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Evaluating international impacts of China-specific shocks in an input-output framework

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Abstract

The slowing in China's massive economy has wide implications. China plays an essential role in international production chains, so disturbances can spill over to other economies in the global production network. We evaluate the international transmission and impact of various China-specific shocks with an input-output framework applied to the World Input-Output Database (WIOD). We consider shocks to Chinese final demand at the aggregate level, bilateral import tariffs between the US and China and sector-specific shocks to Chinese final demand and supply. Our results suggest that aggregate level shocks, as well as certain sector-specific shocks originating in China, may have large impacts elsewhere. Transmission of shocks through the global production network, however, is mitigated by the relatively low import-intensity of Chinese production.

Keywords: Chinese economy, shock transmission, input-output, international production network
JEL codes: C67, F14, F43

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1 Introduction

Four decades of spectacular growth have made China one of world's largest economies. Growth has been supported by heavy investment and integration in the global economy (Dieppe et al., 2018), factors that have helped the Chinese economy develop in qualitative terms shifting gradually from low-value-added, labor-intensive production to more complicated, higher-value tasks. China is a significant node in the global production network and an important trading partner for many countries (Baldwin & Lopez-Gonzalez, 2015; Timmer et al., 2016; Simola, 2018).

The loss of steam in the Chinese economy in recent years partly reflects a natural, desirable economic rebalancing from heavily investment-led growth to a consumption-oriented paradigm. While the slowdown in growth has been gradual, the risks of economic weakness and a hard landing loom – especially given China's massive indebtedness (Dieppe et al., 2018). China is aiming at large and much-needed structural reforms such as liberalization of its financial sector (Lin, 2019; Wagner, 2018). Such comprehensive reforms are difficult to realize for any country and may add uncertainty to the future development of the Chinese economy. Moreover, the growing role of China in world trade can exacerbate economic tensions as seen in the current US-China trade dispute (Liu & Woo, 2018).

Since shocks to the Chinese economy are likely to have repercussions regionally and globally, we evaluate the impact of various shocks originating in China on the global production network, on individual countries and on sectors. Our analysis utilizes an input-output framework that accounts for international production linkages and extends to the disaggregated sectoral level. First, we examine the effects of aggregate-level demand shocks originating in China on other countries and across sectors. Next, we analyze the effects of bilateral import tariffs that could be imposed in the context of the current trade disputes between the US and China. Finally, we examine the transmission of sector-specific shocks to Chinese final demand and production.

This work relates to the recent strand of literature that examines the propagation of sub-aggregate level shocks to the aggregate level. Defying the traditional view that idiosyncratic shocks average out at the aggregate level, a number of recent studies find that sector-specific (and even firm-specific) shocks can result in fluctuations in national aggregates due to network structure of production (Gabaix, 2011; Acemoglu et al., 2012; Acemoglu et al., 2016). In the international context, the role of production networks has been shown to be important from the viewpoint of trade policy magnifying the impacts of trade barriers and having indirect effects on third countries (Miroudot et al., 2013; Caliendo & Parro, 2015; Johnson & Noguera, 2017) and affecting the transmission of exchange rate movements (Bems & Johnson 2017). There is also a vast body of literature dealing with the effect of international production chains on the differences between gross and value-added trade (Johnson & Noguera, 2012; Koopman et al., 2014; Los et al., 2015).

There are several China-specific studies that evaluate the consequences of a shock on growth at the aggregate level with various methodologies. In a GVAR setting, a 1 % shock to Chinese output is typically estimated to have an impact of 0–0.6 % for the output of other countries in the short and medium term (Cesa-Bianchi et al., 2012; Korhonen & Feldkircher, 2012; Dreger & Zhang, 2014; Faryna & Simola, 2018). Dreger & Zhang (2014) find slightly smaller effects than in the GVAR setting utilizing the structural NiGEM model to evaluate the effects of Chinese fiscal stimulus on other countries. Ahuja & Nabar (2012), using a FAVAR model to evaluate the spillovers from Chinese investment slowdown, show that a 1 percentage point slowdown in Chinese investment is associated with a reduction of global growth of just under one-tenth of a percentage point. The estimates of Furceri et al. (2017), which are based on single-equation panel framework, range from 0.1-0.2 % in the short term (depending on the region) up to 0.7 % in the medium term. Dieppe et al. (2018) present estimates calculated with several models, including the ECB’s semi-structural global model and the IMF’s global DSGE model. Their estimates suggest that a 0.7 percentage-point drop in Chinese GDP growth (with some rebalancing of demand from investment to consumption) translates to a drop in GDP growth in other countries of 0–0.5 percentage points in the medium term (and possibly more for oil exporting countries). These studies generally agree that the international impact of Chinese shocks has increased significantly in recent decades.

An input-output framework is utilized by Ma et al. (2016) for assessing the consequences of rebalancing of the Chinese economy for domestic production and international trade. They find that shift from investment to consumption in Chinese demand is likely to negatively affect the exports from most economies to China. Hardest hit countries are East Asian technology exporters such as Taiwan and South Korea and raw material exporters such as Saudi Arabia and Chile. Methodologically, the most important study for this work is Vandenbussche et al. (2019), which examines the effects of tariff increases resulting from Brexit in the input-output framework. Bems and al. (2010) have also used input-output framework for analyzing the transmission of various demand shocks during the global financial crisis. Huidrom et al. (2019), Vandenbussche et al. (2017) and Ali-Yrkkö & Kuusi (2017) apply input-output analysis to examine the effects of recent US import tariffs, illustrating their impacts through production chains on third countries not directly targeted by tariffs.

