Industry-specific productivity and spatial spillovers through input-output linkages: Evidence from Asia-Pacific value chain[1]

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[1] **THE SIXTH WORLD KLEMS CONFERENCE 2021, March 9-10, 16-17, online.**

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- Global value chains (GVCs) promote the diffusion of knowledge and technology among the participants in the international production network and accelerate knowledge sharing and vertical specialization.
- Recall the importance of knowledge spillovers in Eva and Matilde's work on LA countries using the LA KLEMS.
- These technological spillovers are main drivers of technological progress and the long-term growth of participating countries.
- For our Asia/US KLEMS data the intersectoral network corresponding to the world input–output matrix in 1995 is in the figure below.
- Each vertex corresponds to a country-specific sector and the edges between nodes represent intermediate flows of both upstream and downstream resources between sectors.

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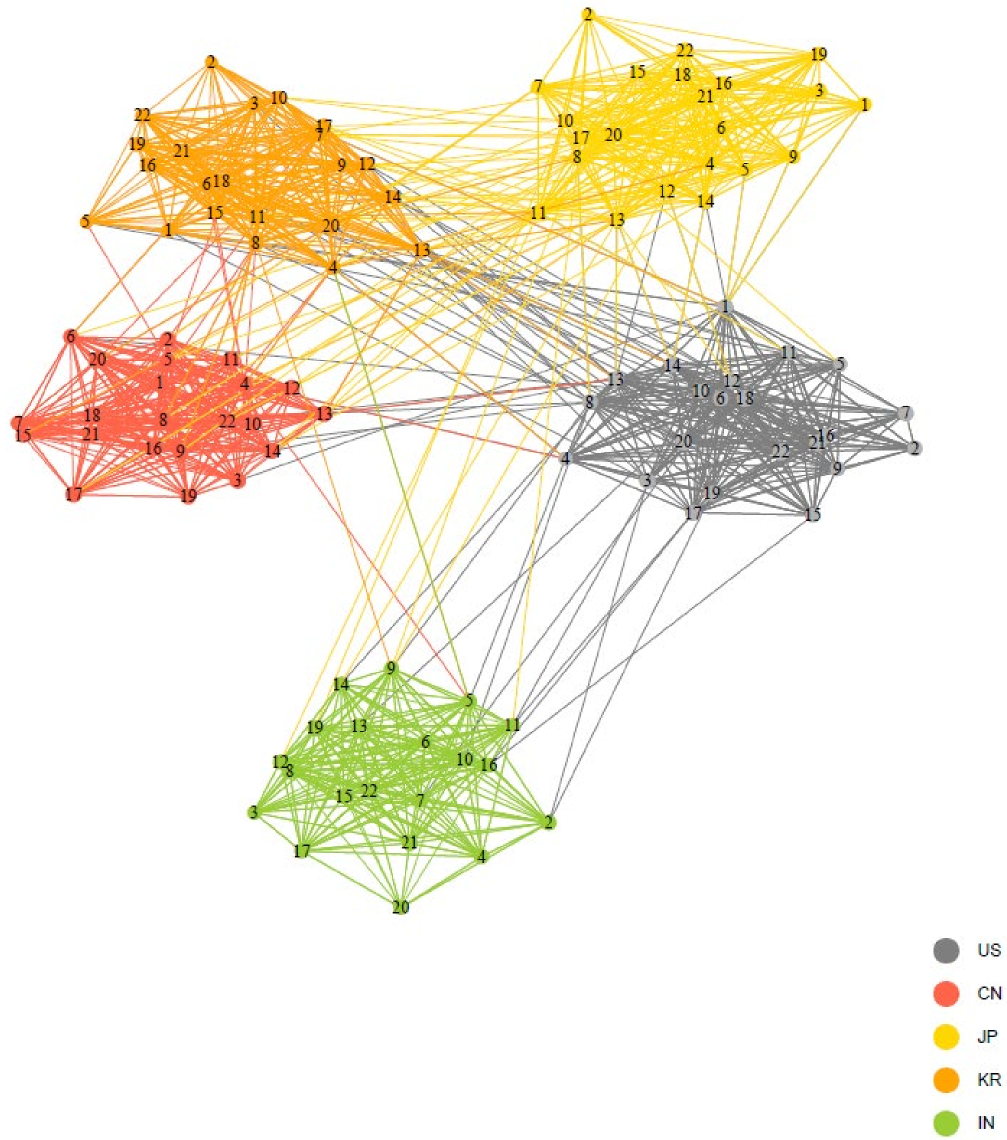
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- Our paper develops an empirical growth model that combines spatial spillovers and productivity growth heterogeneity at the industry-level.
- We exploit the GVCs' linkages from inter-country input-output tables to describe the spatial interdependencies in technology.
- The spillover effects from capital deepening, intermediate deepening, and technical change are identified using a spatial econometric specification.
- We use local Leontief matrices to decompose these effects into the domestic value chain spillovers transmitted within a country and the international value chain spillovers transferred across the borders.
- We use industry-level KLEMS data from 1995 to 2010 (22 sectors for China, Korea, Japan and the US and 20 sectors in India due to the lack of information on the agriculture and wholesale and retail sectors).
- We find that ignoring the spatial interactions leads to an overestimation of China's productivity growth, and underestimation of productivity growth in developed countries such as the US and Japan.
- The spillover effects of capital and intermediate inputs per capita are found to be significantly positive.

