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Propagation of Epidemics' Economic Impacts via Production Networks: The Cases of China and ASEAN during SARS and COVID-19*

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Abstract

Two decades after the SARS outbreak, Asia is confronted with COVID-19 which has caused a greater economic impact to the region. In this paper, using China and the ASEAN's experiences of SARS and COVID-19 as a case study, we aim to identify the economic impact of a pandemic that is associated with global production linkages. We construct a novel general equilibrium model of production networks with epidemiological dynamics. Calibrating the model with the OECD inter-country input-output tables for the pre-SARS and pre-COVID-19 periods, and controlling for disease dynamics across years, we find that, in the absence of policy intervention, greater importance of China in the global value chains is associated with greater economic impacts, both within China and in the ASEAN region. Our sensitivity analyses further show that China's containment efforts reduce the spillover effects to the ASEAN.

Keywords: COVID-19, Production Network, China, SIR Model
JEL classification: E2, F1, I1

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1 Introduction

Two decades after the outbreak of the Severe Acute Respiratory Syndrome (SARS), Asia was confronted again with Coronavirus Disease 2019 (COVID-19). As of June 6 2020, based on data from the World Health Organization, 6.8 million people have been infected with COVID-19 with 400,000 deaths worldwide. Similar to the SARS episode, soon after the COVID-19 outbreak in China, countries in the Association of Southeast Asian Nations, commonly known as the ASEAN, was one of the first regions affected due to its close geographical proximity, business travel, tourism and supply chain links to China. Aside from the human costs shown in Fig. 1, economies had also suffered. Comparing between the SARS and COVID-19 episodes, Fig. 2 shows more synchronized decline in GDP growth at the beginning of the COVID-19. Some have ascribed the heavier economic damage to the higher contagiousness of the coronavirus, while others have attributed it to the government mandated lockdowns around the world. There has also been a debate on whether China's increasing importance in the global value chains (GVCs) contributed to the current global economic downturn. Nevertheless, the jury is still out on the reason behind COVID-19's greater impact.

In this paper, we focus on one specific transmission channel. We ask: *What is the role of international production networks in the propagation of an epidemic's economic impact?* We derive the answers from the experiences of China and the ASEAN during the SARS and the COVID-19 periods.

Thus far, existing empirical analyses on the impact of disease outbreaks have faced a few challenges. Firstly, each epidemic, for example, the SARS or the 1918 Spanish Flu, has unique characteristics. They could differ in terms of the degrees of contagiousness, or the spreading media. Without sufficient incidents of such pandemics, it is difficult to control for these characteristics in an empirical analysis. An implication of this challenge is that findings from historical events may not be applicable for emerging new epidemics. Secondly, production and consumption linkages between and within countries have evolved. Taking China as an example, its growing importance in the GVCs was coupled with an expanding services sector domestically (Liao, 2020). The simultaneously evolving international and domestic economic conditions raise challenges in pinning down the transmission channels for economic impact.

This paper provides an analysis via a set of counter-factual simulations, which is particularly suited for singling out a specific transmission channel. For this purpose, all we need is the ability in an analytical framework to control for the variables mentioned previously. We construct a multi-country and multi-sector model with production networks. An SIR-Macro framework proposed by Eichenbaum et al. (2020) is used to capture the epidemiological dynamics. With the SIR-Macro model, we calibrate the population dynamics so that human costs of the disease outbreak are the same across scenarios, thus addressing the challenge of different disease char-

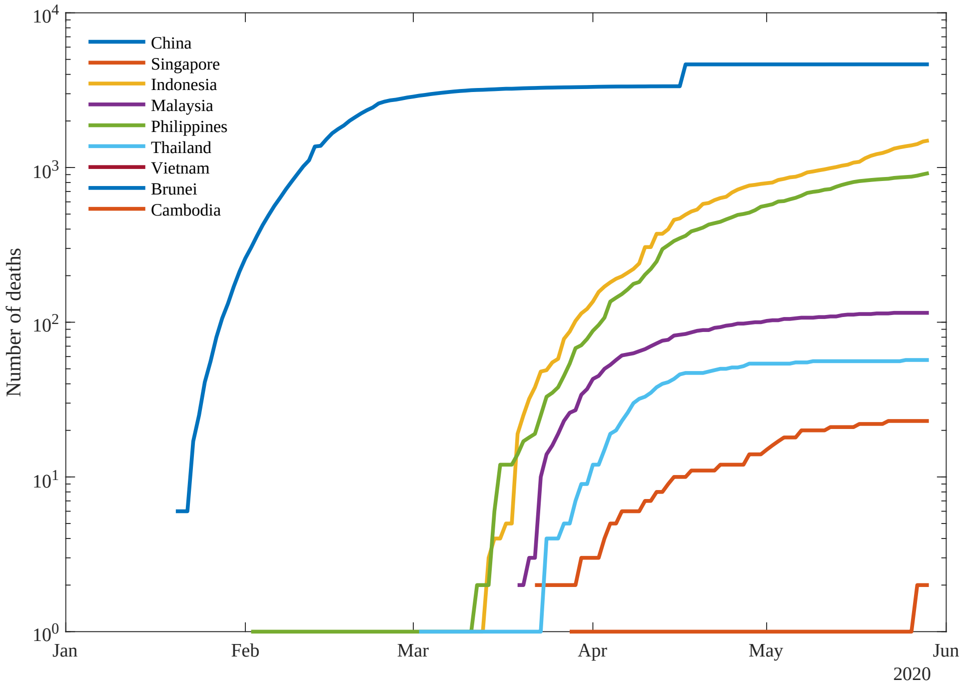

Figure 1: Cumulative death cases of COVID-19 in China and ASEAN.

acteristics. We then focus on sectoral dynamics using the framework proposed by Krueger et al. (2020): agents voluntarily substitute consumption in the more contagious sectors with those in the less contagious sectors. The setup of global production networks eventually allows this reallocation effect to propagate among trading partners. While calibrating the model, we choose the pre-SARS and pre-COVID-19 years as the normal-time scenarios. In the case of China and the ASEAN, this two time periods are largely similar in terms of domestic consumption and output patterns, but the latter is characterized by more integrated GVC networks. With these in hand, we have a toolkit for analyzing the transmission of an epidemic's economic impacts via global production networks.

We contribute to the growing discussion of the macroeconomic impact of COVID-19 in the context of production networks. Baqaee and Farhi (2020), Bonadio et al. (2020), and Luo et al. (2020) examine the impact on aggregate output based on the US economy. Perhaps the most closely related studies are Çakmaklı et al. (2020); Luo and Tsang (2020). Çakmaklı et al. (2020) consider the context of a small and open economy with trade and capital flows. Luo and Tsang (2020) study the impact on the world due to a shortage of labor in China. In our model, we do not assume exogenous shocks in macroeconomic variables, but an exogenous disease shock in population dynamics. All dynamics in the macroeconomic variables are outcomes of economic agents' welfare-maximizing behaviors following the disease outbreak.

Our innovation is also in the synthesized study of historical global pandemics. As mentioned, due to heterogeneity in disease characteristics, conclusions from historical analyses are

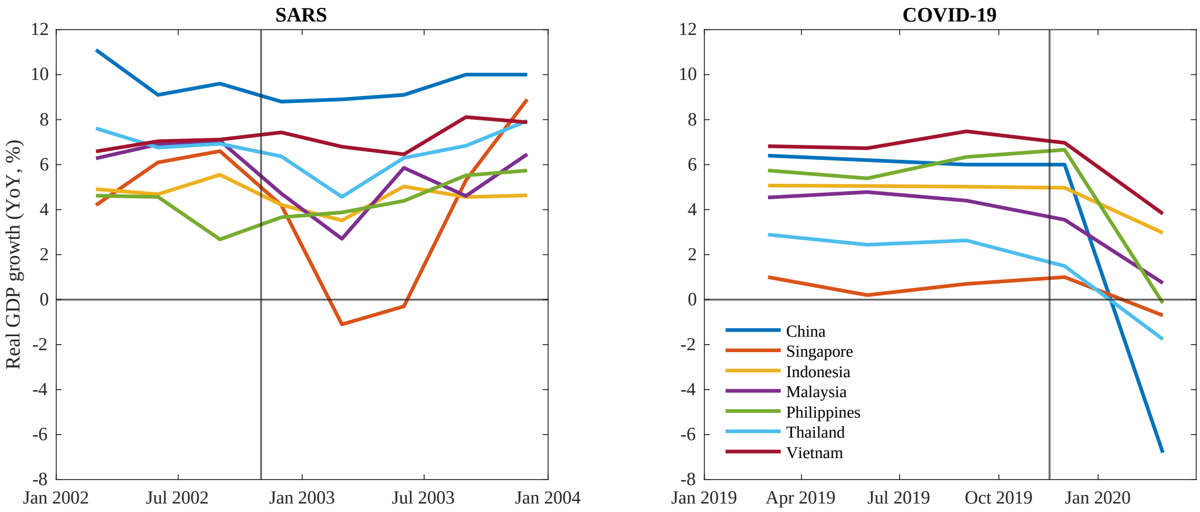

Figure 2: Real GDP of China and the ASEAN countries: Year-on-Year Change. The vertical lines indicate the dates of first cases.

often not applicable to new events, unfortunately. Case studies on China and the ASEAN are perhaps among the exceptions due to their common experiences in the SARS and COVID-19, as well as the similarity between the two viruses. It is opportune and instructive to make comparisons between now and then, and across countries on the economic impacts. By simply tweaking the infection parameters, our counter-factual simulations facilitate such comparisons by providing controlled settings across the two events. It is also possible for our model to be calibrated against actual population dynamics in a specific event.

The main findings of the paper show that the increasingly integrated production networks would contribute to the greater economic impacts of COVID-19. This is seen from three aspects. First, the within-country economic impacts on China during the time of COVID-19 is greater than during the SARS period, whereas the ASEAN would experience similar impact across the years. Second, despite the limited sizes, the spillover effects between China and ASEAN are larger during COVID-19 than during SARS. We argue that this is a result of evolving production linkages and trading patterns. Third, containment efforts in China helped reduce economic costs in the ASEAN.

Before proceeding to the remainder of the paper, it is equally important for our readers to bear in mind that the model presented in this paper is only a stylized one. Such simplicity is necessary for us to understand the transmission mechanism via the production networks, which is the key objective of ours. Producing empirically precise results, however, requires models in which the interactions are too complicated to be disentangled. We therefore leave the more complicated models for future research.

The remainder of the paper is organized as follows. Section 2 provides some facts on recent trends in global value chains, particularly in China and the ASEAN. Section 3 describes the model. Section 4 discusses the results from our simulations. Section 5 conducts sensitivity analyses on parameter values. Section 6 concludes.

