

The Impact of Pandemic Control on GVCs and welfare: A Simulation Analysis Based on COVID-19

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Contents

- 1 Introduction
- 2 Theoretical Framework
- 3 Numerical Calculation

Research Background

Impacts of COVID-19 on global trade

- In 2020, global merchandise trade dropped by 7.4% and services trade by 20.0% (Source: *UNCTAD Handbook of Statistics 2021*)
- In 2020, global trade declined by 9.2% (Source: *WTO World Trade Report 2021*)

Research Background

The COVID-19 also exposed the vulnerability of GVCs

- Increasing transportation costs
- Affecting business profits, and offsetting the advantages brought by economies of scale and efficiency gains.
- The market price to ship a 40-foot container increased by up to 660% between 2020 and 2021.

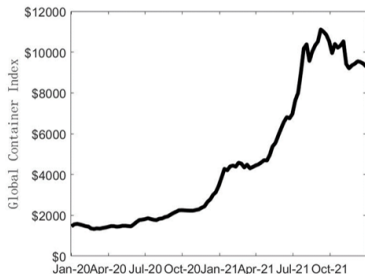


Figure 1: Global Container Index for 2020-2021

Research Question

The COVID-19 also exposed the vulnerability of GVCs.

- Dilemma of shortages of pharmaceutical products and medical equipments
- Huge impacts on industries that heavily rely on the GVCs

The existing GVC division system has undergone profound changes.

- Some countries and regions begin to reconsider the layout and security of their GVCs.

What is the potential impact of pandemic control on GVCs and welfare?

Trade in Value-Added and GVC Participation

- *Johnson and Noguera (2012); UNCTAD (2013); Aslam et al. (2017); Wang et al. (2017); Borin and Mancini (2019)*

Research on the Impact of Pandemic Control

- Measurement of Pandemic Control: *Hale et al.(2020);*
- Impact of Pandemic Control on Trade: *Berthou and Stumpner (2022); Guan et al.(2020); Bonadio et al.(2021); Espitia et al.(2021); Wang et al.(2021); Wuri et al.(2022,2023)*
- Impact of Pandemic Control on Welfare: *Leibovici and Santacreu(2020); Kaplan et al.(2020); Kikuchi et al.(2020); Liu et al.(2021); An and Ruan(2022); Hausmann and Schetter(2022); Antràs et al.(2023)*

Main findings

- Pandemic control has significantly affected the trade costs of all economies.
- Pandemic control leads to lower degree of GVC participation.
- The welfare analysis indicates an average global decline of 1.85% in welfare, with a corresponding decline of 0.51% for China.

Contents

- 1 Introduction
- 2 Theoretical Framework
- 3 Numerical Calculation

Quantitative Trade Model

- Quantitative Trade Model: Caliendo and Parro (2015)
- An extension of the improved Ricardo trade model by Eaton and Kortum (2002) and pioneeringly introduces intermediate goods trade, sectoral heterogeneity, and input-output linkages.
- Pandemic control shocks are defined as changes in trade costs.

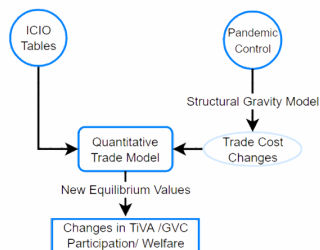


Figure 2: Research Framework

Model Settings

World economy: N -country, J -sector, 1-factor (labor)

- In each sector $s \in [1, 2, \dots, J]$ of country $n \in [1, 2, \dots, N]$:
 - There is a continuum of sector-specific intermediate goods $\omega^s \in [0, 1]$, produced from labor and composites of intermediate goods m^k , $k \in [1, 2, \dots, J]$.
 - m^k is a CES aggregate of intermediate goods sourced globally.

International Trade:

- Labor can move freely across sectors but is immobile across borders.
- Intermediate goods can be traded internationally and incur trade costs τ^s when crossing borders.