- Domar-weighted direct technical change growth rates for China, Korea, US, Japan and India are estimated to be 2.02%, 1.51%, 1.00%, 0.95% and 0.93%.
- The spillovers received account for 32% to 40% of their total technological growth.
- The estimated international spillovers offered suggest that US is the main contributor of international knowledge diffusion.
- Electrical and Optical Equipment sector of the US has the fastest productivity growth and offers the most spillovers.
- These findings provide a better understanding of how technical changes are distributed and diffused within the GVCs network.
- Capital-deepening and intermediate deepening in neighbor industries have positive spillover effects.
- The spillover effect occupies a considerable proportion of the impact of technical change.
- These results have implications for countries in their choice of strategies to participant in the global value chain.

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MODEL

- To account for the technology spillover through the linkage of industries, the effect of cross-sectional dependence should be considered in the production functions.
- We allow each industry *i* to have its own level of technical progress while at the same time allow the industry to absorb knowledge diffusion from its neighbors.
- Productivity growth originating in supplier industries may bring higher quality intermediates and know-how to downstream industries.
- Also, productivity growth occurring in customer industries may increase the requirement of intermediate quality and thus stimulate learning and capability building to upstream industries.
- We start by allowing knowledge diffusion for the i^{th} sector to be influenced by the strength of linkage with neighbor-industry *j* (w_{ij}) and neighbor-industry *j*'s percapita output y_{jt}
- Productivity growth is then modeled as

$$A_{it} = e^{R_i'\delta_i} \prod_{j \neq i}^{N} y_{jt}^{\rho W}$$

leading to the per worker production function

$$y_i(t) = e^{R_i'\delta} \prod_{j \neq i}^{N} y_j(t)^{\rho w_{ij}} k_i(t)^{\alpha} m_i(t)^{\beta} exp(v_{it})$$

and this leads to a Spatial Autoregressive (SAR) model

$$\ln y_{it} = \rho \sum_{j \neq i}^{N} w_{ij} \ln y_{jt} + \alpha \ln k_{it} + \beta \ln m_{it} + R_t'\delta_g + R_i'u_i + v_{it}.$$

- In the general case we study technical spillovers can be influenced not only by other sectors' labor productivity, but by the other sectors' technology A_{jt}, capital-labor ratio k_{jt}, and intermediate-labor ratio m_{jt} (modified SDM).
- The capital deepening in supplier or customer industries may increase aggregate social capital and thus accumulate knowledge and provide productivity improvement to the industry in question.

- This is in accordance with the Arrow-Romer's work on physical capital externalities (Arrow,1962; Romer, 1986).
- Analogously, the increase in intermediate input per capita in supplier or customer industries may also be beneficial to productivity growth because of the deepening in division and specialization among industries, in accordance with the theory of vertical specialization (denoted as intermediate deepening).

Technology Spillovers, Spatial Elasticities, Domestic and International Spillovers

- As demonstrated in LeSage and Pace (2009), for spatial models the usual interpretation of α and β as elasticities of input factors is not valid.
- They instead suggest the following approach to calculate direct, indirect, and total marginal effects.
- The reduced form expression allows us to construct the direct and indirect effects for each industry by input as well as by time, which we use as a proxy for technical change.

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- In the production system of the global value chain, knowledge spillovers not only involve industries within a country, but knowledge spillovers also cross-national borders and has been observed in both global value chains and regional/local value chains (Charlotte et al, 2021).