2 China and ASEAN in the Global Value Chains

In the recent two decades, both China and the east Asian countries have worked towards building more integrated production networks (Huang et al., 2017), with more emphases on regional collaborations.

China has become an important demand and supply hub in international trade and GVC networks in recent years. According to UNIDO (2018), China is at the heart of GVCs for many goods and both at supply and demand. For instance, China has a huge consumer market for global commodities and industrial products. Meanwhile, it is primary producer of many high-value intermediate and final products. China has a relative high GVCs participation rate with a value of 34.8 in 2015. GVCs participation indicates an economy's exports that is part of multistage production process of goods and services, by adding to the foreign value added used in exports and domestic value added supplied to partner economy's exports. GVCs participation rate is measure of a country's involvement international production networks.

If one looks at the change of GVCs participation of China with the world in Fig. 3, it has a decreasing trend. China's forward GVCs participation rate rises from 15.6 in 2005 to 17.5 in 2015. The forward GVCs participation corresponds to the ratio of domestic value added sent to third economies to the economy's total exports. It captures the domestic value added contained in inputs sent to third economies to further processing and export through value chains. Increasing forward GVCs indicates that China is moving toward a more upstream position in production network by strengthening its domestic value added in exports. However, backward GVCs participation rate of China decreases from 26.3 to 17.3 percent over the decade. Backward GVCs participation is known as the ratio of foreign value added content of exports to the economy's total exports. It indicates an economy's reliance on foreign inputs. In total,the declining GVCs participation of China in the world is driven by the shrinkage in backward participation. China is participating more in the regional production network rather than global network. As shown in Fig. 3, the value chain participation ratio between China and ASEAN increases from 4.8 in 2005 to 5 in 2015 due to increasing forward participation ratio from China to ASEAN. However, the GVCs participation of China with ROW declines from 2005 to 2015.

As the top trade partner of China, ASEAN has been moving towards becoming a highly integrated and cohesive economy, by participating more in GVCs and international trade. In 2015, ASEAN accounted for 7.2 percent of global exports and 6.6 percent of global imports. Of the total ASEAN exports, 28.2 percent comprised of foreign value added. It is crucial to recognise the role of China as an important source of value added in ASEAN, especially in

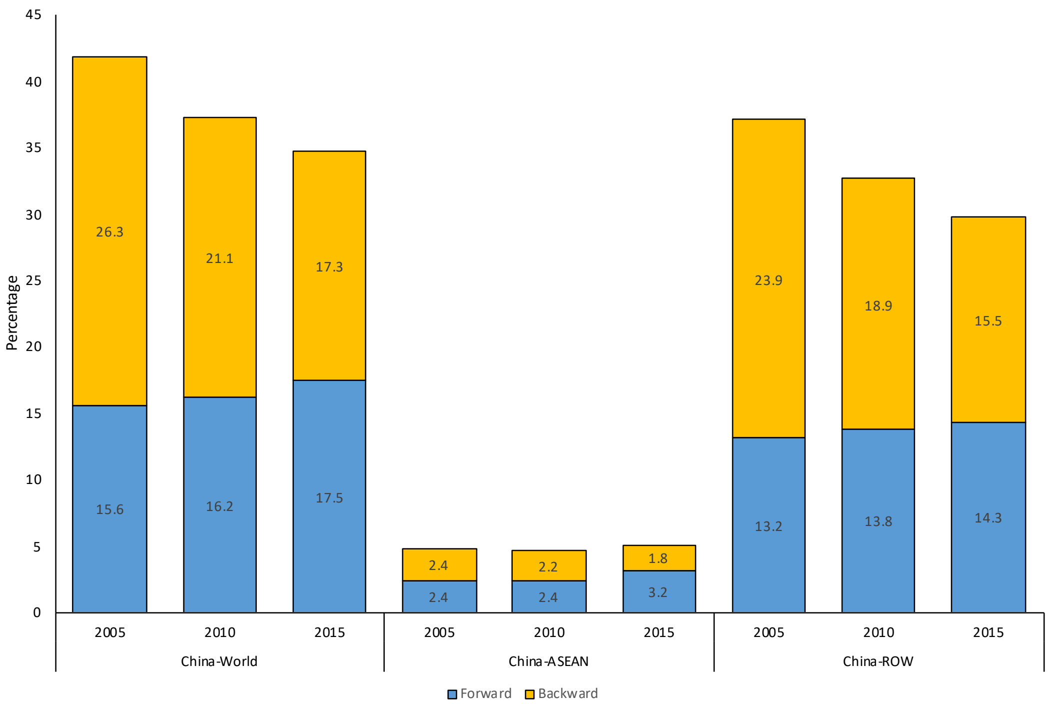

Figure 3: Value chain participation of China.
Source: OECD TiVA database

the goods sector. As shown in Fig. 4, China's share in the foreign value added content of the ASEAN's exports of goods increased from 3.6 percent in 2005 to 8 percent in 2015. The increase in China's share in the foreign value added of ASEAN's services is relatively smaller, from 0.9 percent to 2.1 percent. In other words, inputs from China became more important for ASEAN's exports in both goods and services sectors. In addition to the increasing trend in the share of foreign value added from China, there is a high and stable ratio of domestic and intra-regional value added in exports. This is mainly because of the deeper regional integration and growing intra-regional trade, which has allowed countries to specialize and create favorable conditions for trade in intermediate goods and services within ASEAN.

ASEAN has a relatively high GVCs participation rate, with a value of 45.9 in 2015 (see Figure 5; ASEAN-World). GVCs participation rate of ASEAN has been declining over time on account of lower backward GVCs participation as shown in Fig. 5. The region's forward GVCs participation stays consistently below backward participation, indicating the economy's greater involvement in downstream activities. While GVCs participation from ASEAN to the world declined, the value chain linkages between ASEAN and China have strengthened from 2005 to 2015. The increase in the ratio is primarily driven by backward participation, which is consistent with the previous argument that inputs from China increasingly contributes to ASEAN's value added exports. In contrast, backward ratio between ASEAN and rest of the world (ROW) falls from 28.5 in 2005 to 22.7 in 2015.

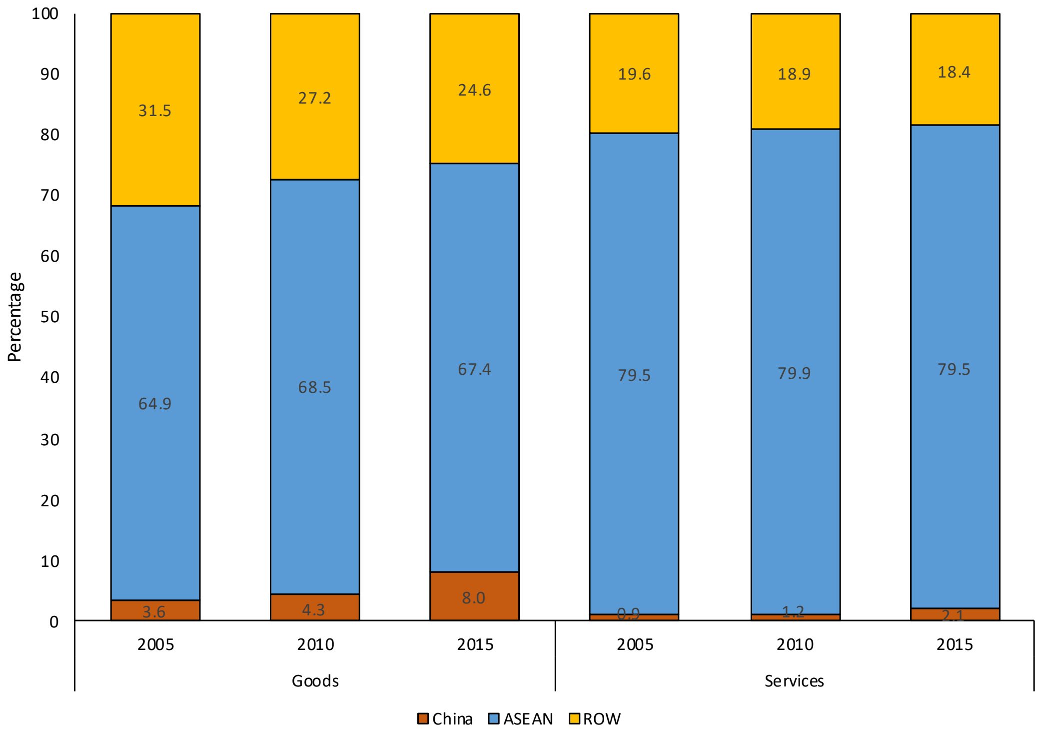

Figure 4: Value added of ASEAN exports by origin in goods and service sectors.
Source: OECD TiVA database

Aside from the international production networks, ASEAN countries have been integrated into a regional production network. Regional value chains (RVCs) are a part of GVCs. From 2005 to 2015, RVCs of ASEAN increased from 13.6 to 15.2 while GVCs decreased from 48.4 to 45.9. Overall, Fig. 5 shows that ASEAN countries seem to place more emphasis on regional production networks (with China and intra-ASEAN) over time, than with ROW.

We have therefore seen that the ASEAN and China have become more closely related in the recent years. This closer tie has important implications for the spillover of epidemic shocks. As we will soon put forward, epidemic shocks leads to reallocation of economic activities in an economy. Due to the production network that exists between two economies, the reallocation in one leads to varying demands for final and intermediate goods from another. As a result, the evolving role of one economy in the GVCs may lead to different impact across time.

