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The COVID-19 pandemics and import demand elasticities: evidence from China's customs data

Weikang Zhang[1,2]✉, Isabel K. M. Yan[3] & Yin-Wong Cheung[4]

We study China's import demand elasticities using HS 8-digit customs data on China's provincial imports during January 2019 to March 2021. It is found that both direct bilateral exchange rate elasticity and third-country exchange rate elasticity are affected by (1) policies that these Asian economies adopted to alleviate the adverse impacts of the COVID-19 pandemic and (2) the degree of concentration of exporters exporting a certain product to a certain Chinese provincial market. It is found that economic support policies will lower the bilateral exchange rate elasticity of trade flows, or even alter the sign of the bilateral exchange rate elasticity of China's imports. Besides, the economic support policies can alleviate the pressure of foreign competition on exporters and make the exporters more resilient to the impacts of foreign competitors' exchange rate depreciation. In contrast, the degree of market concentration of exporters in a certain provincial market affects the exchange rate and the third-country exchange rate elasticity differently. A higher market concentration lowers the bilateral exchange rate elasticity of trade flows but magnifies the impact of foreign competitors' currency depreciation on exporters. These results are robust to alternative modes of trade, regional heterogeneity, product heterogeneity, various measures of policy responses to the pandemic, and alternative database.

[1] Shanghai University of Finance and Economics, Shanghai, China. [2] CIB Research Co., Ltd., Shanghai, China. [3] Department of Economics and Finance, City University of Hong Kong, Hong Kong, China. [4] Department of Economics, University of California, Santa Cruz, CA, USA. ✉email: zhangweikang@mail.shufe.edu.cn

Introduction

Understanding how international trade reacts to exchange rate movements has been an important research question in international economics (Amiti et al. 2014; Li et al. 2015). This topic is of particular interest in the COVID-19 period because policymakers have made efforts to maintain stability in trade flows, and it is quite meaningful to interpret how exchange rate movements can affect the trade flows and balance of payments since the COVID-19 outbreak. In terms of policy responses, for example, the State Bank of Vietnam has intervened in the foreign exchange market to smooth exchange rate volatility and trade flows, and the Bank of Korea has created a repo facility to allow financial institutions to receive foreign exchange from the central bank to maintain exchange rate stability (Alberola et al. 2021).

However, the policy effect on the exchange rate elasticity during the COVID-19 period is currently under-researched. To fill this gap, we investigate the impacts of policy responses to the COVID-19 pandemic on exchange rate elasticity of trade. We use the Python crawler to obtain the first-hand monthly Chinese provincial customs data that can cover the period since the COVID-19 outbreak. We focus on China's imports from Asian trading partners because China has become the largest importer in Asia and the central node of global value chain (GVC) networks. In addition, over 50% of China's imports were from Asian trading partners, as shown in Figures S1 and S2 in the supplementary information. The policy response effectiveness may not only affect the economic recovery of Asian trading partners' exports, but also affect China's sourcing of imported inputs from Asian economies for further production. With data on different Asian economies' exports to China, we can identify the impact of pandemic-induced policy responses adopted by Asian policymakers on international trade.

To anticipate the main results, we find that the exchange rate elasticity of China's imports from Asian partners is significantly affected by government's support policies in response to COVID-19. The more aggressive fiscal and monetary policies against the pandemic imposed by Asian economies have reduced the export responsiveness to the bilateral exchange rate movements or even alter the sign of the bilateral exchange rate elasticity. In addition, the depreciation of foreign competitors' currencies has deterred the Asian economy's exports to China, and a lower degree of market concentration would further amplify this foreign competition effect. Moreover, a strong support policy can help to reduce the responsiveness to foreign competitors' exchange rate movements. Furthermore, we highlight the product quality channel of the policy effect, which suggests that economic support packages in response to the COVID-19 can decrease the bilateral exchange rate elasticity of trade flows via an upgrade of the quality of products exported to China. The main results remain robust to different trade modes, alternative measures for policy responses, and the inclusion other controls. Furthermore, we conduct the additional analyses regarding the regional heterogeneity, the product heterogeneity, and the extensive margin to further interpret our research questions from new angles.

This paper is mainly related to two strands of literature. First, our paper is related to the literature on the effects of the COVID-19 pandemic on international trade. Gruszczynski (2020) find that the pandemic has severely affected both global supply chains and global demand for foreign goods, which is also highlighted by a group of studies (Che et al. 2020; Vidya and Prabheesh, 2020; Hayakawa and Mukunoki, 2021; Zhao et al. 2021). In addition, Liu et al. (2021) employ China's export data in the whole year of 2020 to show the importance of the third-country effects, suggesting that the weak economic condition of other countries has indirectly boosted China's imports. They also argue that product and country heterogeneity is significant in analyzing the effects of the COVID-19 outbreak on international trade. In contrast, we employ the crawler technique via Python to obtain the latest monthly provincial customs data of China, which allow us to capture the heterogeneous effects across various Chinese provinces. In addition, as the pandemic-induced policy effect and the foreign competition effect may occur rapidly, our highly disaggregated monthly data can reflect rapid dynamics related to the COVID-19 outbreak.

Second, this paper blends into the recent and growing literature on the effect of competitor countries' exchange rate movements on domestic exchange rate elasticity. Feenstra et al. (2002) show that the significant devaluation of the RMB in 1994 has significantly curtailed the export performance of South Korea. By adding ASEAN countries' trade-weighted exchange rates against the US, Cheung et al. (2016) find that the competition between China and ASEAN in the US market drives China's export to negatively respond to ASEAN's currency depreciation. Moreover, Mattoo et al. (2017) empirically show that when one product exported by a developing country involved in more intense competition with Chinese exporters in the US markets, the depreciation of RMB vis-à-vis the dollar leads to a greater reduction in that country's exports of this product to the US. Furthermore, Pennings (2017) emphasizes the role of third-country (competitors) exchange rate movements in affecting the US import prices as well as producer prices by using the Bureau of Labor Statistics microdata. He argues that omitting competitors' exchange rate effects may cause upward biases towards the estimates of bilateral exchange rate pass-through (ERPT).

Our paper is distinct from those existing studies, however, in several aspects. To the best of our knowledge, it is the first paper that systematically analyzes the exchange rate elasticity of trade flows in the COVID-19 period with first-hand highly disaggregated trade data. In addition, we attempt to bring new insights into the important topic of the exchange rate elasticity by considering the foreign competition and pandemic-induced policy responses to highlight the role of these two mechanisms. Moreover, our results have significant policy implications for the price and quantity adjustments to both bilateral and third-country exchange rate movements in the context of the COVID-19 crisis and thus may help policymakers design further policies targeting on the exchange rate and balance of payments to further boost economic recovery.

The rest of this paper is organized as follows. Section "Data Descriptions" describes the data used in this paper. Section "Theoretical Model" provides a theoretical model to guide further empirical exercises. Section "Empirical Strategy" lays out the model specification. Section "Empirical Result" discusses the empirical results, including baseline results, mechanism analysis, heterogeneous analyses, robustness checks, and extensions. Section "Concluding Remarks" offers some concluding remarks.

Data descriptions

Database. The main database is the monthly provincial-product-level Chinese customs data from January 2019 to March 2021 at HS 8-digit level. The advantage of this database is that it is very recent and detailed. It allows us to conduct heterogeneous analysis on different provinces, products, trading patterns, trade modes, domestic sourcing of inputs verse imported inputs, etc. In addition, the classification of products is harmonized to the 2017 version of the 8-digit-level HS code, which means that the HS codes are directly comparable across different years and months.[1] In the analysis of exchange rate elasticity, it is important to

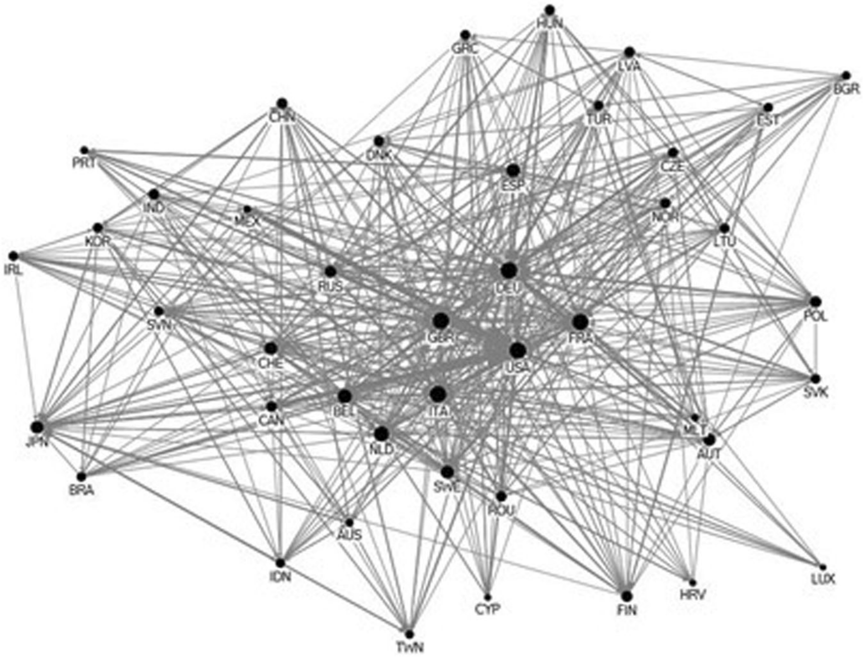

Fig. 1 Network graph of foreign value added from all sectors, 2000. Source *WIOD* 2016.

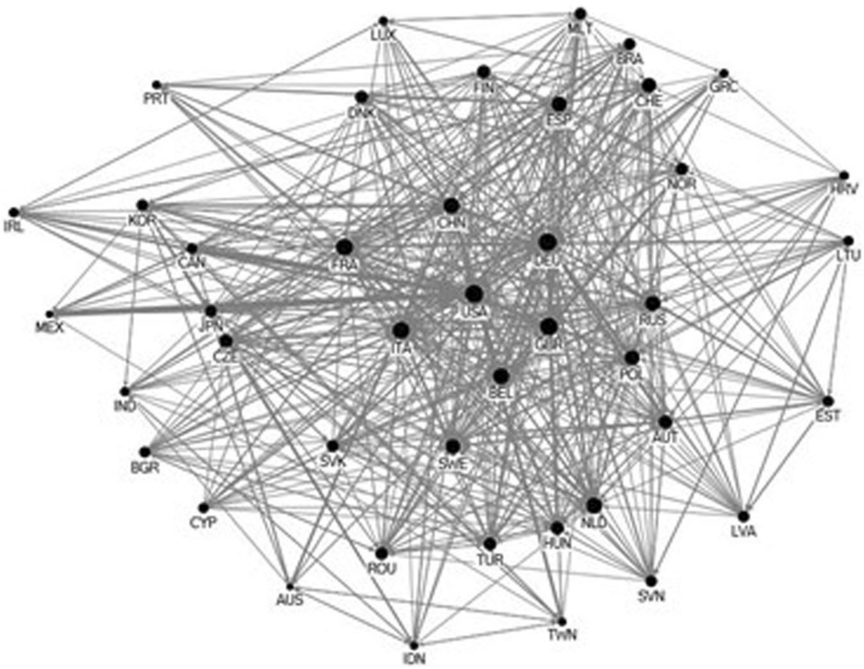

Fig. 2 Network graph of foreign value added from all sectors, 2014. Source *WIOD 2016*. Note for Figs. 1 and 2: We draw the network graph of trade in intermediate inputs (Amador and Cabral, 2017). Each country is represented by a circle, with arrows pointing from the supplier to the receiver. The linkage is based on value-added trade, and a thicker line between two nodes implies a stronger linkage. From the receiver's perspective, those cross-border value-added flows are the foreign value added. The size of each node is proportional to its degree. In general, a more important supplier of value-added tends to have bigger nodes and to locate in the center of the network.

distinguish between the response of unit price and that of quantity. Our database contains the price and quantity information required for this study. In this study, the import price is taken to be the CIF price (including cost, insurance, and freight) measured in RMB.

We take China as an example to examine how its imports would be affected by a set of exchange rate effects because China has become the central node of global value chain (GVC) network in Asia, which means that China imports many intermediate inputs for further production or exports via both ordinary trade and processing trade (Friedt and Zhang, 2020). After comparing the network graphs (Figs. 1 and 2) between the year 2000 and 2014, we find that the evolution of the GVC network is substantial: The overall network became denser, indicating that the rising GVC integration, which has been one of the most significant improvements in the 21st-century trade, cannot be

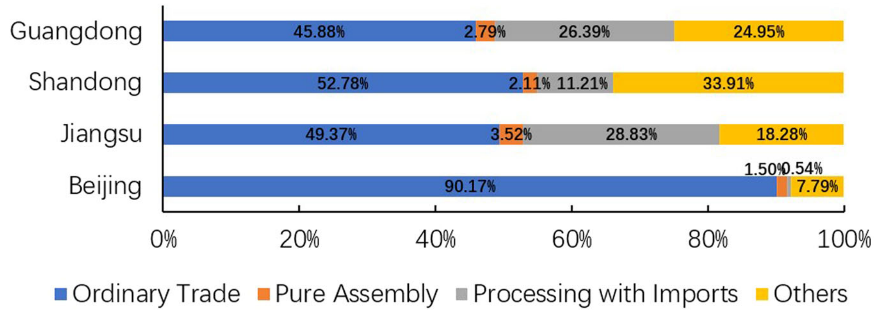

Fig. 3 Shares of various trade modes in selected Chinese provinces, December 2020. Source General Administration of Customs PRC.

ignored when we discuss the evolving structure of input-output analyses on international trade. Furthermore, the US, Germany, and China have become the inner cores of the GVC networks, which are three important suppliers of foreign inputs sourced by global trading partners (Bretton, 2022). Therefore, it is important to identify whether China's position in Asian GVC network has been affected by the COVID-19 pandemic. Under this question, we will focus on how the imports of intermediate inputs respond to exchange rate movements and emphasize the role of foreign competition and policy responses to the COVID-19 in impacting international trade within Asia.