WEIGHT MATRIX

- We use the inter-industry intermediate flows in the World Input-Output table to construct the spatial weight matrix on an industry level.
- The input-output table reflects the channel of spillovers that comes from producing for the users of the intermediate product, which is consistent with the theory of "learning-by-doing" in the endogenous economic growth literature.
- We obtain a symmetric spatial weight matrix by summing the original and transposed matrix of the input-output table.
- The matrix represents the channel of spillover that comes from not only producing for downstream users but also absorbing technical know-how embodied in intermediates from upstream suppliers.

- The spatial weights matrix has entries $w_{ij} = w_{ji} = IO_{ij} + IO_{ji}, \forall j \neq i$, $\forall jj \neq ii$, with diagonal elements zero.
- We assume that the productivity spillover is dependent on the share weighted sum of the productivity of their intermediate partners, which is consistent with the seminal article of Coe and Helpman (1995) and use row normalization.

DATA

- We extract the output measures of gross output and input measures of capital service, labor service and intermediate input from the KLEMS database and from the China Industrial Productivity (CIP) Database.
- We use 2005 as the base year for the countries in our study.
- The inter-country input-output data are drawn from the WIOD database.
- We omitted non-market economy industries, which are mostly local public services that include Housing, Public Administration and Defense, Education, Health and Social Work, Other Community, Social and Personal Services.

EMPIRICAL RESULTS

- The estimated technical change in the SDM-Up+Downstream model suggests that China has the fastest aggregate productivity growth of 1.99%.
- But comparing this with the value of 3.86% in the non-spatial model, ignoring the spatial interactions appears to leads to an overestimation of China's productivity growth.
- However, for the developed countries, such as the US and Japan, the non-spatial model results indicate a lower level of TFP growth rates.
- They are 0.87% and 0.61% in the non-spatial model and 0.97% and 0.92% in the SDM-Up+Downstream model.