3 A Model with International Production Networks

We construct a general equilibrium model with multiple countries and multiple sectors. During normal time, agents consume from all sectors of the economy which sell composite items produced by domestic and foreign firms. At the same time, households supply labor to domestic firms of all sectors. The firms produce heterogeneous outputs, using labor from the households

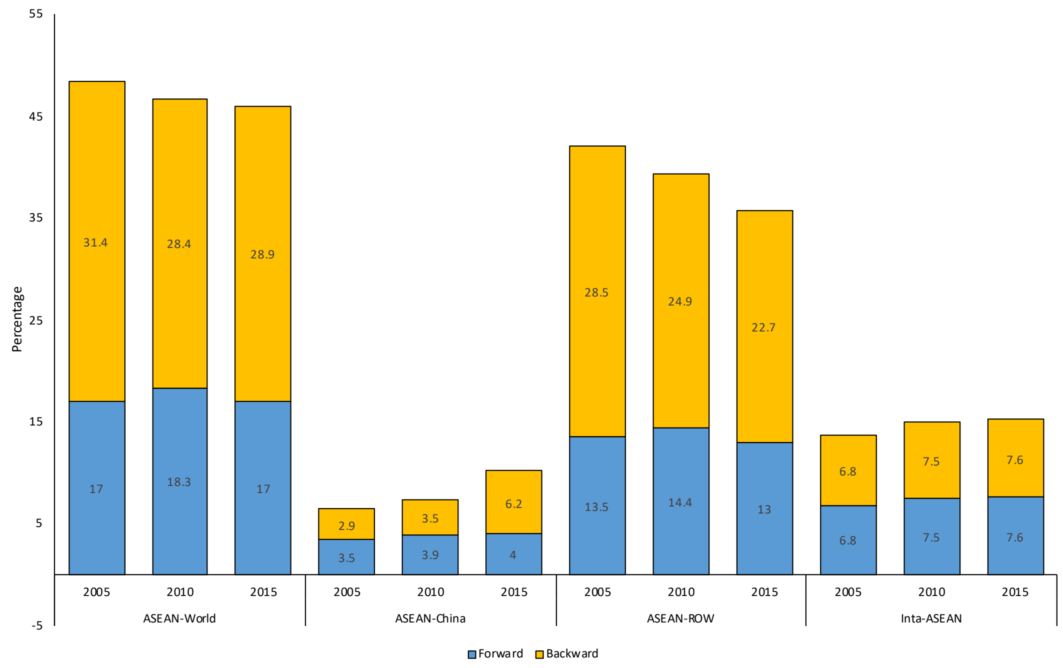

Figure 5: Value chain participation of ASEAN.
Source: OECD TiVA database and UNCTAD-Eora Global Value Chain Database

and intermediate outputs from all sectors of the economy. The intermediate outputs can be domestically produced or imported. The market is competitive. Nominal variables, including prices, wages, and nominal exchange rates, are assumed to be constant.

In the event of a pandemic, agents become heterogeneous as some of them contract the disease. Agents contract the disease while interacting with infected agents participating in the same consumption activity. The mechanism follows Eichenbaum et al. (2020). In addition, following Krueger et al. (2020), we differentiate the economic sectors by the degree of consumer interaction. A sector is said to be more infectious if consumers in this sector need to extensively interact among themselves, and vice versa. By consuming goods from the high-infection sectors, an agent faces increased risk of contracting the disease which reduces future welfare. All agents are initially susceptible. Upon contracting the disease, they become infected, who subsequently recover or decease. Susceptible, infected, and recovered agents behave differently due to their different utility functions. The aggregate economic outcomes are the resultant interactions of all agents.

3.1 Normal time

A representative agent in country ℓ derives utility from a consumption bundle and disutility from supplying labor. The agent's lifetime utility is given by

$$U_0(\ell) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t u\left(C_t(\ell), N_t(\ell)\right) \tag{1}$$

$$u\left(C_t(\ell), N_t(\ell)\right) = \log C_t(\ell) - \frac{\theta(\ell)}{2} N_t(\ell)^2 \tag{2}$$

where β is the discount factor, $C_t(\ell)$ is an aggregate of goods from all sectors, and $N_t(\ell)$ is the labor supply to domestic firms. The consumption bundle is a CES aggregate of goods from all sectors indexed by j:

$$C_t(\ell) = \left(\sum_j \upsilon(j,\ell)^{\frac{1}{\eta}} \cdot c_t(j,\ell)^{1-\frac{1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{3}$$

where $\upsilon(j,\ell)$ is the share of sector-j goods in the consumption basket, $\sum_j \upsilon(j,\ell) = 1$, and $c_t(j,\ell)$ is country ℓ's demand for goods from sector j. η is the elasticity of substitution across varieties of goods. Sector-j goods are packaged by an entrepreneur who aggregates the same goods from around the world

$$c_t(j,\ell) = \left(\sum_m \upsilon^*(j,\ell,m)^{\frac{1}{\zeta}} \cdot c_t^*(j,\ell,m)^{1-\frac{1}{\zeta}}\right)^{\frac{\zeta}{\zeta-1}} \tag{4}$$

where $\upsilon^*(j,\ell,m)$ is the share of sector-j goods imported from country m, $\sum_m \upsilon^*(j,\ell,m) = 1$, and $c_t^*(j,\ell,m)$ is country ℓ's final demand for sector-j goods produced in country m. When $\ell \neq m$, goods are imported from country m to country ℓ. ζ is the elasticity of substitution among goods of different origins. Assume that all prices equal to 1. The budget constraint of the agent in country ℓ is

$$\sum_j c_t(j,\ell) + b_t(\ell) = w_t(\ell) \cdot N_t(\ell) + \pi_t(\ell) \tag{5}$$

where $b_t(\ell)$ is the holding of net foreign assets. $w_t(\ell)$ is the nominal wage. $\pi_t(\ell)$ is the transfer payment from the government. Firms produce output using domestic labor and intermediate outputs from all sectors

$$y_t(j,\ell) = A(j,\ell) \cdot n_t(j,\ell)^{1-\alpha(j,\ell)} \cdot \left(\prod_{k,m} z_t(k,m,j,\ell)^{\gamma(k,m,j,\ell)}\right)^{\alpha(j,\ell)} \tag{6}$$

where $A(j,\ell)$ is the level of technology. $n_t(j,\ell)$ is the labor input for sector j. The intermediate output $z_t(k,m,j,\ell)$ are produced by sector k in country m for use in sector j in country ℓ. Similar to the case of consumption, when $\ell \neq m$, the intermediate goods are imported, and when $k \neq j$, the intermediate output is produced by a different sector. $\gamma(k,m,j,\ell)$ is the share in intermediate output required for production. $\alpha(j,\ell)$ is the share of intermediate outputs in all inputs of production. The firms' objective is to maximize the profits

$$\max_{n,z} y_t(j,\ell) - w_t(\ell) \cdot n_t(j,\ell) - \sum_{k,m} z_t\left(k,m,j,\ell\right) \tag{7}$$

Under perfect competition, firms set price at the marginal cost of production:

$$1 = \frac{1}{A(j,\ell)} \left(\frac{w_t(\ell)}{1-\alpha(j,\ell)}\right)^{1-\alpha(j,\ell)} \prod_{k,m} \left(\frac{1}{\alpha(j,\ell) \cdot \gamma(k,m,j,\ell)}\right)^{\alpha(j,\ell)\cdot\gamma(k,m,j,\ell)} \tag{8}$$

The nominal wage is constant and is a function of $A(j,\ell)$. Maximize Eq. (7) subject to Eq. (6). The first-order conditions posits that for any sector-k intermediate output from country m, the marginal product of labor equals the marginal product of any intermediate output:

$$\frac{\partial y_t(j,\ell)}{\partial n_t(j,\ell)} = \frac{\partial y_t(j,\ell)}{\partial z_t(k,m,j,\ell)} \tag{9}$$

The goods market clears when the supply of sector-j goods meets the demand, consisting of intermediate outputs demanded by domestic and foreign firms of all sectors, and consumption goods demanded by domestic and foreign households, less a lump-sum tax collected by the government:

$$y_t(j,\ell) = \sum_{k,m} z\left(j,\ell,k,m\right) + \sum_{m} c_t^*\left(j,m,\ell\right) - \pi_t \tag{10}$$

The clearing condition in the labor market is

$$\sum_{j} n_t(j,\ell) = N_t(\ell) \tag{11}$$

The international asset market clears when $\sum_\ell b_t(\ell) = 0$.

3.2 Epidemic

We now describe agents' behavior during an epidemic. There are four types of agents in the society, namely, susceptible, s, infected, i, recovered, r, deceased, d. A susceptible agent may contract the disease while interacting with an infected agent in any market j. The probability of getting infected is given by the aggregate risk from all consumption activities:

$$\tau_t(\ell) = \pi_s(\ell) I_t(\ell) \sum_j \phi(j, \ell) \cdot c_t^s(j, \ell) \cdot c_t^i(j, \ell) \tag{12}$$

where $\pi_s(\ell)$ is general risk of infection in country ℓ. $I_t(\ell)$ is the size of the infected population. $\phi(j, \ell)$ measures the degree of interaction in market j. $c_t^s(j, \ell)$ and $c_t^i(j, \ell)$ are sectoral consumption as defined in Eq. (4), with the superscripts indicating the agent types. As in Krueger et al. (2020), the degree of interaction has a mean value 1:

$$\sum_j \upsilon(j, \ell) \cdot \phi(j, \ell) = 1 \tag{13}$$

The newly infected agents in each period come from the group of susceptible people, and is given by:

$$T_t(\ell) = \tau_t(\ell) S_t(\ell) \tag{14}$$

As a result, the population dynamics evolve according to the following equations:

$$S_t(\ell) = S_{t-1}(\ell) - T_{t-1}(\ell) \tag{15}$$

$$I_t(\ell) = I_{t-1}(\ell) + T_{t-1}(\ell) - (\pi_r + \pi_d) I_{t-1}(\ell) \tag{16}$$

$$R_t(\ell) = R_{t-1}(\ell) + \pi_r I_{t-1}(\ell) \tag{17}$$

$$D_t(\ell) = D_{t-1}(\ell) + \pi_d I_{t-1}(\ell) \tag{18}$$

At the beginning of the pandemic, we assume that a very small proportion of the population contract the disease from an unknown source. This is represented by the initial state: $I_0(\ell) = \varepsilon$, $S_0(\ell) = 1 - \varepsilon$, $R_0(\ell) = D_0(\ell) = 0$.

Susceptible Lifetime utility of a susceptible household is expressed in the following Bellman equation:

$$U_t^s(\ell) = u\left(C_t^s(\ell), N_t^s(\ell)\right) + \beta\left[\left(1 - \tau_t(\ell)\right) U_{t+1}^s(\ell) + \tau_t(\ell) U_{t+1}^i(\ell)\right] \tag{19}$$

In the next period, with a probability $\tau_t(\ell)$, a susceptible agent contracts the disease and becomes an infected agent, while with a probability $1 - \tau_t(\ell)$, the agent remains susceptible. Maximize

Eq. (19) subject to Eqs. (5) and (12). The first-order conditions are:

$$v(j,\ell)^{\frac{1}{\eta}} \cdot \frac{1}{C_t^s(\ell)} \left(\frac{C_t^s(\ell)}{c_t^s(j,\ell)}\right)^{\frac{1}{\eta}} - \theta N_t^s(\ell) = \pi_s(\ell)\lambda_{\tau,t}(\ell) \cdot I_t(\ell) \cdot \phi(j,\ell) \cdot v(j,\ell) \cdot C_t^i(\ell) \tag{20}$$

$$\beta\left(U_{t+1}^i(\ell) - U_{t+1}^s(\ell)\right) + \lambda_{\tau,t}(\ell) = 0 \tag{21}$$

where $\lambda_{\tau,t}$ is the Lagrangian multiplier for the constraint 12.

