adding also time fixed effects, the coefficient becomes statistically insignificant. In column 4, we add the interaction term with the pandemic dummy. Interestingly now, the correlation between economic activity and global value chain pressure appears to be positive and statistically significant before the pandemic, and negative and statistically significant during the pandemic (fourth column). This is particularly true if we only consider the manufacturing industries (fifth column). Quantitatively, the standard deviation

	Y:GDP growth rate					
	X:GSCPINEW					
Pandemic dummies	No	No	No	Yes	Yes	Yes
Type of industries					Manufacturing industries	Non Manufacturing industries
GSCPINEW	-0.015*	-0.014*	0.009	0.114***	0.174***	0.010
	(-1.89)	(-1.87)	(0.82)	(7.29)	(4.85)	(0.41)
z				-0.147***	-0.312***	-0.073
				(-6.80)	(-6.06)	(-1.50)
Constant	1.347***	1.920***	4.230*	8.165***	20.783***	9.802**
	(14.36)	(5.08)	(1.70)	(3.09)	(3.60)	(2.52)
Industry FE	NO	YES	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	YES	YES

Robust t-statistics in parentheses, Number of obs= 7,812

*** p<0.01, ** p<0.05, * p<0.1

Table 3.1: the results of models between GDP growth rate and GSCPINEW

of GSCPINEW is 23.56(23.52 for the five-year average). Across all industries, the increase of GDP following one standard deviation of GSCPINEW before the pandemic is 2.69 (2.75 for the five-year average), and the decrease of GDP following an increase of one standard deviation of the independent variable during the pandemic is 0.78% (0.78% also for five-years average). However, within the manufacturing industry, the impact of the GSCPINEW variable on the dependent variable is more significant, and the pandemic dummies also exhibit a stronger influence (fifth column). The increase of one standard deviation of GSCPINEW leads to an increase of 4.10 (4.23 for five years average), and one standard deviation increment in the independent variable GSCPINEW during the pandemic results in a drop of 3.25 (3,29 for five years average) in GDP.

Figure 2.6 presents that between 2015 and January 2020, while the GDP of various manufacturing industries was growing slowly, the GSCPI was gradually increasing. The increase in demand during this period may have contributed to both an increase in economic growth and an increase in the supply chain pressure. During the pandemic, instead, supply factors are likely to have determined the increase in the index of pressure on global supply chains, leading also to a decrease in economic activity. This is further confirmed by studying the correlation between GVC pressure and inflation,

	Y:GDP growth rate					
	X:GSCPINEW					
Pandemic dummies	No	No	No	Yes	Yes	Yes
Type of industries					Manufacturing industries	Non Manufacturing industries
GSCPINEW_1	-0.014*	-0.013*		0.117***	0.180***	0.035
	(-1.79)	(-1.76)		(7.65)	(4.94)	(1.46)
z_1				-0.150***	-0.320***	-0.098**
				(-7.05)	(-6.17)	(-2.03)
Constant	1.348***	1.921***	4.230*	8.183***	21.040***	9.838**
	(14.39)	(5.08)	(1.70)	(3.09)	(3.62)	(2.53)
Industry FE	NO	YES	YES	YES	YES	YES
Time FE	NO	NO	YES	YES	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.2: the results of models between GDP growth rate and GSCPINEW if Exposure is the average of five years

This table employed a different independent variable GSCPINEW. The equation of GSCPCINEW is the same: $GSCPINEW_t^i = EXPOSURE_t^i * GSCPI_t$. However, the $Exposure_t^i$ is the average of every five years' exposure: 1998-2002, 2003-2007,2008-2012,2013-2018,2019-2022

Y:PPI inflation X:GSCPINEW				
Pandemic dummies	No	No	No	Yes
GSCPINEW	0.052***	0.052***	0.162***	0.153***
	(11.23)	(12.08)	(10.84)	(4.83)
z				0.014
				(0.36)
Constant	1.872***	2.402***	-9.093***	-9.681***
	(23.27)	(24.74)	(-3.35)	(-3.15)
Industry FE	NO	YES	YES	YES
Time FE	NO	NO	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.3: the results of models between PPI inflation and GSCPINEW

to which we turn next.