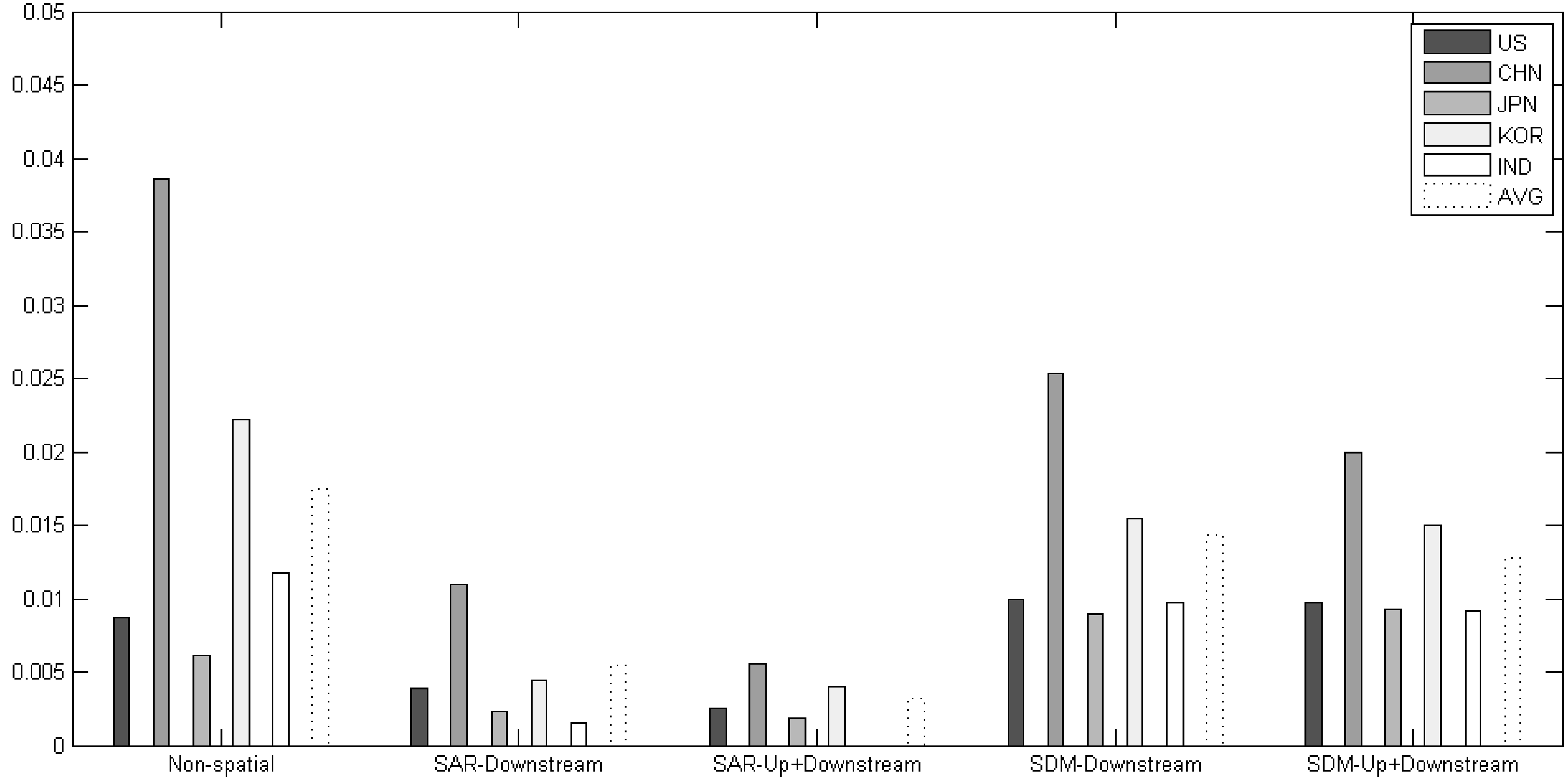
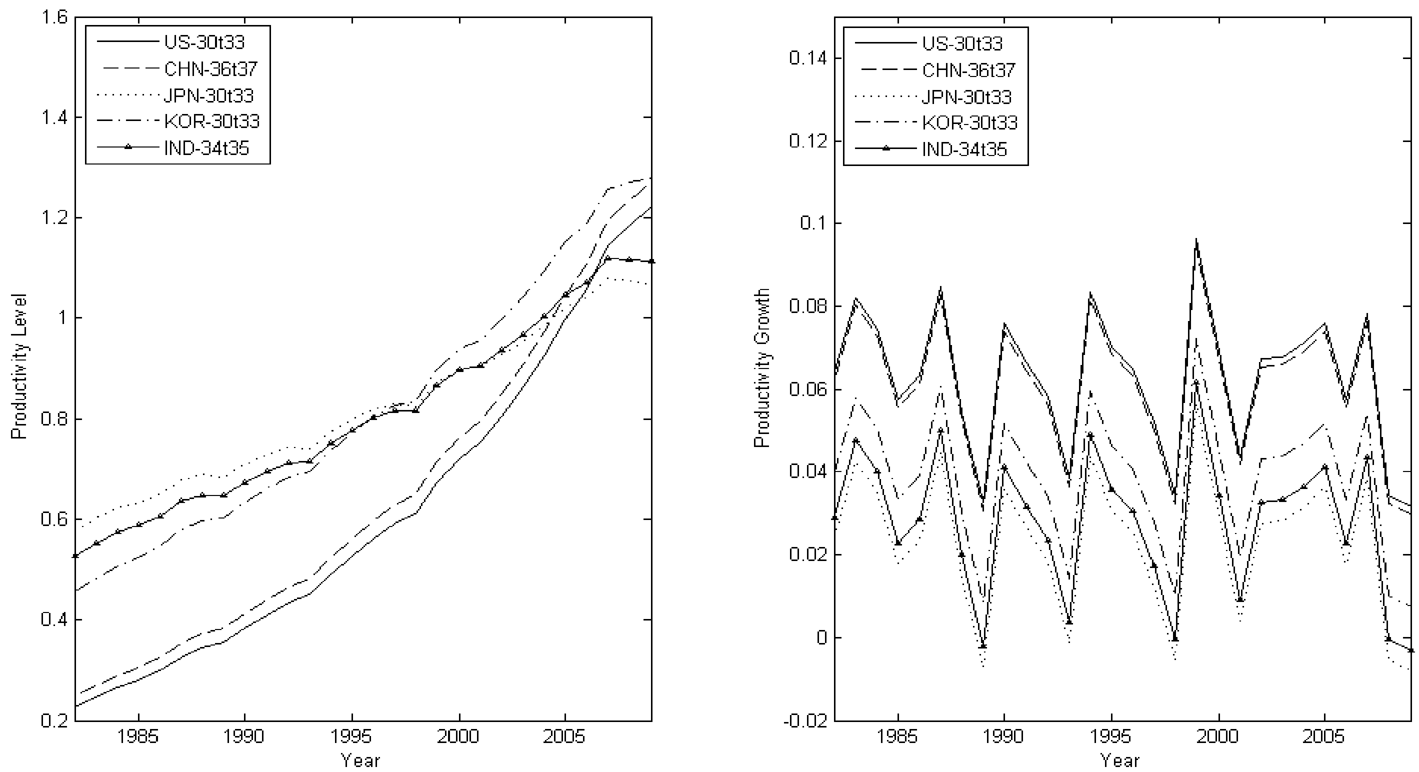