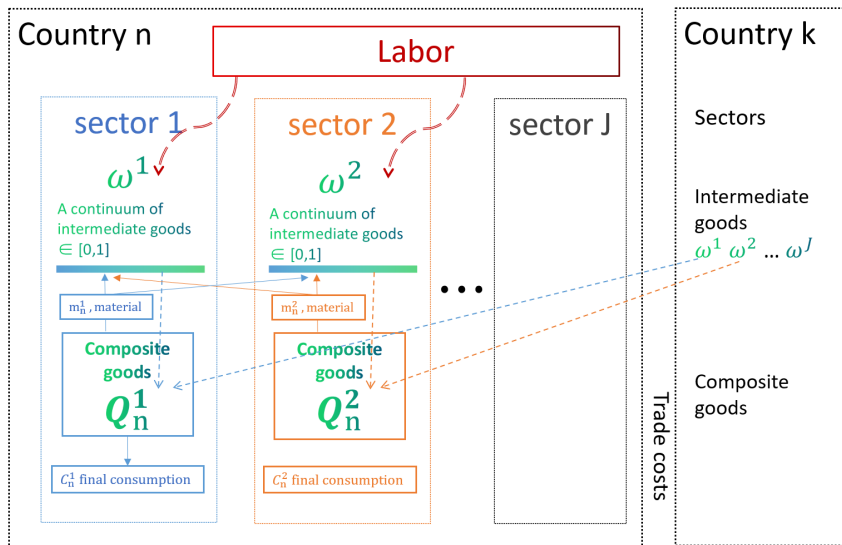


Figure 3: The model economy

Intermediate Goods

A continuum of intermediate goods is produced by firms in sector s .

e.g. s is clothing sector, ω^s can be cotton, silk, wool, nylon...

$$q_n^s(\omega^s) = z_n^s(\omega^s) l_n^s(\omega^s)^{\gamma_n^s} \prod_{k=1}^J [m_n^{s,k}(\omega^s)]^{\gamma_n^{s,k}}$$

$z_n^s(\omega^s)$: productivity of intermediate goods

$l_n^s(\omega^s)$: labor input

$m_n^{s,k}(\omega^s)$: composite intermediate goods from sector k ,

$k \in [1, 2, \dots, J]$.

Fréchet distribution: $F_n^s(z) = Pr [Z_n^s(\omega^s) \leq z] = e^{-T_n^s z^{-\theta^s}}$

Equilibrium Conditions

Cost of an input bundle: $c_n^s = \Upsilon_n^s w_n^{\gamma_n^s} \prod_{k=1}^J (P_n^k)^{\gamma_n^{s,k}}$

Price index:

$$P_n^s = \left[\Gamma \left(1 + \frac{1-\sigma^s}{\theta^s} \right) \right]^{1/(1-\sigma^s)} \left(\sum_{i=1}^N T_i^s (c_i^s \tau_{ni}^s)^{-\theta^s} \right)^{-1/\theta^s}$$

$$\text{Trade/expenditure share: } \pi_{ni}^s = \frac{T_i^s (c_i^s \tau_{ni}^s)^{-\theta^s}}{\sum_{i=1}^N T_i^s (c_i^s \tau_{ni}^s)^{-\theta^s}}$$

$$\text{Total expenditure: } X_n^s = \sum_{k=1}^J \gamma_n^{s,k} \sum_{i=1}^N \pi_{in}^k X_i^k + \alpha_n^s I_n$$

$$\text{Trade balance: } D_n = \sum_{s=1}^J \sum_{i=1}^N \pi_{ni}^s X_i^s - \sum_{s=1}^J \sum_{i=1}^N \pi_{in}^s X_n^s$$

Exact-Hat Algebra

For any variable x , let x' denote the variable after the policy shock, and $\hat{x} = x'/x$ represents the relative change in x

Calculate the relative changes in variables resulting from policy shocks

$$\hat{C}_n^s = \hat{w}_n^{\gamma_n^s} \prod_{k=1}^J (\hat{P}_n^k)^{\gamma_n^{k,s}}$$

$$\hat{P}_n^s = \left(\sum_{i=1}^N \pi_{ni}^s (\hat{C}_n^s \hat{T}_{ni}^s)^{-\theta^s} \right)^{-1/\theta^s}$$

$$\hat{\pi}_{ni}^s = \left(\frac{\hat{C}_n^s \hat{T}_{ni}^s}{\hat{P}_n^s} \right)^{-\theta^s}$$

