Responses to the reviewer's comments on the manuscript

"The asymmetric impact of natural disasters on China's bilateral trade"

The authors would like to thank the reviewer for your efforts on this manuscript and providing us with insightful comments and suggestions to improve the quality of this manuscript. The following responses have been prepared to address reviewers' comments in a point –by-point fashion. And the sentences in red are the corresponding revised parts in our manuscript. We also attach a copy of the marked-up revised manuscript to make the reversion notable.

Comment: i) It seems authors use simple cross-section analysis. Panel analysis has to be preferred in this framework.

Response: Thanks for your suggestion.

We have tried fixed effect and random effect models in this study but the outcomes are statistically unacceptable. Thus, we used the pooled panel analysis here.

We add a paragraph at the beginning of section "Results and analysis" (Page 2012, Line 8) to explain the selection of analysis method:

"In the estimation, pooled panel analysis is employed rather than fixed effect and random effect models due to a couple of reasons. First, we estimate the random effects and do the Hausman test. The chi-square statistic value is 76.04 and the probability of accepting the null hypothesis is almost 0. Therefore, random effects are not appropriate herein. Then we estimate the fixed effects, but the results are far from acceptable. To be more specific, if country-fixed effects are added, the variables like Distance, Border are omitted because of collinearity. While period-fixed effects are added, variables like China's GDP, China's Disaster, are omitted because of collinearity. However, all the above omitted variables are essential or even indispensable to this study. Thus, the fixed effects are not appropriate, either. Taken together, the pooled panel analysis is employed."

Comment: ii) estimation by means of ordinary least squares in a log-log setting bias the results.

Response: Thanks for your comment.

We agree that ordinary least squares (OLS) may bias the results, which is especially a matter of concern when dealing with the heteroskedasticity (Silva and Tenreyro, 2006). The Poisson Pseudo-Maximum Likelihood (PPML) technique is capable of making the bias smaller comparing with OLS (Silva and Tenreyro, 2006;Anderson, 2010). Thus, we used the PPML technique to re-estimate the parameters in our models. The results are showed in Table 6 and Table 7.

One point to note is that the results are a little different from the previous ones, which may confirm the bias estimation of OLS in a log-log setting. The first difference is the estimation of China's disasters in import models (Table 6). In the previous models, estimated by OLS, China's disasters have significantly positive impacts on the imports but no significant impacts on the exports. While the present results, estimated by PPML, show that China's disasters' positive impacts on imports is not significant, but the impacts on exports become significant and positive. The second one is that the estimation of the interaction term ln(Importer's disasters)× Developed in the export models (Table 7, Figure 1). It changes from positive to negative. Apart from these, the other coefficients' estimations are also different, but not essential. Figure 2 shows the marginal effects of natural disasters in partner countries on China's bilateral trade as a function of land area, which is the revised version of Fig. 3 in our manuscript. It's obvious that the basic pattern showed in this figure remains the same. Based on the results of revised models, the corresponding statements in our manuscript are all revised.

Correspondingly, we rewrote the econometric analysis as the reviewer suggests. These revisions are mainly in the "Results and analysis" section.

On Page 2011, a paragraph is added in Section "Results and analysis":

"Ordinary Least Squares (OLS) is the widely used method to estimate the gravity model. But Silva and Tenreyro (2006) point out that the parameters of log-linearized models estimated by OLS lead to biased estimates of the true elasticities under heteroskedasticity. Thus, Poisson Pseudo-Maximum Likelihood (PPML) technique is used in this study."

On Page 2011, Line 17, "and all variables had statistical significances exceeding the 0.1 level" is changed as "and all variables had statistical significances exceeding the 0.1 level except China's disasters."

On Page 2011, Line 22, "Variables like China's disasters and common borders, however, did not enter the export models. But other variables were all statistically significant" is changed as "Variables like Importer's disasters and APEC were not statistically significant, but other variables were."

On Page 2012, Line 2~3, "Distance and China's population are negative factors" is changed as "Distance is a negative factor"

On Page 2012, Line 6, "A common boundary promoted national imports, but had no significant impact on exports." is changed as "A common boundary promotes national imports and exports."

On Page 2012, Line 11, "In Model 2, the coefficient of disasters in China was significant and positive, indicating that an increase in disasters raises bilateral imports of the country." is changed as "In Model 2, the coefficient of disasters in China is positive but not significant, indicating that domestic disasters have no significant impact on China's import."

On page 2012, Line 23, "Model 7 shows that disasters in China had no significant impact on its bilateral exports." is changed as "Model 7 shows that disasters in partner countries have no significant impact on its bilateral exports."

On page 2012, Line 24, "The coefficient of disasters in partner countries is significant and negative, indicating that an increase in those countries' disasters reduced bilateral exports from China." is changed as "But an increase in China's disasters increases bilateral exports from China."

On page 2012, Line 26, "In Model 8, the interaction term of importer natural disasters and development level is significant and positive. Thus, the marginal effect of natural disasters increased when the importer was a developed country." is changed as "In Model 8, the interaction term of importer natural disasters

and development level is significant and negative. Thus, the marginal effect of natural disasters decreases when the importer is a developed country."

On page 2013, Line 8, paragraph "Figure 2 indicates that …" is changed as "Figure 2 indicates that natural disasters in partner countries have more negative effects on China's imports when the partner is a developed country, the same for exports. The marginal effect of partner natural disasters on China's imports decreases about 7.8% when the partner is a developed country, relative to a developing one. The corresponding difference for the exports is a decrease of 4.5%."

On page 2013, Line 12, paragraph "Figure 3 indicates that …" is changed as "Figure 3 indicates that land area is a very important factor when natural disasters strike partner countries of China. Figure 3a suggests that these disasters are less detrimental to the country's imports as partner land area increases. When that area exceeds 13.44 million km2, the marginal effect of the disasters on those imports becomes positive. Figure 3b suggests that the disasters are more detrimental to China's exports as partner land area swells. If that area is smaller than 0.35 million km2, the marginal effect of the disasters on those exports becomes positive."

On page 2013, Line 24, "Disaster impacts on exports are greater than on imports relative to China's bilateral trade, (Tables 1 and 2), especially when the disasters are in developed countries." is changed as "Partner disaster impacts on imports are greater than on exports relative to China's bilateral trade, especially when the disasters are in developed small countries."

On page 2014, Line 3, the paragraph "It is easy to interpret …" is changed as "It is easy to interpret the increase of import value caused by domestic disasters. Because of reconstruction efforts for damaged infrastructure, increased domestic demand turns to foreign markets to some degree. But this kind of effect to China is not significant. Further, domestic natural disasters may also increase the export value of the country due to seeking for the trade balance or some other reasons. And this effect is embodied in China's export."

On page 2014, Line 9~11, "First, if a natural disaster affects a developed partner of China, it faces a larger decline in imports from that partner but a smaller decrease in exports to that partner" is changed as "First, if a natural disaster affects a developed partner of China, it faces a larger decline both in imports and exports".

On page 2014, Line 15, "The smaller decrease in exports may be associated with the stable demand market of developed countries and stable export capacity of China" is changed as "The larger decrease in exports may be associated with the recession in demand of developed countries".

On page 2014, Line 28, "Overall, from the perspective of reducing disaster risk of trade, it is favorable for China to import more from large developing countries and to export more to small developed countries" is deleted.

On page 2015, Line 8, "An increase in China's disasters increases its imports but has no significant impact on exports" is changed as "An increase in China's disasters increases its exports but has no significant impact on imports".

On page 2015, Line 12, "the decrease of Chinese imports is significant, but the decrease of exports is insignificant" is changed as "the decreases of China's bilateral imports and exports are both larger".

Comment: iii) The change in sign in models (9) and (10) for importer's disaster variable might denote the presence of multicollinearity.