The recent interest in the impacts of import tariffs in the context of the US trade policy, and trade disputes between the US and China in particular, has engendered several studies estimating the effects of various “trade war” scenarios. These suggest that punitive bilateral tariffs between the US and China could lead to losses of up to 0.3–0.4 % of GDP for both the US and China (Bellora

& Fontagne, 2019; Caceres et al., 2019; Charbonneau & Landry, 2018; Felbermayr & Steiniger, 2019). The Chinese sectors hit hardest are Chinese manufacturing, particularly electronics and machinery, while the biggest losers in the US are agriculture, food production and manufacturing of transport equipment (Bellora & Fontagne, 2019; Felbermayr & Steininger, 2019; Freund et al., 2018). The effect on several third countries (e.g. Canada, Mexico and Japan) is estimated to vary between -0.1 % and 0.3 % of GDP (Bellora & Fontagne 2019, Caceres et al. 2019, Charbonneau & Landry 2018). The magnitude of the effects obviously depends in part also on the details of the scenarios evaluated, as there is some variation in the scenarios considered in different studies.

This work also relates to the literature on sub-aggregate level supply shocks. Much of the discussion in this area concerns the short-term impacts of natural disasters or other abrupt disturbances. The input-output framework has been relatively popular in this type of study (Santos & Haimes, 2004; Hallegatte, 2008; Rose & Wei, 2013). The demand-driven nature of the input-output approach poses particular limitations on the analysis of supply shocks, but its transparency and relative incomplexity in combination with detailed sector-level interlinkages are considered as its main advantages in comparison to CGE models (Galbusera & Giannopoulos, 2018). In the context of China, Wu et al. (2012) examine the nation-wide effects of the 2008 Wenchuan earthquake. MacKenzie et al. (2012) analyze the effects of Japanese Tohoku earthquake and tsunami nationally and internationally, comparing the effects of hypothetical shocks to car production chains in several countries, including China. Recently, the input-output framework has also been combined with network analysis for estimating effects of supply shocks (Acemoglu et al., 2015; Lee, 2019). Previous literature on the international impact of Chinese supply shocks focuses on the effects of Chinese imports on local labor markets, especially in the US (Autor et al., 2013; Acemoglu et al., 2016; Feenstra & Sasahara, 2018).

This work contributes to several branches. First, our results for sector-specific shocks in China support the view that sub-aggregate-level idiosyncratic shocks in one country (at least in a globally important economy like China) may have important repercussions for international fluctuations. Second, on the more practical side, we provide for the first time quantitative estimates on the effect of various China-specific shocks in the common framework of input-output analysis. We also give more detailed sector-level analysis than most other studies. Moreover, we examine the international effects of supply shocks originating in China, which, to our best knowledge, are rarely addressed in the previous literature. Finally, our results suggest that despite its simplicity, the input-output framework produces estimates of the impacts of various shocks that are relatively close to the results achieved by more complex approaches. They provide valuable complementary insights, in particular, for evaluating short-term effects and sector-level analysis.

The rest of the paper is constructed as follows. In section 2, we discuss the theoretical framework providing micro-level foundations for the input-output framework and relating it to the traditional gravity model of international trade. Section 3 presents the data and methodology used in calculating the effects of various China-related shocks. In section 4, we give the results of our analysis and compare our estimates to those from the previous literature. Section 5 concludes.

2 Theoretical framework

In this section, we present the theoretical framework underpinning our analysis. Utilizing a gravity-type approach as in Anderson and van Vincoop (2003), we augment it with trade in value added as in Noguera (2012) and multisector production as introduced in Vandenbussche et al. (2019), which we follow in deriving the model. Markets are assumed to be competitive and technology constant. The model is based on the Armington assumption, resulting in imperfect substitutability between goods produced in different countries. Regarding notation, superscripts are used to denote the country and sector of origin and subscripts the country and sector of destination. Upper-case letters refer to real quantities; lower-case letters to nominal terms.

2.1 Model setup

Starting from the consumer side, a representative household in country k maximizes its utility of the following form:

$$U_k = \prod_{s=1}^{S} [F_k^s]^{\alpha_k^s}, \tag{1}$$

which is a Cobb-Douglas combination of final goods from all sectors and α^s_k the corresponding share in total expenditure. The sector-specific final good is a CES aggregate of the varieties produced in different countries:

$$F_k^s = \left[\sum_{i=1}^{n} \left(F_k^{is}\right)^{\frac{\sigma_s - 1}{\sigma_s}}\right]^{\frac{\sigma_s}{\sigma_s - 1}}, \tag{2}$$

where $\sigma_s > 1$ is the elasticity of substitution (for final goods) between varieties from different countries in sector s.

In the production side, output of sector z in country k is given by a Cobb-Douglas production function:

$$Y^{kz} = (L_{kz})^{1-\beta^{kz}} (X_{kz})^{\beta^{kz}}, \tag{3}$$

where L_{kz} is labor used in the production of sector *z* in country *k*, X_{kz} is a composite of intermediate inputs and β^{kz} is the corresponding share in the total sales of country *k*'s sector *z*. The composite of intermediate inputs X_{kz} is:

$$X_{kz} = \prod_{s=1}^{S} [X_{kz}^{s}]^{\gamma_{kz}^{s}}, \tag{4}$$

implying that X_{kz} is a Cobb-Douglas combination of intermediate inputs from all sectors and γ^{s}_{kz} is the corresponding share in the total expenditure on inputs. Similarly, as on the consumption side, the sector-specific intermediate good X^{s}_{kz} is a CES aggregate of the varieties produced in different countries:

$$X_{kz}^{s} = \left[\sum_{i=1}^{N} \left(X_{kz}^{is}\right)^{\frac{\rho_s - 1}{\rho_s}}\right]^{\frac{\rho_s}{\rho_s - 1}}, \tag{5}$$

where $\rho_s > 1$ is the elasticity of substitution (for intermediate goods) between varieties from different countries in sector *s*.