Infected and recovered Lifetime utility of an infected household

$$U_t^i(\ell) = u\left(C_t^i(\ell), N_t^i(\ell)\right) + \beta\left[(1 - \pi_r - \pi_d)\, U_{t+1}^i(\ell) + \pi_r U_{t+1}^r(\ell) + \pi_d \times 0\right] \tag{22}$$

With a probability π_r, the agent recovers. The agent may also die with probability π_d. In the event of death, the agent derives zero utility. First-order condition is:

$$v(j,\ell)^{\frac{1}{\eta}} \frac{1}{C_t^i(\ell)} \left(\frac{C_t^i(\ell)}{c_t^i(j,\ell)}\right)^{1/\eta} = \theta N_t^i \tag{23}$$

Note that the right-hand side of the equation is independent of j. The solutions to Eq. (23) are

$$c_t^i(j,\ell) = v(j,\ell) \cdot C_t^i(\ell) \tag{24}$$

$$N_t^i(\ell) = \frac{1}{\theta} \cdot \frac{1}{C_t^i(\ell)} \tag{25}$$

Lifetime utility of a recovered agent

$$U_t^r(\ell) = u\left(C_t^r(\ell), N_t^r(\ell)\right) + \beta U_{t+1}^r(\ell) \tag{26}$$

It can be shown that the solutions to a recovered agent's problem are the same as an infected agent's. In what follows, we use superscript i to represent a recovered agent's consumption and labor supply.

Equilibrium The market clearing conditions in Eqs. (10) and (11) are rewritten as follows, taking into account the population dynamics:

$$y_t(j,\ell) = \sum_{k,m} z(j,k,\ell,m) + \sum_m S_t(m) \cdot c_t^{*s}(j,m,\ell) + [I(m) + R(m)] \cdot c_t^{*i}(j,m,\ell) - \pi_t(j,\ell) \tag{27}$$

$$\sum_j n_t(j,\ell) = S_t(\ell) N_t^s(\ell) + (I_t + R_t)\, N_t^i(j,\ell) \tag{28}$$

By Walras' law, the net foreign assets sum to 0

$$\sum_{\ell} S_t(\ell)b_t(\ell) + [I_t(\ell) + R_t(\ell)] \left[w_t N_t^i(\ell) + \pi_t(\ell) - \sum_j c_t^i(j, \ell) \right] = 0. \tag{29}$$

3.3 Data and Parameterization

Our main data source is the inter-country input-output table (ICIO) database from the Organisation for Economic Co-operation and Development (OECD). There are 67 economies in the ICIO, including China and eight countries from the ASEAN, each with 36 sectors. The ASEAN countries included in the ICIO are Brunei Darussalam, Indonesia, Cambodia, Malaysia, Philippines, Singapore, Thailand, and Viet Nam. The table describes the input-output linkages between any pair of sectors from the same or different countries. In this paper, we are particularly interested in the linkages among sectors in China and in the ASEAN economies.

The parameters pertaining to the steady state of the model are calibrated using the ICIO. Since the region experienced both the SARS and the COVID-19, we compare the economic environments prior to both disease outbreaks. For the impact of the SARS episode, we choose 2002 to be the base year, since the SARS outbreak happened in early 2003. For the COVID-19 outbreak, we choose 2015, which is slightly earlier than the beginning of COVID-19. Two reasons explain our choice of base year for the COVID-19 episode. Firstly, according to Luo and Tsang (2020), the later half of the 2010s saw a series of events that disturbed the global trade patterns, particularly the trade war. Data from a slightly earlier year help capture a normal-time scenario prior to the disease outbreak. Secondly, the Chinese economy has undergone a transformation with increasing concentration of services sectors taking over the manufacturing sectors since early 2010s. We find that in year 2015, the distribution of goods and services sectors within China was largely similar to that in the pre-SARS period. As we are interested in the different impacts due to cross-nation production networks, this similar distribution of domestic sectors helps minimize any effects that could arise from a changing domestic economic landscape. In the remainder of the paper, since we calibrate the disease dynamics to be the same, the terms 'SARS' and 'COVID-19' merely refer to the time when they happened.

We reduce the dimensions in the ICIO in this paper. We keep the elements for China, and aggregate those for the ASEAN countries. All elements of the other countries are grouped as the Rest of the World (ROW). The sectors are grouped into two broad sectors, namely the goods and the services. The detailed groupings are summarized in Appendix B. Since the original ICIO tables are expressed in nominal terms, we rebase the values for the pre-SARS period to 2015 dollar by multiplying them with the gross world consumer price inflation between 2002 and 2015. The inflation data is obtained from the World Bank, and the deflator is found to be 1.62. The reduced input-output tables in 2015 price are shown in Tables 1 and 2. Notably,

Table 1: Three-country two-sector input-output table, pre-SARS (US$ trillion, 2015p).

		China		ASEAN		ROW		Final demand			Total use
		Goods	Services	Goods	Services	Goods	Services	China	ASEAN	ROW	
China	Goods	2.018	.468	.015	.002	.158	.049	1.325	.006	.190	4.231
	Services	.479	.379	.003	.002	.033	.023	.836	.005	.087	1.847
ASEAN	Goods	.028	.001	.547	.127	.146	.039	.011	.445	.134	1.477
	Services	.006	.001	.157	.209	.038	.033	.005	.407	.073	.929
ROW	Goods	.239	.006	.160	.021	14.345	5.332	.091	.062	16.279	36.535
	Services	.074	.009	.062	.047	7.616	14.927	.042	.057	31.416	54.250
Value added		1.387	.983	.534	.521	14.199	33.848				51.471
Total inputs		4.231	1.847	1.477	.929	36.535	54.250	2.310	.982	48.179	150.741

Table 2: Three-country two-sector input-output table, pre-COVID-19 (US$ trillion, 2015p).

		China		ASEAN		ROW		Final demand			Total use
		Goods	Services	Goods	Services	Goods	Services	China	ASEAN	ROW	
China	Goods	9.768	1.145	.111	.017	.711	.255	5.886	.044	.848	18.785
	Services	2.348	2.101	.009	.004	.059	.040	3.737	.005	.095	8.398
ASEAN	Goods	.116	.012	1.211	.277	.223	.072	.036	.998	.229	3.174
	Services	.017	.007	.356	.503	.051	.102	.021	.923	.111	2.091
ROW	Goods	.893	.070	.241	.038	18.222	5.807	.301	.104	19.803	45.479
	Services	.155	.064	.083	.100	7.910	19.455	.199	.103	38.259	66.328
Tax less subsidies		.688	.354	.030	.015	.940	.649	.568	.057	2.352	5.653
Value added		4.798	4.645	1.134	1.138	17.362	39.948				69.024
Total inputs		18.785	8.398	3.174	2.091	45.479	66.328	10.748	2.233	61.696	218.933

outputs in both China and the ASEAN have expanded faster than the ROW between pre-SARS to pre-COVID-19 periods. We also see that the ASEAN has used more intermediate inputs from China for production.

Two sets of parameters are calculated based on the input-output tables in Tables 1 and 2, corresponding to the pre-SARS and the pre-COVID-19 periods respectively. The steady-state parameters are summarized in Tables 4 to 6. On the consumption side, Table 4 calculates the shares of consumption by source and by sector. These values correspond to parameters $\upsilon^*(j, \ell, m)$ and $\upsilon(j, \ell)$. The shares of goods in China and the ASEAN's consumption baskets have remained similar between the pre-SARS and pre-COVID-19 periods, at 0.62 and 0.53, respectively. On the production side, the labor share parameters, $1 - \alpha(j, \ell)$, are shown in Table 5. China experienced a decline in labor share in the goods sector, and a slight increase in the services sector. Whereas, in the ASEAN and the ROW, there have been slight declines in the labor share in their services sectors. In Table 6, we show the shares of intermediate inputs $\gamma(k, m, j, \ell)$. Cells for domestic intermediate inputs are shaded for ease of reading. We see that China has used less intermediate inputs from outside the country, with the decline being larger for intermediate inputs from the ROW. For production in the ASEAN, more intermediate inputs were from China, while less were from the ROW.

There is a measure for forward and backward linkages which captures the relationship be-

Table 3: Table of Linkages for China and ASEAN

	CHN goods				CHN services			
	Forward Linkage	R^2	Backward Linkage	R^2	Forward Linkage	R^2	Backward Linkage	R^2
Pre-SARS	1.19	1.87	1.23	1.75	1.00	1.50	.98	1.53
Pre-COVID-19	1.18	1.96	1.30	1.78	1.05	1.49	.87	1.74
	ASEAN goods				ASEAN services			
	Forward Linkage	R^2	Backward Linkage	R^2	Forward Linkage	R^2	Backward Linkage	R^2
Pre-SARS	1.08	1.58	1.12	1.50	.93	1.49	.87	1.59
Pre-COVID-19	1.07	1.58	1.13	1.50	.93	1.48	.89	1.59

tween a particular sector j and other industries from which it purchases or supplies input to. The derivations are presented in Appendix A. The linkages of China and ASEAN are given in Table 3. China services' backward linkages decreased from pre-SARS period to pre-COVID-19 period (0.98 to 0.87), implying increased independence, and is less reliant on ASEAN and the rest of the world upstream. Furthermore, its R^2 value increased from 1.53 to 1.74, implying more uneven trading with the different economies. This supports the observation that China participates more unevenly in trade, with an increasing importance in ASEAN and less with the world. For the same period, ASEAN goods backward linkage, and services forward and backward linkages, all increased from pre-SARS period to pre-COVID-19 period. It became more integrated with other industries, supporting the claim that ASEAN has become more integrated with China in the GVCs.

To calibrate the country-specific labor preference parameter $\theta(\ell)$, we make use of the representative agent's first-order condition with respect to labor supply:

$$\theta(\ell) = \frac{1}{C(\ell) \cdot N(\ell)}. \tag{30}$$

The productivity parameters, $A(j, \ell)$'s, are calibrated according to Eq. (8).