It is worth noting that the processing trade system in China has two sub-categories: pure assembly (PA) and processing with imports (PI) (Manova and Yu, 2016). Pure assembly (PA) is the type of trade that a Chinese firm receives raw materials and intermediate inputs from a foreign company and then process or assemble according to the foreign company's requirement. Under this mode, the Chinese firm does not need to purchase the foreign inputs and incurs no costs in using the foreign inputs. In contrast, under processing with imports (PI), a Chinese firm needs to pay for the imported inputs and then process to customize the products according to the foreign buyer's specification, and the foreign buyer typically is not the same as the foreign input supplier. Under either mode, the Chinese processing firm is exempted from import duty. The distinct characteristics of those different trade modes are also of interests when we analyze the exchange rate elasticity.

The share of each trade mode in China is quite persistent over time but is quite heterogeneous across provinces. Figure 3 compares the trade modes across several provinces. Three coastal provinces in the figure (Guangdong, Jiangsu, and Shandong) were ranked as the top three based on the provincial GDP, while Beijing is an interior municipality directly under the central government, which is de facto equivalent to a province. In general, coastal provinces are more diversified in trade modes and have high share of processing with imports (PI) compared with Beijing. In Beijing, ordinary trade takes up about 90%. In each province, ordinary trade accounts for the largest share in all types of trade, and pure assembly (PA) only accounts for a quite small portion.

As the novel coronavirus spread across the globe, governments have launched many rounds of fiscal and monetary measures to boost economic recovery, and the policy responses have effectively provided relief and support to firms and household (Alberola et al. 2021). To quantify the effects of government policies against the pandemic-induced supply and demand shocks, we employ the Oxford COVID-19 economic support index from the Oxford COVID-19 Government Response Tracker (OxCGRT) constructed by Hale et al. (2021). The index quantifies the policies regarding income support for unemployed people, debt relief, fiscal stimulus, and other public expenditure to boost economic recovery from COVID-19. This index is published on a monthly basis for most of the countries in the world, which can be merged with the Chinese monthly customs data to measure the effectiveness of the policies adopted by China's Asian trading partners to mitigate the economic effects of the pandemic.

COVID impacts on China's imports. Before embarking upon the formal empirical analysis, we would like to highlight several stylized facts of China, especially during the COVID-19 period. Since the accession to the WTO, China has become the largest exporter and the second largest importer in the world, providing and sourcing intermediate inputs and final goods around the globe. Although there has been a growing literature on the impact of COVID-19 on China's exports, there are limited studies on China's imports since the pandemic outbreak. To fill this gap, we perform detailed analysis of the impacts of COVID-19 on China's imports.

The National Bureau of Statistics of China publishes one manufacturing Purchasing managers' index (PMI) related to China's imports: the PMI import index, and a PMI below 50 suggests deterioration compared with the previous month. As shown in Fig. 4, the PMI on China's imports declined considerably in the first quarter of the year 2020 due to the worsening COVID-19 pandemic. The first wave of pandemic outbreak started in the late January of 2020.[2] The lockdown and sudden stop of economic activities severely dampened the prospect of China's imports. Subsequently, the PMI on imports gradually improved alongside with the recovery of the Chinese economy. While China started experiencing the economic recovery in the second quarter of 2020, the COVID-19 began to spread to the rest of the world. Therefore, there has been a mismatch between China's recovery and its trading partners' supply and demand shocks during the pandemic outbreak.

Figure 5 shows the total imports of the Hubei province from Asia, which was the epidemic center at the onset of the COVID-19 outbreak. It illustrates the impacts of COVID-19 on the international trade of the Asian economies during January 2019 to March 2021. As a result of the COVID-19 outbreak, China's import first shrank notably due to the disturbed domestic economic condition, but then rebounded because of the strong and effective government policy responses. Figure S3 in the supplementary information indicates that there exists provincial heterogeneity, though various provinces still shared some common time dynamics.

The focal point of this paper is to study the effect of the government's economic support policies (targeting at boosting the economic recovery) on China's import. Figure 6 plots Asian economies' fiscal measures (as a percentage of GDP) in response to COVID-19 as stated in the IMF quarterly report. We find that advanced economies, such as Singapore and Japan, have exhibited larger fiscal response than most of the emerging market economies. Relatively low-income countries, such as Kazakhstan

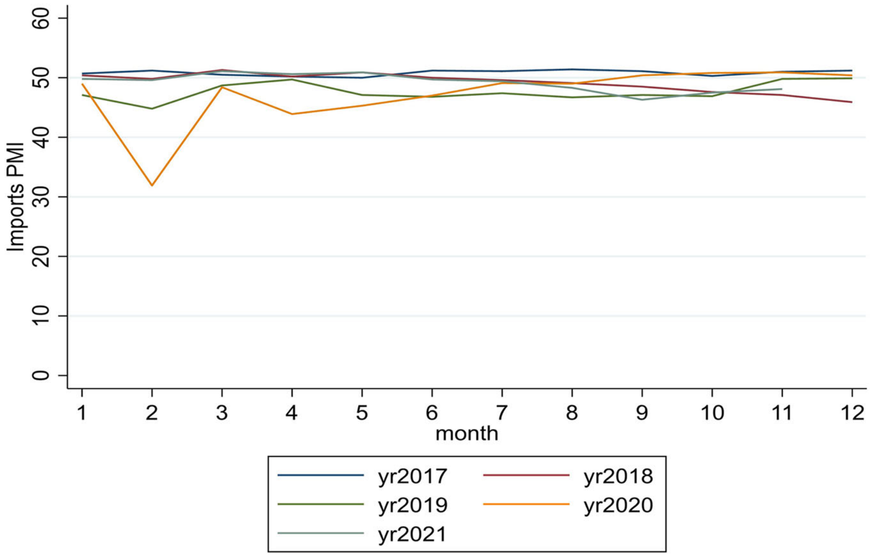

Fig. 4 Purchasing Managers' Indexes on Imports in China, 2017.1–2021.11. Source National Bureau of Statistics of China.

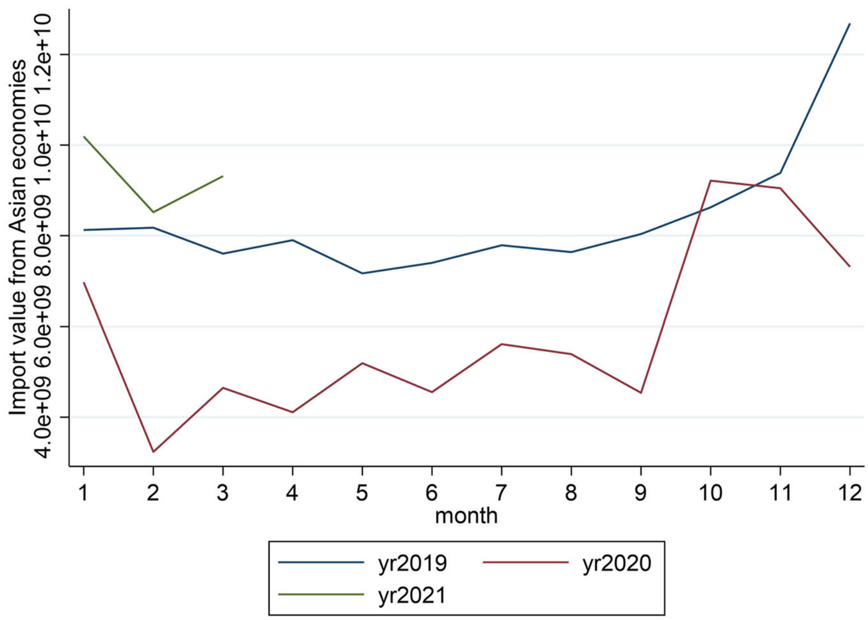

Fig. 5 Hubei province's import values from Asian economies, 2019.1-2021.3. Source General Administration of Customs PRC.

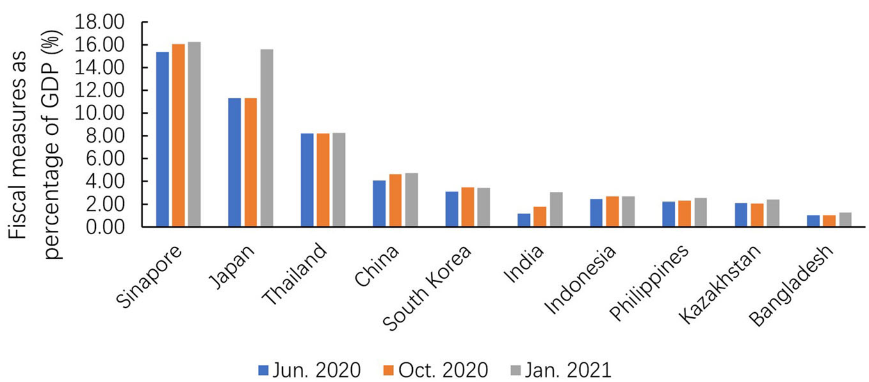

Fig. 6 Fiscal measures in response to COVID-19 taken by Asian economies. Source IMF Fiscal Monitor Database.

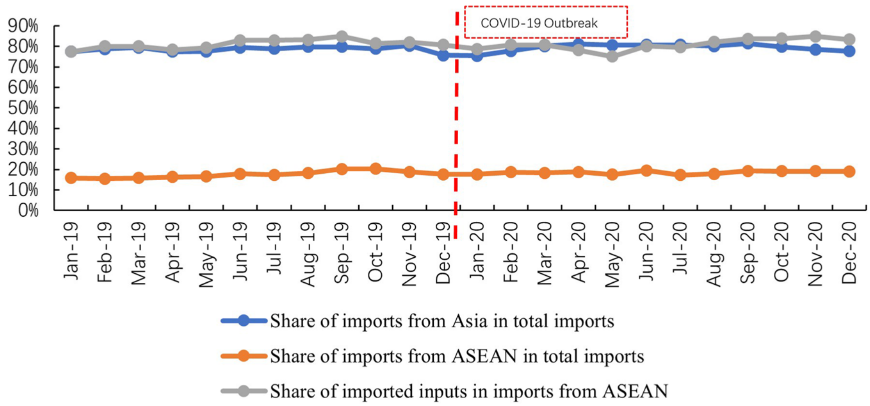

Fig. 7 Guangdong province's import shares, 2019.1–2020.12. Source General Administration of Customs PRC.

and Bangladesh, have limited fiscal capability and hence the size of economic support was quite small (Alberola et al. 2021). In addition, the scale of fiscal measures has gradually increased, meaning that most economies have spent more efforts in launching economic policies to combat economic contraction due to the pandemic. Therefore, it would be important to assess the policy effects during the COVID-19 period.

Figure 7 plots Guangdong provinces' import shares from 2019 to 2020. We choose Guangdong province as an example because it has the highest provincial GDP and import values during this period. First, we note that the imports from Asia accounted for around 80% of the total imports of Guangdong Province, indicating a strong trade relationship between China and the other Asian economies. Second, this share has remained quite stable throughout this period, even with the COVID-19 shock, indicating that the trade relationship between China and its Asian trading partners was quite resilient to the COVID-19 shock. Third, in terms of the imports from the ASEAN-10 group, imported intermediate inputs account for around 80%, suggesting that ASEAN-10 countries mainly export parts and components to China for China's further GVC activities (Thorbecke, 2018).[3] This pattern had not been significantly twisted by the pandemic. As the ASEAN-10 group has been the largest trading partner of China since 2020, this pattern is important for maintaining China's position in the GVC network. In our empirical investigation, we will also highlight the role of intermediate inputs in China's imports.

In sum, though the COVID-19 pandemic has generated important economic impacts, the effective economic support policies adopted by many Asian economies had brought their domestic production and export activities back on track. As a result, these policies were important in helping China resume its imports from its Asian trading partners. To examine the policy effect more closely, we decompose the total value of trade flows into price and quantity movements, considering product and provincial heterogeneity. We also proceed to analyze how these economic support policies impacted the exchange rate elasticity of China's imports.

Theoretical model

In this section, we present a model of exchange rate effects on trade behaviors, which provides theoretical conjectures on how the policy effect and the foreign competition effect may influence the exchange rate elasticity of trade flows. We introduce global competition and economic support policies into the model developed by Melitz and Ottaviano (2008) and Dhingra (2013) to deliver two propositions, which will closely guide our empirical analyses.

Demand. We follow Dhingra (2013) to extend the monopolistically competitive model proposed by Melitz and Ottaviano (2008) to define the following preferences for each identical agent c in country j:

$$U_j^c = q_{0j}^c + \alpha Q_j^c - \frac{\delta}{2}\int_{k\in\Omega}\int_{i\in\Theta}\left(q_{ijk}^c\right)^2 didk - \frac{\gamma}{2}\int_{k\in\Omega}\left(q_{jk}^c\right)^2 dk - \frac{\eta}{2}\left(Q_j^c\right)^2. \tag{1}$$

In Eq. (1), q_{0j}^c and q_{jk}^c represent the agent c's consumption levels of the homogenous numeraire good and each variety k of the differentiated good, respectively. Their consumption level over a continuum of differentiated varieties is $Q_j^c = \int_{k\in\Omega} q_{jk}^c dk$, and Ω indexes the set of varieties.

Additionally, agent c's consumption level of the differentiated good k is $Q_{jk}^c = \int_{i\in\Theta} q_{ijk}^c di$, where q_{ijk}^c is their consumption for a specific quality of good k. Smartphones, which can be regarded as the variety k, may serve as an example: one agent may simultaneously buy an iPhone Pro (a high-quality smartphone) for daily use and an iPhone SE (a relatively low-quality smartphone) as a backup device. In this case, the subscript i denotes different levels of quality (i.e., iPhone Pro and iPhone SE) for the consumption of smartphones. This scheme also exists when agent purchases shoes, clothing, and many other products.

Θ indexes the set of quality levels for variety k. α and η index the elasticity of substitution among homogenous and differentiated goods, respectively: an increase in α or a decrease in η can boost the demand for differentiated goods against homogenous goods. In addition, δ captures the degree of differentiation across different qualities (i.e., from different sourcing countries) and how easily can the goods with differentiated quality be substituted with each other. γ captures the substitution pattern across the differentiated good k. The parameters introduced above are all strictly positive.

With an equilibrium in country j, the inverse demand function for good k is

$$p_{ijk} = \alpha - \delta q_{ijk}^c - \gamma Q_{jk}^c - \eta Q_j^c. \tag{2}$$

From Eq. (2), we have three types of consumption: the quality-level consumption q_{ijk}^c, the variety-level consumption Q_{jk}^c, and the global-market-level consumption Q_j^c.