FIGURE 1
Aggregate Productivity Growth of Each Country by Model

- The results for productivity levels and growth of each industry for the SDM-Up+Downstream model indicate that *Electrical and Optical Equipment* of US exhibits the most rapid productivity growth compared with other US' sectors and all sectors of the other countries, with an average growth rate of 6.37%.
- *Electrical and Optical Equipment* is also the fastest growing industry in both Japan and Korea, with a 2.4% and 3.95% growth rate.
- *Manufacturing NEC and Recycling* in China and the *Transport Equipment* in India show the most rapid growth in each country of 6.18% and 2.9%.
- In Figure 2 we list the industries that exhibit the highest productivity growth in the five countries based on our preferred SDM model.



(a) Productivity Level

(b) Productivity Growth

FIGURE 2
Highest Productivity Growth Industries in Five Countries

- In Figure 3 we show the portion of technological growth measured by the direct and indirect effects from both the receiving and offering perspective.

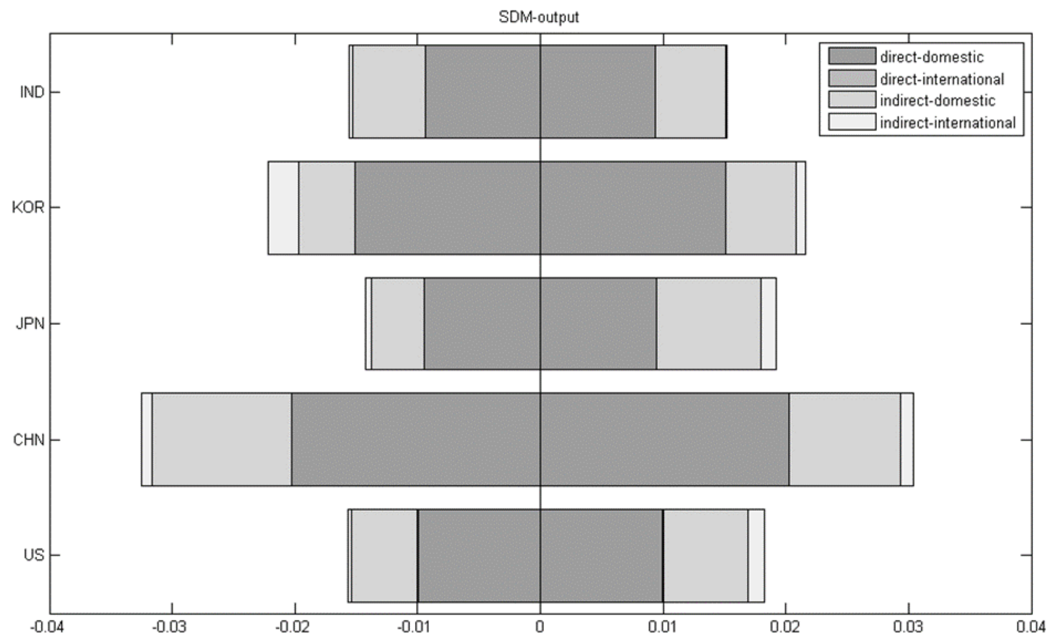


FIGURE 3
Direct and Indirect Effect of Technological Change

- The direct effect represents the technological growth by the industry itself that mostly comes from the independent innovation or improvement within the industry.
- On a country level, China exhibits the most rapid internal technological growth measured by the direct effect at 2.02%, while the growth rates for US, Korea, Japan and India are 1.51%, 1.00%, 0.95% and 0.93%.
- The indirect effects represent the technology spillovers that industries receive through producing intermediate inputs for their user industries.
- The weighted average indirect effects for China, Korea, India, US and Japan are 1.22%, 0.71%, 0.63%, 0.57% and 0.48%.
- Spillovers received account for 32% to 40% of the total technological growth of the countries in our sample.
- By decomposing the indirect effects into domestic and international spillovers, Korea is found to have benefited most from international spillovers, with an international indirect effect of 2.51‰, which constitutes 35.3% of the total spillovers that Korea's industries received.