Response:

We calculate the Variance Inflation Factor (VIF) of each variable in previous models estimated by OLS (Table 1), and find the VIFs of variables China's GDP, China's Population, Partner' s Disaster, Partner's Disaster&Area are larger than 10. Therefore, it is very likely that the estimations are influenced by the multicollinearity. Since the population is not a key variable in our study, it is dropped from the models for the sake of eliminating multicollinearity in the revised version. The results show that R^2 changes very little. The interaction variable between partner disaster and land area is important to this study. From the global perspective, The smaller a country the more are its trade flows reduced in case it is struck by a disaster, which is especially true for exporters (Gassebner et al., 2006). Regarding the case of China and its trade partners, the land area is also believed to play a crucial role. So we keep this interaction variable. Table 2 lists the variables included in our revised models, and we also rename all the variables in order to make the results (Table 3, Table 4 and Table 5) displayed more structured.

On page 2009, Line 16, the model is changed as:

$$\ln Y_{it} = \alpha_0 + \alpha_1 ln(GDP_t) + \alpha_2 \ln(GDP_{it}) + \alpha_3 \ln(Dist_{it}) + \alpha_4 ln(Disa_t) + \alpha_5 ln(Disa_{it}) + \alpha_6 ln(Disa_{it}) \times Developed_i + \alpha_7 ln(Disa_{it}) \times ln(Area_{it}) + \alpha_8 APEC_{it} + \alpha_9 WTO_{it} + \alpha_{10} Bd_{it} + \varepsilon_{it}$$

On page 2009, Line 6, "Variables such as population, Asia–Pacific Economic …" is changed as:

"Variables such as Asia–Pacific Economic …"

On page 2009, Line 8, "Undoubtedly, the population problem is a great challenge for China's social and economic development." is deleted.

On page 2009, Line 19~27, all the population related variable descriptions are deleted.

On page 2010, Line 12, ", population (in million)" is deleted.

To make the econometric analysis more reliable, we add the variables' correlation matrix (Table 3, Table 4) to our manuscript. In addition to that, we list the VIFs of each variable in the revised models as in Table 5.

On page 2011, Line 7, a paragraph is added as follows:

"In order to make the results displayed more structured, we rename the variables with several English letters (Table 1). Table 2 and Table 3 show the variables' correlation matrix."

On page 2012, Line 1, a paragraph is added, as follows:

"Multicollinearity is another issue that has to be considered carefully. We calculate the Variance Inflation Factor (VIF) of each variable (Table 4). Model 4, 5, 9 and 10, including interaction variable DA, exhibit the highest mean and individual VIFs, which are larger than 10. While the other models' are far less than 10. By further checking the correlation matrix showed in Table 2 and Table 3, it's obvious that only the correlations between PD and DA are larger than 0.8 and the high VIFs are solely attributed to the interaction variable DA. The same phenomenon also arises in the study of Oh and Reuveny (2010)"

Oh and Reuveny (Oh and Reuveny, 2010) claim that "The average VIF score of Model (4) is larger than 10. A closer examination reveals that the average score is solely attributed to the interaction terms included

in this model, which cannot be helped". We have the same challenge, but the interaction variable is meaningful and this issue cannot be helped.

The changing sign problem still exist in model 8, 9 and 10. Actually, we found this phenomenon in the very beginning of our study. To explain this phenomenon, the sentence "The sign of the variable importer disasters is positive, opposite that from Models 7 and 8. This indicates that disasters in importer countries increased the export value of China, but importer land area reduced positive disaster effects even to the point of becoming negative.", On page 2013, Line 2~5, is changed as :

"The sign of the variable importer disasters changes from negative to positive, and the impact changes from insignificant to significant as the interaction terms are added to the model. This indicates that disasters in importer countries have no significant impact on China's export unless the development and land area interaction effects are taken into account. The similar phenomenon exists in the Model 3, 4 and 5. The coefficient of Exporter's disasters changes from -0.0386 to -0.0224 when adding the development level interaction term. And it further changes to -0.238 when adding the land area interaction term, which is a big change even though the sign remains the same. All these changes are attributed to the interaction effects. That is to say, the interaction effects change the main effect of the variable, which should not be considered as a problem caused by multicollinearity."

Comment: iv) the estimated for China's disaster are not reported even though they are essential in the analysis.

Response:

The variable of China's disaster is essential, but it was automatically removed from the regression model in the procedure of stepwise regression algorithm. In other words, the variable of China's disasters has no significant contribution to China's export based on the former analyses. In the revised models, the estimated for all variables are reported (Table 6, Table 7). In addition to that, we give a specific description to this variable in the response to the reviewer's comment ii).

Comment: v) disasters are considered only in numbers but not in magnitude.

Response:

It is truly better to consider disasters in magnitude than in numbers. But the available global disaster database (i.e. EM-DAT) is not complete enough for this purpose. There is no magnitude information in the database, even a number of events have no loss record. Therefore, we only considered numbers in our models.

References

Anderson, J. E.: The gravity model, National Bureau of Economic Research, 2010.

Gassebner, M., Keck, A., and Teh, R.: The impact of disasters on international trade, WTO Staff Working Paper, 2006.

Oh, C. H., and Reuveny, R.: Climatic natural disasters, political risk, and international trade, Global Environmental Change-Human and Policy Dimensions, 20, 243-254, DOI 10.1016/j.gloenvcha.2009.11.005, 2010.

Silva, J. M. C. S., and Tenreyro, S.: The log of gravity, Review of Economics and Statistics, 88, 641-658, DOI 10.1162/rest.88.4.641, 2006.

Table 1 the VIFs of variables in the models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ln(China's disasters)		1.38	1.67	5.12	5.12	--	--	--	--	--
ln(Partner's disasters)		1.78	2.02	**39.93**	**40.10**	--	1.74	1.96	**36.43**	**36.57**
ln(Partner's disasters)×Developed			1.38		1.70	--	--	1.62	--	1.66
ln(Partner's disasters)×ln(Partner's Area)				**44.40**	**45.36**	--	--	--	**39.79**	**40.62**
ln(China's GDP)	9.05	**11.19**	**11.23**	**11.20**	**11.25**	9.44	9.45	9.50	9.46	9.51
ln(Partner's GDP)	2.40	2.42	3.26	2.48	3.27	2.62	2.66	3.55	2.68	3.55
ln(Distance)	1.43	1.45	1.45	1.61	1.61	1.16	1.17	1.17	1.22	1.22
APEC	1.28	1.37	1.37	1.49	1.49	1.25	1.32	1.33	1.41	1.41
WTO	2.08	2.18	2.18	2.21	2.21	2.10	2.11	2.11	2.14	2.14
Border	1.36	5.12	5.12	1.46	1.47					
ln(China's population)	7.69	**17.54**	**17.54**	**17.59**	**17.59**	7.83	7.89	7.89	7.90	7.90
ln(Exporter's population)	2.28	2.99	3.37	3.10	3.55	2.40	3.17	3.60	3.30	3.81

Table 2 Table 1 Variable names

Variable	Name
ln(China's Import)	CI
ln(China's Export)	CE
ln(China's disasters)	CD
ln(Partner's disasters)	PD
ln(Partner's disasters)×Developed	DD
ln(Partner's disasters)×ln(Partner's Area)	DA
ln(China's GDP)	CG
ln(Partner's GDP)	PG
ln(Distance)	Di
APEC	APEC
WTO	WTO
Border	Bd

Table 3 Table 2 the correlation matrix for China as an importer

	CI	CD	PD	DD	DA	CG	PG	Di	APEC	WTO
CI										
CD	0.237									
PD	0.303	0.154								
DD	0.401	-0.0355	0.361							
DA	0.339	0.132	**0.986**	0.386						
CG	0.348	0.745	0.119	-0.0563	0.0959					
PG	0.769	0.0536	0.339	0.558	0.379	0.110				
Di	-0.220	0.00660	-0.111	-0.0183	-0.0839	0.0248	-0.105			
APEC	0.452	0.128	0.338	0.255	0.364	0.115	0.337	-0.304		
WTO	0.296	0.580	0.134	0.0103	0.107	0.737	0.119	0.104	0.0959	
Bd	0.00590	0.0210	0.169	-0.101	0.182	0.00960	-0.105	-0.423	0.0118	-0.0949