If we assume L_j consumers in country j, the demand function of good k becomes

$$q_{ijk} \equiv L_j q_{ijk}^c = \frac{1}{\delta}\left(\alpha L_j - \gamma Q_{jk} - \eta Q_j\right) - \frac{L_j}{\delta} p_{jk}. \tag{3}$$

The total consumption of country j for differentiated good k imported from N different levels of quality is $Q_{jk} = L_j Q_{jk}^c$.

Subsequently, we reach the following expression for Q_{jk}:

$$Q_{jk} = \int_{i \in \Theta^*_{jk}} q_{ijk} di = \frac{N^*_{jk}}{\delta}\left(\alpha L_j - \gamma Q_{jk} - \eta Q_j\right) - \frac{N^*_{jk} L_j}{\delta} \bar{p}_{jk}. \quad (4)$$

In Eq. (4), $\bar{p}_{jk} = \frac{1}{N^*_{jk}} \int_{i \in \Theta^*_{jk}} p_{ijk} di$ indexes the average price of differentiated good k consumed in home country j. Similarly, the market demand system for varieties is given by

$$Q_j = \int_{k \in \Omega^*_k} q_{jk} dk = \frac{N^*_{jk} L_j}{\delta + (\gamma + \eta) N^*_{jk}} (\alpha - \bar{p}_j). \quad (5)$$

In Eq. (5), $\bar{p}_j$ is the average price of all varieties available in country j. After combining Eqs. (4) and (5), the quantity Q_{jk} can be written as

$$\begin{aligned} Q_{jk} &= \frac{N^*_{jk}}{\delta + \gamma N^*_{jk}} (\alpha L_j - \eta Q_j) - \frac{N^*_{jk}}{\delta + \gamma N^*_{jk}} L_j \bar{p}_{jk} \\ &= \frac{N^*_{jk}}{\delta + \gamma N^*_{jk}} \left(L_j (\alpha - \bar{p}_{jk}) - \frac{N^*_{jk} L_j \eta}{\delta + (\gamma + \eta) N^*_{jk}} (\alpha - \bar{p}_j) \right) \end{aligned}. \quad (6)$$

Then, we employ the expressions in Eqs. (5) and (6) to further derive the demand function (3):

$$q_{ijk} \equiv L_j q^c_{ijk} = \frac{L_j}{\delta} \left(\frac{\delta}{\delta + (\gamma + \eta) N^*_{jk}} \alpha + \frac{\gamma N^*_{jk}}{\delta + \gamma N^*_{jk}} \bar{p}_{jk} + \frac{\delta N^*_{jk} \eta}{\left(\delta + \gamma N^*_{jk}\right)\left[\delta + (\gamma + \eta) N^*_{jk}\right]} \bar{p}_j - p_{ijk} \right), \forall k \in \Omega^*. \quad (7)$$

The set Ω^* in Eq. (7) is defined as the largest subset that can satisfy

$$p_{ijk} \le \frac{\delta}{\delta + (\gamma + \eta) N^*_{jk}} \alpha + \frac{\gamma N^*_{jk}}{\delta + \gamma N^*_{jk}} \bar{p}_{jk} + \frac{\delta N^*_{jk} \eta}{\left(\delta + \gamma N^*_{jk}\right)\left[\delta + (\gamma + \eta) N^*_{jk}\right]} \bar{p}_j \equiv p^{\max}_{jk}, \quad (8)$$

where $p^{\max}_{jk}$ denotes the upper price bound at which the demand for one variety falls to zero. Melitz and Ottaviano (2008) provide a framework in which the price elasticity of demand increases with the price faced by agents when they decide their consumption. The demand function can yield the price elasticity of demand:

$$\varepsilon_{ijk} = -\frac{\left(\frac{\partial q}{\partial p}\right) p_{ijk}}{q_{ijk}} = \frac{p_{ijk}}{p^{\max}_{jk} - p_{ijk}} = \left(\frac{p^{\max}_{jk}}{p_{ijk}} - 1 \right)^{-1} = \left(\frac{\delta}{L_j} \frac{q_{ijk}}{p_{ijk}} \right)^{-1}. \quad (9)$$

Production and trade. In the global markets, a home country exports differentiated good k to country j. We assume that the product quality of the variety k exported from different countries is differentiated in the set Θ. Therefore, we can continue to use subscript i to denote different levels of quality for variety k as well as different countries exporting to country j. Moreover, for country i to produce good k, φ_{ik} indexes the productivity of producing good k, which is the output per unit of labor input.

p^l_{ijk} indexes the export price denominated in local currency in country i, and e_{ij} is the bilateral exchange rate between country i and country j with an indirect quotation, leading to the price of good k faced by the importer in country j: $p^l_{ijk} = p_{ijk}/e_{ij}$.

Furthermore, during the COVID-19 period, governments worldwide have launched many rounds of fiscal and monetary measures to boost economic recovery, and the policy responses have effectively provided relief and support to firms (Alberola et al. 2021). This additional support from the side of government can be captured by λ, where we assume that λ ($0 < \lambda < 1$) units of foreign input factors are sourced without government supports, and 1-λ units of domestic input factors are stemmed from the government in order to support firms against the pandemic. We assume that with stronger government support, the domestic economy would recover at faster pace, leading to a more effective domestic supply chain to provide intermediate inputs. In short, a lower λ captures a larger scale of economic supports from the government.

Based on the discussion of the export behaviors in the context of GVCs, the profit function for trading good k can be given by

$$\pi_{ijk} = \left(p^l_{ijk} - \tau_{ij} \frac{w_i (e_{ij}\lambda + 1 - \lambda)}{\varphi_{ik}} \right) q_{ijk}. \quad (10)$$

After solving the profit maximization problem, we derive the export unit price of good k denominated in local currency:

$$p^l_{ijk} = \left[\frac{\delta}{\delta + (\gamma + \eta) N^*_{jk}} \alpha + \frac{\gamma N^*_{jk}}{\delta + \gamma N^*_{jk}} \bar{p}_{jk} + \frac{\delta N^*_{jk} \eta}{\left(\delta + \gamma N^*_{jk}\right)\left[\delta + (\gamma + \eta) N^*_{jk}\right]} \bar{p}_j \right] \frac{1}{2 e_{ij}} + \frac{\tau_{ij} w_i \left(e_{ij}\lambda + 1 - \lambda\right)}{2 \varphi_{ik}}. \quad (11)$$

In Eq. (11), $\bar{p}_{jk}$ captures the average price of other goods in competition with good k in country j. As other goods can be from domestic and foreign firms, $\bar{p}_{jk} = (e_{jm})^{\omega} \bar{p}$, where e_{jm} is the exchange rate between country i and foreign competing country m, and ω ranges between 0 and 1. In addition, N^*_{jk} is the number of goods in competition with good k in country j.

Exchange rate elasticity of quantity in international trade. After characterizing the demand in country j and production in country i, we can theoretically analyze how exchange rate movements can affect the export volume.

After solving the profit-maximizing problem, the quantity (volume) is given by

$$q_{ijk} = \frac{1}{2} w \left(e_{ij}\lambda + 1 - \lambda \right) \tau_{ij} e_{ij} \left(\frac{1}{\varphi^*_i} - \frac{1}{\varphi} \right), \quad (12)$$

where,

$$\frac{1}{\varphi^*_i} = \frac{1}{w_i \left(e_{ij}\lambda + 1 - \lambda\right) e_{ij} \tau_{ij}} \left[\frac{\delta}{\delta + (\gamma + \eta) N^*_{jk}} \alpha + \frac{\gamma N^*_{jk}}{\delta + \gamma N^*_{jk}} \bar{p}_{jk} + \frac{\delta N^*_{jk} \eta}{\left(\delta + \gamma N^*_{jk}\right)\left[\delta + (\gamma + \eta) N^*_{jk}\right]} \bar{p}_j \right]. \quad (13)$$

In Eq. (13), $\frac{1}{\varphi^*_i}$ represents the productivity threshold for a firm to export. In other words, in this condition, the profit for this firm to export to country j is zero. Therefore, the exchange rate elasticity of export volume is given by

$$\begin{aligned} \varepsilon^q_{ijk} &= -\frac{\partial q_{ijk}}{\partial e_{ij}} \frac{e_{ij}}{q_{ijk}} = \frac{w_i \left(e_{ij}\lambda + 1 - \lambda\right) \tau_{ij} e_{ij}}{w_i \left(e_{ij}\lambda + 1 - \lambda\right) \tau_{ij} e_{ij} - \varphi_{ik} p^{\max}_{jk}} \\ &= \frac{w_i \left(e_{ij}\lambda + 1 - \lambda\right) \tau_{ij} e_{ij}}{2\left[w_i \left(e_{ij}\lambda + 1 - \lambda\right) \tau_{ij} e_{ij} - \varphi_{ik} p^l_{ijk} \right]}. \end{aligned} \quad (14)$$

In our empirical exercises, different Asian trading partners export to different Chinese provinces. In other words, one

Chinese province imports good k from various Asian economies. The model delivers the following propositions.

Proposition 1: *The Policy Effect can be characterized as*:

$\frac{\partial \epsilon_{ijk}^{q}}{\partial \lambda} > 0$: *The responsiveness of export quantity to exchange rate movements decreases with a higher degree (i.e., a lower λ) of economic support policies from the domestic government.*

Proposition 2: *The Foreign Competition Effect can be characterized as*:

(a) *When a foreign competitor's currency depreciates against one country's currency, the country will lose competitiveness in its domestic exports to its foreign competitors, leading to a decline in its export quantity.*

(b) *The foreign competition effect can be captured by the average price of competitive goods,* $\bar{p}_{jk}$*, and the number of competitive goods,* N_{jk}^{*}*: a lower* $\bar{p}_{jk}$ *and a larger* N_{jk}^{*} *can represent a tougher competitive environment from competitors exporting to the same destination.*

In sum, for theoretical predictions, this model leads to two propositions. Proposition 1 pertains to the policy effect, suggesting that the government policies would affect the exchange rate responsiveness. Proposition 2 focuses on the foreign competition effect, when different exporters export to the same destination. In our empirical analyses, one specific Chinese province imports from different Asian trading partners, so those Asian economies would compete with each other in exporting to the same Chinese province. Therefore, China's import behaviors would be influenced by both the policy effect and the foreign competition effect. These two propositions guide our empirical analyses.

Empirical strategy

We estimate how the foreign competition and government policies affect the exchange rate elasticity using the monthly trade data at HS 2017 8-digit level. The estimated model takes the form:

$$\begin{aligned}\Delta \ln IM_{ijkt} = {} & \beta_0 + \beta_1 \Delta \ln RER\_CNY_{ij,t-1} + \beta_2 \Delta lnRER\_CNY_{ij,t-1} \\ & \times Policy_{i,t} + \beta_3 \Delta lnRER\_CNY_{ij,t-1} \times HHI_{jk,t-1} \\ & + \beta_4 \Delta \ln RER\_Comp_{ijk,t-1} + \beta_5 \Delta lnRER\_Comp_{ijk,t-1} \\ & \times Policy_{i,t} + \beta_6 \Delta \ln RER\_Comp_{ijk,t-1} \times HHI_{jk,t-1} \\ & + \beta_5 \Delta \ln COVID_{i,t} + \lambda_{jt} + \delta_{ijk} + \tau_t + \varepsilon_{ijkt}.\end{aligned} \quad (15)$$

The dependent variable IM_{ijkt} represents either the total value of import (in RMB), the import unit price (in RMB), or the import quantity of product k exported from Asian economy i to Chinese province j at the 8-digit HS 2017 disaggregation level in period t. Each period refers to a specific month between January 2019 and March 2021. The dependent variables are expressed in log difference, which can help to eliminate any time-invariant exporter-importer-product characteristics.

A set of regressors have been included in the regression. First, $\Delta lnRER\_CNY_{ij}$ measures the real depreciation of RMB (Chinese yuan) against China's Asian trading partners. This real exchange rate is deflated using China's provincial CPI and the trading partners' CPI. The monthly bilateral exchange rates are obtained from the International Monetary Fund (IMF) database.

Second, to investigate the effect of the economic support policies on the exchange rate elasticity of trade, we interact the exchange rate variables with the Oxford economic support index to form the variable $\Delta lnRER\_CNY_{ij} \times Policy_i$.[4] This effect is the focus of this study. The coefficient β_2 of this interaction term captures the policy effect on the bilateral exchange rate elasticity and is expected to be negative according to **Proposition 1** in the theoretical model.

To measure the economic support policies implemented in different countries, we adopt the Oxford Economic support index to quantify the income support for the unemployed people, the debt relief, fiscal stimulus, and other public expenditure used to boost the economic recovery from the COVID-19 setback. Because the Oxford index is measured on a daily basis, we calculate the monthly average of this index and then rescale it from 0–100 to 0.01–1, following Liu et al. (2021). For robustness check, we also employ the Oxford containment and health index as an additional analysis.

Third, we include the competitors' real exchange rates $lnRER\_Comp_{ijk}$ which is calculated as the trade-weighted average of bilateral real exchange rates of the countries that export product k to province j at time t during the period of 2019 to 2021.[5] An increase in $\Delta lnRER\_Comp_{ijk}$ indicates a real appreciation of the competitors' currencies, which is the movements of third-country exchange rates at the exporter-product-importer level. Its coefficient β_4 measures the foreign competition effect (Chen et al. 2018; Mattoo et al. 2017; Pennings, 2017) and is expected to be positive based on Proposition 2 from the theoretical model. As this competition effect can be affected by the different support policies adopted in different countries in response to COVID-19, we augment the regression with the interaction term $\Delta lnRER\_Comp_{ijk} \times Policy_i$ to examine how the policies in other trading competitors modifying the competition effect from these countries. This impact is dubbed the competition channel of the policy effect, which is captured by the coefficient β_5.

In real-world business activities, firms are unlikely to respond instantaneously to exchange rate changes but exhibit in a "wait and see" manner. Exporters or importers may need time to adjust their trading behaviors to the exchange rate movements or other economic conditions due to pre-signed contracts or lagged responses (Clark et al. 2004; Thorbecke, 2008; Dao et al. 2021). Because we employ a monthly panel, it would be necessary for us to used lagged terms for the exchange rate variables. In this paper, we follow a series of studies on the exchange rate elasticity to use one-period lagged terms for the exchange rate variables (Sukar and Hassan, 2001; Taylor et al. 2021).