$$X_n^{s'} = \sum_{k=1}^J \gamma_n^{s,k} \sum_{i=1}^N \pi_{ni}^{k'} X_i^{k'} + \alpha_n^s I_n'$$

$$D_n = \sum_{s=1}^J \sum_{i=1}^N \pi_{ni}^{s'} X_i^{s'} - \sum_{s=1}^J \sum_{i=1}^N \pi_{in}^s X_n^s$$

$$I_n' = \hat{w}_n w_n L_n + D_n$$

Welfare indicator

Real wages:

$$\frac{\hat{w}_i}{\hat{P}_i} = \frac{\hat{w}_i}{\prod_{s=1}^J \left(\frac{\hat{P}_i^s}{\alpha_i^s} \right)}$$

- Real wages reflect consumer welfare
- Under perfect competition and no tariff revenue, consumer welfare = total welfare

GVC Indicators

Value added export ratio (Johnson and Noguera, 2012):

$$\frac{VAX_i}{E_i} = \frac{\sum_{n \neq i}^N \sum_{s=1}^J VA_{ni}^s}{\sum_{n \neq i}^N \sum_{s=1}^J E_{ni}^s}$$

- A lower value of VAX ratio signifies that economy i relies more on intermediate goods from other economies, the involvement in the GVC division system is deeper.

GVC participation (Aslam et al., 2017):

$$GVCP_i = \frac{FVA_i}{E_i} + \frac{DVX_i}{E_i}$$

- When $\frac{FVA_i}{E_i}$ is higher, it indicates that economy i relies more on foreign intermediate use. When $\frac{DVX_i}{E_i}$ is higher, an economy's exports can better satisfy other economies' demand for intermediate use.

OECD-ICIO tables of 2021 version

- Coverage: 66 economies and 45 sectors each
- Time Span: 1995–2018

UN Comtrade

- Monthly bilateral merchandise trade data
- HS 2-digit level

Required Parameters:

- From OECD-ICIO tables: 1. Trade share 2. Intermediate goods share 3. Value added share 4. Sectoral consumption share
- By Regression: 5. μ
- Estimated by Caliendo and Parro (2015): 6. Sectoral trade elasticity θ

Trade Cost Specification

- Iceberg Costs: The trade cost of goods from sectors of exporter i to importer n is denoted as τ_{ni}^s ($\tau_{ni}^s > 1$)
- $\tau_{nit}^s = d_{ni} e^{\mu_n^s \text{stringency}_{nt} + \mu_i^s \text{stringency}_{it} + \beta x_{ni}}$
- d_{ni} : Physical distance between the two economies
- x_{ni} : Dummy variables that affect the bilateral trade (contiguity, common official language, common colonial history, and trade agreements)
- stringency_{nt} , stringency_{it} : Pandemic Control Index at time t
- μ_n^s : the sensitivity of trade costs to changes in the Pandemic Control Index

Pandemic Control Index

- Based on Stringency Index (Hale et al., 2020)
- Daily records of 9 discrete policy indicators:
 1. School closures
 2. Workplace closures
 3. Cancellation of public events
 4. Restrictions on public gatherings
 5. Closures of public transport
 6. Stay-at-home requirements
 7. Public information campaigns
 8. Restrictions on internal movements
 9. International travel controls
- Each indicator has a discrete range (e.g., 0–2, 0–3)
- Daily Index = Average of 9 indicators

Key Explanatory Variable

- Time span:
1/22/2020-12/31/2022
- The key explanatory variable
Pandemic Control Index
 stringency_{nt} is given by averaging
the Stringency Index on a monthly
basis and then dividing by 100.
- Value range: 0-1

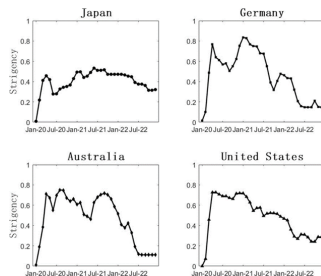


Figure 4: Pandemic Control Index of Sample Economies

The Case of China

- Unlike other economies, China consistently maintained a high Pandemic Control Index throughout these 3 years.
- This value remains stable at a relatively high level of 0.7.