Table 4 Table 3 the correlation matrix for China as an exporter

	CE	CD	PD	DD	DA	CG	PG	Di	APEC	WTO
CE										
CD	0.400									
PD	0.339	0.175								
DD	0.366	-0.0183	0.357							
DA	0.355	0.153	**0.985**	0.384						
CG	0.571	0.750	0.153	-0.0260	0.132					
PG	0.761	0.0860	0.352	0.545	0.394	0.174				
Di	-0.306	-0.0228	-0.126	-0.0444	-0.107	-0.0292	-0.180			
APEC	0.397	0.132	0.334	0.267	0.363	0.133	0.348	-0.315		
WTO	0.469	0.578	0.161	0.0351	0.137	0.736	0.176	0.0581	0.114	
Bd	0.0783	0.0400	0.187	-0.0864	0.201	0.0355	-0.0482	-0.425	0.0236	-0.0705

Table 5 Table 4 VIFs of variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CD		2.3	2.3	2.3	2.3		2.35	2.35	2.35	2.35
PD		1.3	1.37	44.91	44.91		1.31	1.38	43.03	43.03
DD			1.6		1.6			1.57		1.57
DA				47.83	47.88				45.94	46.05
CG	2.23	3.32	3.37	3.33	3.38	2.24	3.41	3.45	3.41	3.46
PG	1.16	1.27	1.64	1.42	1.78	1.19	1.31	1.67	1.48	1.82
Di	1.39	1.4	1.4	1.61	1.61	1.41	1.42	1.43	1.6	1.6
APEC	1.25	1.34	1.35	1.45	1.45	1.25	1.34	1.34	1.43	1.44
WTO	2.26	2.28	2.28	2.31	2.31	2.25	2.27	2.27	2.3	2.3
Bd	1.28	1.35	1.36	1.48	1.49	1.27	1.35	1.36	1.46	1.47
Mean	1.59	1.82	1.85	11.85	10.87	1.6	1.84	1.87	11.44	10.51

Table 6 Table 5 Regression results for China as an importer (1980–2012)

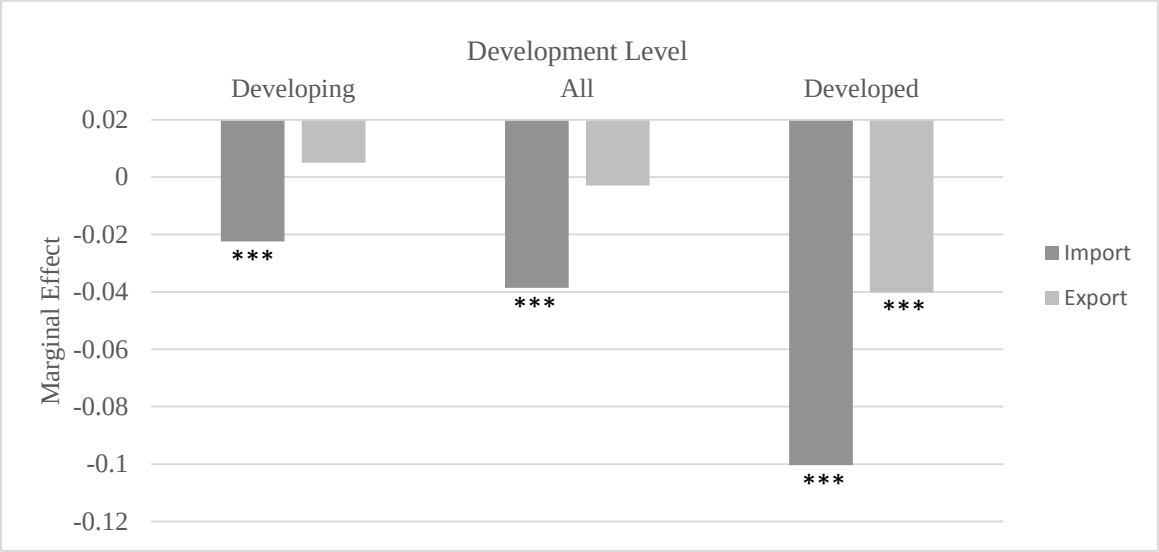
	(1)	(2)	(3)	(4)	(5)
ln(China's disasters)		0.00943	0.0113	0.0124	0.0146
		(0.0200)	(0.0200)	(0.0200)	(0.0200)
ln(Exporter's disasters)		-0.0386***	-0.0224***	-0.238***	-0.249***
		(0.0075)	(0.0077)	(0.0470)	(0.0450)
ln(Exporter's disasters)×Developed			-0.0780***		-0.0820***
			(0.0097)		(0.0100)
ln(Exporter's disasters)×ln(Exporter's Area)				0.0145***	0.0166***
				(0.0035)	(0.0032)
ln(China's GDP)	0.111***	0.106***	0.0984***	0.107***	0.0995***
	(0.0077)	(0.0087)	(0.0086)	(0.0086)	(0.0086)
ln(Exporter's GDP)	0.182***	0.188***	0.201***	0.182***	0.196***
	(0.0029)	(0.0031)	(0.0036)	(0.0032)	(0.0038)
ln(Distance)	-0.0904***	-0.0845***	-0.0780***	-0.111***	-0.107***
	(0.0100)	(0.0100)	(0.0097)	(0.0120)	(0.0120)
APEC	0.143***	0.169***	0.176***	0.141***	0.145***
	(0.0140)	(0.0140)	(0.0140)	(0.0160)	(0.0160)
WTO	0.0367**	0.0434**	0.0452**	0.0522***	0.0552***
	(0.0180)	(0.0180)	(0.0180)	(0.0180)	(0.0180)
Border	0.0620***	0.0924***	0.0695***	0.0553**	0.0254
	(0.0210)	(0.0220)	(0.0230)	(0.0240)	(0.0250)
Constant term	-0.580***	-0.665***	-0.805***	-0.209	-0.298
	(0.1900)	(0.1900)	(0.1900)	(0.2100)	(0.2200)
N	3468	3468	3468	3468	3468
R^2	0.6700	0.6700	0.6800	0.6700	0.6800

*/**/*** indicates significance at 0.1/0.05/0.01 levels (two-tailed test). Standard errors shown in parentheses.

Table 7 Table 6 Regression results for China as an exporter (1980–2012)

	(6)	(7)	(8)	(9)	(10)
ln(China's disasters)		0.0687***	0.0701***	0.0679***	0.0695***
		(0.0160)	(0.0160)	(0.0160)	(0.0160)
ln(Importer's disasters)		-0.0029	0.0050	0.0537*	0.0520*
		(0.0049)	(0.0050)	(0.0280)	(0.0280)
ln(Importer's disasters)× Developed			-0.0451***		-0.0444***
			(0.0072)		(0.0073)
ln(Importer's disasters)×ln(Importer's Area)				-0.0042**	-0.00350*
				(0.0020)	(0.0020)
ln(China's GDP)	0.177***	0.163***	0.159***	0.163***	0.158***
	(0.0050)	(0.0054)	(0.0055)	(0.0054)	(0.0055)
ln(Importer's GDP)	0.147***	0.148***	0.155***	0.149***	0.156***
	(0.0021)	(0.0021)	(0.0026)	(0.0022)	(0.0027)
ln(Distance)	-0.137***	-0.137***	-0.133***	-0.130***	-0.128***
	(0.0081)	(0.0081)	(0.0081)	(0.0089)	(0.0090)
APEC	0.0111	0.00817	0.0132	0.0164	0.0198*
	(0.0100)	(0.0110)	(0.0110)	(0.0120)	(0.0110)
WTO	0.0523***	0.0459***	0.0465***	0.0433***	0.0444***
	(0.0100)	(0.0110)	(0.0110)	(0.0110)	(0.0110)
Border	0.0725***	0.0724***	0.0612***	0.0829***	0.0702***
	(0.0150)	(0.0150)	(0.0160)	(0.0160)	(0.0160)
Constant term	-0.253*	-0.272*	-0.345**	-0.394**	-0.444***
	(0.1500)	(0.1500)	(0.1500)	(0.1600)	(0.1600)
N	4035	4035	4035	4035	4035
R^2	0.7800	0.7800	0.7800	0.7800	0.7800

*/**/*** indicates significance at 0.1/0.05/0.01 levels (two-tailed test). Standard errors shown in parentheses.