Moreover, the market concentration of trade environment, HHI, is calculated as the sum of the squared import shares for each province importing from each country around the world at the product level. Specifically,

$$HHI_{jkt} = \sum_{i \in \Omega}^{n} \left(\frac{IM_{ijkt}}{IM_{jkt}} \right)^2 \quad (16)$$

In Eq. (16), HHI_{jkt} denotes the concentration index for one specific product k imported by province j at time t. Given province j's imports of product k, $\frac{IM_{ijkt}}{IM_{jkt}}$ denotes the share of import from country i relative to the overall provincial imports of this product at time t. Country i belongs to the set of global exporters, Ω. As a result, HHI_{jkt} captures the concentration of foreign competitors (at the HS 8-digit level) in China for a given pair of an Asian economy (the exporter) and a province (the importer) in period t. Therefore, β_3 and β_6 capture how the degree of market concentration would affect the bilateral and the third-country (competitors) exchange rate elasticity of China's imports from Asian trading partners.

In the regression, we also include the newly confirmed COVID-19 cases in the Asian exporting country each month. It measures the number of cases per millions of populations, which is used to capture how the severity of the pandemic affects the trade flows (Liu et al. 2021; Zhao et al. 2021).

To alleviate the possible endogeneity issue, we use the lagged value of the exchange rate movements and the concentration index because trade growth may reversely affect the change of exchange rate against RMB and the intensity of foreign competition among Asian exporters. Furthermore, the trading value is at

Table 1 Descriptive statistics of major variables.

Variable	Observation	Mean	Std. Dev.	25th	75th	Source
Export value, yuan	2614489	3874398.8	61919414	6157	487080	Customs data
Export unit price, yuan	2614489	1154371	28649871	9	5683	Customs data
Export volume, unit	2481061	56048.82	3189501.9	27.97	885	Customs data
Monthly COVID-19 new confirmed cases in an Asian economy, per millions of populations	2572154	421.04	1800.59	1.71	265.42	JHU CRC
HHI	2614489	0.55	0.29	0.3	0.82	Customs data
Real exchange rate (CNY/Foreign currency)	2301049	0.68	1.38	0.06	1.15	IMF
Foreign competitors' trade-weighted exchange rate	2614489	2.31	2.35	0.25	3.93	IMF
Economic support index (policies in response to COVID)	2614489	0.52	0.32	0.38	0.75	OxCGRT
Containment and health index (policies in response to COVID)	2614489	0.5	0.18	0.38	0.65	OxCGRT

Note: Columns named "25th" and "75th" report the 25^{th} percentile and 75^{th} percentile, respectively. Please note that for COVID-related variables, the number of observations only counts for the year of 2020 and 2021, but we follow the literature use the value of 0 for non-COVID period in our empirical analysis for those COVID-related variables. The customs data are from the General Administration of Customs of the PRC. The customs data are at the importer-exporter-product level with HS2017 8-digit product codes. "JHU CRC" stands for the Johns Hopkins Coronavirus Resource Center. "NHC PRC" is the National Health Committee of the People's Republic of China. "OxCGRT" stands for the Oxford COVID-19 Government Response Tracker.

the provincial level, but the bilateral exchange rate is at the country-level, which can further mitigate the endogeneity concern. In terms of the foreign competition effect, the competitors' real exchange rates RER_Comp_{ijk} is calculated as the trade-weighted average of bilateral real exchange rates of the countries that export product k to province j at time t: this trade-weighted setting can also alleviate the issue of reverse causality.

Moreover, we add a set of high-dimensional fixed effects to control for a wide range of omitted variables, as the omitted variable bias is also an important source of endogeneity. First, the time-varying province FE can account for provincial characteristics across different time periods, which allows us to control for omitted provincial-specific factors. Then, we include the province-product-destination fixed effect δ_{ijk}, which accounts for trends in the prices and exports at the province-product-destination level.[6] We also include the monthly fixed effect τ_t to account for seasonality.

One caveat is that, exchange rate variation may be affected by the COVID-19 and the pandemic-induced government policies (Wang et al. 2023). Therefore, we use a lagged value for the bilateral exchange rate variable and the competitors' trade-weighted exchange rate variable, but the policy variable is not lagged, as we assume that the economic support policies would result in immediate policy effect. This setting could alleviate the casual issue due to the correlation between those variables.

The summary statistics for the variables used in the empirical analyses are listed in Table 1.

Empirical results

Baseline results. We begin by estimating Eq. (15) for two groups of imports. Columns (1) to (3) of Table 2 report the results for China's imports of all types of goods from other Asian economies, and Columns (4) to (6) for the imports of intermediate inputs, classified by the Broad Economic Categories (BEC). For each group, the dependent variables include the change in the total import value (v), import price (uv), and import quantity (q).

Exchange rate effects and the policy effect. Columns (1) to (3) of Table 2 show that China's imports of all types of goods from Asian exporters is quite responsive to the bilateral exchange rate movements *RER_CNY*. In Column (1), we estimate that a 10% real depreciation of RMB will boost the average provincial import by around 17.58% on average. Whilst this finding seems to be at odds with the usual economic intuition that exchange rate depreciation discourages imports, this effect has been documented in several empirical studies on China's imports behavior. For examples, Cheung et al. (2012, 2016), Marquez and Schindler (2007) and Wang and Lee (2012) use the Chinese trade data from different sample periods find that real RMB appreciation can lower China's imports. Similar negative real RMB appreciation effects on China's imports from Asian trading partners are also reported in Herrero and Koivu (2008) and Xing (2012).

Hooy et al. (2015), for instance, notes several factors underlying this seemingly counter-intuitive exchange rate effect. They point out that RMB appreciation lowers the competitiveness of China's exports and, thus, reduces China's import demand for intermediate inputs from other ASEAN countries. Further, the negative RMB appreciation effect can be attributed to the complementarity between China's imports and Asian countries' exports of high- and medium-tech parts and components to China (see, also, Eichengreen et al. 2007; Thorbecke and Smith, 2012).

However, we find that the policy responses of various countries to COVID-19 can alter the sign of the exchange rate elasticity from positive to negative. More specifically, the marginal exchange rate effect conditional on the policy variable is given by $\beta_1 + \beta_2 \text{Policy}_{i,t}$. That means, the exchange rate effect depends on the estimates of β_1 and β_2 and the policy pursued by the exporting country.

As shown in Fig. 8, when we take the policy effect into account, the counter-intuitive finding can be altered. With an average policy response (corresponding to an economic support index of around 0.52), the bilateral exchange rate elasticity would reduce to almost zero, and an above-average policy response can turn the import elasticity to exchange rate from positive (the counter-intuitive scenario) to negative (the intuitive scenario). Specifically, the marginal exchange rate effect is significantly negative when the policy support is strong, meaning that an RMB appreciation would lead to an increase in China's imports. One reason is that, with stronger economic support policies in country i (a higher value of $Policy_{i,t}$), more of its firms can resume their normal production and business operations, and thus regain their normal export including the export to China. A positive coefficient of β_1 coupled with a negative coefficient of β_2 indicates that stronger economic support policies can turn the counter-intuitive positive import exchange rate elasticity to the intuitive negative exchange rate elasticity of import (exchange rate appreciation encourages imports). The negative coefficient of β_2 is also consistent with Proposition 1.

Further, when we focus on the *imports of intermediate inputs* in Columns (4) to (6), the pattern of policy effect on the bilateral exchange rate elasticity ($RER\_CNY \times Policy$) is qualitatively similar to the aggregated imports. However, the magnitude of the policy effect on the import total value and quantity of

Table 2 Baseline results for aggregated imports.

All trade modes	All goods: (1)-(3)			Intermediate inputs: (4)-(6)		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	1.758***	−0.0360	1.854***	2.087***	−0.145	2.342***
	(0.361)	(0.113)	(0.377)	(0.378)	(0.142)	(0.345)
Δ ln RER_CNY × Policy	−3.296***	−0.0566	−3.399***	−3.878***	0.0206	−4.100***
	(0.583)	(0.155)	(0.688)	(0.651)	(0.166)	(0.745)
Δ ln RER_CNY × HHI	0.865**	0.0889	0.802**	0.820**	0.215*	0.605*
	(0.377)	(0.095)	(0.317)	(0.400)	(0.117)	(0.316)
Δ ln RER_Comp	0.115***	0.0133***	0.100***	0.102***	0.00817***	0.0911***
	(0.011)	(0.002)	(0.011)	(0.011)	(0.002)	(0.010)
Δ ln RER_Comp × Policy	−0.0251***	−0.00326	−0.0215***	−0.0242***	−0.000306	−0.0236***
	(0.007)	(0.002)	(0.007)	(0.007)	(0.003)	(0.008)
Δ ln RER_Comp × HHI	−0.0871***	−0.00933***	−0.0802***	−0.0725***	−0.00681**	−0.0687***
	(0.009)	(0.002)	(0.009)	(0.010)	(0.002)	(0.010)
Δ ln Cases in exporting country	−0.0153***	0.00279***	−0.0180***	−0.0135***	0.00418***	−0.0172***
	(0.003)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)
Constant	−0.111***	−0.0151***	−0.0788***	−0.106***	−0.00842**	−0.0756***
	(0.010)	(0.003)	(0.006)	(0.011)	(0.003)	(0.010)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2352568	2248753	2248764	1529934	1449191	1449192
R^2	0.052	0.032	0.049	0.049	0.030	0.047
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. Columns (1) to (3) are for all types of goods, and Columns (4) to (6) are for inputs, classified by the Broad Economic Categories (BEC). An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. The HHI itself and the policy variable itself are also included in the regressions but not reported. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.
We do not report the estimated coefficients of the HHI variable and the policy variable, which are measured at level, not in the form of the logarithmic change.

intermediate inputs (as shown in Column (4) and (6)) is larger than that for other types of products (as shown in Column (1) and (3)). It indicates that the import of intermediate inputs from Asian trading partners is more sensitive to the policy effect than the import of other types of products.

One important advantage of our Chinese customs data is that we can distinguish between changes in trade quantity (volume) and unit price, which may drive the export or import behaviors differently. As shown in Table 2, the RMB exchange rate movements would mainly induce quantity adjustments as reported in Columns (3) and (6) instead of unit price adjustments as reported in Columns (2) and (5). Moreover, the interaction term between exchange rate movements of domestic currency against RMB and the policy index (*RER_CNY × Policy*) registers significantly positive negative in Columns (1) and (3), indicating that more fiscal and monetary stimulus would decrease the exchange rate elasticity of import total value and quantity, but has no significant impact on the import unit price.

There are a number of reasons regarding why it is the trade volume, not trade unit value that responds to exchange rate changes. First, Meade (1988) proposes that changes in exchange rate can affect the nominal trade balance directly through export and import prices, and indirectly through the response of export and import volumes to alteration in relative prices. The indirect effect is captured in the theoretical import demand equation in which the quantity demand for imports is determined by the relative prices (which is driven by exchange rate movements) and other control variables (Feenstra, 2004; Feenstra and Taylor, 2014; Krugman and Obstfeld, 2009). Specifically, Feenstra (2004) defines the demand equation in international trade by using the quantity as the dependent variable and using the import price and the domestic price as the independent variables. Similarly, Krugman and Obstfeld (2009) also use the import quantity as the dependent variables as a function of foreign and domestic prices. In fact, the relative price of foreign and domestic price is also related to exchange rate, which is focus of our study.

Basing on China's import demand function, Tang (2003) and Fukumoto (2012) estimate how the relative prices and macroeconomic variables affect China's import quantity. In addition, Marquez and Schindler (2007) show that China's import quantity demand does respond to the RMB exchange rate. In our study, we follow this line of literature to estimate whether the policy effects on exchange rate elasticity would impact China's import demand. Furthermore, with the focus on the short-run effects, Marquez and Schindler (2007) and Zhang et al. (2015) employ China's monthly trade data to show that the exchange rate movements also exhibit the short-run impact on the import quantity. In addition to the studies on China, Kim (2017) uses the monthly data to find that South Korea' imports are sensitive to the exchange rate movements and volatility. Similarly, in our study, we find that the import quantity is empirically quite responsive to exchange rate movements and related policy effects.

The foreign competition effect. Regarding the foreign competition effect, we obtain a positive coefficient for β_4 (where an increase in *RER_Comp* means an appreciation of the competitor's currencies), which is consistent with Proposition 2. This suggests that when a foreign competitor's currency depreciates against one country's currency, the country will lose competitiveness in its domestic exports to its foreign competitors, leading to a

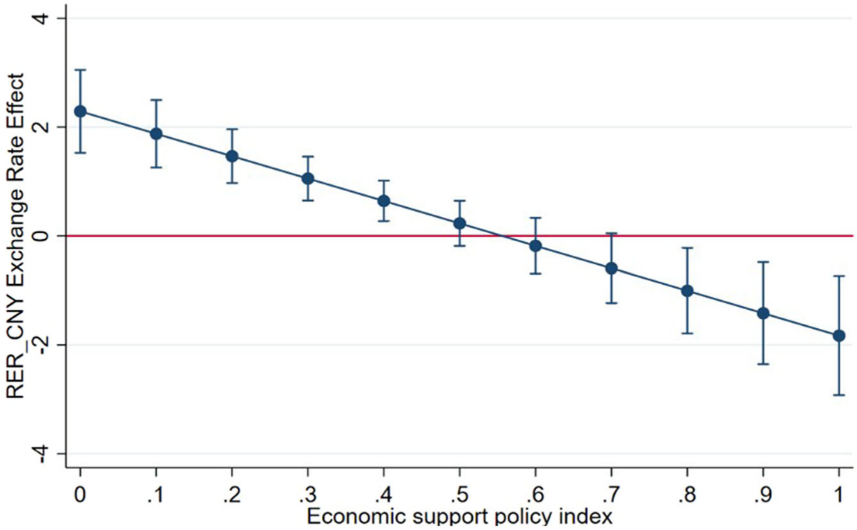

Fig. 8 Average marginal effect of the RMB exchange rate movements on China's total import from itsAsian trading partners in response to different degree of economic support policy of the Asian tradingpartners (with 95% confidence interval), 2019m1 to 2021m3. Source Authors' calculation based on the regression result from Column (1) of Table 2.

decline in its exports. This pattern is regarded as the *foreign competition effect* or the *third-country exchange rate effect* in the exchange rate elasticity of trade (Chen et al. 2018; Mattoo et al. 2017; Pennings, 2017). This finding is consistent with the third-country effect or the competitors' exchange rate effect documented in the literature (Chen et al. 2018; Mattoo et al. 2017; Pennings, 2017).