We calibrate the parameters for the degree of consumer interactions using the labor market proximity index, following Çakmaklı et al. (2020), shown in Appendix B. The proximity index measures the distance between workers in 36 industries. We adopt this index for household consumption, as Krueger et al. (2020) have shown that infection via the labor market is isomorphic to that in the consumption market. We transform the proximity index so that the numbers are normally distributed with mean 1. Let δ_j be the original proximity index for sector j. The normalized proximity index is calculated as $\delta_j^n = \frac{\delta_j - \mu_\delta + 1}{\sigma_\delta} \sim N(1, 1)$, where μ_δ is the mean value of the original proximity index, and σ_δ is the standard deviation. We then calculate the

Table 4: Shares of consumption by source and sector

ℓ	m \ j	Pre-SARS				Pre-COVID-19			
		Goods		Services		Goods		Services	
		$v^*(j,\ell,m)$	$v(j,\ell)$	$v^*(j,\ell,m)$	$v(j,\ell)$	$v^*(j,\ell,m)$	$v(j,\ell)$	$v^*(j,\ell,m)$	$v(j,\ell)$
	China	.929		.947		.946		.944	
China	ASEAN	.008	.618	.006	.382	.006	.611	.005	.389
	ROW	.064		.048		.048		.050	
	China	.010		.011		.039		.005	
ASEAN	ASEAN	.867	.522	.867	.478	.871	.527	.895	.473
	ROW	.123		.122		.091		.100	
	China	.011		.003		.041		.002	
ROW	ASEAN	.008	.345	.002	.655	.011	.352	.003	.648
	ROW	.980		.995		.948		.995	

Table 5: Labor shares in total inputs, $1-\alpha(j,\ell)$.

	Pre-SARS		Pre-COVID-19	
	Goods	Services	Goods	Services
China	.328	.532	.265	.577
ASEAN	.362	.561	.361	.548
ROW	.389	.624	.390	.608

Table 6: Shares of intermediate inputs, $\gamma(k,m,j,\ell)$.

k	j / m \ ℓ	China		ASEAN		ROW	
		Goods	Services	Goods	Services	Goods	Services
Pre-SARS							
China	Goods	.710	.542	.016	.005	.007	.002
	Services	.169	.438	.004	.005	.001	.001
ASEAN	Goods	.010	.001	.580	.313	.007	.002
	Services	.002	.001	.166	.512	.002	.002
ROW	Goods	.084	.007	.170	.051	.642	.261
	Services	.026	.010	.066	.115	.341	.732
Pre-COVID-19							
China	Goods	.735	.337	.055	.018	.026	.010
	Services	.177	.618	.005	.004	.002	.002
ASEAN	Goods	.009	.003	.602	.296	.008	.003
	Services	.001	.002	.177	.536	.002	.004
ROW	Goods	.067	.021	.120	.040	.671	.226
	Services	.012	.019	.041	.106	.291	.756

Table 7: Table of $\phi(j,\ell)$ values

ℓ	j	$\upsilon(j,\ell)$	δ^n_j	$\phi(j,\ell)$
		Pre-SARS		
China	Goods	.618	.710	.704
	Services	.382	1.491	1.478
ASEAN	Goods	.522	.710	.656
	Services	.478	1.491	1.376
ROW	Goods	.345	.710	.581
	Services	.655	1.491	1.220
		Pre-COVID-19		
China	Goods	.611	.710	.701
	Services	.389	1.491	1.471
ASEAN	Goods	.527	.710	.658
	Services	.473	1.491	1.381
ROW	Goods	.352	.710	.584
	Services	.648	1.491	1.226

mean normalized proximity index for groups of goods and services sectors, respectively. The country-invariant normalized proximity index of sector j, δ^n_j is used with country ℓ's sectoral market shares $\upsilon(j,\ell)$, to calculate the country sectoral-specific value of $\phi(j,\ell)$ according to

$$\phi(j,\ell) = \frac{\delta^n_j}{\sum_j \upsilon(j,\ell)\cdot\delta^n_j} \tag{31}$$

and presented in Table 7. Eq. (13) is hence satisfied.

The calibration of π_r, and π_d follows Eichenbaum et al. (2020). The initial size of the infected population is $\varepsilon = 0.001$. The values of $\pi_s(\ell)$ are such that each country's infection curve is peaked at 1% of the population. Such a specification controls the spread of the disease in each economy. Specifically, the values of $\pi_s(\ell)$ are calibrated to be 6.4×10^{-8} and 3.77×10^{-7} for the pre-SARS period, and 9.95×10^{-9} and 2.33×10^{-7} for the pre-COVID-19 period, for China and the ASEAN respectively. The model is numerically solved in Dynare 4.6.1 using the perfect foresight solver. In what follows, we examine the economic impacts of different scenarios of disease outbreaks.

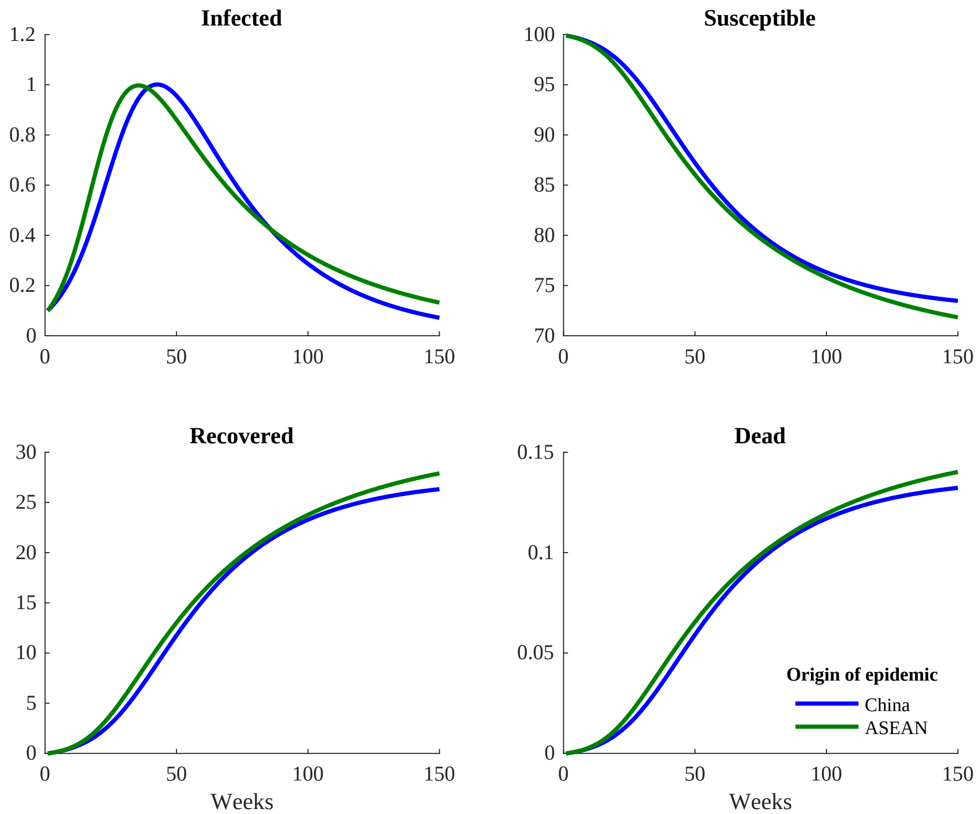

Figure 6: SIRD model population dynamics in China and ASEAN following a single country epidemic.

4 Numerical Results

4.1 Epidemic in a Single Country

An epidemic occurs in the country when a small fraction (ε) of the susceptible population is infected by a disease from an unknown source. The population dynamics following the initial disease outbreak are detailed from Eq. (16) to Eq. (18). Fig. 6 shows the hypothetical population dynamics during a single country epidemic in China and ASEAN at the time of COVID-19. The blue line in Fig. 6 depicts the equilibrium population dynamics in China following an epidemic in China. The green line in Fig. 6 shows the equilibrium population dynamics in ASEAN following an epidemic in ASEAN. We control the population dynamics, so that the infected population peaks at 1% . This is done by adjusting the $\pi_s(\ell)$ values for individual countries.

The slight differences in the population dynamics are due to the different sectoral distributions in China and in the ASEAN seen in Table 4. In China, the infected population peaks at around 1% of the population in 47 weeks and thereafter falls with fewer susceptible population. Infected population peaks earlier for ASEAN at 36 weeks. A larger services sector in the ASEAN causes the infected numbers to increase faster, and to decay slower. Percentage of susceptible population declines at a faster rate in the ASEAN when compared to China. For all single country epidemics, the recovery rate edges to around 30% of the population in the long run. For a disease outbreak during the time of SARS, the population dynamics are set to be the same as in Fig. 6.

4.1.1 Within-country Impacts

Our first simulation exercise examines the within-country impact of an epidemic. In Fig. 7, we show China's responses to an epidemic in China (blue lines) and the ASEAN's responses to an epidemic in the ASEAN (green lines). We conduct the simulations for the SARS period (dashed lines) and the COVID-19 period (bold lines).

The immediate effect of the epidemic is seen from the changes in consumption of goods and services. Due to different degrees of contagiousness, consumers choose to consume in the sector that is less infectious in the event of an epidemic. As a result, consumption of goods increased while that of services declined. Because we assume constant prices and nominal exchange rate, the imports for goods and services consumption declined by exactly the same magnitudes as domestic goods and services consumption respectively. The overall effect on consumption is a decline. In general, the ASEAN experienced larger impacts than China at the sectoral level, but smaller impacts in aggregate. This result implies that consumers in the ASEAN substitute services consumption with goods consumption more extensively, mitigating the adverse effect at the aggregate level. Comparing between the SARS and the COVID-19 periods, one finds the impacts were greater during the COVID-19 period, and were more distinct in the case of China as seen from the wider gaps between the bold and dashed lines in blue.

Accordingly, a larger domestic demand for the goods sector increases the imports of goods for final consumption. Imports of inputs (both goods and services) to goods sector output also increased. The rise in imports was felt more in ASEAN in both periods when compared to China.

The changes in consumption induced dynamics in sectoral industrial outputs. As expected, the 'highly infectious' services sector output declines and the 'less infectious' goods sector output rises when faced with an epidemic in both China and ASEAN. The relative rise (decline) in goods (services) sector output is larger in ASEAN than China. It is interesting to note that there is not much difference to ASEAN response to 'own' country epidemic (both services and goods sector output) in both periods. However, we see that China's response to an own country epidemic is larger in the COVID-19 period. In particular, response of China's goods sector revolved around the steady state in the SARS period. In principle, these equilibrium dynamics are jointly explained by domestic and foreign consumption demand. From a comparison between China's domestic demand for goods and services, we see negligible change across the two periods. Therefore, foreign demands for consumption and production are likely to account for the different impact of the epidemic in within China.

Similar to the case of consumption, the imports of inputs for goods sector output response is largely muted for China in the SARS period. On the other hand, imports of services for final consumption and imports of inputs for services production decline with the largest dip felt by ASEAN in the COVID-19 period.