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- China and Japan have international effects of 0.86‰ and 0.50‰ respectively, which constitutes 7.05% and 10.4% of the total spillover received by the industries of China and Japan.
- The international parts are relatively small for the US and India, with 5.58% and 5.41% in total received spillovers.
- The right side of Figure 3 represents the technological growth of each country from the offering perspective.
- Direct effects are comparable to values on the left side of Figure 3.
- The aggregated indirect effects for China, Korea, India, US, and Japan are 1.22%, 0.71%, 0.63%, 0.57% and 0.48%.
- However, the international spillovers that each country offers are different from those that they receive.
- US and Japan the contribute the most international spillovers with a growth impact of 1.29‰ and 1.25‰, which accounts for 15.6% and 12.9% of their total offered spillovers.
- The international spillovers for China, Korea and India are 1.07‰, 0.74‰ and 0.06‰.

- Our results suggest that while China is the most rapidly growing economy in the world, the developed countries, such as US and Japan, still contribute the most to international knowledge diffusion.
- Combined with the results of the international spillovers received by each country, the US and Japan made the most net contributions with net international spillovers at 0.97‰ and 0.75‰, followed by China at 0.21‰.
- Korea benefits most with net international spillovers at -1.77‰.
- The relatively small role for India in terms of international spillovers is mirrored by its relatively small international indirect effect of 0.06‰, which is only 1% of its indirect effect, suggesting the outward international technology linkages of Indian industries are still under-developed compared to other countries in our sample.

Productivity level and change for selected industries: electrical and optical equipment

- The information and communication technology (ICT) industry is one of the fastest growing industries in the world and highlights the increasingly important role of the global production system in the past 30 years.
- Jorgenson et al. (2012) note the important role of ICT-producing industries, including software and hardware manufacturing and services, and they found a substantial contribution of these industries to economic growth.
- Productivity change and spillovers in the electrical and optical equipment industry measured in our models are shown in Figure 3.
- Panel (a) and (b) are the total factor productivity estimates of Electrical and Optical Equipment in each country based on the estimation results of the non-spatial model and SDM-Up+Downstream model.