The estimate of the interaction term $RER\_Comp \times Policy$ (β_5) is significantly negative for China's import value, suggesting that government's fiscal and monetary policies can alleviate the competition effect caused by foreign countries' exchange rate depreciation, as indicated by the marginal effect shown in Fig. 9 below. This result implies that, exporters can benefit from the government's economic support policies to expediate their production recovery and become less vulnerable to foreign competitors' currency depreciation, thus reducing the foreign competition effect.

Furthermore, the *degree of market concentration* is found to affect the magnitude of this "beggar-thy-neighbor" effect at the exporter-product-importer level. The effect would become larger for an Asian economy with a lower degree of market concentration of foreign competitors exporting to China. This is indicated by a statistically significant negative estimated coefficient for the interaction term $RER\_Comp \times HHI$, where an increase in *HHI* represents a higher degree of market concentration. Our result in Column (1) shows that increasing the market concentration by one standard deviation will boost the response of import values to competitors' trade-weighted exchange rates by 21.94%. This is because a lower degree of concentration may lead to a less monopolistic environment, and then the competitors' actions would have a larger impact (Matsumoto et al. 2012; Spiegel, 2021).[7]

The effect of pandemic severity. The number of new COVID cases in the exporting Asian countries has a significant negative effect on the total value of exports to a Chinese province, as indicated by a negative β_7. This result reflects that a more severe pandemic would cause greater interruption to the production and slowdown trade activities. The negative effect on total trade flows is consistent with the findings in other studies such as Friedt and Zhang (2020), Vidya and Prabheesh (2020), Liu et al. (2021), and Zhao et al. (2021).

China's processing trade. As we discussed in Section "Database", there are significant differences between ordinary trade and processing trade in China. Within China's processing imports from Asian trading partners, we would like to highlight the differences between processing trade and ordinary trade. According to Cheung et al. (2012), Li et al. (2015), and Dai et al. (2016), the involvement of processing trade plays an important role in the exchange rate elasticity of trade flows because it affects the cost structure and productivity of firms. Moreover, the special pattern of processing trade also affects import and export behaviors due to the consideration of operation cost, tariffs, and other factors (Dai et al. 2016; Manova and Yu, 2016). For example, processing imports subjected to favorable tariff rates can be used to produce finished goods for further exports to other countries, leading to some interesting facts for the exchange rate elasticity in our specification (Cheung et al. 2012).

The government support policies in face of COVID-19 boost China's economic recovery, leading to a strong rebound of the imports of intermediate inputs for further production, which can be captured by the processing trade. Furthermore, because imported inputs take up a large portion of China's imports from Asian trading partners and underpin China's position as the central node in the GVC network in Asia, it is important for us to perform a thorough investigation of processing trade (Liu et al. 2021). In general, there are major differences between ordinary imports and processing imports in China.

According to Table 3, for processing imports, the coefficients of the RMB exchange rate movements and the related policy effect ($RER\_CNY \times Policy$) are larger in magnitude than the corresponding ones for the ordinary imports, indicating that exchange rate effects on processing imports would be more sensitive to government policies in response to the pandemic than ordinary imports. In addition, compared between those two types of trade, the coefficient of $RER\_Comp \times Policy$ is larger in absolute value for processing imports, indicating stronger economic support policies would further dampen the foreign competition effect for processing trade. Furthermore, the severity of the pandemic in the exporting countries is more economically significant for ordinary imports than processing imports.

Furthermore, within processing imports, we will distinguish between processing with imported materials (PI) and pure assembly (PA), which have been introduced in Section "Database".

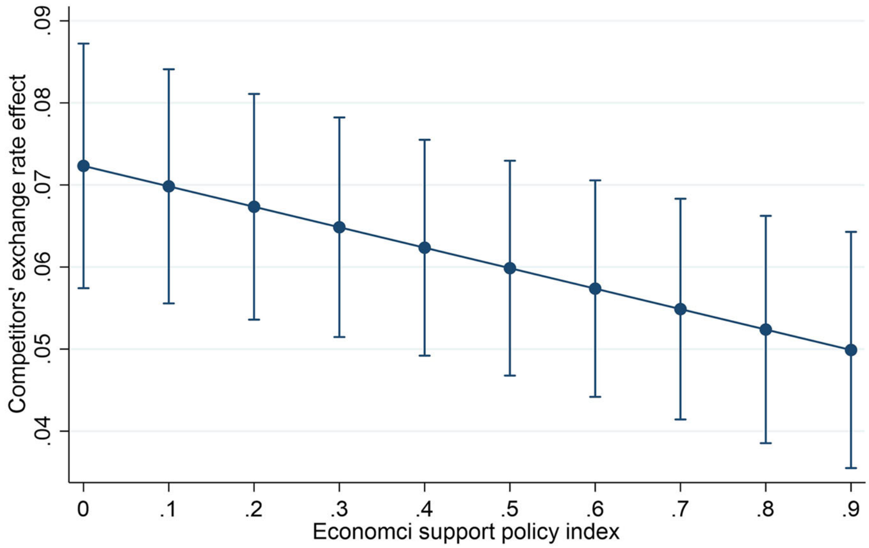

Fig. 9 Average marginal effect of the competitors' exchange rate movements on China's total import fromits Asian trading partners in response to different degree of economic support policy of the Asian tradingpartners (with 95% confidence interval), 2019m^1 to 2021m^3. Source Authors' calculation based on the regression result from Column (1) of Table 2.

Table 4 reports the estimation results for these two types of processing imports by using the specification in Eq. (15). In terms of the exchange rate elasticity, we find that, for the PI mode, the total value and quantity are sensitive to both the bilateral exchange rate movements and competitors' trade-weighted (third-country) exchange rate movements, while the import price (unit value) does not respond to those exchange rate variables in a significant manner. The positive coefficient of the RMB exchange rate movements is larger in magnitude than the corresponding one in Table 2, which uses aggregated imports as the dependent variable. In addition, for the PA mode (pure assembly), the price response is negatively associated with RMB appreciation, and a higher degree of market concentration would mitigate this effect. Furthermore, the coefficient of the interaction term $RER\_CNY \times Policy$ is significantly negative for the import quantity, same as the effect on the aggregated imports, though being insignificant for the import price. For the PI mode (processing with imported materials), the interaction term $RER\_Comp \times Policy$ is significant at the 1% level for quantity, but is insignificant for unit price.

Robustness and further discussions. In this section, we explore a battery of robustness exercises and extensions to further investigate the exchange rate elasticity of trade flows and the impact of policy responses to the COVID-19 pandemic.

Discussion on the mechanisms. The baseline results indicate that the pandemic-induced economic support packages reduce the exchange rate elasticity of China's imports from its Asian trading partners. We have also examined the foreign competition channel of the policy effect. In this section, we will further explore another channel, the product quality channel, as suggested in the literature.

As documented in the literature, the upgrade of product quality can increase the export performance in the global markets (Yu, 2010; Feng et al. 2016). With more effective economic support policies in response to the COVID-19 outbreak, firms can recover their production more swiftly, and enhancing their capability to raise the quality of their products. The improvement in the quality of their products attracts more purchases from the Chinese importers. As a result, they would export more finished goods instead of imported inputs to China, leading to a theoretically expected effect of the RMB exchange rate movements.

To examine this product quality channel, we first establish a measure of the export quantity. We then infer the export quality at the province-product level using the methodology proposed by Khandelwal et al. (2013).

$$\ln(ExQuantity_{ijkt}) = \sigma \ln(ExPrice_{ijpt}) + \O_k + \O_{jt} + \varepsilon_{ijkt} \quad (17)$$

In this equation for quality inference, $\O_k$ is the HS 6-digit product fixed effects and $\O_{jt}$ is the destination-month fixed effects. The elasticity of substitution across different products σ is taken from Broda and Weinstein (2006). The intuition behind the quality inference is that, conditional on export price, the varieties with higher export volume have higher quality. We then estimate this equation by OLS panel regression with high-dimensional fixed effects and then take the residuals $\widehat{\varepsilon_{ijkt}}$ as a measure of the product quality.

According to Table 5, after setting the quality as the dependent variable based on the baseline model, the estimated coefficient of the policy effect on the bilateral exchange rate movement ($RER\_CNY \times Policy$) enters with a significantly negative sign, which is consistent with our conjecture.

Next, to verify that changes in the quality of products will affect the policy effect on exchange rate elasticity of trade flows, we interact the quality measure with the interaction term between the real exchange rate and policy variable $RER\_CNY \times Policy$. From Table 6, the estimated coefficients of this triple interaction term are significantly negative in Columns (1) and (3), which is consistent with our conjecture that product quality is a significant channel for the policy effect on the bilateral exchange rate elasticity of China's imports from Asian trading partners.

Compared with the foreign competition channel, we have stated that economic support policies can promote economic recovery and attract more foreign orders for export products, thus offsetting the negative impact caused by foreign competitors' currency depreciation. In our results, the interaction term $RER\_Comp \times Policy$ is significantly negative, confirming the above argument that the foreign competition channel could offset the competitors' exchange rate changes and thus reduce the third-country exchange rate elasticity of trade flows.

Table 3 Estimation results for ordinary trade and processing trade.

	Ordinary Trade			Processing Trade		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	1.609***	0.0137	1.589***	2.979***	−0.194	3.203***
	(0.345)	(0.097)	(0.387)	(0.279)	(0.153)	(0.231)
Δ ln RER_CNY × Policy	−2.754***	−0.292	−2.499***	−4.816***	0.157	−5.016***
	(0.690)	(0.199)	(0.842)	(0.936)	(0.293)	(0.808)
Δ ln RER_CNY × HHI	0.307	0.0574	0.291	0.542*	0.0975	0.381*
	(0.455)	(0.161)	(0.431)	(0.275)	(0.132)	(0.211)
Δ ln RER_Comp	0.143***	0.0124***	0.128***	0.0698***	0.0105***	0.0576***
	(0.012)	(0.002)	(0.012)	(0.007)	(0.003)	(0.008)
Δ ln RER_Comp × Policy	−0.0251**	−0.00514	−0.0194*	−0.0352***	−0.000386	−0.0373***
	(0.010)	(0.003)	(0.010)	(0.010)	(0.003)	(0.010)
Δ ln RER_Comp× HHI	−0.106***	−0.00806***	−0.0998***	−0.0653***	−0.0121**	−0.0490***
	(0.010)	(0.002)	(0.009)	(0.009)	(0.004)	(0.010)
Δ ln Cases in exporting country	−0.0147***	0.00371*	−0.0181***	−0.0116**	0.00520***	−0.0171***
	(0.005)	(0.002)	(0.004)	(0.005)	(0.0007)	(0.005)
Constant	−0.208***	−0.0183***	−0.165***	−0.178***	−0.0133**	−0.153***
	(0.013)	(0.005)	(0.013)	(0.016)	(0.006)	(0.014)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1276121	1226051	1226054	580896	567005	567006
R^2	0.070	0.052	0.065	0.067	0.032	0.064
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: Columns (1)-(3) use samples of ordinary trade, and Columns (4)-(6) use samples of processing trade, including both the PA mode and the PI mode. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Imported inputs from ordinary trade. When Chinese firms source intermediate inputs from the global market, they may opt for ordinary trade to gain more flexibility instead of processing trade which is subject to tighter specification requirement by the foreign partners. In contrast to pure assembly (PA) trade which are not sensitive to exchange rate movements because they directly sign contracts with foreign companies and then purely process without "autonomy", both processing with imports (PI) and ordinary trade firms are more sensitive to exchange rates because they can decide where to import inputs and where to export their final products. Therefore, we examine whether the baseline results remain robust when we focus on ordinary trade.

Table 7 reports the estimation results for ordinary trade. We obtain larger estimated coefficients in absolute value on both the bilateral exchange rate movements (*RER_CNY*) and the policy effect on the bilateral exchange rate elasticity (*RER_CNY* × *Policy*) for imported inputs from ordinary trade. Regarding the foreign competition effect, the depreciation of foreign competitors' currencies would deter the exports of Asian trading partners to China via both price adjustments and quantity adjustments. This adverse third-country exchange rate effect is weaker for the intermediate inputs (reported in Columns (4) to (6)) than the overall imports (reported in Columns (1) to (3)). Overall, the estimation results are qualitatively and quantitatively similar to the baseline results, indicating that our main findings remain robust.

Heterogeneous effects across regions. In this section, we assess the robustness of the baseline results to different estimation samples. In the previous sections, we have shown that the policy effect is important in determining the exchange rate elasticity of trade in Asia. However, different Chinese provinces and Asian trading partners could react to this effect differently. In view of this, we perform robustness checks by subdividing the data into different subsamples of importers and exporters with heterogeneous regional characteristics.

To start with, we study whether different groups of Asian countries (exporters) at different level of development and wealth may have different exchange rate elasticity responds to foreign competition and to pandemic-induced economic support policies. Table 8 compares between high-income Asian countries exporting to China and non-high-income Asian countries exporting to China. In terms of the magnitude of the policy effect measured by *RER_CNY* × *Policy*, it is notably higher for high-income countries than for relatively low-income ones, as shown in Columns (1) and (2). After decomposing the total value into unit price and quantity, we find that, for both high-income countries and relatively low-income countries as exporters towards the Chinese market, the depreciation of trade-weighted competitors' currencies would deter the exports more through quantity adjustment than through price adjustment. Moreover, when interacted with the policy variable, competitors' exchange rate variable is not significant for high-income Asian economies.

Next, we proceed to examine whether the effect exhibits provincial heterogeneity. In particular, we estimate the responses of China's imports to exchange rate movements for coastal and interior provinces. The results are reported in Table 9. Compared between Columns (1) and (2), the policy effect on the bilateral exchange rate elasticity is larger in absolute value for coastal

Table 4 Estimation results for two types of processing trade.