We assume iceberg-type trade barriers, implying that for delivering one unit of its output to country *j*, the sector *z* in country *k* needs to produce $\tau^{kz}{}_{j} > 1$ units. Therefore, the price of one unit of output of sector *z* in country *k* equals $p^{kz}{}_{j} = \tau^{kz}{}_{j} p^{kz}$.

Households in country *k* maximize their utility as expressed in equation (1) with respect to their income, which consists of the wage w_{kz} they receive from supplying labor L_{kz}:

$$I_k = \sum_{z=1}^{S} w_{kz} L_{kz} \,. \tag{6}$$

Firms maximize their profits taking factor and goods prices as given. Solving the maximization problems gives us the following nominal demands (i.e. multiplied by corresponding prices and denoted by lower-case symbols) for final and intermediate goods:

$$x_{kz}^{is} \equiv p_k^{is} X_{kz}^{is} = \tau_k^{is} p^{is} X_{kz}^{is} = \left(\frac{\tau_k^{is} p^{is}}{P_k^{s}}\right)^{1-\sigma_s} \gamma_{kz}^{s} \beta^{kz} y^{kz} \tag{7}$$

$$f_k^{is} \equiv p_k^{is} F_k^{is} = \tau_k^{is} p^{is} F_k^{is} = \left(\frac{\tau_k^{is} p^{is}}{P_k^{s}}\right)^{1-\sigma_s} \alpha_k^{s} \sum_{z=1}^{S} \left(1 - \beta^{kz}\right) y^{kz} \,, \tag{8}$$

where the CES price index in country *k* of goods from sector *s* equals:

$$P_k^{s} = \left[\sum_{i=1}^{N} \left(p_k^{is}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} . \tag{9}$$

We have assumed for simplicity that $\sigma_s = \rho_s$, implying that the price of a good produced in sector *s* is the same whether it is sold for final consumption or as an intermediate input. The result is identical price indices for final and intermediate goods.

2.2 Market clearing

In this section, we derive gravity equations for the exports of final and intermediate goods at the sector level following Vandenbussche et al. (2019).

We define the nominal gross exports from sector *z* of country *k* to country *j* as:

$$e_j^{kz} \equiv f_j^{kz} + \sum_{s=1}^{S} x_{js}^{kz} \,, \tag{10}$$

with the first term depicting exports for final consumption and the second term exports for intermediate inputs for all sectors *s*. Market clearing requires:

$$y^{kz} = \sum_{j=1}^{N} e_j^{kz}. \tag{11}$$

Next, we denote world nominal output by y^w and define the share of sector *z* of country *k* in world output as $\Theta^{kz} = y^{kz}/y^w$. Substituting the nominal demands for final and intermediate goods from (7) and (8) to the export equation (10) allows us to solve for prices p^{is}. Inserting these into the price index in (9) and the resulting expression for the price index back to the demand equations (7) and (8) gives the following equations for bilateral exports of intermediate inputs and final goods:

$$x_{js}^{kz} = \frac{y^{kz}\gamma_{js}^{z}\beta^{js}y^{js}}{y^w}\left(\frac{\tau_j^{kz}}{\Pi^{kz}P_j^z}\right)^{1-\sigma_s} \tag{12}$$

$$f_j^{kz} = \frac{y^{kz}\alpha_j^z \sum_{s=1}^{S}(1-\beta^{js})y^{js}}{y^w}\left(\frac{\tau_j^{kz}}{\Pi^{kz}P_j^z}\right)^{1-\sigma_s} \tag{13}$$

with the multilateral resistance terms given by:

$$P_j^z = \left[\sum_{i=1}^{N} \theta^{kz}\left(\frac{\tau_j^{kz}}{\Pi^{kz}}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} \text{and}$$

$$\Pi^{kz} = \left[\sum_{j=1}^{N} \varphi_j^z\left(\frac{\tau_j^{kz}}{P_j^z}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}},$$

where

$$\varphi_j^z = \sum_{s=1}^{S} \theta^{js}\left[\gamma_{js}^z\beta^{js} + \alpha_j^z\left(1-\beta^{js}\right)\right]$$

depicts the importance of goods from sector *z* for producers and consumers in country *j*, taking into account the dependence of producers on intermediate inputs from sector *z* in country *j* and the final demand for sector *z* goods in country *j*.

As we can see from equations (12) and (13), exports from sector *z* in country *k* to country *j* depend on the relative sizes of the countries (y^{kz}/y^{w} and y^{js}/y^{w}), the bilateral trade costs ($\tau^{kz}{}_{j}$) and outward and inward multilateral resistance terms (Π^{kz} and $P^{z}{}_{j}$). In addition, exports of final goods depend on the share of sector *z* in final consumption ($\alpha^{z}{}_{j}$) and the exports of intermediate goods on the share of intermediate inputs in production (β^{js}) and on the share of sector *z* inputs in the total expenditure on inputs ($\gamma^{z}{}_{js}$).

2.3 Input-output linkages

To highlight the input-output linkages, we first divide both sides of the intermediate goods export equation (12) by y^{js}:

$$\frac{x_{js}^{kz}}{y^{js}} \equiv a_{js}^{kz} = \frac{y^{kz}\gamma_{js}^{z}\beta^{js}}{y^{w}}\left(\frac{\tau_j^{kz}}{\Pi^{kz}P_j^{z}}\right)^{1-\sigma_s}. \qquad (14)$$

Equation (14) shows the value of inputs from sector *z* of country *k* needed to produce a dollar's worth of output in sector *s* of country *j*, i.e. the technical coefficient $a^{kz}{}_{js}$.