The rise in goods sector output of China causes the total exports for final consumption to increase in the COVID-19 period. However, exports for final consumption in ASEAN witnesses a slight dip in COVID-19 as service sector exports decline. Although exports for final consumption rise for China in COVID-19, the decline in aggregate consumption leads to the furthest decline in the aggregate output of China in COVID-19.

Two observations can be summarised from this set of results. Firstly, the substitution effects between goods and services are stronger in ASEAN than in China, due to the larger services sector in the ASEAN. Secondly, across time, an epidemic has lead to greater impact on China during COVID-19 than during SARS. In the next set of results, we examine the spillover effect across countries.

4.1.2 Cross-country Impacts

Our second set of results examines the spillover effect of one country's epidemic shock to another. The responses of the macroeconomic variables are shown in Fig. 8. This entails China's response to an epidemic in ASEAN (blue lines) and ASEAN's response to an epidemic in China (green lines). We conduct the simulations for the SARS period (dashed lines) and the COVID-19 period (bold lines).

On account of the epidemic, a lower demand for the 'highly infectious' services and a higher demand for the 'less infectious' goods arise from the 'other' country. Hence, the immediate impacts we observe are a rise in goods sector output and a decline in services sector output.

The epidemics in China have led to some interesting dynamics in the ASEAN. Overall consumption in the ASEAN increased in both the SARS period and COVID-19 period. Two factors have contributed to the rise in consumption; labor hours and net foreign assets. First, we see from Fig. 8 that in both periods, ASEAN's labor hours fell as the decline in service sector output outweigh the rise in goods sector output. Second, we also see that ASEAN experienced a fall in the net foreign assets in both periods. Net foreign assets in our model is equivalent to net exports (both inputs and final goods). Hence, the contraction in ASEAN's net foreign assets can be attributed to the lower services demand from China. The dynamics of labor hours and net foreign assets affect total consumption through the budget constraint in Eq. (5). With wage normalized as one and no change in transfers from the government, the relatively bigger decline in net foreign assets in comparison to labor hours caused total consumption to fall in ASEAN.

Comparing between the SARS and COVID-19 periods, we notice that the impacts are in

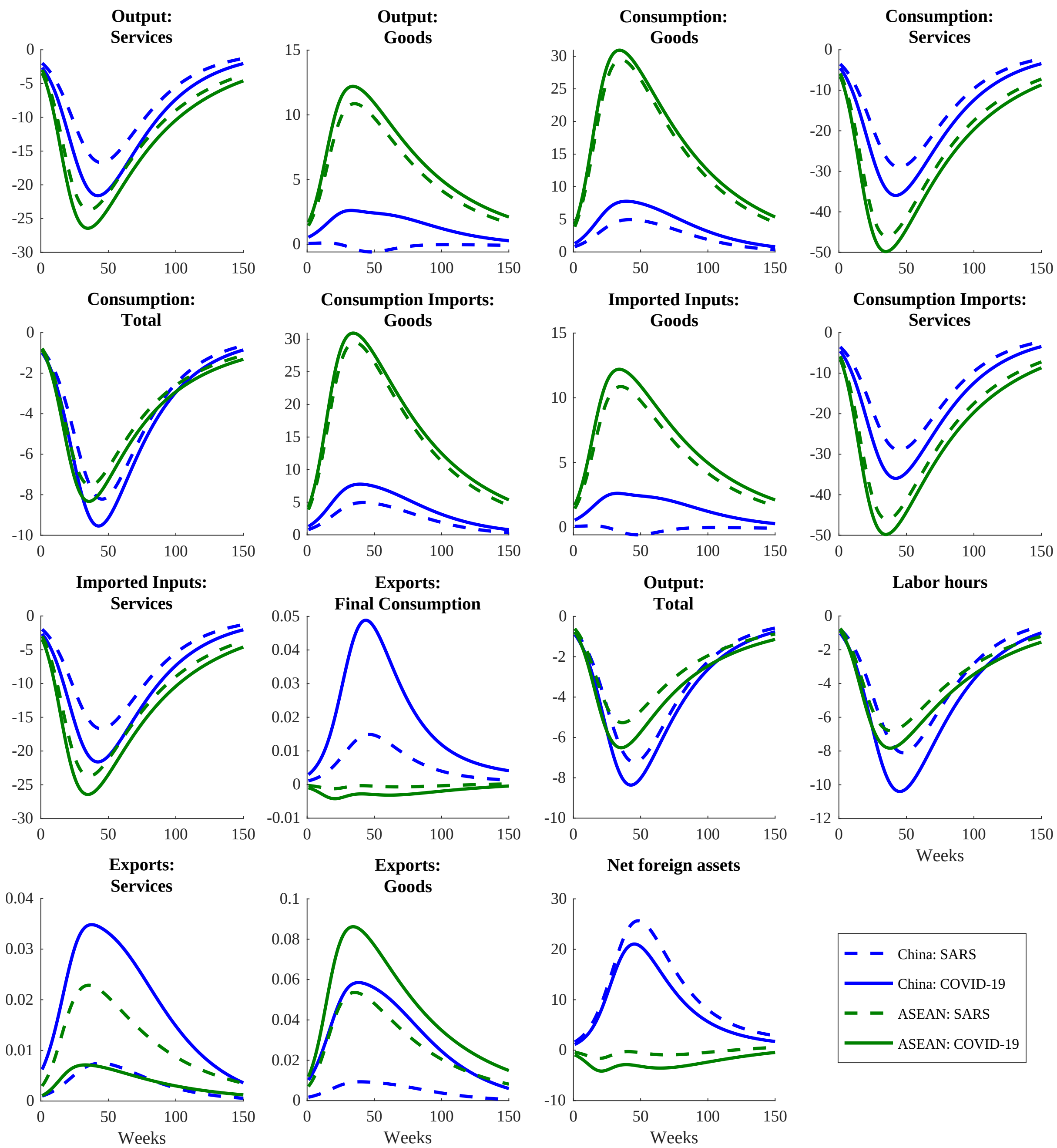

Figure 7: Within-country response to an epidemic.

Note: Green lines indicate ASEAN's response to an epidemic in ASEAN. Blue lines indicate China's response to an epidemic in China. Bold lines refer to COVID-19 period and dashed lines refer to SARS period. X axis represents weeks and Y axis represents percentage deviation from the initial state.

general larger for ASEAN during the later period. Two reasons have led to this outcome. First, China consumed more goods during the COVID-19 period than the SARS period as shown in the third panel of Fig. 7. As China's goods sector accounted for more than 60% of overall consumption, this increase in goods consumption translated into huge increase in the demand for the ASEAN's goods output. Second, the ASEAN's goods sector relies more on China's intermediate inputs during the COVID-19 period than the SARS period. This is seen from Table 6 in which the intermediate inputs from China for the ASEAN's goods production increased from 1.6% to 5.5%. As China's goods output increased, so did the supply of intermediate inputs for the ASEAN's production. The increased use of intermediate inputs from China further increased the impacts. The combined effect of demand- and supply- side factors together explain the substantial increase in the ASEAN's goods output. The larger decline in the ASEAN's services sector output, on the other hand, was mainly pulled by China's decreased demand for services. Although the services sector in the ASEAN also used more intermediate inputs from China's goods sector, this supply-side effect is not large enough to offset the drop in demand during the COVID-19 period.

China experienced smaller impacts from disease outbreaks in the ASEAN. The main difference lies in the fact that the increased goods demand from the ASEAN causes China to accumulate net foreign assets. Larger demand for goods sector output also increased the labor hours in China. The relatively larger rise in net foreign assets than labor hours caused aggregate consumption in China to decline through Eq. (5). Across the two periods, China imported less from ASEAN for final consumption, while the ASEAN had imported more goods from China. The increased exports from China to the ASEAN meant that during an epidemic, as the ASEAN increased its consumption of goods, China benefited from increased goods production and total output.

4.2 Response to a pandemic

A pandemic arises when ASEAN and China face an epidemic simultaneously. The path of the population dynamics are similar to Fig. 6. Hence, there are no observable spillover effects of the population dynamics across countries when a pandemic occurs. In Fig. 9, we see the response of China (blue lines) and ASEAN (green lines) to a pandemic. The dynamics of Fig. 9 closely follows the dynamics of Fig. 7 for all variables except for exports for final consumption, services exports, goods exports and net foreign assets. This indicates the dominance of own country effects (own country epidemic) over cross country effects (other country epidemic). Exports are primarily driven by the demand from the ”other country”. Hence, we see that cross country effects has a larger impact on exports and net foreign assets. Dynamics of exports for final consumption, services exports and goods exports in Fig. 9 resemble Fig. 8.