3.2.2 GVC, GSC and inflation- two-way fixed effects models.

The first column of Table 3.3 is the result of regression between the GDP growth rate and GSCPINEW, while Table 3.4 employed a different independent variable GSCPINEW. The equation of GSCPCINEW is the same:

$GSCPINEW_t^i = EXPOSURE_t^i * GSCPI_t$

However, the $EXPOSURE_t^i$ is the average of every five years' exposure: 1998-2002, 2003-2007,2008-2012,2013-2018,2019-2022.

As mentioned in Chapter 2, the two industries Coke and refined petroleum products industry and transport equipment, are removed as disturbing variables. According to the figure below, the wood and paper products industry is also a confounding variable; therefore, when doing the regression, we only considered the effect of 11 industries.

Based on the results from Table 3.3 and Table 3.4, it can be observed that there is a positive and strongly statistically significant unconditional correlation between the global supply chain pres-

Y:PPI inflation X:GSCPINEW				
Pandemic dummies	No	No	No	Yes
GSCPINEW_1	0.052***	0.052***	0.164***	0.157***
	(11.27)	(12.11)	(10.81)	(4.77)
z_1				0.010
				(0.26)
Constant	1.872***	2.403***	-9.264***	-9.687***
	(23.28)	(24.74)	(-3.39)	(-3.15)
Industry FE	NO	YES	YES	YES
Time FE	NO	NO	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.4: the results of models between PPI inflation and GSCPINEW if exposure is the average of 5 years.

sure index and PPI inflation (first column). This result remains sturdy even after accounting for industry-fixed effects (Second column). Upon inclusion of time-fixed effects, the coefficient appears to be larger(Third column). It's interesting to note that the interaction term of pandemic dummy Z is insignificant in the fourth column. From a quantitative perspective, an increase of one standard deviation in the independent variable GSCPINEW during the pandemic corresponds to an increase of 5.24 (5.23 for the five-year average) in PPI inflation when considering the time-fixed effect and industry-fixed effectthird column).

Upon introducing the pandemic dummy variable, the coefficient for the pandemic variable (z) is found to be statistically insignificant. This implies that the positive correlation between GVC pressure and inflation is not found to be different between the period pre-pandemic and during the pandemic. This is consistent with both demand factors and supply factors affecting the correlation between supply chain pressure, economic activity and prices. Before the pandemic, demand factors are likely to have played a more important role. This could explain the finding of a positive correlation between GVC pressure and both economic activity and prices. During the pandemic, the supply side factors have likely being dominant, as reflected in a positive correlation between the GCV pressure and prices but a negative correlation with economic activity.

CONCLUSION

In this thesis, we provide an overview of the dependence of various industries in Canada on international trade flows. The objective is to measure the degree of dependence that different sectors in Canada have on global value chains and to assess the consequence of global supply chain disruptions in the supply chain at the industry level.

Our analysis reveals that Canadian manufacturing is more dependent on global supply chains compared to China and the United States, making it more vulnerable to supply chain disruptions. We also summarize the GDP and PPI inflation trends in different industries in Canada from 1998 to 2022. By combining the exposure of Canadian manufacturing and non-manufacturing sectors to bottlenecks with global supply chain pressure, we establish a two-way fixed effects (TWFE) model that links GDP and inflation growth rates to supply chain disruptions.

Our findings indicate that the growth of PPI inflation is influenced by the expansion of domestic demand and subsequent increases in prices of final goods and intermediate products. Moreover, this correlation remains consistent both before and during the pandemic. We argue that the positive correlation between economic activity and GVC pressure observed before the pandemic may be attributed to demand factors. However, since the onset of the pandemic, the negative effects of the outbreak on supply chains have led to a significant decline in GDP.

The findings of this study have significant benefits for Canada. They provide valuable insights into the dependence of Canadian industries on global value chains and the potential impacts of future supply chain disruptions. This knowledge allows policymakers to develop tailored strategies and policies to enhance the resilience and competitiveness of Canadian industries, minimize negative effects, and better prepare for future disruptions.