Processing trade	PI mode			PA mode		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	3.021***	−0.0269	3.210***	3.950***	−0.804**	4.303***
	(0.329)	(0.191)	(0.311)	(0.554)	(0.305)	(0.369)
Δ ln RER_CNY × Policy	−4.865***	0.0248	−5.035***	−4.283**	0.485	−4.272**
	(1.027)	(0.267)	(0.983)	(1.651)	(0.664)	(1.605)
Δ ln RER_CNY × HHI	0.215	−0.186	0.104	−0.517	1.052***	−1.134**
	(0.383)	(0.208)	(0.337)	(0.606)	(0.373)	(0.522)
Δ ln RER_Comp	0.0772***	0.00792	0.0669***	0.0735***	0.0202***	0.0493**
	(0.008)	(0.005)	(0.008)	(0.022)	(0.006)	(0.021)
Δ ln RER_Comp × Policy	−0.0284***	0.00346	−0.0352***	−0.0568*	−0.0108**	−0.0438
	(0.009)	(0.004)	(0.007)	(0.030)	(0.004)	(0.028)
Δ ln RER_Comp× HHI	−0.0681***	−0.0112*	−0.0523***	−0.0660***	−0.0183**	−0.0415**
	(0.013)	(0.006)	(0.011)	(0.019)	(0.008)	(0.020)
Δ ln Cases in exporting country	−0.0133***	0.00473***	−0.0178***	−0.00630	0.00757*	−0.0165
	(0.003)	(0.001)	(0.004)	(0.014)	(0.004)	(0.013)
Constant	−0.250***	−0.00633	−0.220***	−0.337***	−0.0357***	−0.276***
	(0.018)	(0.008)	(0.017)	(0.051)	(0.010)	(0.051)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	446603	435644	435645	134293	131361	131361
R^2	0.074	0.037	0.069	0.095	0.047	0.090
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: Columns (1)-(3) use samples of the PI mode, and Columns (4)-(6) use samples of the PA mode. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 5 Estimation results for using quality as the dependent variable.

Full sample	Y = Δ ln Quality		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)
	All	Ordinary	Processing
Δ ln RER_CNY	0.552***	0.263	1.284***
	(0.153)	(0.190)	(0.154)
Δ ln RER_CNY × Policy	−1.586***	−0.857***	−2.831***
	(0.236)	(0.266)	(0.284)
Δ ln RER_CNY × HHI	0.131	0.0437	−0.260
	(0.142)	(0.220)	(0.319)
Δ ln RER_Comp	0.0381***	0.0444***	0.0244***
	(0.003)	(0.003)	(0.003)
Δ ln RER_Comp × Policy	−0.00841***	−0.00786*	−0.00524
	(0.002)	(0.004)	(0.003)
Δ ln RER_Comp× HHI	−0.0333***	−0.0380***	−0.0231***
	(0.002)	(0.003)	(0.005)
Δ ln Cases in exporting country	−0.00558***	−0.00529**	−0.00620**
	(0.002)	(0.002)	(0.002)
Constant	−0.208***	−0.0183***	−0.165***
	(0.013)	(0.005)	(0.014)
Controls	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	1272973	696152	374452
R^2	0.073	0.101	0.083
Prob > F-statistic	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 6 Product quality channel and foreign competition channel.

Monthly: 2019m1 to 2021m3	(1)	(2)	(3)
Full sample	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY × Policy × Quality	−0.267*** (0.094)	−0.00953 (0.052)	−0.189** (0.082)
Δ ln RER_CNY × Policy	−3.317*** (0.519)	−0.131 (0.145)	−3.228*** (0.581)
Δ ln RER_Comp × Policy	−0.0255*** (0.006)	−0.00210 (0.002)	−0.0220*** (0.006)
Δ ln RER_Comp × Quality	−0.00478*** (0.001)	−0.00377*** (0.001)	−0.000887 (0.001)
Δ ln RER_Comp × HHI	−0.128*** (0.008)	0.000125 (0.002)	−0.124*** (0.007)
Constant	−0.334*** (0.011)	0.0777*** (0.008)	−0.438*** (0.015)
Controls	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	2213981	2181128	2181129
R^2	0.136	0.055	0.178
F-statistic	0.000	0.000	0.000

Note: The measure of quality is based on Khandelwal et al. (2013). We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. ** and *** indicate variables significant at 5% and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 7 Estimation results for ordinary trade.

Ordinary trade	All goods: (1)-(3)			Intermediate inputs: (4)-(6)		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	1.609*** (0.345)	0.0137 (0.0973)	1.589*** (0.387)	1.771*** (0.478)	−0.0975 (0.146)	1.854*** (0.461)
Δ ln RER_CNY × Policy	−2.754*** (0.690)	−0.292 (0.199)	−2.499*** (0.842)	−3.256*** (0.805)	−0.323 (0.262)	−2.926*** (0.923)
Δ ln RER_CNY × HHI	0.307 (0.455)	0.0574 (0.161)	0.291 (0.431)	0.480 (0.501)	0.403** (0.181)	0.126 (0.449)
Δ ln RER_Comp	0.143*** (0.012)	0.0124*** (0.002)	0.128*** (0.012)	0.133*** (0.013)	0.00590** (0.002)	0.122*** (0.011)
Δ ln RER_Comp × Policy	−0.0251** (0.010)	−0.00514 (0.003)	−0.0194* (0.010)	−0.0239*** (0.008)	−0.00311 (0.005)	−0.0194* (0.010)
Δ ln RER_Comp × HHI	−0.106*** (0.0101)	−0.00806*** (0.002)	−0.0998*** (0.009)	−0.0947*** (0.012)	−0.00617** (0.003)	−0.0891*** (0.011)
Δ ln Cases in exporting country	−0.0147*** (0.005)	0.00371* (0.002)	−0.0181*** (0.004)	−0.0119*** (0.004)	0.00506** (0.002)	−0.0160*** (0.004)
Constant	−0.208*** (0.013)	−0.0183*** (0.005)	−0.165*** (0.014)	−0.221*** (0.011)	−0.00836 (0.006)	−0.181*** (0.014)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1276121	1226051	1226054	766851	731486	731487
R^2	0.070	0.052	0.065	0.069	0.052	0.065
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. Columns (1) to (3) are for all types of goods, and Columns (4) to (6) are for inputs, classified by the Broad Economic Categories (BEC). An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

provinces. In addition, the quantity adjustment of this policy effect is only significant for coastal provinces' imports, as shown in Column (5). Besides, the estimated coefficient for the competitors' exchange rate movements (*RER_Comp*) is smaller for coastal provinces than for interior ones, suggesting that the imports of coastal provinces from other Asian countries are less sensitive to the movements of competitors' currencies.

Heterogeneous effects across industries and products. To examine how the GVC integration would impact the policy effect in response to the COVID-19 pandemic, we incorporate the Chinese customs data with the Asian Development Bank Multi-regional input-output (ADB MRIO) database, which covers much more Asian economies than other input-output tables, such as the WIOD 2016 and the OECD input-output tables.

Table 8 Exchange rate elasticity of total import value with country heterogeneity.

All trade modes	Y= Δ ln v		Y= Δ ln uv		Y= Δ ln q	
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	High-income	Middle- and low-income	High-income	Middle- and low-income	High-income	Middle- and low-income
Δ ln RER_CNY × Policy	−1.934***	−1.498*	−0.301	0.380***	−1.957**	−2.172**
	(0.624)	(0.840)	(0.365)	(0.0987)	(0.945)	(0.856)
Δ ln RER_Comp	0.122***	0.111***	0.0173***	0.00759**	0.104***	0.0988***
	(0.013)	(0.009)	(0.003)	(0.003)	(0.012)	(0.009)
Δ ln RER_Comp × Policy	−0.00289	−0.0197***	0.00217	−0.00290	−0.00900	−0.0131**
	(0.008)	(0.005)	(0.003)	(0.003)	(0.007)	(0.005)
Δ ln RER_Comp × HHI	−0.0789***	−0.152***	−0.0109***	−0.0167***	−0.0724***	−0.131***
	(0.010)	(0.008)	(0.003)	(0.003)	(0.011)	(0.007)
Constant	−0.0839***	−0.0960***	−0.0135***	−0.0206***	−0.0481***	−0.0673***
	(0.013)	(0.017)	(0.003)	(0.004)	(0.012)	(0.014)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1242476	1110092	1188647	1060106	1188652	1060112
R^2	0.053	0.056	0.031	0.034	0.049	0.053
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: The classification of countries based on income level is from the World Bank Country and Lending Groups Classification. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 9 Exchange rate elasticity of total import value with provincial heterogeneity.

All trade modes	Y= Δ ln v		Y= Δ ln uv		Y= Δ ln q	
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Coastal	Interior	Coastal	Interior	Coastal	Interior
Δ ln RER_CNY × Policy	−3.976***	−1.851*	0.143	−0.489*	−4.292***	−1.482
	(0.589)	(0.917)	(0.156)	(0.255)	(0.601)	(1.204)
Δ ln RER_Comp	0.110***	0.126***	0.0111***	0.0184***	0.0979***	0.106***
	(0.0139)	(0.0207)	(0.00177)	(0.00327)	(0.0137)	(0.0184)
Δ ln RER_Comp × Policy	−0.0272**	−0.0207**	−0.00373	−0.00218	−0.0232**	−0.0179***
	(0.0103)	(0.00901)	(0.00296)	(0.00309)	(0.00933)	(0.00598)
Δ ln RER_Comp × HHI	−0.0807***	−0.101***	−0.00803**	−0.0124***	−0.0758***	−0.0900***
	(0.0116)	(0.0209)	(0.00257)	(0.00309)	(0.0109)	(0.0171)
Constant	−0.108***	−0.117***	−0.0146***	−0.0163*	−0.0780***	−0.0796***
	(0.00839)	(0.0278)	(0.00317)	(0.00834)	(0.00556)	(0.0168)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1602342	750226	1539828	708925	1539836	708928
R^2	0.051	0.055	0.030	0.035	0.048	0.053
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

To quantify the global value chain (GVC) position from the input-output structure, Wang et al. (2017) propose an alternative approach to measure the GVC position index based on the decomposition of production length, which is defined as the average number of production stages between the initial inputs in a country-industry to the final goods or services in another country-sector. The interpretation is: if a country-industry is more upstream than another, then it would have a

Table 10 Estimation results for the effect of global value chain (GVC) positions.

Monthly: 2019m1 to 2021m3	(1)	(2)	(4)	(5)
GVC position index	Upstream & All trade modes	Upstream & Ordinary trade	Downstream & All trade modes	Downstream & Ordinary trade
Δ ln RER_CNY	1.545** (0.608)	1.523** (0.574)	2.534*** (0.657)	2.473*** (0.818)
Δ ln RER_CNY × Policy	−2.410** (0.884)	−1.972 (1.218)	−5.290*** (0.928)	−5.051*** (1.332)
Δ ln RER_CNY × HHI	−0.0543 (0.750)	−0.620 (0.719)	0.975* (0.542)	0.804 (0.656)
Δ ln RER_Comp	0.135*** (0.0117)	0.162*** (0.0123)	0.105*** (0.0135)	0.131*** (0.0186)
Δ ln RER_Comp × Policy	−0.0206* (0.0103)	−0.0188 (0.0157)	−0.0244** (0.00890)	−0.0237 (0.0164)
Δ ln RER_Comp× HHI	−0.108*** (0.0119)	−0.141*** (0.0111)	−0.0717*** (0.0109)	−0.0837*** (0.0146)
Δ ln Cases in exporting country	−0.0234*** (0.00398)	−0.0274*** (0.00653)	−0.00542 (0.00446)	−0.00498 (0.00609)
Constant	−0.208*** (0.013)	−0.0183*** (0.005)	−0.178*** (0.016)	−0.0133** (0.006)
Controls	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
N	504169	316494	443762	257803
R^2	0.061	0.076	0.056	0.074
Prob > F-statistic	0.000	0.000	0.000	0.000

Note: The global value chain (GVC) position indices at the country-industry level based on Wang et al. (2017) are obtained from the UIBE GVC Index Database and the Asian Development Bank multiregional input-output tables. Columns (1)-(2) are for samples with Top 25% GVC position index, and columns (3)-(4) are for those with bottom 25% GVC position index. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

higher GVC position index based on the decomposition of production length. This country-industry GVC position index can be directly downloaded from the University of International Business and Economics (UIBE) GVC Indicator Database, provided by Wang et al. (2017)[8].

After incorporating the country-industry-level GVC position index of different Asian trading partners, we split the whole sample into four portions based on different percentiles of the position index (0–25%, 26–50%, 51–75%, and 76–100%). Then, we investigate the effects of GVC integration by comparing the regression results with the top 25% GVC position indices and those with the bottom 25% position indices. Table 10 shows the results. The estimated coefficients of *RER_CNY × Policy* in columns (1)-(2) are larger than those in columns (3)-(4), indicating the policy effect would be larger in magnitude when one Chinese province imports from a country-industry positioned downstream along the global value chains. In addition, the foreign competition effect is larger in magnitude when industries positioned upstream export to Chinese provinces, as suggested by larger estimated coefficients of *RER_Comp* in columns (1)-(2).

Furthermore, product heterogeneity may cause different responsiveness to exchange rate changes (Atkeson and Burstein, 2008; Chen and Juvenal, 2016). We classify the products into five categories or industries based on Lall (2000): primary products industry, resource-based manufacturing industry, low-technology manufacturing industry, medium-technology manufacturing industry, and high-technology manufacturing industry. Then, we study whether the provincial customs data exhibit heterogeneous import responses to exchange rates movements.

As indicated in Table 11, the policy effect on the bilateral exchange rate elasticity, *RER_CNY × Policy*, is larger for medium- and high-technology manufacturing products than for low-technology products. Moreover, the magnitude of this estimate is also large for the imports of resources reported in Column (2). This heterogeneous result indicates that when Asian countries export relatively high-technology (high value-added) products to the Chinese provinces, stronger economic support policies would reduce or even alter the bilateral exchange rate elasticity by a larger magnitude, compared with the exports of low-technology products. In addition, stronger economic support policies would dampen the foreign competition effect, especially for high-technology products, as shown by a larger coefficient estimate for *RER_Comp* and *RER_Comp × Policy* in Column (5).

Alternative measures of the policy effect. In the previous analysis, we include the interaction term between the changes in exchange rates and the policy variable and then graphically show the marginal effect. In this subsection, we specify the policy variable as a categorical variable that contains 4 quartiles (measured as 1 (weakest policy) to 4 (strongest policy)). As shown in Table 12, we find that the coefficient of the interaction term between the quantile policy variable and the exchange rate movements remain significantly negative, indicating that the policy effect on the exchange rate elasticity is robust to this alternative specification.