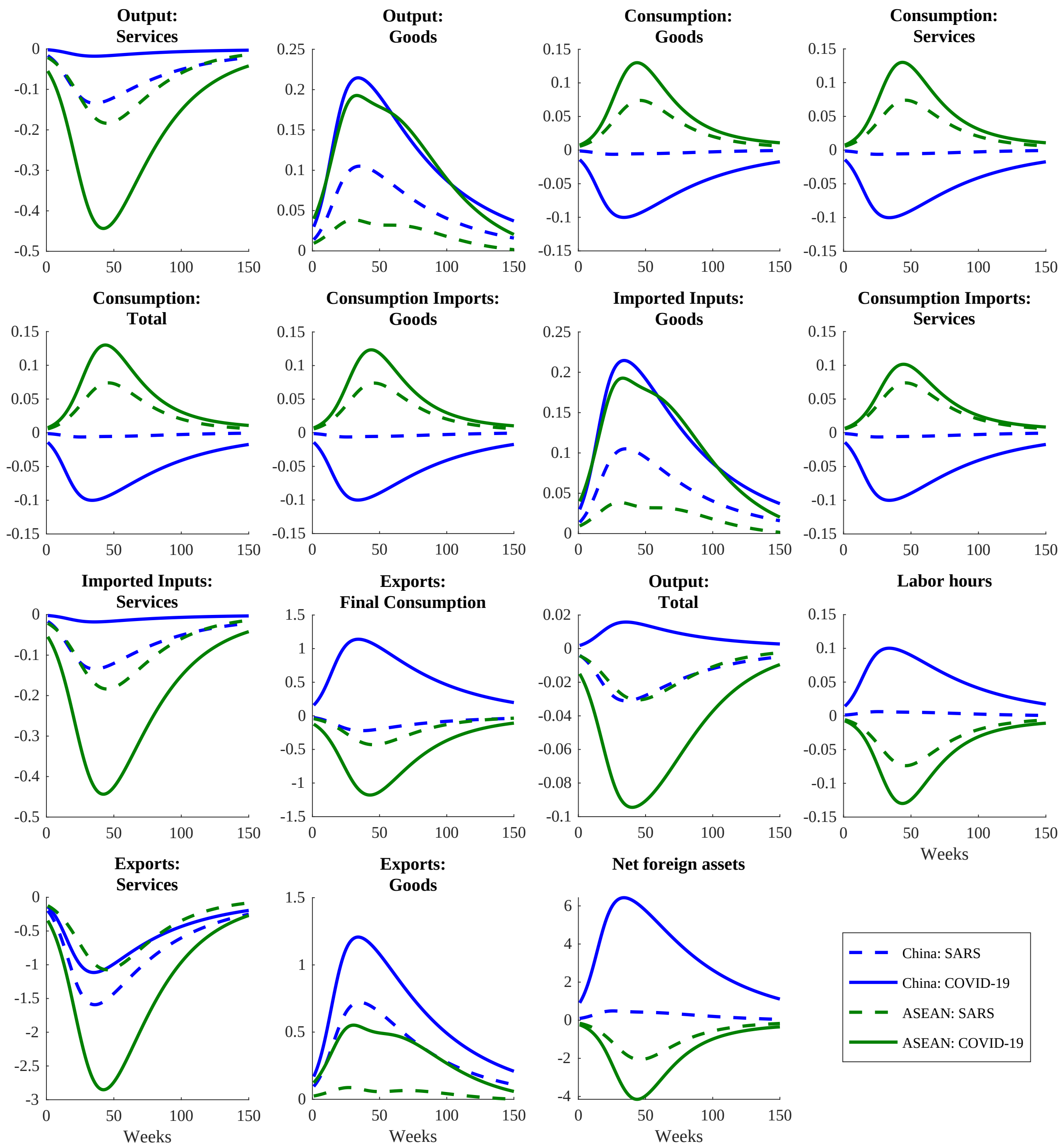

Figure 8: Cross-country response to an epidemic.

Note: Green lines indicate ASEAN's response to an epidemic in China. Blue lines indicate China's response to an epidemic in ASEAN. Bold lines refer to COVID-19 period and dashed lines refer to SARS period. X axis represents weeks and Y axis represents percentage deviation from the initial state.

In Fig. 9, net foreign assets response of China is very similar in both periods. The amount of rise in China's net foreign assets at the peak of the epidemic is very large when compared to ASEAN who witnesses a subdued decline in net foreign assets. This signifies the larger role of China in trade linkages in the context of a pandemic.

5 Sensitivity Analyses

5.1 Elasticity of Substitution

So far, our previous analyses have assumed the elasticity of substitution between goods and services to be $\eta = 10$. In reality, this value may be different, leading to different macroeconomic outcomes. In this section, we conduct a sensitivity analysis on the value of η which determines the elasticity of substitution between consumption of goods and services. As seen from Fig. 10, in general, with a higher elasticity of substitution, an epidemic shock leads to higher goods sector output and lower services sector output. The resultant effect, however, is a smaller decline in aggregate output and consumption. It is important to note that, an elasticity smaller than unity implies that goods are services are complements instead of substitutes. In such a scenario, it is interesting to observe that goods sector output falls in tandem with the services sector. We therefore see that the infected population is the highest.

5.2 Containment Efforts in China

The results in the previous section highlighted the larger impact of the China epidemic for both China and ASEAN during the COVID-19 period. In this section, we examine the scale of the response in aggregate variables when China contains the 'own' epidemic once it started. We represent China's containment efforts with decreasing values of $\pi_s(\ell)$. Figure 11 shows China's population dynamics when the infected population peaks at 1% (baseline), 0.75%, 0.5% and 0.25%. $\pi_s(\ell)$ values are adjusted to obtain the different peaks of the infected population following the epidemic. We see from Figure 12 that a higher containment of the epidemic in China (a lower peak in the infected population) leads to a substantially smaller impacts in all the aggregate variables for both China and ASEAN during the COVID-19 period.

6 Conclusion

In this paper, we discuss the different economic impacts of a pandemic shock that are associated with evolving economic landscapes and production linkages. We use China and ASEAN in this case study due to the fact that both countries / regions have been hit by both the SARS and

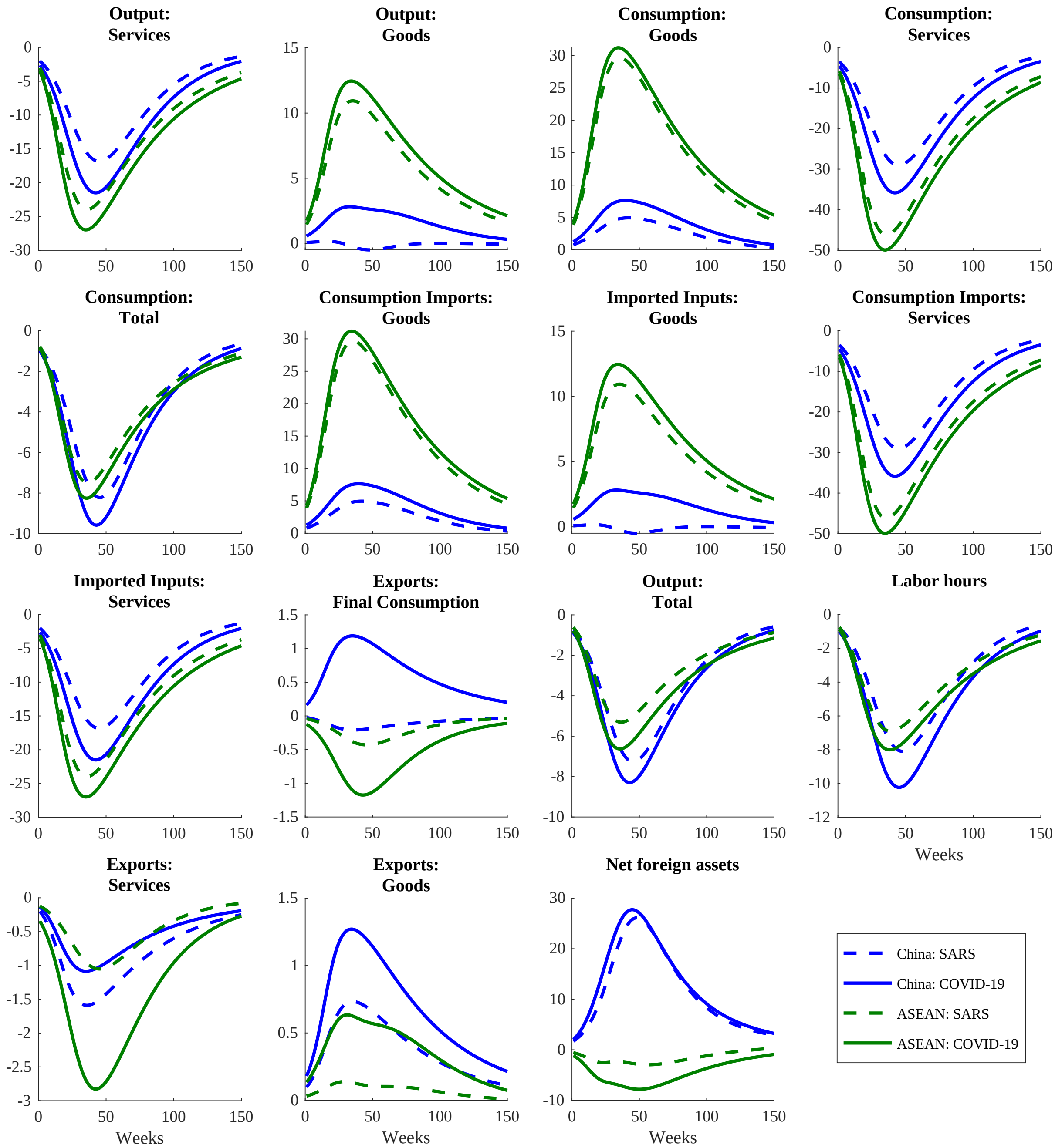

Figure 9: Response to a pandemic.

Note: Green lines indicate ASEAN's response to a pandemic. Blue lines indicate China's response to a pandemic. Bold lines refer to COVID-19 period and dashed lines refer to SARS period. X axis represents weeks and Y axis represents percentage deviation from the initial state. $\pi_s(\ell)$ values remain the same as in the single country epidemic.

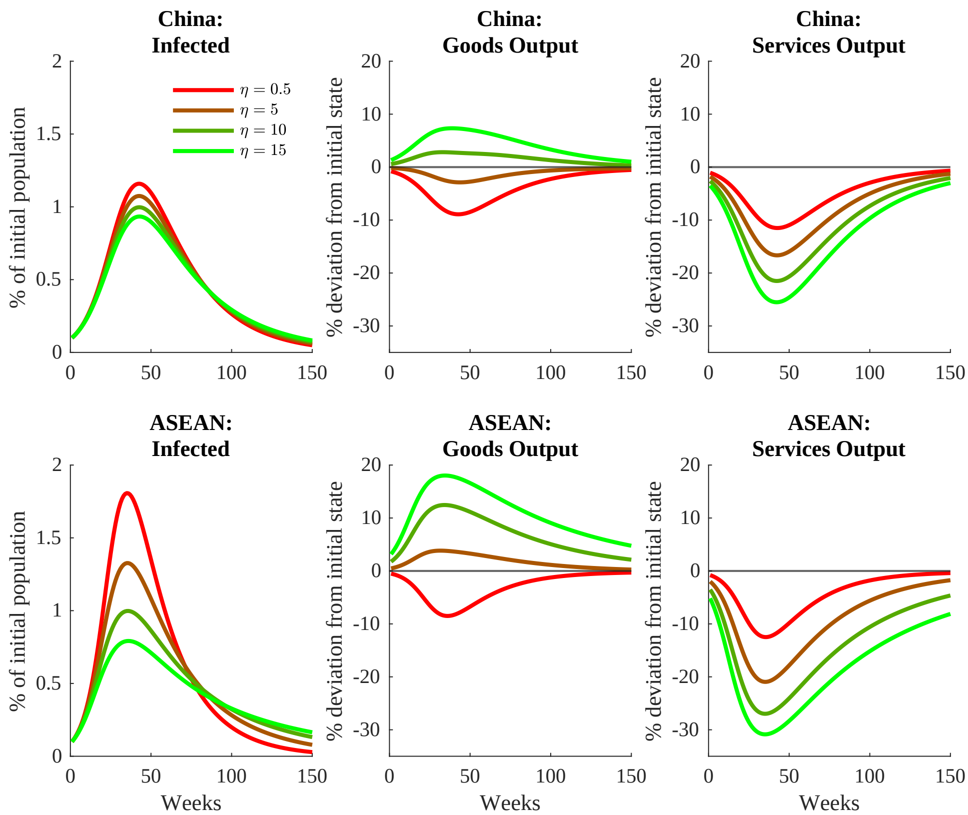

Figure 10: Effect of substitution elasticity, η.