Inserting the technical coefficients to the market clearing condition given by equation (10) we get:

$$y^{kz} = \sum_{j=1}^{N}\left(\sum_{s=1}^{S} x_{js}^{kz} + f_j^{kz}\right) = \sum_{j=1}^{N}\sum_{s=1}^{S} a_{js}^{kz}\, y^{js} + \sum_{j=1}^{N} f_j^{kz}$$

and summarizing for all countries and sectors:

$$\boldsymbol{Y} = \boldsymbol{AY} + \sum_{j=1}^{N} \boldsymbol{f_j}\,, \qquad (15)$$

where

$$\boldsymbol{Y} = \begin{bmatrix} y^{1,1} \\ \vdots \\ y^{N,S} \end{bmatrix}; \quad \boldsymbol{A} = \begin{bmatrix} a_{1,1}^{1,1} & \cdots & a_{N,S}^{1,1} \\ \vdots & \ddots & \vdots \\ a_{1,1}^{N,S} & \cdots & a_{N,S}^{N,S} \end{bmatrix}; \qquad \boldsymbol{f_j} = \begin{bmatrix} f_j^{1,1} \\ \vdots \\ f_j^{N,S} \end{bmatrix}$$

with f_j the (S*N) x 1 vector of country *j*'s final demands and A the (S*N) x (S*N) global input-output matrix at country-sector level.

We can re-write equation (15) in the form:

$$(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{Y} = \sum_{j=1}^{N} \boldsymbol{f_j}\,, \qquad (16)$$

where **I** is a (S*N) x (S*N) identity matrix. If the matrix (**I**-**A**) can be inverted, nominal output is given by:

$$\boldsymbol{Y} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \sum_{j=1}^{N} \boldsymbol{f_j} = \boldsymbol{L} \sum_{j=1}^{N} \boldsymbol{f_j} \,, \tag{17}$$

where **L** is the Leontief inverse matrix. Its elements give the dollar value of goods of sector z of country k needed to fulfill one dollar's worth of final demand in sector s of country i.

Combining to this the export equation of final goods from (13) gives the nominal output of sector z in country k in the form:

$$y^{kz} = \sum_{i=1}^{N} \sum_{s=1}^{S} L_{is}^{kz} \sum_{j=1}^{N} f_j^{is} = \sum_{i=1}^{N} \sum_{s=1}^{S} L_{is}^{kz} \sum_{j=1}^{N} \left(\frac{y^{is} \alpha_j^s \sum_{r=1}^{S} (1-\beta^{jr}) y^{jr}}{y^w} \left(\frac{\tau_j^{is}}{\Pi^{is} P_j^s} \right)^{1-\sigma_s} \right) \tag{18}$$

We still want to get from this gross output the value-added production. Following Vandenbussche et al. (2019), we assume that the value-added share in the sector z of country k is the share of labor in the production. According to production function (3), the labor share is $(1-\beta^{kz})$. Thus, the value added created in sector z of country k is:

$$va^{kz} = v^{kz} \sum_{i=1}^{N} \sum_{s=1}^{S} L_{is}^{kz} \sum_{j=1}^{N} f_j^{is}, \tag{19}$$

where $v = (1-\beta^{kz})$ is the value-added-to-output ratio.

3 Data and methodology

For the empirical application, we utilize the World Input-Output Database (WIOD), like previously done by Vandenbussche et al. (2019), Huidrom et al. (2019) and Bems & Johnson (2017). WIOD is a publicly available outcome of a project commissioned by the European Commission. WIOD tables are constructed by combining and harmonizing national accounts data from various countries with detailed customs and balance of payments statistics and augmented with estimated inputs for gaps as discussed in Timmer et al. (2015) and Timmer et al. (2016). The resulting global input-output tables present the distribution of global supply and use by countries and sectors.

The latest version of WIOD global input-output tables covers 43 countries and a rest-of-the-world bloc. The countries range from the 28 members of the European Union to other major economies of the world, including emerging economies such as China. The input-output tables are further divided into 53 sectors according to the International Standard Industrial Classification revision 4 (ISIC Rev. 4) and presented in accordance with System of National Accounts standard SNA 2008. WIOD provides a comparable annual series of global input-output tables for 2000–2014. Values are expressed in current US dollars.

3.1 Demand and supply shocks

We start from a shock to final demand in China which effects can be calculated by inserting expression (17) to equation (19) and differentiang it with respect to final demand as shown e.g. by Miller & Blair (2009). If the final demand in China changes, then the change in value added in sector z of country k is given by:

$$dva^{kz} = v^{kz} L \, d \, f_{CN}. \quad (20)$$

We next consider a supply shock. Since the input-output framework is essentially a demand-led model of the economy with exogenous demand defining the production side,[1] the possibilities for examining supply shocks are rather specific. We thus consider as a supply shock an exogenous disturbance that leads to a change in the output of sector s in China that is transmitted to supplier sectors through production network linkages by reducing demand for intermediate inputs. For this, we define $L^*=L(L\sim)^{-1}$, where L~is a diagonal matrix created from the on-diagonal elements of L. Following Miller and Blair (2009), if the output of sector s in China changes, the change in the value added of sector z in country k is given by:

$$dva^{kz} = v^{kz} L^* \, d \, x_{CNs} \, . \quad (21)$$

To examine the implications of demand and supply shocks, we use the latest WIOD table available, i.e. 2014. Despite the lag of several years, the data should be quite relevant as economic structures change relatively slowly. After removing missing values, we get a 2289 x 2289 matrix that depicts the global production network structure. With this basis for our analysis, it is relatively straightforward to calculate the effects of various demand and supply shocks on different countries and industries according to equations (20) and (21).