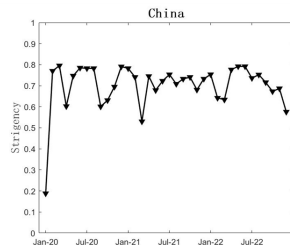


Figure 5: Pandemic Control Index of China

Specification of Regression

$$\frac{X_{nit}^s}{X_{wit}^s} = e^{-\theta^s \mu_n^s \text{stringency}_{nt} + \gamma_{ni}^s + \delta_t^s} + \varepsilon_{nit}^s$$

$$\frac{M_{int}^k}{M_{iwt}^k} = e^{-\theta^k \mu_i^k \text{stringency}_{it} + \gamma_{in}^k + \delta_t^k} + \varepsilon_{int}^k$$

- Due to a large number of 0 values in trade values, Poisson Pseudo Maximum Likelihood (PPML) estimation is adopted.
- $\frac{X_{nit}^s}{X_{wit}^s}$, $\frac{M_{int}^k}{M_{iwt}^k}$: Export/Import share
- μ_n^s : Trade cost elasticity
- γ_{ni}^s : Economy-pair fixed effect
- δ_t^s : Time fixed effect
- θ^s : Trade elasticity by Caliendo and Parro (2015)

Regression Result for μ

- Monthly bilateral merchandise trade data for the top 30 economies at HS 2-digit level
- Time span: January 2020 - December 2021

Table 1: Coefficient for Subsample Regression Equation

Sector	$-\theta^s \mu_n^s$	$-\theta^k \mu_i^k$
Agriculture	-0.256***	0.021
Food	-0.093*	-0.100**
Mining	-0.086	0.025
Petroleum	-0.142*	0.091
Chemicals&Medical	0.06	0.027
Textile	-0.187***	-0.443***
Wood	-0.034	-0.312***
Paper	-0.160***	-0.077**
Mineral	-0.01	-0.278***
Metal	-0.319***	-0.126**
Machinery	-0.132***	-0.336***
Electrical	-0.179***	-0.308***
Transport	-0.581***	-0.148
Electronic&Optical	-0.027	-0.178***

Regression Result for μ

Table 2: Trade Cost Elasticity Coefficient

Sector	μ^s	μ^h	Sector	μ^s	μ^h
Agriculture	0.032	-0.003	Minerals	0.003	0.101
Food	0.037	0.039	Basic Metals	0.040	0.016
Mining	0.005	-0.002	Metal Products	0.074	0.029
Petroleum	0.003	-0.002	Machinery	0.087	0.221
Chemicals&Medical	-0.012	-0.005	Electrical	0.017	0.029
Plastic	0.069	0.137	Transport	0.116	0.030
Textile	0.034	0.080	Electronic&Optical	0.002	0.014
Wood	0.003	0.029	Other Manufacture	0.031	0.033
Paper	0.018	0.008	Services	0.031	0.033

- The relative changes of trade costs after the pandemic is given by
$$\widehat{\tau}_{nit}^s = e^{\widehat{\mu}_n^s \Delta \text{stringency}_{nt}} + \widehat{\mu}_i^s \Delta \text{stringency}_{it}$$
- The value of $\widehat{\tau}_{nit}^s$ depends on μ and the Pandemic Control Index for both economies.

Contents

- 1 Introduction
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- 3 Numerical Calculation**

Simulation Scenario

According to the values of Pandemic Control Index:

- January 2020 - December 2021: Global pandemic control maintained at a high level.
- December 2022 - Present: China also reopens, and the world enters the post-pandemic era.

Each economy takes its own average level of Pandemic Control Index between 2020 and 2021 (mean value 0.537), simulating the effects of pandemic control during the outbreak.

Impact on Trade Costs

The actual data in 2018 from OECD-ICIO tables is set as the base year values. By introducing relative changes in trade costs into the model, we can compare the changes in various indicators before and after the pandemic control.

For China, pandemic control results in a 3.57% increase in trade costs as an importer and a 4.92% increase as an exporter.

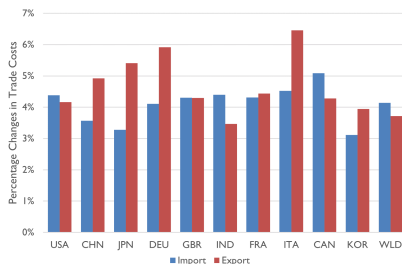


Figure 7: Percentage Changes in Trade Costs for Main Economies

Impact on Trade in Gross

The world average trade values decrease by 11.23%

For China, imports decrease by 12.50%, and exports decrease by 12.00%.