*/**/*** indicates significance at 0.1/0.05/0.01 levels

Figure 1 Fig. 2 Marginal effects of natural disasters in partner countries on China's bilateral trade versus development levels

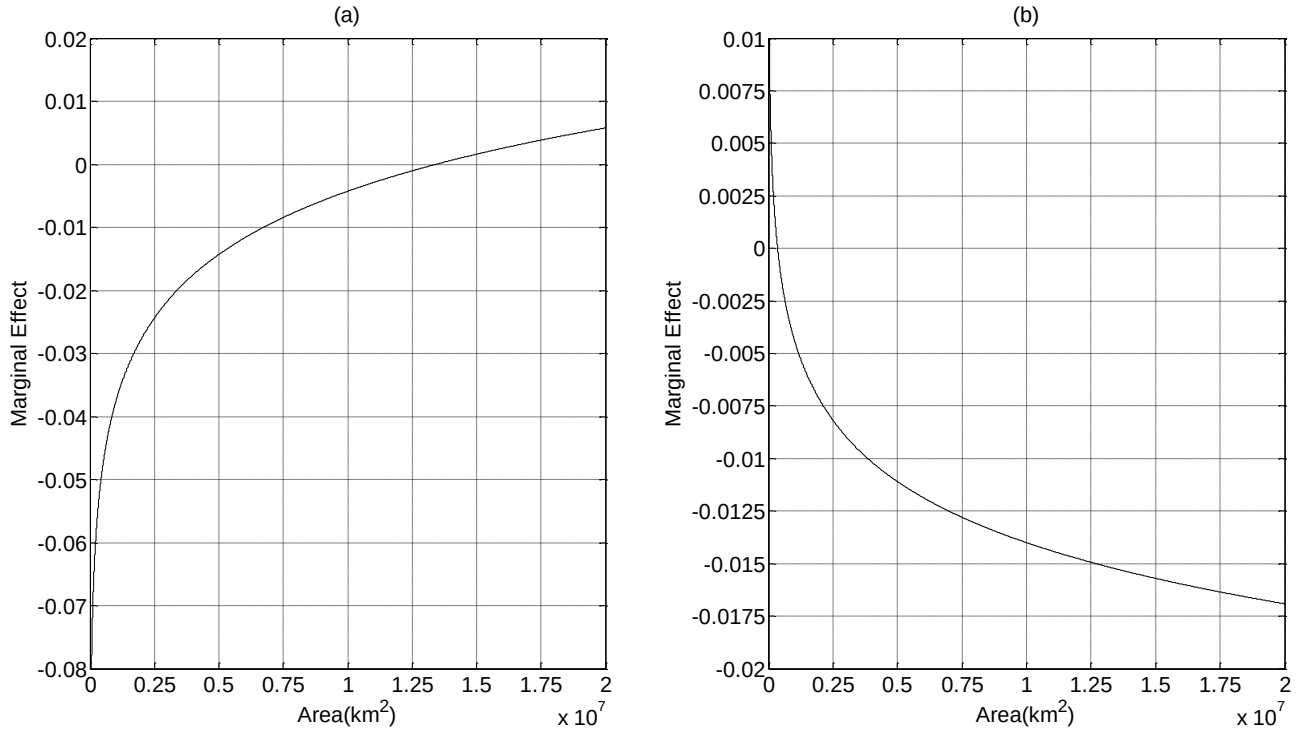


Figure 2 Fig. 3 Marginal effect of natural disasters in partner countries on China's bilateral trade as a function of land area. (a) is for Chinese imports; (b) is for its exports.

The asymmetric impact of natural disasters on China's bilateral trade

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Abstract

Globalization and technological revolutions are making the world more interconnected. International trade is one of the major approaches linking the world. Since the 2011 Tohoku earthquake and tsunami in Japan shocked the global supply chain, more attention has been paid to the global impact of large-scale disasters. China is the second largest trader in the world and faces the most frequent natural disasters. Therefore, this study proposes a gravity model for China's bilateral trade tailored to national circumstances, and estimates the impact of natural disasters in China and trading partner countries on Chinese imports and exports. We analyzed Chinese and trading partner statistical data from 1980 to 2012. Study results show that: 1) China's natural disasters have a positive impact on imports, but have no significant impact on exports; 2) trading partner countries' natural disasters reduce Chinese imports and exports; 3) both development level and land area of the partners are important in determining the intensity of natural disaster impacts on China's bilateral trade. The above findings suggest that the impact of natural disasters on trade is asymmetric and significantly affected by other factors, which demand further study.

1 Introduction

Globalization and technological revolutions are changing traditional ways of life. Today there is a worldwide exchange of people, goods, money, information, and ideas, which have formed complex global networks and produced many new opportunities, services and benefits for humanity. At the same time, the underlying networks have created pathways along which dangerous and damaging events can spread rapidly and globally(Helbing, 2013). The increasing numbers of international trade flows are undoubtedly an important part of these networks.

Natural disasters, especially large-scale ones, are becoming severe challenges for human society and development. According to historical records, the average number of people affected by natural disasters rose from about 25 million per year in the 1960s to 300 million since 2000(Guha-Sapir et al., 2013). The effects of large-scale disasters (LSDs) are increasing on the global scale. For instance, the WTO(WTO, 2012) claimed that the 2011 Tohoku earthquake and tsunami in Japan and flooding in Thailand contributed to below average growth in international trade in 2011, because of the damage to global supply chains, especially the electric, semiconductor and automaker chains. An extreme event has effects in every corner of the world. The global impact of LSDs demands global countermeasures for their risk governance(Shi et al., 2011).

Research on the economic impact of disasters is generally categorized into two approaches. One approach, case studies, focus on direct/indirect loss of an actual disaster. There are several widely used models, including before-and-after macroeconomic(Albalabertrand, 1993), input–output (IO) model(Okuyama and Santos, 2014;Akhtar and Santos, 2013;Rose and Wei, 2012;Lin et al., 2012;Haimes et al., 2005;Rose et al., 1997), and general equilibrium models(Xie et al., 2014;Rose et al., 2007). The other approach uses multi-country/disaster statistics models from a macroscopic viewpoint, using econometric statistical models to analyze the impact of per capita income(Kahn, 2005), education attainment, trade openness(Toya and Skidmore, 2007), investment climate(Raschky, 2008), and others on disaster effects.

Also analyzed are the effects of disasters on regional economic development(Noy, 2009) and consumption(Auffret and Turk, 2003).