Note: $\eta = 10$ is the baseline.

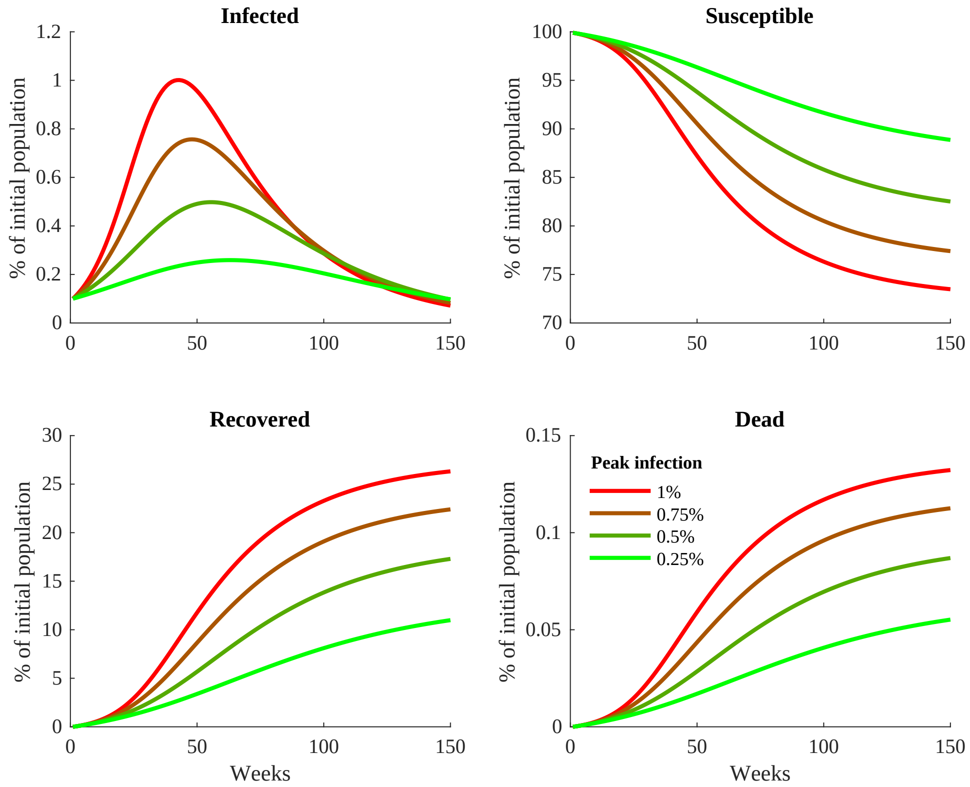

Figure 11: SIRD population dynamics of China during the COVID-19 period.

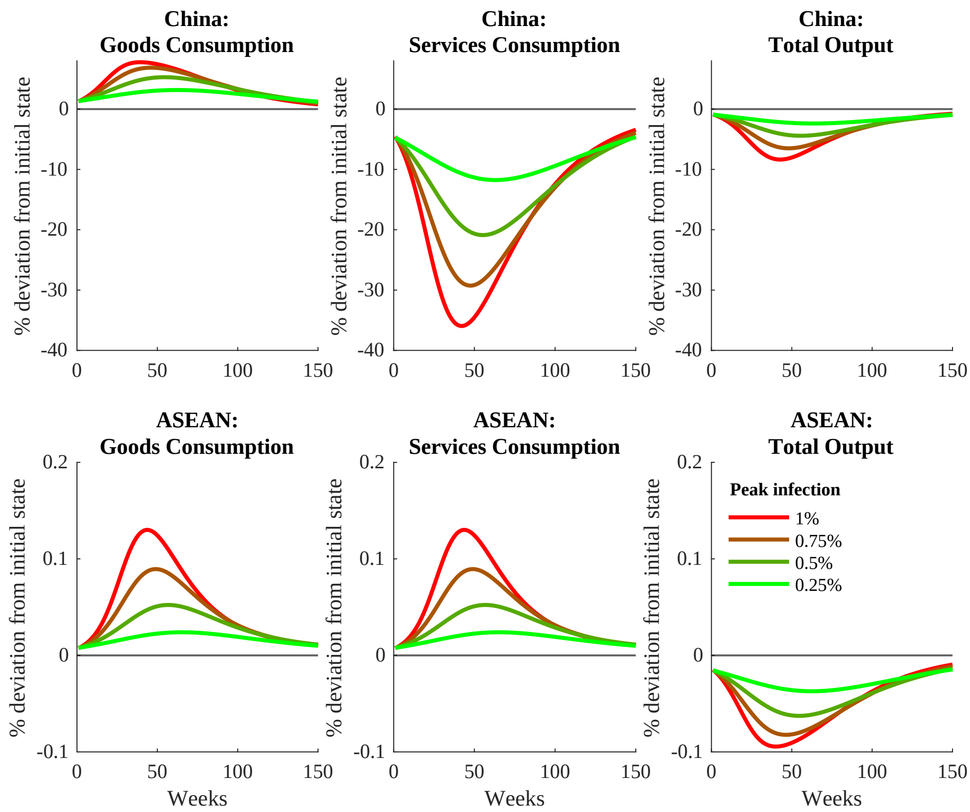

Figure 12: Response to an epidemic in China during the COVID-19 period.

the COVID-19. We introduce an SIR framework to a general equilibrium model of production networks. In order to identify the effect of economic landscapes and production linkages, we control the population dynamics so that they are similar in both China and the ASEAN.

Our results support that the greater economic impact of a pandemic over the years is associated with China's evolving role in the global value chains over the years. Our results for the within-country impact show that China would experience greater impact on aggregate consumption and production in COVID-19 period than in SARS period, while the impact on the ASEAN would be similar. Moreover, our results for cross-country spillover impact show that the ASEAN would experience much greater decline in aggregate output in COVID-19 period than in SARS period, should a pandemic arise in China.

It is worth noting a few key limitations of our study which pave way for future research. Firstly, we have ignored frictions in the labor market in this paper. An implication is that workers are free to find jobs in the less infectious sector should they leave the high infectious sector. Our frictionless labor market leads to an under-estimation of the level of economic losses. Nevertheless, we are still able to derive relative impacts of the pandemic between the scenarios discussed. Secondly, we have conducted the analyses without a formal assumption on the policy interventions. Our intention was only to study the propagation channels of pandemic shock within and across countries. However, our sensitivity analysis show that once the infection rate in China has lowered, either due to a change in the virus' characteristics, or a containment effort by the government, the spillover effect to the ASEAN can be reduced accordingly. We therefore encourage future research to focus on the impact on the labor market, as well as the interaction between policy interventions and economic outcome.

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A Forward and Backward Linkages

The forward and backward linkages which capture the relationship between a particular sector j and other industries from which it purchases or supplies input to. In an economy with n industries, the vector of sector linkages, $\mathbf{L}$ can be given as:

$$\mathbf{L} = \frac{n}{|\mathbf{1}^{\intercal}\mathbf{\Lambda}\mathbf{1}|}\mathbf{\Lambda}^{\intercal}\mathbf{1} \tag{32}$$

where $\mathbf{\Lambda}$ is the $n \times n$ matrix of coefficients representing the change in output in response to an increased dollar of final demand (backward linkage)/available input for production (forward linkage). $\mathbf{1}$ is a $n \times 1$ column vector of 1s.

The coefficient of variations, R^2 can also be calculated and used to compare how evenly a sector interacts with all other sectors. A larger value of R^2 implies that the sector mainly trades with a few industries, while a smaller R^2 implies that the sector interacts evenly with many industries. The vector of R^2 values, $\mathbf{CV}$ can be calculated as such

$$\mathbf{CV} = \frac{n}{\sqrt{n-1}}(\mathbf{\Lambda}^{\intercal}\mathbf{1})^{-1}(\mathbf{I} \circ (\mathbf{\Lambda}^{\intercal}\mathbf{K}\mathbf{\Lambda}))^{\frac{1}{2}} \tag{33}$$

where $\mathbf{I}$ is the identity matrix, $\mathbf{K} = \mathbf{I} - \frac{1}{n}\mathbf{1}\mathbf{1}^{\intercal}$ and $\circ$ represents the Hadamard product.

B Sector Groupings

Table 8: Sector groupings

ICIO Code	Industry	Proximity Index	Broad sector
D01T03	Agriculture, forestry and fishing	0.86	Goods
D05T06	Mining and extraction of energy producing products	1.08	
D07T08	Mining and quarrying of non-energy producing products	1.06	
D09	Mining support service activities	1.21	
D10T12	Food products, beverages and tobacco	1.12	
D13T15	Textiles, wearing apparel, leather and related products	1.09	
D16	Wood and products of wood and cork	1.03	
D17T18	Paper products and printing	1.08	
D19	Coke and refined petroleum products	1.11	
D20T21	Chemicals and pharmaceutical products	1.06	
D22	Rubber and plastic products	1.10	
D23	Other non-metallic mineral products	1.08	
D24	Basic metals	1.09	
D25	Fabricated metal products	1.08	
D26	Computer, electronic and optical products	1.03	
D27	Electrical equipment	1.07	
D28	Machinery and equipment, nec	1.06	
D29	Motor vehicles, trailers and semi-trailers	1.09	
D30	Other transport equipment	1.06	
D31T33	Other manufacturing; repair and installation of machinery and equipment	1.07	
D35T39	Electricity, gas, water supply, sewerage, waste and remediation services	1.08	Services
D41T43	Construction	1.21	
D45T47	Wholesale and retail trade; repair of motor vehicles	1.13	
D49T53	Transportation and storage	1.18	
D55T56	Accommodation and food services	1.26	
D58T60	Publishing, audiovisual and broadcasting activities	1.11	
D61	Telecommunications	1.07	
D62T63	IT and other information services	1.01	
D64T66	Financial and insurance activities	1.02	
D68	Real estate activities	1.10	
D69T82	Other business sector services	1.09	
D84	Public admin. and defence; compulsory social security	1.16	
D85	Education	1.22	
D86T88	Human health and social work	1.28	
D90T96	Arts, entertainment, recreation and other service activities	1.18	
D97T98	Private households with employed persons	—	