For further robustness check, we adopt another measure for the policy response. In the baseline results, we focus on the policy on economic support packages in response to the pandemic by employing the Oxford COVID-19 Government Response Tracker (OxCGRT) constructed and maintained by Hale et al. (2021), which quantifies income support for unemployed people, debt relief, fiscal stimulus, and other public expenditures implemented to boost economic recovery from COVID-19. However, as opposed to the measure of economic support in terms of fiscal and monetary assistance, policy responses can also be measured in terms of a containment and health index which is constructed based on the stringency of health policies, such as lockdown, contact tracing, mandatory use of facial coverings, and investments in medical industries. To measure this, we employ the containment and health index compiled by OxCGRT to check whether an alternative policy measure would affect our main results.

Table 13 reports the estimation results with the Oxford containment and health index as an alternative measure of the policy reactions to the pandemic. The coefficients on bilateral exchange rate movements, on competitors' trade-weighted exchange rate movements, and on new COVID cases are quantitively and qualitatively similar to those of the baseline

Table 11 Exchange rate elasticity of total import value with product heterogeneity.

Monthly: 2019m1 to 2021m3 All trade modes (Y = Δ ln v)	(1) Primary	(2) Resource	(3) Low-tech	(4) Medium-tech	(5) High-tech
Δ ln RER_CNY × Policy	−2.408*** (0.812)	−3.856*** (0.630)	−2.401* (1.187)	−3.806*** (0.650)	−3.482*** (0.470)
Δ ln RER_Comp	0.0980*** (0.015)	0.113*** (0.020)	0.110*** (0.013)	0.113*** (0.014)	0.138*** (0.015)
Δ ln RER_Comp × Policy	−2.408*** (0.812)	−3.856*** (0.630)	−2.401* (1.187)	−3.806*** (0.650)	−3.482*** (0.470)
Δ ln RER_Comp × HHI	−0.0253 (0.018)	−0.0211** (0.009)	−0.0194 (0.012)	−0.0202** (0.009)	−0.0526*** (0.011)
Constant	−0.103*** (0.030)	−0.113*** (0.015)	−0.142*** (0.016)	−0.0975*** (0.010)	−0.0824*** (0.010)
Controls	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
N	82160	289194	666605	780891	506739
R^2	0.075	0.059	0.059	0.051	0.047
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000

Note: Product classification is based on Lall (2000). We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 12 Estimation results after breaking the policy variable into quantiles.

All trade modes	All goods: (1)-(3)			Intermediate inputs: (4)-(6)		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	1.935*** (0.420)	−0.00210 (0.077)	1.986*** (0.436)	2.260*** (0.407)	−0.0963 (0.108)	2.460*** (0.385)
Δ ln RER_CNY × Policy (1st)	0.401 (1.166)	−0.521* (0.305)	0.626 (1.492)	0.773 (1.109)	−0.432 (0.270)	0.834 (1.389)
Δ ln RER_CNY × Policy (2nd)	−2.305*** (0.655)	0.0118 (0.145)	−2.277*** (0.671)	−2.892*** (0.547)	0.141 (0.164)	−3.012*** (0.682)
Δ ln RER_CNY × Policy (3rd)	−2.397*** (0.475)	−0.0799 (0.118)	−2.377*** (0.516)	−2.630*** (0.548)	0.0630 (0.105)	−2.725*** (0.520)
Δ ln RER_CNY × Policy (4th)	−2.295*** (0.543)	−0.0367 (0.126)	−2.388*** (0.612)	−2.740*** (0.673)	−0.171 (0.204)	−2.791*** (0.783)
Δ ln RER_Comp	0.112*** (0.011)	0.0129*** (0.002)	0.0982*** (0.011)	0.0994*** (0.011)	0.00797*** (0.002)	0.0892*** (0.011)
Δ ln RER_Comp × Policy (1st)	−0.0171*** (0.003)	0.00322 (0.003)	−0.0112*** (0.003)	−0.0124** (0.005)	0.00387 (0.003)	0.00591 (0.005)
Δ ln RER_Comp × Policy (2nd)	−0.0219*** (0.005)	0.00453** (0.002)	−0.0145*** (0.003)	−0.0179*** (0.005)	0.00217 (0.002)	−0.0126** (0.005)
Δ ln RER_Comp × Policy (3rd)	−0.0161** (0.007)	−0.00297* (0.002)	−0.0115* (0.006)	−0.0179** (0.007)	−0.000108 (0.002)	−0.0164** (0.008)
Δ ln RER_Comp × Policy (4th)	−0.0562*** (0.008)	−0.00889** (0.004)	−0.0442*** (0.008)	−0.0525*** (0.009)	−0.00544** (0.003)	−0.0427*** (0.010)
Constant	−0.191*** (0.065)	−0.122 (0.089)	−0.0505 (0.153)	−0.138*** (0.009)	−0.00812** (0.004)	−0.107*** (0.008)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2352568	2248753	2248764	1529934	1449191	1449192
R^2	0.050	0.032	0.047	0.046	0.029	0.045
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: The policy variable is broken into 4 quartiles. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. Columns (1) to (3) are for all types of goods, and Columns (4) to (6) are for inputs, classified by the Broad Economic Categories (BEC). An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. Other explanatory variables are the same as the baseline specification. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 13 Estimation results with alternative measure of policy response.

All trade modes	All goods: (1)-(3)			Intermediate inputs: (4)-(6)		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q	Y= Δ ln v	Y= Δ ln uv	Y= Δ ln q
Δ ln RER_CNY	1.686***	−0.0721	1.793***	2.024***	−0.148	2.228***
	(0.388)	(0.0696)	(0.425)	(0.330)	(0.101)	(0.331)
Δ ln RER_CNY × Policy	−3.236***	0.0718	−3.350***	−3.860***	0.167	−3.976***
	(0.558)	(0.146)	(0.650)	(0.569)	(0.123)	(0.636)
Δ ln RER_CNY × HHI	0.934**	0.0346	0.915**	1.096***	0.133	0.951**
	(0.395)	(0.0838)	(0.398)	(0.383)	(0.110)	(0.386)
Δ ln RER_Comp	0.104***	0.0110***	0.0928***	0.0930***	0.00691***	0.0849***
	(0.010)	(0.002)	(0.010)	(0.010)	(0.002)	(0.010)
Δ ln RER_Comp × Policy	−0.0131***	−0.00463**	−0.00517**	−0.00775*	−0.00380	−0.000471
	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)	(0.003)
Δ ln RER_Comp × HHI	−0.0866***	−0.00931***	−0.0796***	−0.0723***	−0.00694***	−0.0684***
	(0.009)	(0.002)	(0.009)	(0.010)	(0.003)	(0.010)
Δ ln Cases in exporting country	−0.0153***	0.00266***	−0.0177***	−0.0135***	0.00424***	−0.0172***
	(0.003)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)
Constant	−0.152***	−0.00873**	−0.124***	−0.151***	−0.00396	−0.125***
	(0.008)	(0.003)	(0.006)	(0.009)	(0.004)	(0.008)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2352568	2248753	2248764	1529934	1449191	1449192
R^2	0.049	0.031	0.047	0.046	0.029	0.045
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: The policy measure is the containment and health index provided by Oxford COVID-19 Government Response Tracker. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. Columns (1) to (3) are for all types of goods, and Columns (4) to (6) are for inputs, classified by the Broad Economic Categories (BEC). An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Table 14 Estimation results for the effects of both economic support policies and containment policies.

All trade modes	All products		High-technology products	
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)
	Y= Δ ln v	Y= Δ ln q	Y= Δ ln v	Y= Δ ln q
Δ ln RER_CNY	1.841*** (0.367)	1.932*** (0.384)	1.695*** (0.328)	1.903*** (0.390)
Δ ln RER_CNY × Economic Policies	−1.893*** (0.576)	−2.104*** (0.678)	−2.557*** (0.570)	−2.638*** (0.705)
Δ ln RER_CNY × Containment Policies	−1.471* (0.733)	−1.370* (0.768)	−1.187** (0.499)	−1.379** (0.659)
Controls	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
N	2352568	2248764	506739	492421
R^2	0.052	0.049	0.048	0.043
Prob > F-statistic	0.000	0.000	0.000	0.000

Note: In this table, we compare the effects of economic policies and those of containment and health policies by employing the OxCGRT database. We estimate for all products in columns (1)-(2) and for high-technology products according to Lall (2000) in columns (3)-(4). An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Robust standard errors are reported in parenthesis.

results that use the economic support index. Moreover, in Columns (1) and (3), the estimated coefficients on the interaction terms $RER\_CNY \times Policy$ and $RER\_Comp \times Policy$ remain negative and significant, indicating that government's health policies in response to the COVID-19 pandemic would still reduce the exchange rate elasticity, mainly through quantity adjustments.

Furthermore, after introducing the containment and health policies, we would like to compare which type of policies has exhibited greater impact during the pandemic. As indicated in Table 14, the effect of economic support policies is at a larger magnitude than the containment and health policies, indicating that the economic support measures would be more effective than the containment measures for the recovery of exporting firms in Asia.

Table 15 Estimation results for the nonlinear effects of exchange rate movements.

	Full sample		
	(1)	**(2)**	**(3)**
	Y= Δ ln v	**Y= Δ ln uv**	**Y= Δ ln q**
Squared Δ ln RER_CNY	**19.83*** (3.273)**	**−0.818 (1.518)**	**19.29*** (2.867)**
Squared Δ ln RER_Comp	**0.00602*** (0.0009)**	**0.000627*** (0.0001)**	**0.00501*** (0.0008)**
Δ ln RER_CNY	1.606*** (0.375)	−0.0282 (0.109)	1.706*** (0.377)
Δ ln RER_CNY × Policy	−2.975*** (0.627)	−0.0717 (0.142)	−3.086*** (0.708)
Δ ln RER_CNY × HHI	0.779** (0.374)	0.0900 (0.094)	0.721** (0.317)
Δ ln RER_Comp	0.0919*** (0.013)	0.0109*** (0.002)	0.0809*** (0.012)
Δ ln RER_Comp × Policy	−0.0244*** (0.007)	−0.00318 (0.002)	−0.0210*** (0.006)
Δ ln RER_Comp× HHI	−0.0531*** (0.012)	−0.00577** (0.002)	−0.0517*** (0.011)
Δ ln Cases in exporting country	−0.0164*** (0.003)	0.00284*** (0.001)	−0.0191*** (0.003)
Constant	−0.114*** (0.010)	−0.0152*** (0.003)	−0.0812*** (0.006)
Controls	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	2352568	2248753	2248764
R^2	0.052	0.032	0.049
Prob > F-statistic	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. ** and *** indicate variables significant at 5% and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Nonlinear effect of exchange rate movements. As an additional investigation, we analyze whether the exchange rate movements, both the bilateral and the competitors' weighted-average exchange rates, may exhibit nonlinear effects. To measure the nonlinear effect, we follow Priestley and Ødegaard (2007) to lay out a new specification by adding two squared terms to capture simple nonlinearities, as shown in Eq. (18). Therefore, the estimated results of β_7 and β_8 are of interest.

$$\begin{aligned}\Delta \ln IM_{ijkt} = {} & \beta_0 + \beta_1 \Delta \ln RER\_CNY_{ij,t-1} + \beta_2 \Delta lnRER\_CNY_{ij,t-1} \\ & \times Policy_{i,t} + \beta_3 \Delta lnRER\_CNY_{ij,t-1} \times HHI_{jk,t-1} \\ & + \beta_4 \Delta \ln RER\_Comp_{ijk,t-1} \beta_5 \Delta lnRER\_Comp_{ijk,t-1} \\ & \times Policy_{i,t} + \beta_6 \Delta \ln RER\_Comp_{ijk,t-1} \times HHI_{jk,t-1} \\ & + \beta_7 \left(\Delta lnRER\_CNY_{ij,t-1}\right)^2 + \beta_8 \left(\Delta lnRER\_Comp_{ijk,t-1}\right)^2 \\ & + \beta_4 \Delta \ln COVID_{i,t} + \lambda_{jt} + \delta_{ijk} + \tau_t + \varepsilon_{ijkt}\end{aligned} \tag{18}$$

Table 15 reports the estimation results for the non-linear exchanger rate effects. We obtain positive signs on two statistically significant quadratic terms. In other words, the slope of the import value with respect to exchange rate movements depends on coefficients of both the linear term and the nonlinear term. Given the convex relationship, the positive effect of RMB depreciation (i.e., an increase in $\Delta lnRER\_CNY$) on imports, which does not match usual economic intuition and has been discussed in the baseline analysis, would be magnified with a larger scale of RMB depreciation. However, with RMB appreciation, the effect would experience a turning point: when the magnitude of appreciation is large, it can lead to higher import quantity and total value, a situation that can match the usual economic intuition. Furthermore, the effect of competitors' exchange rate movements exhibits a similar pattern, as both the linear term and the quadratic term also registers positive in a significant manner.

Additional robustness checks: alternative database, dominant currency effect, and lagged variables. One limitation of the Chinese provincial customs data is that we can only extend to March 2021. Alternatively, to obtain a full picture of the COVID impacts, we adopt the Python crawler to collect monthly data from January 2019 to December 2022 from United Nations (UN) Comtrade. We focus on bilateral trade of China's imports from different Asian trading partners. After employing this alternative database with extended sample coverage of the COVID-19 period, as shown in Table 16 the estimated coefficients of *RER_CNY* and *RER_CNY × Policy* are quantitively and qualitatively similar to the baseline results. In other words, the economic support policies would reduce or even alter both bilateral and competitors' exchange rate elasticities, which further confirms the baseline results.

In the baseline regressions, we focus on the effects of the bilateral exchange rate and the third-country exchange rate on China's imports from other Asian economies. In this section, we checked whether our results are driven by the dominant currency effect (Amiti et al. 2020; Chen et al. 2022; Gopinath and Stein, 2021) by adding the US dollar exchange rate and the Japanese Yen exchange rate into the baseline trade equation. As reported in Table 17, we find insignificant effect for these two exchange rate variables. In contrast, we find that the effects from the movements of RMB exchange rate against its trading partners, the weighted average competitors' exchange rate, and the policy responses are still significant and are consistent with our baseline results.

In addition, since we have observed a consistently insignificant exchange rate effect on the unit price adjustment, we follow Thorbecke and Smith (2010) to explore whether the exchange rate effect may appear after lags. To examine this, we augment the regression with lagged exchange rates to check the cumulative impacts. As seen in Table 18, even after we have included 3 lags of the RMB exchange rate movements, all the exchange rate variables still register insignificant in the regression.