However, research on disaster impacts on regional trade is rare. Gassebner et al.(Gassebner et al., 2006) quantitatively estimated these impacts on international trade at global scale. They found that disasters reduced trade in both exporter and importer countries. Oh and Reuveny (Oh and Reuveny, 2010) examined the impact of climatic disasters and political risk on international trade from the standpoint of global climate change. They also found that an increase in climatic disasters in either importer or exporter countries reduced their bilateral trade. Both the aforementioned studies used gravity models of global trade. They concluded that disasters had negative impacts on bilateral trade, but neglected regional diversity. The latter means that the impact of a disaster varies significantly by region of the world. Ando et al.(Ando and Kimura, 2012) examined the impact of two crises, the 2009 global financial crisis and 2011 Tohoku Earthquake, on Japanese exports from the viewpoint of domestic and international machinery production network. Li et al.(Li et al., 2014) compared the impacts of these two crises on the exports out of Japan to China from the angle of multi-industry trade. Both studies compared intensities and durations of the impacts, which revealed a part of the impact of external shocks on China's bilateral trade, but not the full picture.

According to leading exporters and importers of merchandise trade in 2012 as listed by the WTO (WTO, 2013), the import value of China in 2012 was 1.814 trillion USD, which makes it the second largest importer after the United States. China is the largest exporter, with export value for 2012 of 2.049 trillion USD. There is no denying that China is extremely important in the network of international trade. It is also the country affected by the most natural disasters over the last decade, followed by the United States, Philippines, India, and Indonesia(Guha-Sapir et al., 2013). China has a vast, diverse landscape and the largest population in the world. It is at the intersection of two of the world's major natural disaster zones, the Pacific Rim and mid–northern latitude zones. Therefore, various hazards, complex environments, and rapid economic growth caused

by reform and opening-up policies further complicate the assessment of the impact of natural disasters on China's bilateral trade.

Do natural disasters have significant impact on China's bilateral trade? Are the effects of disasters in China the same as those outside China? This study proposes a trade gravity model based on the national situation, introduces a natural disaster variable, and quantitatively estimates the impact of those disasters on the nation's imports and exports to answer those two key questions.

2 Gravity model

2.1 Theory

From a global perspective, natural disasters have negative trade effects (Oh and Reuveny, 2010;Gassebner et al., 2006). However, if we focus on a specific country or region, the result may be totally different. Figure 1 shows interactions between trade system and disasters. We assume three regions, A, B and C. Region B has trade relationships with both A and C. Each region consists of four components, production (P), demand (D), import (I) and export (E). The three regions are in an equilibrium state with these four components, and disasters are external shocks to them.

When a disaster strikes region A, it may damage infrastructure, production equipment, and cause loss of life, thus directly reducing production. The production of region A, P_A, links with three components, E_A, I_A and D_A. Starting from E_A, the fall of P_A may lead to a drop in E_A and shrink imports of region B. Region B may increase domestic production or import more from region C. Regarding I_A, the fall of P_A may lead to the decline of I_A, which means that the intermediate demand of A from B may decrease and the exports from region B will decrease. Finally, for D_A, the flow from P_A to D_A decreases while D_A remains constant. To meet the demand of region A, I_A should be increased, which results in increasing exports from region B.

The above impacts are all triggered by the fall of P_A. However, the disaster may also have impacts on D_A; it may increase D_A because of reconstruction needs, which may

increase P_A, I_A, or both. The disaster may also reduce D_A by exhausting people and reducing their willingness to engage in normal economic activities, such as consumption. When D_A decreases, P_A and I_A may automatically decrease but, in such a case, the decrease in P_A will not ripple to E_A.

The dashed arrow in Fig. 1 between *Disasters* and D_A is a double arrow. This indicates that the trade can have feedbacks to the disaster through the demand side. If the post-disaster demand can be met by increase of I_A, reconstruction and lives of the people in a disaster area can benefit from the trade. In other words, regional trade makes the regional economic system resilient to disasters.

Disaster in region A may also contribute directly to variations of bilateral trade between regions B and A. Region A may choose policies aimed at increasing its bilateral trade flows. For instance, reconstruction efforts for damaged infrastructure in that region may rely on imports of materials, technology, and skills. External aid may intensify this effect by providing foreign currency. Seeking to rebuild areas affected by the disaster, the region may increase exports to obtain foreign currency and even liberalize its export and import markets, which will likely further promote its trade flows. However, direct negative impacts of the disaster in region A may increase the cost and risk of trade. Consequently, traders in region B are likely to exit markets of region A or reduce trade flow.

The contradictory effects of natural disasters on trade can lead to various combined effects in different countries and regions, and some of those effects are mainly driven by positive ones, and some mainly driven by negative ones. These combined effects can be estimated by empirical analysis. The trade gravity model is one of the most widely used methods, which is analogized from the law of universal gravitation and can estimate the impacts of various factors on trade.

The basic form of this model is

$$Trade_{ij} = C \times \frac{GDP_i\, GDP_j}{D_{ij}} \quad (1)$$

That is, bilateral trade flow ($Trade_{ij}$) is in proportion to gross domestic product (GDP_i, GDP_j) of two countries (i, j) and in inverse proportion to the distance (D_{ij}) between them. Other factors that impact bilateral trade can be introduced to this model, such as population, tariffs, exchange rates, language, common borders, colonial relationships, and regional free trade. In this way, the gravity model can give reasonable explanations of impacts of various factors on bilateral trade.

2.2 Model, variables and data

In research into trade gravity models, widely used variables are institutional, such as tariffs, laws and political risks, geographic variables like boundaries, lands and oceans, and social variables like language, history and culture. However, the present study focuses on impacts of disasters on bilateral trade of China, and its national situation is taken into account. Variables such as ~~population,~~ Asia–Pacific Economic Cooperation (APEC), World Trade Organization (WTO), borders, and disasters are incorporated in the basic trade gravity model. ~~Undoubtedly, the population problem is a great challenge for China's social and economic development.~~ APEC is the most important economic cooperation organization that the country has joined. The WTO has significant impact on its member countries. A common border can reduce trade cost significantly. It is widely accepted that developed countries are more resilient to natural disasters; however, whether trade between them and China is also more resilient is inconclusive. In addition, Gassebner et al.(Gassebner et al., 2006) claims that the physical size of a country appears to play a role in terms of natural disaster trade effects. Consequently, our model is built as

$$\ln Y_{it} = \alpha_0 + \alpha_1 ln(GDP_t) + \alpha_2 \ln(GDP_{it}) + \alpha_3 \ln(Dist_{it}) + \alpha_4 \sout{ln(Pop_t) + \alpha_5 \ln(Pop_{it}) + \alpha_6 lnln}(Disa_t) + \sout{\alpha_7}\alpha_5 ln(Disa_{it}) + \sout{\alpha_8}\alpha_6 ln(Disa_{it}) \times Developed_i + \sout{\alpha_9}\alpha_7 ln(Disa_{it}) \times ln(Area_{it}) + \sout{\alpha_{10}}\alpha_8 APEC_{it} + \sout{\alpha_{11}}\alpha_9 WTO_{it} + \sout{\alpha_{12}}\alpha_{10} Bd_{it} + \varepsilon_{it} \quad (2)$$

Here, subscript i denotes the trading partner of China, t the year, and Greek symbols coefficients to be estimated empirically. The dependent variable Y_{it} is the real value

of trade flow between country *i* and China. If *Y* designates the import value of China from country *i*, Equation (2) represents the Chinese import model; if *Y* is instead its export value to country *i*, Equation (2) represents the export model. GDP_t, ~~Pop_t, GDP_{it} and Pop_{it}~~GDP_{it} are China's and *i*'s real GDP~~ and population size~~ in year *t*. $Dist_{it}$ is the distance between China and *i*. $Disa_t$ and $Disa_{it}$ measure natural disasters in China and *i* during *t*, respectively. $Area_{it}$ is the land area of *i* in *t*. $Developed_i$ is set to 1 if *i* is a developed country, and $APEC_{it}$, WTO_{it} and Bd_{it} are set to 1 if China and *i* belong to APEC, WTO, or share a common border in *t*. Otherwise, they are set to 0. Finally, ε_{it} is a residual term.