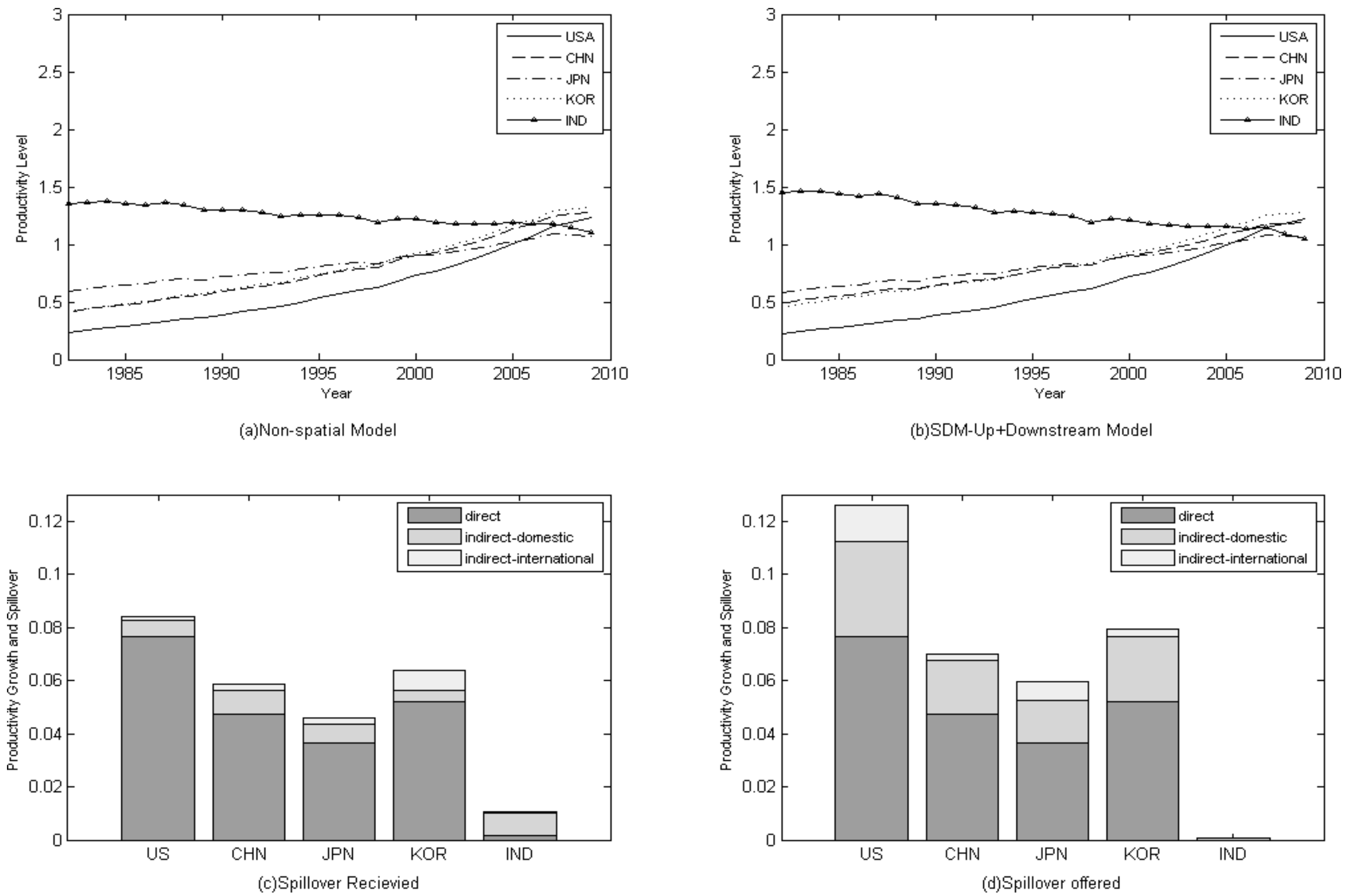

FIGURE 3
Productivity Level, Growth and Spillover of Electrical and Optical Equipment

Panel (c) and (d) of Figure 3 provide more detailed comparisons for productivity growth spillovers from the perspective of receiving and offering.

ADDENDUM

Simulation of the impact of supply chain disruption: scenarios of the COVID-19 pandemic outbreak

- We have also looked into the impacts of COVID
- Recall that in the Russell/Stewart study on Day 1 of our conferences they pointed to that fact that changes in industry composition are essential in properly understanding productivity dynamics and impacts of COVID.
- Recall as well the Fernald/Li study on the decline in potential output due to COVID and the O'Mahony/Samek paper in which Lea mentioned spillovers and the direct and indirect impacts of COVID.

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- Our model provides an option for estimating the compound impacts of epidemics. In our simulations, we assume the economy is affected through three different channels: (i) reduced labor supply; (ii) shortage of international intermediate input supply; (iii) disruption of technology spillovers through international linkages.
- i and ii may reflect the short term effect, and iii may reflect the long term effect.
- We follow WTO (2020) to illustrate the potential impacts of the Covid-19 pandemic on the economy based on two distinct scenarios.
- The first is the optimistic V-shaped and the second is the pessimistic L-shaped recovery.
- In the V-shaped recovery the spread of the pandemic will be under control in a relatively short period because of weather conditions or medical solutions and thus social distancing measures can be relieved in three months.
- The percentage of reduced labor supply can be estimated based on Table 8, which illustrates the magnitude of influence due to the factors such as falling ill, death, and loss of productivity when working at home and the distractions that may hold, including caring for children after school closures.
- World merchandise trade is expected to fall by 13% on average forecasted by WTO.

- In the L-shaped recovery the spread of the pandemic is out of control and leads to a higher percentage of morbidity and mortality.
- The social distancing measures would need to last for 1 year until an effective vaccine is developed.
- World trade is expected to fall by 32% on average. Given the level of uncertainties, it is worth emphasizing that these scenarios should be viewed as explorations of different possible trajectories for the crisis rather than specific predictions of future developments.
- The impact of the pandemic can be attributed to three aspects of our spatial production model.
- First, as shown in Table F.2, the annual reduction of labor supply in each country in the two scenarios is calculated based on the contribution of the four factors.
- Second, the fall in exports and imports will lead to a shortage of intermediate input supply.
- With the assumption that the domestic intermediate input is unaffected, we can estimate the magnitude of shortage of the intermediate input.

- Third, in our model, international trade also plays an important role as the channel of knowledge spillovers, which contributes to output growth.
- The fall in international trade will weaken the international intermediate linkages in the global value chain.
- For brevity, we assume that during this period the individual time trend and relative output elasticities of input factors are fixed, in which case W can be expressed in terms of five components that represent the contribution of intermediate linkages, capital, labor, intermediate input, and time trend
- We also assume in this baseline simulation that the capital input and technical change are not influenced by the disease.
- The estimated impacts of the pandemic on the total output of each country are shown in Figure 5.
- In the V-shaped scenario, the annual average output of US, China, Japan, Korea and India industries will drop by 2.5%, 3.7%, 2.6%, 6.2%, and 4.9%.
- If we look at the composition of the impact by these three channels, we find that the contributions of reduced labor supply are similar in each country and leads to a 0.65%~0.95% drop in output.