3.2 Trade cost shocks

We also consider a shock on bilateral trade costs τ. Following Vandenbussche et al. (2019), we calculate the change in the value-added production of sector z in country k resulting from a change in the trade costs from equation (19) after substituting (18). From this, we obtain:

[1] There exists a supply-driven version of the input-output framework, but it has been criticized for highly unrealistic features e.g. by Oosterhaven & Bouwmeister (2016). Many studies in this field rely on an “input-output inoperability model,” but as argued by Dietzenbacher & Miller (2015) and Oosterhaven & Bouwmeister (2016), it is essentially a transformation of the standard input-output model.

$$dva^{kz} = -v^{kz} \sum_{i=1}^{N} \sum_{s=1}^{S} (\sigma_s - 1) L_{is}^{kz} \sum_{j=1}^{N} \left[\frac{d\tau_j^{is}}{\tau_j^{is}} - \frac{d\Pi^{is}}{\Pi^{is}} - \frac{dP_j^s}{P_j^s} \right] \left[f_j^{is} + \sum_{r=1}^{S} x_{jr}^{is} \right]$$
$$= -v^{kz} \sum_{i=1}^{N} \sum_{s=1}^{S} (\sigma_s - 1) L_{is}^{kz} \sum_{j=1}^{N} \frac{d\tau_j^{is}}{\tau_j^{is}} e_j^{is} + v^{kz} \sum_{i=1}^{N} \sum_{s=1}^{S} (\sigma_s - 1) L_{is}^{kz} \sum_{j=1}^{N} \left[\frac{d\Pi^{is}}{\Pi^{is}} + \frac{dP_j^s}{P_j^s} \right] e_j^{is}, \quad (22)$$

where the first term is (in the case of an increase in trade costs) the trade destruction effect that is caused directly by the reduced trade due to higher trade costs and the second term is the trade diversion effect that results from the increase in relative bilateral trade costs as measured by the multilateral resistance terms. Because we are focusing on short-term effects, however, we follow Vandenbussche et al. (2019) and take only the first term as a proxy for the effects of trade cost changes.[2]

As a case study for empirical application of trade cost shocks, we take the tariffs imposed in context of the ongoing trade dispute between the US and China. First, we examine the effect of tariffs imposed by the US on imports from China. We use 25 % import tariffs across all sectors as we cannot separate individual products in our framework. This choice is supported by the fact that tariffs are currently already imposed on a majority of US imports from China. This scenario also facilitates comparison of our results with previous research. Additionally, we calculate a second scenario augmented with potential symmetric Chinese retaliation.

For the value-added flow data, we again use the WIOD 2014 table as for the demand and supply shocks. The US and Chinese tariff levels preceding the trade disputes are taken from WTO data. We use the aggregate MFN applied tariffs for product groups, since the WIOD contains sector-level data. The US tariffs range from 0.6 % for wood and paper to 11.7 % for clothing. The Chinese tariffs range from 4.1 % for wood and paper to 16 % for clothing. For the trade elasticity, we choose a conservative estimate of 2 following Vandenbussche et al. (2017) and Ali-Yrkkö & Kuusi (2017). This is because our data is on a relatively aggregate level and there is typically large variation in the elasticity estimates across products and countries (Caliendo & Parro, 2015; Imbs & Mejean, 2017). Even with this moderate elasticity estimate, the imposition of tariffs reduces demand notably both in the US and China. Obviously, the decline would be even larger with higher trade elasticity.

4 Results

We present the results on the effects of shocks originating in China in this section.[3] We start from the aggregate level and examine first two scenarios of shocks to China's final demand. We then consider trade cost shocks in the form of import tariffs imposed bilaterally by the US and China

[2] As noted by Vandenbussche et al. (2019), the trade diversion effects of tariffs are usually found to be relatively small compared to the trade destruction effects.
[3] In this section, "China" is synonymous with mainland China.

again under two scenarios. Finally, we move to the sector level to examine sector-specific demand and supply shocks.

4.1 Chinese aggregate demand shocks

The main use of input-output analysis is to explicate shocks to final demand. To facilitate comparison with results from previous literature, we calibrate the aggregate shocks to China's final demand to a magnitude where they correspond to a 1 % negative shock to China's GDP. First, we consider a simple 1 % shock to China's GDP keeping the structure of final demand unchanged (i.e. final demand for all sectors declines by the same amount in relative terms). The effect is slightly negative for all countries, leading on average to a negative shock of 0.04 % of the GDP for other countries. As Table 1 shows, the largest effects are recorded for Taiwan and Korea (0.12 % and 0.08 %, respectively). The smallest, 0.01 %, are experienced by some countries in Southern Europe. At the sector level, Taiwanese and Korean manufacturing of electronics and Australian mining are among the hardest hit industries.

In the second scenario, we also consider rebalancing from investment to private consumption. We again assume a shock that corresponds to a 1 % negative shock to Chinese GDP, but further assume it changes the structure of final demand so that the share of private consumption in final demand increases by 5 percentage points and the share of fixed investment declines correspondingly. Since the change between the shares is large, demand in some consumer sectors actually rises (although the shock is negative at the aggregate level). Admittedly, the change in the structure of final demand is quite strong for short-term horizon, but it illustrates more clearly the significance of rebalancing for effects on other countries.

Table 1 Effects of Chinese aggregate final demand shock in selected countries, % of GDP

	Negative shock: 1% of GDP	Negative shock: 1 % of GDP with shift in final demand structure
Korea	–0.08	–0.32
Australia	–0.05	–0.15
Germany	–0.03	–0.12
Japan	–0.03	–0.11
EU-28	–0.02	–0.05
US	–0.01	–0.02
Brazil	–0.02	0.01
Global (excl. China)	–0.03	–0.07

Source: Author's calculations based on WIOD.

Indeed, the effects on other countries are stronger in the rebalancing scenario and there is much more variation across countries. The average effect is now –0.08 % of GDP, ranging from –0.49 %

to a slightly positive effect of 0.01 %. With rebalancing, the economies hardest hit are Taiwan and Korea (–0.49 % and –0.32 %, respectively), whereas the effect is slightly positive for Brazil and Ireland. The positive effects experienced by Brazil and Ireland reflect the higher consumer demand, particularly foodstuffs, as these countries are relatively more specialized in exporting consumer goods or raw materials for consumer sectors. Indeed, Brazilian agriculture and Irish food industry join Scandinavian medicine industries as sectors experiencing the largest positive effects. At the negative end, we again find Taiwanese and Korean electronics manufacturing and Australian mining and metals.