In the classical trade gravity model, only countries having bilateral trade relationships are incorporated in the sample. There are countries with no bilateral relationship with China or only a unilateral trade relationship. This means the trade flows between China and other countries may be zero, which poses a problem for the log-linearization gravity model, since ln(0) is undefined. Therefore, the present study ignores zero trade flow and only takes non-zero flow country pair data into the sample, which were used to estimate the coefficients in Equation (2).

Trade data were from the Direction of Trade Statistics of the International Monetary Fund. This source provides data in millions of current USD. Data of GDP (in million USD~~), population (in million~~) and land area (in km^2) were from the World Bank. Distance between two countries (in kilometers) was represented by that between two corresponding most populous cities. The list of developed countries was from the Central Intelligence Agency's World Fact Book. The data of trade and GDP are deflated using the US GDP deflator from the World Bank.

Data on natural disasters were from the Emergency Events Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of the Catholic University of Louvain(Guha-Sapir et al.). EM-DAT contains data from a wide array of national sources that report natural disaster events, including geophysical, meteorological, hydrological, climatological and biological. For a disaster to be entered

into the database, at least one of the following criteria must be fulfilled: (1) 10 or more reported fatalities; (2) 100 or more affected; (3) declaration of a state of emergency; (4) a call for international assistance. Technological disasters, like industrial and transport accidents, are also included in EM-DATA, which are not within the scope of this study.

There are several ways to describe the impact intensity of natural disasters, including occurrence, number of people killed or affected, and monetary cost. However, some of the data on fatalities and those affected were unavailable, as was the case for damage data. Worse, observation data always involve uncertainty and competing assessments, whereas disaster occurrence is very clear. In light of the above considerations, we measured natural disasters based on their annual total number in a country, as did Gassebner and Oh (Oh and Reuveny, 2010;Gassebner et al., 2006). In some cases, however, there were no disasters (zero number), which also causes the ln(0) problem. One simple solution to this problem is adding 1 to the disaster count.

3 Results and analysis

~~Coefficients of~~ In order to make the results displayed more structured, we rename the variables ~~were~~with several English letters (Table 1). Table 2 and Table 3 show the variables' correlation matrix.

In the estimation, pooled panel analysis is employed rather than fixed effect and random effect models due to a couple of reasons. First, we estimate the random effects and do the Hausman test. The chi-square statistic value is 76.04 and the probability of accepting the null hypothesis is almost 0. Therefore, random effects are not appropriate herein. Then we estimate the fixed effects, but the results are far from acceptable. To be more specific, if country-fixed effects are added, the variables like Distance, Border are omitted because of collinearity. While period-fixed effects are added, variables like China's GDP, China's Disaster, are omitted because of collinearity. However, all the above omitted variables are essential or even indispensable to this study. Thus, the fixed effects are not appropriate, either. Taken together, the pooled panel analysis is employed.

Ordinary Least Squares (OLS) is the widely used method to estimate the gravity model.

But Silva and Tenreyro (2006) point out that the parameters of log-linearized models estimated by ~~stepwise regression for the sake of coping with the multicollinearity problem.~~ OLS lead to biased estimates of the true elasticities under heteroskedasticity. Thus, Poisson Pseudo-Maximum Likelihood (PPML) technique is used in this study.

The results of import models of China are shown in ~~Table 1.~~Table 5~~5~~. Model 2 adds natural disaster indices on the basis of Model 1, which is the standard gravity model for China's imports. Model 3 adds an interaction term between exporter disasters and development levels and Model 4 adds such a term between exporter disaster and land area. Model 5 includes disasters and both interaction terms. In the estimation, sample sizes were ~~4553~~3468, and R^2 values were all about 0.~~69~~67, suggesting a good fit of the sample. In addition, signs and values of coefficients were consistent across the models, and all variables had statistical significances exceeding the 0.1 level~~.~~ except China's disasters. Taken together, these diagnostics suggest that our modeling platform is robust and statistically reliable.

Results of the export models of China are shown in ~~Table 2.~~Table 6~~Table 6.~~ Models 6–10 had the same compositions of variables as the five models shown in ~~Table 1,~~Table 5~~5,~~ except that China was the exporter and its partner was the importer. Sample sizes were ~~5170~~4035 and R^2 all about 0.~~82~~78, suggesting an even better fit of the sample than import models. Variables like ~~China's~~Importer's disasters and ~~common borders, however, did~~ APEC were not ~~enter the export models. But other variables were all~~ statistically significant, but other variables were. And their signs and values were strongly consistent across the models, except that for importer disasters. Overall, these diagnostics again suggest a robust and statistically reliable modeling platform.

Multicollinearity is another issue that has to be considered carefully. We calculate the Variance Inflation Factor (VIF) of each variable (Table 4~~4~~). Model 4, 5, 9 and 10, including interaction variable DA, exhibit the highest mean and individual VIFs, which are larger than 10. While the other models' are far less than 10. By further checking the correlation matrix showed in Table 2~~2~~ and Table 3~~3~~, it's obvious that only the

correlations between PD and DA are larger than 0.8 and the high VIFs are solely attributed to the interaction variable DA. The same phenomenon also arises in the study of Oh and Reuveny (2010).

As the results of import and export models show, China's GDP and trade partners' both ~~had~~have significantly positive impacts on the country's bilateral trade values. Distance ~~and China's population are~~is a negative factors, consistent with theoretically expected effects of the gravity model. Moreover, APEC and WTO both ~~increased~~increase bilateral trade of the country. This fits the facts very well, since its major trading partners such as the United States and Japan are members of those two organizations. A common boundary ~~promoted~~promotes national imports~~, but had no significant impact on~~ and exports. These results again suggest the robustness and statistical reliability of the model platform.

We further analyzed the key variables, natural disasters in China and its partner countries, and interaction terms between partner natural disasters with development levels and land areas. In Model 2, the coefficient of disasters in China ~~was~~is positive but not significant ~~and positive~~, indicating that ~~an increase in~~domestic disasters ~~raises bilateral imports of the country~~have no significant impact on China's import. The coefficient of disasters in partner countries is significant and negative, indicating that increased disasters in partner countries reduces that import. Model 3 shows that the interaction term of exporter natural disasters and development level is significant and negative. Thus, the marginal effect of natural disasters decreases when the exporter is a developed country. Model 4 shows a significant and positive interaction term of exporter natural disasters and land area. Thus the marginal effect of natural disasters increases with exporter land area. Model 5 includes both the interaction terms in Models 3 and 4. Its result shows that natural disasters in partner countries ~~had~~have a negative effect on China's imports. High development levels intensify this effect, but large land areas restrain it.

From the perspective of exports, Model 7 shows that disasters in ~~China had~~partner

countries have no significant impact on its bilateral exports. ~~The coefficient of disasters in partner countries is significant and negative, indicating that~~But an increase in ~~those countries'~~China's disasters ~~reduced~~increases bilateral exports from China. In Model 8, the interaction term of importer natural disasters and development level is significant and ~~positive~~negative. Thus, the marginal effect of natural disasters ~~increased~~decreases when the importer ~~was~~is a developed country. Model 9 shows that the interaction term of importer natural disasters and land area is significant and negative. Thus, the marginal effect of natural disasters amplified with importer land area. The sign of the variable importer disasters ~~is positive, opposite that from Models 7 and 8. This indicates that disasters in importer countries increased the export value of China, but importer land area reduced positive disaster effects even to the point of becoming negative.~~changes from negative to positive, and the impact changes from insignificant to significant as the interaction terms are added to the model. This indicates that disasters in importer countries have no significant impact on China's export unless the development and land area interaction effects are taken into account. The similar phenomenon exists in the Model 3, 4 and 5. The coefficient of Exporter's disasters changes from -0.0386 to -0.0224 when adding the development level interaction term. And it further changes to -0.238 when adding the land area interaction term, which is a big change even though the sign remains the same. All these changes are attributed to the interaction effects. That is to say, the interaction effects change the main effect of the variable, which should not be considered as a problem caused by multicollinearity. Model 10 includes both the interaction terms in Models 8 and 9, and its result is consistent with those of Models ~~6~~ 8 and 9.