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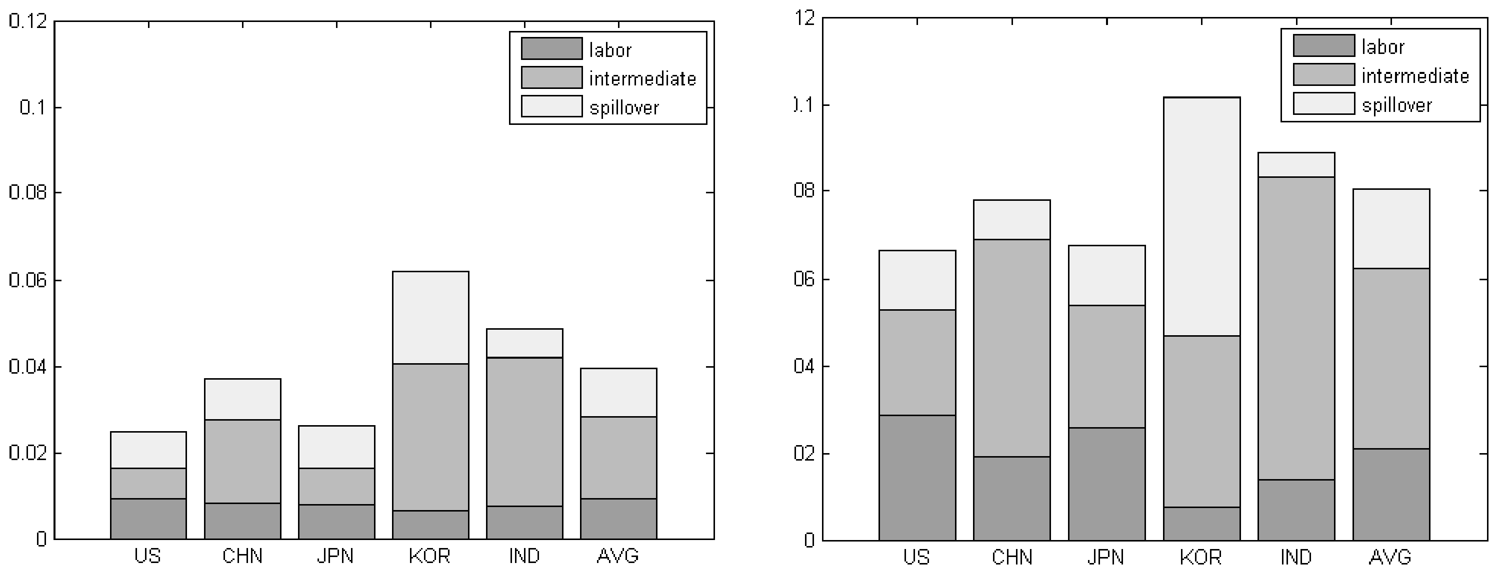
- However, the decline due to intermediate shortage is quite different among countries. India and Korea, which have a high degree of dependence on foreign intermediate products, have an equal 3.4% output reduction due to international intermediate input supply shortages.
- In the US and Japan, the decline due to a shortage of intermediate inputs only leads to 0.69% and 0.84% drop, while in China it leads to 1.9% drop.
- Although China is the largest country in terms of the volume of merchandise trade, domestic intermediate inputs account for a relatively large proportion of intermediate input supply.
- From the perspective of international technology spillover, the decline in Korea of 2.2% is the largest, followed by Japan, China, US, and India at 0.96%, 0.93%, 0.83%, and 0.66%.
- In the L-shaped scenario, as shown in Figure 5(b), the annual decline of average output in the US, China, Japan, Korea and India is 6.64%, 7.79%, 6.75%,10.16% and 8.88%.
- The contributions from each of the three channels expand correspondingly.
- The estimated impacts of the pandemic on the total output of each country are shown in Figure 4.

- In the V-shaped scenario, the annual average output of US, China, Japan, Korea and India industries will drop by 2.5%, 3.7%, 2.6%, 6.2%, and 4.9%.



(a) Percentage of Decline in Output in Scenario 1

(b) Percentage of Decline in Output in Scenario 2

FIGURE 4
Impact of Pandemic on the Output of Each Country through three channels

THANK YOU!