As noted in section 1, the estimates from the previous literature typically put the effect of a 1 % negative shock to Chinese GDP between 0 and –0.6 % of GDP in the short to medium term for other countries (Korhonen & Feldkircher, 2014; Dreger & Zhang, 2014; Furceri et al., 2017; Dieppe et al., 2018).[4] Thus, our results are quite close to previous estimates achieved with various methodologies. When assuming no changes in the demand structure, our results suggest only small effects that are closer to the lower end of previous estimates. This could reflect the fact that our framework only accounts for trade volume effects. Additional effects can occur, however, through commodity price movements and financial markets. China is a top global consumer of several commodities as pointed out by Gauvin and Rebillard (2018). China is still much less integrated globally in financial than goods markets, but there is evidence of additional effects propagating through financial markets (Dieppe et al., 2018). When restructuring of final demand is also assumed, our estimates become much higher than in the baseline case. This reflects the stronger import intensity of Chinese investment than private consumption as observed by e.g. Ahuja & Nabar (2012). It also comports with the results obtained by Bems et al. (2010) on the differential effects of demand changes by aggregate sector.

4.2 US-China bilateral tariff shocks

For tariff shocks, we assume the US imposes a 25 % import tariff on all Chinese goods in our first scenario and augment our second scenario with a corresponding Chinese retaliation on all US goods. In line with the previous literature, the largest effect in both scenarios falls on China, amounting to a drop of 1.02 % in GDP (Table 2). Surprisingly, the impact on the US is much smaller – a drop of just 0.12 % of GDP even with retaliation measures in place. One possible explanation is the higher initial level of Chinese import tariffs. Thus, the price increase caused by the tariff hikes and the following decrease in demand is relatively smaller for China than the US. The indirectly caused

[4] Estimates are rarely explicitly defined in the previous literature as resulting from a demand shock. In the GVAR framework identification between demand and supply shocks is often quite difficult.

impacts for other countries are small in most cases, which is in line with the findings of Charbonneau & Landry (2018), Caceres et al. (2019) and Ali-Yrkkö & Kuusi (2017). However, the drop in Korea is larger (-0.17 % of GDP). Our results also suggest that the negative effect for third countries is mainly caused by the tariffs posed by the US on Chinese products, whereas the additional effect from Chinese retaliation measures is much smaller. This could reflect the higher share of foreign value added in Chinese exports to the US than in the US exports to China.

Table 2 Effects of 25 % bilateral import tariffs between the U.S. and China in selected countries, % of GDP

	25 % tariff on US goods imports from China	25 % tariff on US-China bilateral goods imports
China	–1.02	–1.02
US	–0.01	–0.12
Korea	–0.16	–0.17
Australia	–0.07	–0.07
Japan	–0.04	–0.04
Germany	–0.03	–0.03
Mexico	–0.01	–0.03
EU-28	–0.02	–0.02
Global (incl. China and the US)	–0.17	–0.20

Source: Author's calculations based on WIOD.

Compared to most earlier results in the literature, our estimate is somewhat higher for China and a bit lower for the US.[5] Charbonneau & Landry (2018) estimate the effects at –0.33 % for China and –0.25 % for the US; Ballora & Fontagne (2019) at –0.39 % and –0.28 %; Felbermeyr & Steininger at –0.25 % and –0.14 %; and Freund et al. (2018) at –0.3 % and 0 %. For the other countries, there is great variation in the estimated effects, ranging from –0.11 % to 0.2 % (Charbonneau & Landry, 2018; Ballora & Fontagne, 2019). Most of our estimates fall within this range.[6] Moreover, the positive impact for some countries found in previous studies is due to substitution effects taking place in longer term that cannot be accounted for in our framework.

In sector terms, Chinese manufacturing of miscellaneous products (e.g. furniture and toys), electronics and textiles (–6.79 %, –5.03 % and –2.66 % of the sector value added respectively) are among the hardest-hit industries. Taiwanese electronics manufacturing is also among the sectors hardest hit. From the US side, the largest negative effects concern manufacturing of other transport equipment and manufacturing of machinery. The sector-level results are qualitatively well in line with previous results, and for the most affected sectors also quantitatively quite similar (Caceres et al., 2019; Charbonneau & Landry, 2018; Freund et al., 2018). The main difference is that all effects

[5] The scenarios vary somewhat across studies, but we have tried to use the estimates with background assumptions closest to ours.
[6] No estimates for Taiwan are reported in the previous literature.

are negative in our results as the redistributive effects in our framework would need to be evaluated with additional exogenous assumptions. Therefore, our results should be viewed as short-term effects. With the longer time horizons in the previous literature, we see some sectors may gain from e.g. increased protection or improved price competitiveness relative to countries subject to tariffs.

4.3 Chinese sector-specific demand shocks

We now examine the transmission of sector-specific shocks in China's final demand. We assume a 10 % negative shock to Chinese final demand in each manufacturing sector. We focus on manufacturing sector shocks since the vast majority of final demand in services is fulfilled from domestic sources in China as in other countries (Simola, 2018). The effect accounts for direct loss of production resulting from falling final demand and the indirect loss of production caused by the drop in demand for inputs in the Chinese and foreign sectors supplying goods for China's final demand.

While aggregate-level effects are very small for shocks in most sectors, they are significant for certain sectors (Table 3). In global terms, the largest effects come from a shock in Chinese final demand of machinery, electronics and motor vehicles. For shocks to the final demand in these sectors, the total effect on other countries than China is -0.02 % of their combined value added. The average effect varies by regions between 0 % and -0.03 % of GDP with the most negative impacts recorded again for shocks from manufacturing of machinery, motor vehicles, electronics and food products. For individual economies, the highest negative effects result from shocks in manufacturing of electronics for Taiwan and Korea (0.23 % and 0.17 % of GDP), manufacturing of machinery for Taiwan and Korea (0.12 % and 0.07 % of GDP) and manufacturing of motor vehicles for Slovakia and Germany (0.09 % and 0.06 % of GDP).