Figure 2 indicates that natural disasters in partner countries ~~had~~have more negative effects on ~~Chinese~~China's imports when the partner ~~was~~is a developed country, ~~but less negative~~and the same for exports. The marginal effect of partner natural disasters on China's imports ~~decreased~~decreases about ~~27~~7.8% when the partner ~~was~~is a developed country, relative to a developing one. The corresponding difference for ~~Chinese~~the

exports ~~was an increase~~is a decrease of ~~9%.~~4.5%.

~~Fig.~~Figure 3 indicates that land area ~~and development level are~~ is a very important ~~factors~~factor when ~~a~~ natural ~~disaster strikes a trading~~disasters strike partner countries of China. Figure 3a suggests that these disasters are less detrimental to the country's imports as partner land area increases. When that area exceeds ~~7.35~~13.44 million km^2, the marginal effect of the disasters on those imports becomes positive. Figure 3b suggests that the disasters are more detrimental to China's exports as partner land area swells. If that area is smaller than ~~30 000~~0.35 million km^2, the marginal effect of the disasters on those exports ~~is~~becomes positive~~. Panel (b) may explain the change in sign in models (9) and (10) for importer's disaster variable. It implies that the importer's disasters have a positive impact on China's export when extracting the land area effect~~.

The above results are not completely consistent with those from Gassebner and Oh (Oh and Reuveny, 2010;Gassebner et al., 2006), indicating that the impact of disasters on China is significantly different from that on the entire world. ~~Disaster~~Partner disaster impacts on ~~exports~~imports are greater than on ~~imports~~exports relative to China's bilateral trade, ~~(Tables 1 and 2),~~ especially when the disasters are in developed small countries. In other words, China's bilateral export is more resilient to natural disasters in partners than bilateral import. ~~Moreover, disaster impacts are significant but weaker than those of other variables, such as GDP, population and distance. This suggests that Chinese bilateral trade is relatively resilient to~~While China's domestic natural disasters~~,~~ ~~considering several variables~~ increase the bilateral export, but have no significant impacts on the bilateral import.

It is easy to interpret the increase of ~~Chinese~~ import value caused by domestic disasters. Because of reconstruction efforts for damaged infrastructure, increased domestic demand turns to foreign markets to some degree. ~~Further, the robust export capacity of China is generally acknowledged, which makes it likely that domestic disasters have no significant impact on its exports~~But this kind of effect to China is not significant. Further, domestic natural disasters may also increase the export value of the country

due to seeking for the trade balance or some other reasons. And this effect is embodied in China's export.

The impact of disasters in partner countries is complex, and interactions with development levels and land areas make it more difficult to interpret. First, if a natural disaster affects a developed partner of China, it faces a larger decline both in imports ~~from that partner but a smaller decrease in~~and exports ~~to that partner~~. The larger decrease in imports may be attributed to the structure of the Chinese import system. Products mainly imported from developed countries, such as electrical equipment, machinery and vehicles, are easy for China to find substitutes from other countries and regions. The ~~smaller~~larger decrease in exports may be associated with the ~~stable~~recession in demand ~~market~~ of developed countries ~~and stable export capacity of China~~. But why do Chinese exports not rise because of the demand of partner reconstruction? Manufacturing industries are the major Chinese export industries, but are not needed for post-disaster reconstruction, which may adequately answer this question. Second, land area of China's partners is crucial to its bilateral trade. Because larger land area means a larger buffer pool for natural disasters, a partner with more area presumably has a greater capacity to meet Chinese import demand when struck by disaster. However, the situation is different if China is the exporter. The partner with greater area may focus on dealing with domestic demand in the aftermath of a natural disaster with less help from imports, which may reduce its own exports. The partner would also choose policies aimed at keeping the balance of trade by reducing imports. Consequently, China's exports to this partner would be reduced because most of its export products are not necessities of life in a post-disaster period. ~~Overall, from the perspective of reducing disaster risk of trade, it is favorable for China to import more from large developing countries and to export more to small developed countries.~~

4 Conclusions and discussion

This study examines the impact of natural disasters on China's bilateral trade, using the gravity model. The results show that this model can explain well the total value of this

trade. The impact of natural disasters on this trade is asymmetric, in contrast with the impact on global bilateral trade. An increase in China's disasters increases its ~~imports~~exports but has no significant impact on ~~exports~~imports. An increase of disasters in China's trading partner countries reduces both its imports and exports. Both development levels and land areas of the partners are important in determining the magnitude of disaster impacts on China's bilateral trade. If the partner struck by disaster is a developed country, the ~~decrease~~decreases of ~~Chinese~~China's bilateral imports ~~is significant, but the decrease of~~and exports ~~is insignificant.~~are both larger. Moreover, if the affected partner has a larger land area, the decrease of ~~Chinese~~China's bilateral imports is less, but the decrease of bilateral exports is greater.

Based on the research framework of this study, future investigations can be extended in two ways. Although the present study used total trade value, future research could focus on specific traded commodities and analyze their sensitivity to specific disasters, such as geologic disaster impacts on oil trade and climatic disaster effects on food trade. Since the global distribution of natural disasters has rules, as does the global pattern of imports and exports, various regions may be vulnerable to different disasters. In addition, disaster effects on a country's bilateral trade can be examined. We believe that the impacts of disasters vary significantly by country and that their spatial pattern at a global scale is critical to integrated natural disaster risk management.

However, there are limitations of the research framework. Since natural disasters impact international trade through different ways, the trade gravity model exactly fails to exact the corresponding impact. In other words, we cannot know the mechanism of natural disasters' impact on international trade from this research framework, but can only get an aggregate result.

The disaster variable used herein is number of occurrences, which can hardly measure the disaster intensity accurately. Thus, the measurement of integrated intensity of disasters from the perspective of multi-disaster theory requires further study. Development level and land area of trading partners undoubtedly alter natural disaster

impacts on China’s bilateral trade, but more factors should be examined.

Although it is crucial to probe disaster impacts on regional and international trade from the macroscopic angle, studying the global impact of a specific LSD from a microscopic perspective is also important. For example, the 2010 Iceland volcanic event and 2011 Great East Japan Earthquake and tsunami produced economic losses and social-ecological effects. It is of great urgency and significance to rethink and reassess the complexity of socio-ecological systems, to analyze interactions among subsystems of institutions, society, the economy and ecology, and to determine the transformation, diffusion, and cascading effects of natural disasters.

Acknowledgements

This work was supported by the 111 project "Hazard and Risk Science Base at Beijing Normal University" under Grant B08008, Ministry of Education and State Administration of Foreign Experts Affairs, People’s Republic of China.