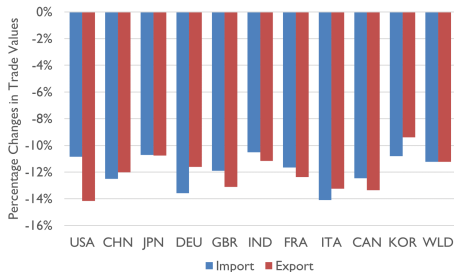


Figure 8: Percentage Changes in Trade Values

Impact on GVCs

$\frac{VAX_i}{E_i}$ (Johnson and Noguera, 2012), When VAX ratio is lower, the involvement in the GVC division is deeper

$GVCP_i = \frac{FVA_i}{E_i} + \frac{DVX_i}{E_i}$ (Aslam et al., 2017), the degree of GVC participation for each economy decreases.

By calculation, the indicators of TiVA and GVC participation are close to that of 2009.

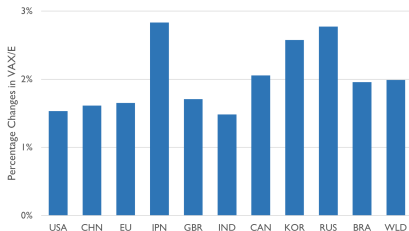


Figure 9: Percentage Changes in VAX/E

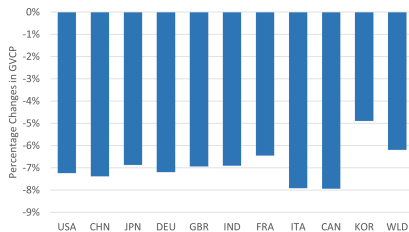


Figure 10: Percentage Changes in GVCP

Impact on Welfare Levels

$\frac{w_n}{P_n}$ real wages, indicator of an economy's welfare level

For China, real wages drop by 0.51%.

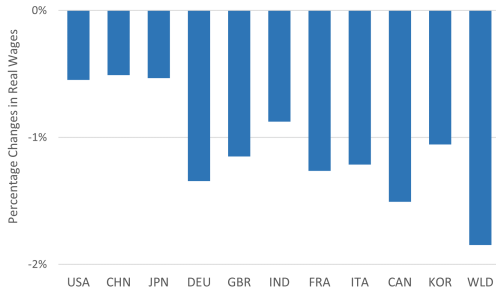


Figure 11: Percentage Changes in Real Wages

Impact on Welfare Levels

The welfare effects of pandemic control are enhanced as the trade openness of economies increases.

From the GVC perspective, the welfare effects of pandemic control are enhanced as the GVC participation of economies increases.

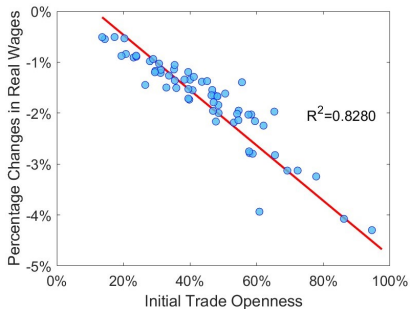


Figure.12: Impact of Trade Openness on Welfare Effects of Pandemic Control

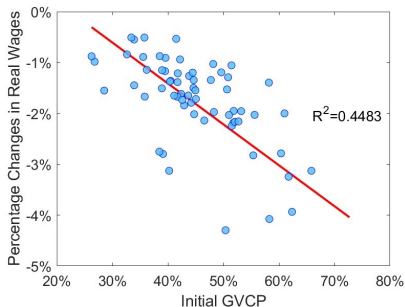


Figure.13: Impact of GVCP on Welfare Effects of Pandemic Control

Conclusion

- The pandemic control has significantly increased the trade costs and reduced the global trade values.
- Pandemic control has reduced the GVC participation.
- Pandemic control has lowered the welfare levels. Pandemic control has an adverse effect on the welfare levels of various economies by reducing the input of foreign intermediate goods, and this effect will increase as the degree of trade openness and GVC participation.

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Thanks