Table 3 Effects of a 10 % negative shock to Chinese final demand in selected sectors on selected countries, % of GDP

	Food	Electronics	Machinery	Motor vehicles
Taiwan	–0.02	–0.23	–0.07	–0.12
Korea	–0.02	–0.17	–0.07	–0.05
Australia	–0.04	–0.01	–0.02	–0.02
Germany	–0.01	–0.02	–0.05	–0.06
US	–0.01	–0.01	–0.01	–0.01
Global (excl. China)	–0.01	–0.02	–0.02	–0.02

Source: Author's calculations based on WIOD.

Drilling down on our sector-level findings, we identify the individual sectors hardest hit by sector-specific Chinese demand shocks (Table 4). Taiwan and Korea again top the list with a shock in

Chinese final demand of electrical equipment leading to a –2.28 % effect on the value-added production of Taiwanese electrical equipment manufacturing, a shock in Chinese final demand of machinery to a –1.87 % effect on Taiwanese machinery manufacturing and a shock in Chinese demand of electronics to a –1.48 % effect on Korean electronics manufacturing. Certain European industries also experience significant effects from Chinese final demand disturbances, including shocks to Chinese motor vehicle demand (–1.07 % on Slovakian motor vehicle manufacturing, as well as – 0.82 % on the British and –0.67 % on the German car sectors) and shocks to Chinese demand for pharmaceutical products (–1.15 % on Norwegian pharmaceutical makers, as well as –0.59 % on the Danish and –0.58 % on the Swedish pharma sectors).

Table 4 Largest individual effects of sector-specific shocks to Chinese final demand, % of sector value added

Chinese final demand sector	Affected production sector	Impact, % of sector value added
Electronic equipment	Taiwanese electronic equipment mfg.	–2.28
Machinery	Taiwanese machinery mfg.	–1,87
Computers and electronics	Korean electronics mfg.	–1.48
Computers and electronics	Taiwanese electronics mfg.	–1.24
Pharmaceutical products	Norwegian pharmaceuticals mfg.	–1.15
Motor vehicles	Slovakian motor vehicle mfg.	–1.07
Computers and electronics	Japanese electronics mfg.	–0.91
Motor vehicles	British motor vehicle mfg.	–0.82
Machinery	Korean machinery mfg.	–0.81
Pharmaceutical products	Taiwanese pharmaceuticals	–0.81
Machinery	German machinery mfg.	–0.76
Machinery	Japanese machinery mfg.	–0.73

Source: Author’s calculations based on WIOD.

4.4 Chinese sector-specific supply shocks

Now we perform a similar exercise as in the previous section, but focus on sector-specific supply shocks instead of shocks to final demand. A supply shock here is an exogenous change in the output of a Chinese sector. In the basic input-output framework, the effect of a supply shock reflects demand changes experienced by the other sectors providing inputs to the sector hit by the shock. Therefore, the effect is partly the same as in the previous section. It again accounts for the inputs needed in the production for domestic final demand, but instead of the production for Chinese final demand it includes the inputs needed in Chinese production for exports. We again consider a 10 % negative shock to each manufacturing sector.

The results for sector-specific supply shocks are quite similar to those for final demand shocks (Table 5). For shocks originating in most sectors, the aggregate effects are quite small, but again with some exceptions. Indeed, some of the effects on other countries are actually even larger than in the case of final demand shocks, reflecting the fact that sectors oriented more towards exports in Chinese production tend to be more import-intensive. In global terms (excluding China itself), the largest effect of 0.04 % of combined value added comes from the manufacturing of electronics. The effect of a shock in manufacturing of basic metals is of similar magnitude. The average effect varies by sectors between 0 and -0.05 % of GDP with the most negative impacts recorded for shocks from manufacturing of electronics and basic metals. In regional terms, the highest negative effects result from shocks in manufacturing of electronics for Taiwan and Korea (0.54 % and 0.23 % of GDP), manufacturing of basic metals for Australia and Russia (0.16 % and 0.09 %)[7] and manufacturing of electronic equipment for Taiwan and Korea (0.14 % and 0.08 % of GDP).

Table 5 Effects of a 10 % negative shock on Chinese output in selected sectors and countries, % of GDP

	Food	Basic metals	Electronics	Electrical equipment
Taiwan	–0.03	–0.08	–0.54	–0.14
Korea	–0.02	–0.06	–0.23	–0.08
Australia	–0.04	–0.16	–0.06	–0.06
Germany	–0.01	–0.02	–0.02	–0.02
US	–0.01	–0.01	–0.01	–0.01
Global (excl. China)	–0.01	–0.04	–0.04	–0.02

Source: Author's calculations based on WIOD.

At the individual sector level, there are similarities and differences compared to the shocks on final demand. Manufacturing of electronics is again – unsurprisingly – the source sector of shocks that results in strongest individual effects (Table 6). Moreover, the hardest-hit sectors again feature a handful of Taiwanese industries[8]. Indeed, the largest individual effects are recorded for shocks in Chinese manufacturing of electronics to Taiwanese electronics manufacturing (–2.78 % of the sector's value added) and for shocks in Chinese manufacturing of textiles for Taiwanese manufacturing of textiles (–1.67 %). On the supply-shock side, manufacturing of textiles, chemicals and basic metals as sources of shocks create higher individual effects. Unlike with demand shocks, the most affected sectors include several Australian industries.

[7] The figure for Russia is probably too small due to the lack of data or the fact that the data are outdated (Timmer et al., 2016).