Overall, we find that our main conclusions are robust to the inclusion of additional controls, the focus on various trade modes, and the use of alternative policy variables. Also, the policy effects on the bilateral and the third-country (competitors') exchange rate elasticities remain significant and have the expected signs.

Table 16 Alternative database with extended time coverage of the COVID-19 period.

All trade modes	UN Comtrade (country-level), 2019m1-2022m12		Chinese Customs (provincial-level), 2019m1-2021m3	
Monthly trade data	(1)	(2)	(3)	(4)
	Y= Δ ln v	Y= Δ ln q	Y= Δ ln v	Y= Δ ln q
Δ ln RER_CNY	2.044*** (0.251)	2.236*** (0.285)	1.758*** (0.361)	1.854*** (0.377)
Δ ln RER_CNY × Policy	−1.806*** (0.467)	−2.432*** (0.554)	−3.296*** (0.583)	−3.399*** (0.688)
Δ ln RER_Comp	0.0332*** (0.00689)	0.0328*** (0.00756)	0.115*** (0.011)	0.100*** (0.011)
Δ ln RER_Comp × Policy	−0.0296** (0.0123)	−0.0308** (0.0138)	−0.0251*** (0.007)	−0.0215*** (0.007)
Controls	Yes	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
N	944592	871979	2352568	2248764
R^2	0.044	0.040	0.052	0.049
Prob > F-statistic	0.000	0.000	0.000	0.000

Note: In columns (1) and (2), we employ the UN Comtrade on China's imports from January 2019 to December 2022, which contain information regarding different Asian countries' exports to different China. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. ** and *** indicate variables significant at 5% and 1% level respectively. Robust standard errors are reported in parenthesis.

Table 17 Estimation results with CNY/USD and CNY/JPY.

Monthly: 2019m1 to 2021m3	(1)	(2)	(3)
All trade modes (Y = Δ ln v)	CNY_USD	CNY_JPY	CNY_USD &CNY&JPY
CNY/USD	−0.480 (0.638)		0.0693 (1.463)
CNY/JPY		−0.453 (0.389)	−0.488 (0.946)
Δ ln RER_CNY	1.955*** (0.432)	1.927*** (0.422)	1.926*** (0.406)
Δ ln RER_CNY × Policy	−4.087*** (0.871)	−4.071*** (0.846)	−4.072*** (0.853)
Δ ln RER_CNY × HHI	0.639* (0.363)	0.628* (0.369)	0.628* (0.365)
Δ ln RER_Comp	0.115*** (0.011)	0.115*** (0.011)	0.115*** (0.011)
Δ ln RER_Comp × Policy	−0.0249*** (0.007)	−0.0249*** (0.007)	−0.0249*** (0.007)
Δ ln RER_Comp × HHI	−0.0870*** (0.009)	−0.0870*** (0.009)	−0.0870*** (0.009)
Constant	−0.00873** (0.003)	−0.124*** (0.006)	−0.151*** (0.009)
Controls	Yes	Yes	Yes
Province-time FE	No	No	No
Province-product-country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	2352568	2352568	2352568
R^2	0.049	0.049	0.049
Prob > F-statistic	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). To be consistent with the baseline regression, we include the lagged one exchange rate movements of the CNY/USD and CNY/JPY to check for whether the dominant currency effect would alter our explanations of the baseline results. A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

Extension: extensive margin with product churning. In this section, we conduct a robustness exercise by exploiting how the exchange rate responses along with the COVID-induced policy responses have affected the extensive margin -- the decision to drop or add the export of a product in a destination market (which is one specific Chinese province in this paper).[9]

Following Tang and Zhang (2012), if province i does not import one type of product (at HS 8-digit level) from Asian economy j in period t but then imports it from that Asian economy in period $t+1$, we define this scenario as "an addition of a product-destination market". We will investigate how the economic support policy would affect this extensive margin with product churning.

Table 19 reports the results using the Probit and Logit estimation. For China's processing imports, the depreciation of RMB against the trading partner's currency increases the probability of adding a new product to China's imports from one certain exporting country. Moreover, when the Asian countries have adopted stronger economic policies against the COVID-19 pandemic, the response to bilateral exchange rate changes becomes smaller. These patterns are consistent with the discussion in the previous sections. Furthermore, an interesting finding is that: the decision of adding a product-destination market is more responsive to competitors' exchange rate movements for ordinary trade than for processing trade. In addition, for processing trade, the response to foreign competitors' exchange rate movements is not affected by the domestic economic support policies.

Concluding Remarks

The worldwide outbreak of the COVID-19 pandemic has triggered global economic turmoil since January 2020. In response to the disorderly market conditions due to the coronavirus emergency,

Table 18 Estimation results with lagged exchange rate variables.

Monthly: 2019m1 to 2021m3 Y= Δ ln uv	(1) Full sample	(2) Inputs	(3) Ordinary
Δ ln RER_CNY (Lagged 1)	−0.172 (0.107)	−0.152 (0.118)	−0.0279 (0.130)
Δ ln RER_CNY (Lagged 1) × Policy	0.0587 (0.249)	0.164 (0.290)	−0.00674 (0.338)
Δ ln RER_CNY (Lagged 2)	0.106 (0.101)	0.0178 (0.122)	−0.0241 (0.163)
Δ ln RER_CNY (Lagged 2) × Policy	−0.218 (0.252)	0.177 (0.331)	−0.256 (0.347)
Δ ln RER_CNY (Lagged 3)	0.0444 (0.111)	0.0824 (0.103)	−0.0250 (0.136)
Δ ln RER_CNY (Lagged 3) × Policy	0.0243 (0.240)	−0.254 (0.262)	0.208 (0.325)
Constant	−0.0121*** (0.003)	−0.00803*** (0.003)	−0.0170*** (0.005)
Controls	Yes	Yes	Yes
Province-time FE	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
N	1749254	1141919	953432
Pseudo R^2	0.024	0.022	0.039
Prob > F-statistic	0.000	0.000	0.000

Note: We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. Columns (1) is for all types of goods with all trade modes, Columns (2) is for inputs with all trade modes, classified by the Broad Economic Categories (BEC), and Column (3) is for ordinary trade. An increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. Other explanatory variables are the same as the baseline specification. *** indicates variables significant at 1% level. Clustered standard errors at provincial level are reported in parenthesis.

Table 19 Extensive margin with product churning.

Y = Pr (Add)	Probit Model			Logit Model		
Monthly: 2019m1 to 2021m3	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample	Processing	Ordinary	Full sample	Processing	Ordinary
Δ ln RER_CNY	0.385	3.936***	0.692	−2.134*	7.333**	−1.934
	(0.438)	(1.068)	(0.579)	(1.144)	(2.879)	(1.519)
Δ ln RER_CNY × Policy	−8.022***	−13.94***	−8.227***	−15.51***	−32.13***	−15.34***
	(0.556)	(1.276)	(0.760)	(1.442)	(3.343)	(1.997)
Δ ln RER_CNY × HHI	−1.763***	−4.500***	−1.040	−1.619	−8.578***	0.871
	(0.521)	(1.240)	(0.701)	(1.266)	(3.190)	(1.667)
Δ ln RER_Comp	0.0689***	0.0600***	0.0705***	0.192***	0.170***	0.195***
	(0.006)	(0.015)	(0.009)	(0.016)	(0.041)	(0.022)
Δ ln RER_Comp × Policy	−0.00977	0.00164	−0.0282***	−0.0236	0.00756	−0.0741***
	(0.007)	(0.016)	(0.009)	(0.017)	(0.042)	(0.024)
Δ ln RER_Comp × HHI	−0.0650***	−0.0618***	−0.0541***	−0.184***	−0.177***	−0.153***
	(0.007)	(0.018)	(0.010)	(0.019)	(0.047)	(0.025)
Constant	−2.934***	−2.983***	−3.006***	−6.176***	−6.377***	−6.374***
	(0.007)	(0.016)	(0.009)	(0.018)	(0.043)	(0.025)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-product-country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2344831	580423	1270864	2344831	580423	1270864
Pseudo R^2	0.067	0.053	0.078	0.066	0.053	0.078
Prob > F-statistic	0.000	0.000	0.000	0.000	0.000	0.000

Note: The dependent variable is the probability of adding a product-destination market for one specific exporter. We employ the Chinese customs data on China's imports, which contain information regarding different Asian countries' exports to different Chinese provinces. An increase in *ΔlnRER_Comp* implies a real appreciation of competitors' currencies, and an increase in *ΔlnRER_CNY* implies a real depreciation of RMB against that one Asian trading partner's currency (bilateral). A larger HHI implies a higher degree of market concentration for Asian economies in exporting to China. *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. Clustered standard errors at provincial level are reported in parenthesis.

many Asian countries have adopted a set of policies to tackle economic downturn and to facilitate economic recovery (Alberola et al. 2021; Hayakawa and Mukunoki, 2021; Furceri et al. 2021). In this paper, we attempt to bring new insights to understand how the pandemic-induced supply and demand shocks have affected the responsiveness of trade flows to exchange rate movements. To answer this question, our research on China's imports from Asian partners offers notable insights because China has become the central node in the global value chain (GVC) network in Asia.

By employing a first-hand Chinese provincial trade dataset at a highly disaggregated exporter-product-importer level from January 2019 to March 2021, we find that both bilateral and third-country exchange rate movements matter. Although we first find that the RMB appreciation would reduce China's imports, the situation can be changed after introducing the policy effects. The government policies adopted by various exporting countries for combating the adverse economic impacts of the pandemic (including the income support for unemployed people, debt relief, fiscal stimulus, and other public expenditure to boost economic recovery) have effectively reduced the sensitivity of their exports to bilateral exchange rate movements or even alter the bilateral exchange rate elasticity from counter-intuitive to intuitive. Moreover, foreign competitors' currency depreciation would compete away a country's exports to China, and the policy strength can reduce this foreign competition effect. The degree of market concentration, however, affects the exchange rate and the third-country exchange rate elasticity differently; market concentration is positively associated with the exchange rate effect but negatively with the third-country exchange rate effect. More specifically, the exchange rate elasticity and the related policy effect are mainly through quantity adjustments rather than price adjustment. Furthermore, we examine the product quality channel of the policy effect. Subsequently, we show that the baseline results are robust to different trade modes, alternative measures for policy responses, and the inclusion other controls. Furthermore, we conduct the additional analyses regarding the regional heterogeneity, the product heterogeneity, and the extensive margin to further confirm the policy effects on the exchange rate elasticity of trade in the COVD-19 period.

This study has important policy implications for understanding how the trade flows react to exchange rate movements in the COVID-19 period. Our empirical results show that, since the onset of the pandemic, many countries have experienced economic and social disruption and lost their trade competitiveness. Therefore, their exports become more vulnerable and more responsive to the depreciation of foreign competitors' currencies, suggesting that policymakers should also consider competitors' exchange rate movements and speeds of recovery when they design policies to boost exports and imports. Furthermore, stricter social containment policy and stronger economic support can reduce the sensitivity to competitors' exchange rate fluctuations, suggesting that policy responses to COVID-19 may mitigate the pressure from foreign competition in the exporting markets, which is of particular interest for implementing policies to maintain stable trade flows and balance of payments.

Since the outbreak of the COVID-19 pandemic, the patterns of global trade have been reshaped, but the pandemic has spread aggressively with various mutations that evade vaccines (Tregoning et al. 2021). The recent release of highly disaggregated trade data in recent period, enable us to investigate whether the foreign competition effect and the policy effect are short-lived or can show continuing consequences. Whilst this paper focuses on the trade flows of goods, it is also of our interest to extend the analysis to trade in services in future research. Furthermore, the future availability of data from global input-output tables for the COVID-19 period, as well as the more recent customs data, can enable researchers to study the impact of GVC integration on exchange rate elasticity of trade. These are several promising future research topics along this line.

Data availability

The customs datasets were collected from the official Chinese customs website (http://stats.customs.gov.cn/queryData/queryDataByWhere) through our Python crawler programming. Because we have put a lot of efforts to write the program for the data collection process, it might not be appropriate to provide public access. But the final customs datasets generated and analyzed during the current study are available from the corresponding author on reasonable request. For other variables used in baseline analyses and robustness checks, the authors calculated the data based on the Oxford COVID-19 Government Responses Trackers (https://ourworldindata.org/covid-stringency-index), the UIBE GVC database (http://gvcdb.uibe.edu.cn/gvc.html) and the UN Comtrade database (https://comtradeplus.un.org/TradeFlow).

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Notes

1 Most existing studies on the COVID impacts on China's international trade uses the old-version customs data, which do not distinguish the trade values in January and February. With the recent data, we can obtain the complete time series with all 12 months in a year on China's international trade, which allows us to measure the COVID impacts on a monthly basis, as the severity of the COVID-19 pandemic can vary from month to month in the year 2020 and 2021.
2 In gauging the dynamic during the COVID-19 pandemic, we control for seasonality and the "Chinese New Year effect" by comparing the PMI on imports with the corresponding month of other years. We find significant and unique effect of COVID-19 starting from February 2020.
3 The imported inputs are classified by the Broad Economic Categories (BEC).
4 We abstract from the time subscript here to simplify the notation.
5 A similar measure is used by Pennings (2017).
6 Same specification is used in Li et al. (2015) and Fernandes and Winters (2021).
7 The related marginal effect is graphically presented in Fig. S4 in the supplementary information.
8 To translate the HS 2017 codes into the industrial classification, which is based on the International Standard Industrial Classification Revision 3 (ISIC Rev. 3), in ADB-MRIO 2018, we combine the correspondence table between the HS 2017 codes and HS 2002 codes from the United Nations Statistics Division and the correspondence table between HS 2002 and ISIC Rev. 3 from the World Integrated Trade Solution (WITS).
9 One caveat about the discussion of the extensive margin is that, since our data does not contain information about the firm's entry or exit decision in the export markets, we can cannot study firms' entry or exit but can only study whether a province continues to import a certain product or not from a specific Asian trading partner.

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Author contributions
These authors contributed equally to this work. Duties of each author are as follows. WZ: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. IK-MY: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. Y-WC: Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

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The authors declare no competing interests.

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Correspondence and requests for materials should be addressed to Weikang Zhang.