However, our model has certain limitations. In our statistical process, we only consider the share of foreign value in gross exports, neglecting the calculation of backward and forward participation of industries, which may result in some value duplications. Additionally, our model does not account for the impact of labor force changes on GDP and inflation. These areas offer potential avenues for future research and exploration.

APPENDIX A
INDUSTRY-LEVEL VARYING GSCPI

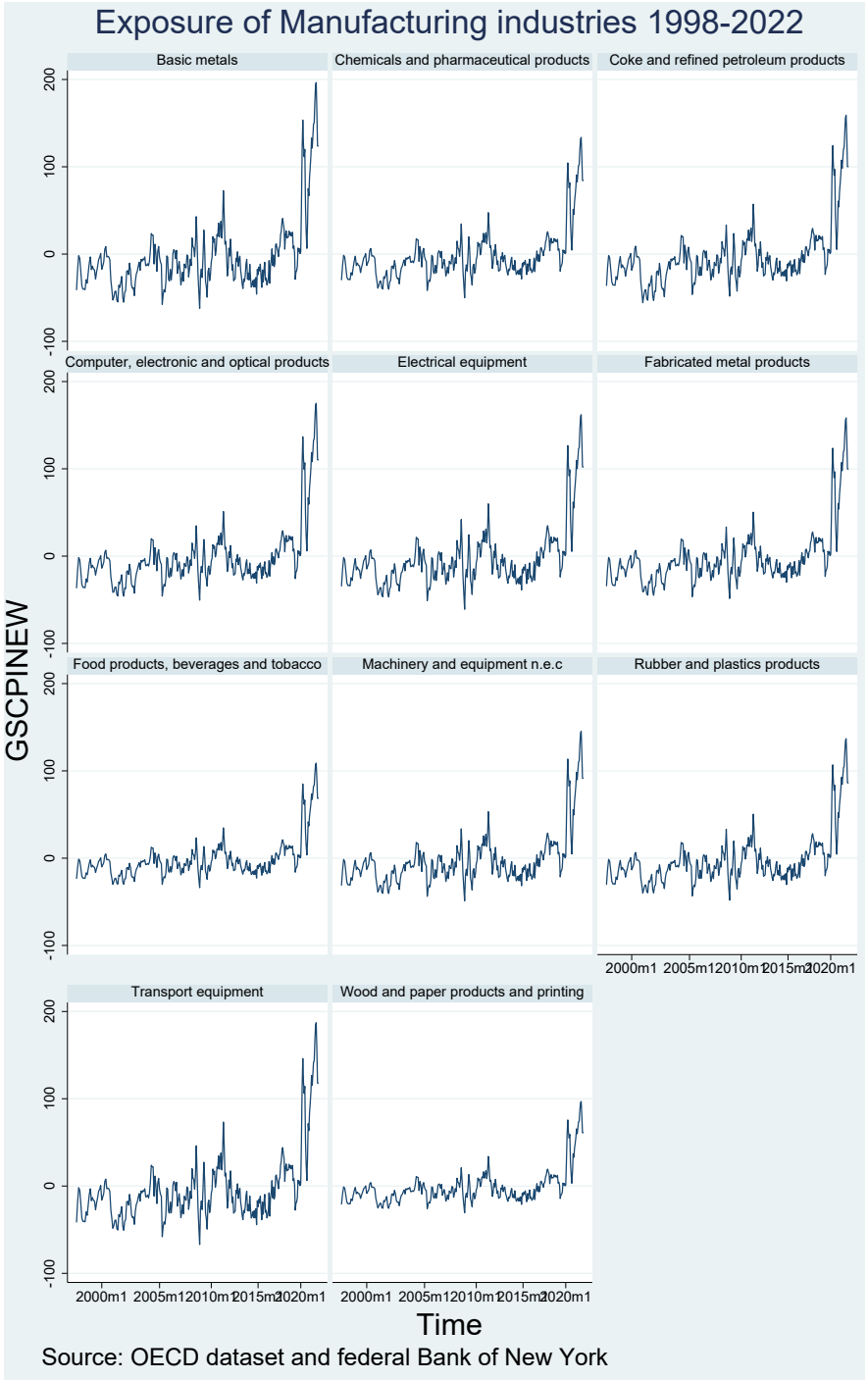


Figure A.1: the industry-level varying GSCPI of manufacturing industries

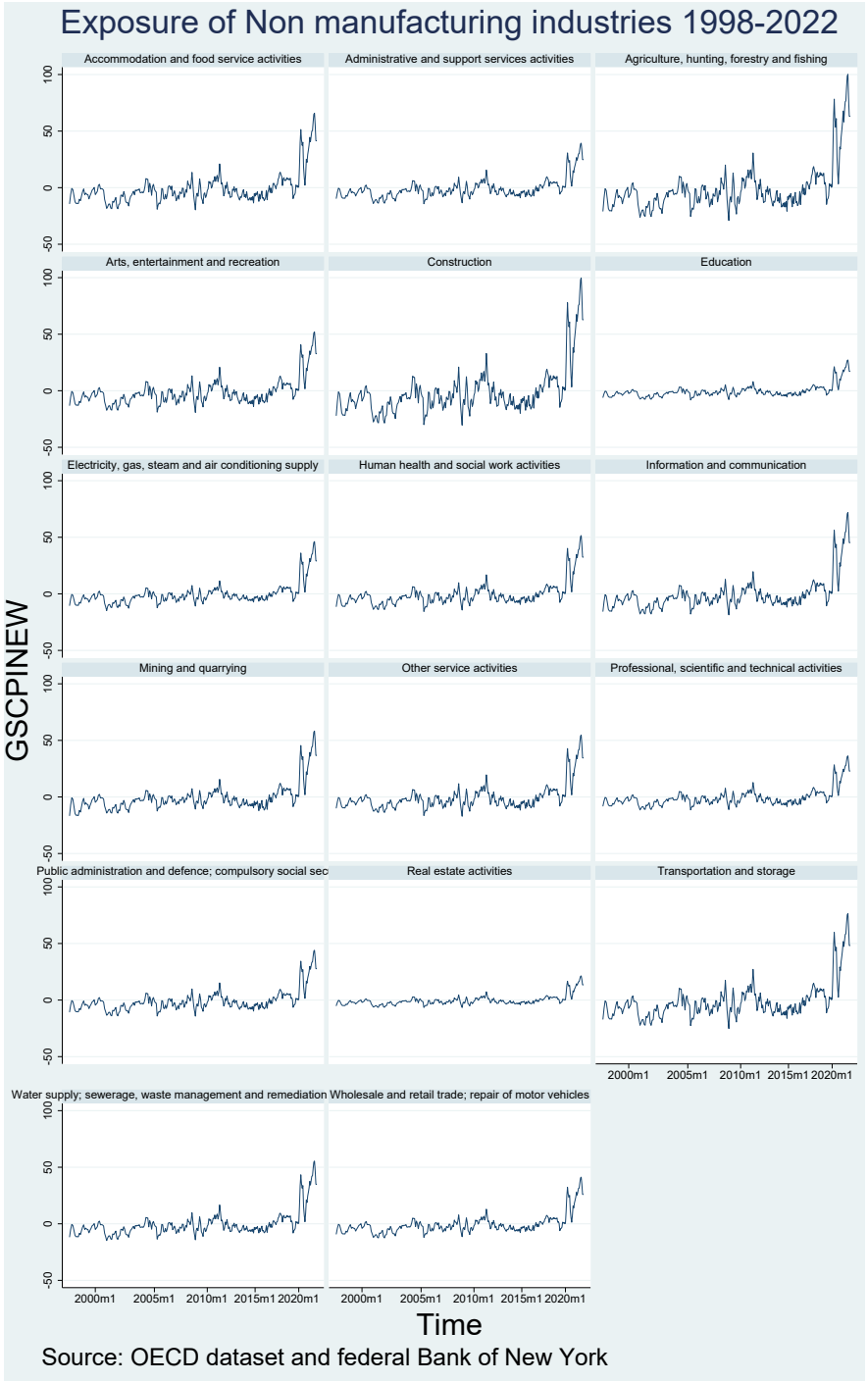


Figure A.2: the industry-level varying GSCPI of nonmanufacturing industries

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