[8] Some of the most affected sectors might seem slightly surprising, as e.g. the relatively strong effect of a shock in Chinese manufacturing of electronics to Taiwanese manufacturing of chemicals, but manufacturing of electronics is actually globally among the top customer sectors of the chemical industry according to Oxford Economics (2019).

Table 6 Largest individual effects of sector-specific shocks to Chinese supply, % of sector value added

Chinese sector	Affected sector	Impact, % of sector value added
Electronics	Taiwanese electronics mfg.	–2.78
Textiles	Taiwanese textiles mfg.	–1.67
Electronics	Korean electronics mfg.	–1.57
Chemicals	Taiwanese chemicals mfg.	–1.37
Basic metals	Australian mining & quarrying	–1.24
Electronics	Japanese electronics mfg.	–0.90
Basic metals	Australian basic metal production	–0.83
Electronics	Taiwanese non-metallic mineral production	–0.80
Chemicals	Korean chemicals mfg.	–0.74
Foodstuffs	Brazilian crop and animal production	–0.66
Electronics	Taiwanese chemicals mfg.	–0.62
Chemicals	Australian mining & quarrying	–0.61

Source: Author's calculations based on WIOD.

In general, the effects of sector-specific shocks to both Chinese final demand and supply seem to be relatively moderate in most cases. As the previous literature lacks similar estimates, we are unable to compare the magnitude of our estimates to the previous literature. The relatively moderate magnitude of the effects could reflect the fact that the Chinese final demand is still quite heavily oriented towards domestic goods. The import intensity of Chinese production chains, which rely mainly on domestic inputs, has actually decreased in recent years as noted in Timmer et al. (2016) and Simola (2018). There are, however, a few exceptions where international spillovers are not negligible. Moreover, such shocks would probably induce additional effects from commodity prices and financial markets that are not accounted for in our framework. Our results are in line with the earlier findings of e.g. Acemoglu and al. (2015) and Lee (2019) that idiosyncratic sub-aggregate level shocks may have important effects on the aggregate level through network-based propagation.

5 Conclusions

We have examined the international propagation and impact of various shocks originating in the Chinese economy on other economies using an input-output framework applied to recently compiled world input-output data. Our motivation was two-fold. First, our goal was to estimate the magnitude of the effects of the shocks in the relatively simple input-output framework and then compare those results to estimates achieved with more complex methodologies. Second, we wanted to examine more closely the transmission of idiosyncratic sector-specific shocks in the international production network to evaluate their importance at the aggregate level. The possibility for sector-level examination is the major advantage of the input-output framework. We are not aware of a similar analysis in the previous literature.

This study starts by considering the effects of an aggregate-level negative shock to Chinese final demand alone and then combined with a shift in the structure of final demand from investment to private consumption. We find that a negative shock of 1 % of Chinese GDP results in an effect of –0.12–0 % of GDP for other countries. With the demand structure change, the effect is in the range of –0.49–0.01%. Our estimates are close to the typical range of 0 % to –0.6% reached in the previous literature. Several of our estimates fall at the lower end of this range, probably due to the fact that our framework is considers the trade channel only and *not* the commodity price and financial market channels that may also contribute additional effects. Our estimates for the demand rebalancing scenario are larger and more heterogeneous due to the higher import intensity of Chinese investment than consumption demand, as well as increased demand in certain consumer sectors due to the shift in the demand structure.

We next examined the effects of negative trade cost shocks with respect to the current US-China trade dispute. In the first scenario, we assume a 25 % tariff on all US goods imports from China. In the second scenario, we add corresponding retaliation measures by China on imports from the US. Our results for the second scenario suggest a negative impact of –1.02 % of GDP for China and a mere –0.12 % of GDP for the US, whereas the earlier estimates are in the range of 0.3–0.4 % for China's loss of GDP and a loss of between 0–0.3 % of GDP for the US. In sector terms, our results are quite well in line with the previous literature for the hardest hit sectors. In the Chinese side, they are manufacturing of miscellaneous products, electronics and textiles, while the largest losses for the US are experienced in transport equipment manufacturing and machinery. Our framework cannot, however, account for the longer term redistributive effects that lead to gains in some sectors in estimates presented in the previous literature.

Finally, focusing on the sector level, we examine the international effects of sector-specific demand and supply shocks originating in China. We find that, in general, the international impact of Chinese sector-specific shocks is relatively modest at the aggregate level for both shocks to final demand and supply. This reflects the fact that Chinese final demand (and increasingly production) mainly rely on domestic supply. There are, however, a few exceptions with larger effects. A 10 % negative shock to Chinese final demand of electronics results in an effect of –0.17 % of GDP for Korea and a corresponding shock to Chinese output of basic metals in an effect of –0.16 % for Australia. At the sector level, the effects are obviously also larger in other affected countries. Several Taiwanese and Korean industries suffer both in the case of demand and supply shocks. Manufacturing of medical products in Scandinavia and motor vehicle manufacturing in Slovakia are among the hardest hit sectors in the case of demand shocks and in the case of supply shocks Australian mining and Brazilian agriculture. Moreover, such shocks would probably also induce additional effects from commodity prices and financial markets that cannot be accounted for in our framework.

To conclude, our results suggest that most estimates calculated with a simple input-output framework are relatively close to those received from more elaborate models. The main advantages of the input-output framework are its simplicity and the fact that it permits examination of sector-level effects and network propagation of shocks more closely than in most other models, thus providing valuable complementary insights. In quantitative terms, our results show that shocks originating in China – even sector-specific shocks – can have important effects also for other countries through transmission in international production networks. These effects seem to be limited, despite China's emergence as one of the largest economies in the world. China still relies largely on domestic supply both for final demand and intermediate inputs. The effects can, however, be amplified through commodity price and financial market channels that cannot be accounted for in our framework. Thus, our results also provide support to the view that idiosyncratic shocks do not always average out at the aggregate level.

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