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Table 1 Variable names

Variable	Name
ln(China's Import)	CI
ln(China's Export)	CE
ln(China's disasters)	CD
ln(Partner's disasters)	PD
ln(Partner's disasters)×Developed	DD
ln(Partner's disasters)×ln(Partner's Area)	DA
ln(China's GDP)	CG
ln(Partner's GDP)	PG
ln(Distance)	Di
APEC	APEC
WTO	WTO
Border	Bd

Table 2 the correlation matrix for China as an importer

	CI	CD	PD	DD	DA	CG	PG	Di	APEC	WTO
CI										
CD	0.237									
PD	0.303	0.154								
DD	0.401	-0.0355	0.361							
DA	0.339	0.132	0.986	0.386						
CG	0.348	0.745	0.119	-0.0563	0.0959					
PG	0.769	0.0536	0.339	0.558	0.379	0.110				
Di	-0.220	0.00660	-0.111	-0.0183	-0.0839	0.0248	-0.105			
APEC	0.452	0.128	0.338	0.255	0.364	0.115	0.337	-0.304		
WTO	0.296	0.580	0.134	0.0103	0.107	0.737	0.119	0.104	0.0959	
Bd	0.00590	0.0210	0.169	-0.101	0.182	0.00960	-0.105	-0.423	0.0118	-0.0949

Table 3 the correlation matrix for China as an exporter

	CE	CD	PD	DD	DA	CG	PG	Di	APEC	WTO
CE										
CD	0.400									
PD	0.339	0.175								
DD	0.366	-0.0183	0.357							
DA	0.355	0.153	0.985	0.384						
CG	0.571	0.750	0.153	-0.0260	0.132					
PG	0.761	0.0860	0.352	0.545	0.394	0.174				
Di	-0.306	-0.0228	-0.126	-0.0444	-0.107	-0.0292	-0.180			
APEC	0.397	0.132	0.334	0.267	0.363	0.133	0.348	-0.315		
WTO	0.469	0.578	0.161	0.0351	0.137	0.736	0.176	0.0581	0.114	
Bd	0.0783	0.0400	0.187	-0.0864	0.201	0.0355	-0.0482	-0.425	0.0236	-0.0705

Table 4 VIFs of variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CD		2.3	2.3	2.3	2.3		2.35	2.35	2.35	2.35
PD		1.3	1.37	44.91	44.91		1.31	1.38	43.03	43.03
DD			1.6		1.6			1.57		1.57
DA				47.83	47.88				45.94	46.05
CG	2.23	3.32	3.37	3.33	3.38	2.24	3.41	3.45	3.41	3.46
PG	1.16	1.27	1.64	1.42	1.78	1.19	1.31	1.67	1.48	1.82
Di	1.39	1.4	1.4	1.61	1.61	1.41	1.42	1.43	1.6	1.6
APEC	1.25	1.34	1.35	1.45	1.45	1.25	1.34	1.34	1.43	1.44
WTO	2.26	2.28	2.28	2.31	2.31	2.25	2.27	2.27	2.3	2.3
Bd	1.28	1.35	1.36	1.48	1.49	1.27	1.35	1.36	1.46	1.47
Mean	1.59	1.82	1.85	11.85	10.87	1.6	1.84	1.87	11.44	10.51

Table 5 Regression results for China as an importer (1980–2012)

	(1)	(2)	(3)	(4)	(5)
ln(China's disasters)		0.00943	0.0113	0.0124	0.0146
		(0.0200)	(0.0200)	(0.0200)	(0.0200)
ln(Exporter's disasters)		-0.0386***	-0.0224***	-0.238***	-0.249***
		(0.0075)	(0.0077)	(0.0470)	(0.0450)
ln(Exporter's disasters)× Developed			-0.0780***		-0.0820***
			(0.0097)		(0.0100)
ln(Exporter's disasters)×ln(Exporter's Area)				0.0145***	0.0166***
				(0.0035)	(0.0032)
ln(China's GDP)	0.111***	0.106***	0.0984***	0.107***	0.0995***
	(0.0077)	(0.0087)	(0.0086)	(0.0086)	(0.0086)
ln(Exporter's GDP)	0.182***	0.188***	0.201***	0.182***	0.196***
	(0.0029)	(0.0031)	(0.0036)	(0.0032)	(0.0038)
ln(Distance)	-0.0904***	-0.0845***	-0.0780***	-0.111***	-0.107***
	(0.0100)	(0.0100)	(0.0097)	(0.0120)	(0.0120)
APEC	0.143***	0.169***	0.176***	0.141***	0.145***
	(0.0140)	(0.0140)	(0.0140)	(0.0160)	(0.0160)
WTO	0.0367**	0.0434**	0.0452**	0.0522***	0.0552***
	(0.0180)	(0.0180)	(0.0180)	(0.0180)	(0.0180)
Border	0.0620***	0.0924***	0.0695***	0.0553**	0.0254
	(0.0210)	(0.0220)	(0.0230)	(0.0240)	(0.0250)
Constant term	-0.580***	-0.665***	-0.805***	-0.209	-0.298
	(0.1900)	(0.1900)	(0.1900)	(0.2100)	(0.2200)
N	3468	3468	3468	3468	3468
R^2	0.6700	0.6700	0.6800	0.6700	0.6800

*/**/*** indicates significance at 0.1/0.05/0.01 levels (two-tailed test). — indicates variables removed from the model by stepwise regression. Standard errors shown in parentheses.

Table 6 Regression results for China as an exporter (1980–2012)

	(6)	(7)	(8)	(9)	(10)
ln(China's disasters)		0.0687***	0.0701***	0.0679***	0.0695***
		(0.0160)	(0.0160)	(0.0160)	(0.0160)
ln(Importer's disasters)		-0.0029	0.0050	0.0537*	0.0520*
		(0.0049)	(0.0050)	(0.0280)	(0.0280)
ln(Importer's disasters)× Developed			-0.0451***		-0.0444***
			(0.0072)		(0.0073)
ln(Importer's disasters)×ln(Importer's Area)				-0.0042**	-0.00350*
				(0.0020)	(0.0020)
ln(China's GDP)	0.177***	0.163***	0.159***	0.163***	0.158***
	(0.0050)	(0.0054)	(0.0055)	(0.0054)	(0.0055)
ln(Importer's GDP)	0.147***	0.148***	0.155***	0.149***	0.156***
	(0.0021)	(0.0021)	(0.0026)	(0.0022)	(0.0027)
ln(Distance)	-0.137***	-0.137***	-0.133***	-0.130***	-0.128***
	(0.0081)	(0.0081)	(0.0081)	(0.0089)	(0.0090)
APEC	0.0111	0.00817	0.0132	0.0164	0.0198*
	(0.0100)	(0.0110)	(0.0110)	(0.0120)	(0.0110)
WTO	0.0523***	0.0459***	0.0465***	0.0433***	0.0444***
	(0.0100)	(0.0110)	(0.0110)	(0.0110)	(0.0110)
Border	0.0725***	0.0724***	0.0612***	0.0829***	0.0702***
	(0.0150)	(0.0150)	(0.0160)	(0.0160)	(0.0160)
Constant term	-0.253*	-0.272*	-0.345**	-0.394**	-0.444***
	(0.1500)	(0.1500)	(0.1500)	(0.1600)	(0.1600)
N	4035	4035	4035	4035	4035
R^2	0.7800	0.7800	0.7800	0.7800	0.7800

*/**/*** indicates significance at 0.1/0.05/0.01 levels (two-tailed test). — indicates variables removed from the model by stepwise regression. Standard errors shown in parentheses.

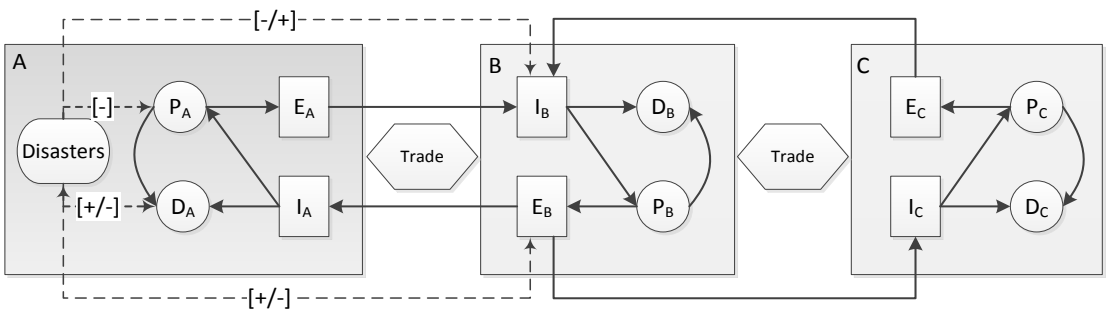
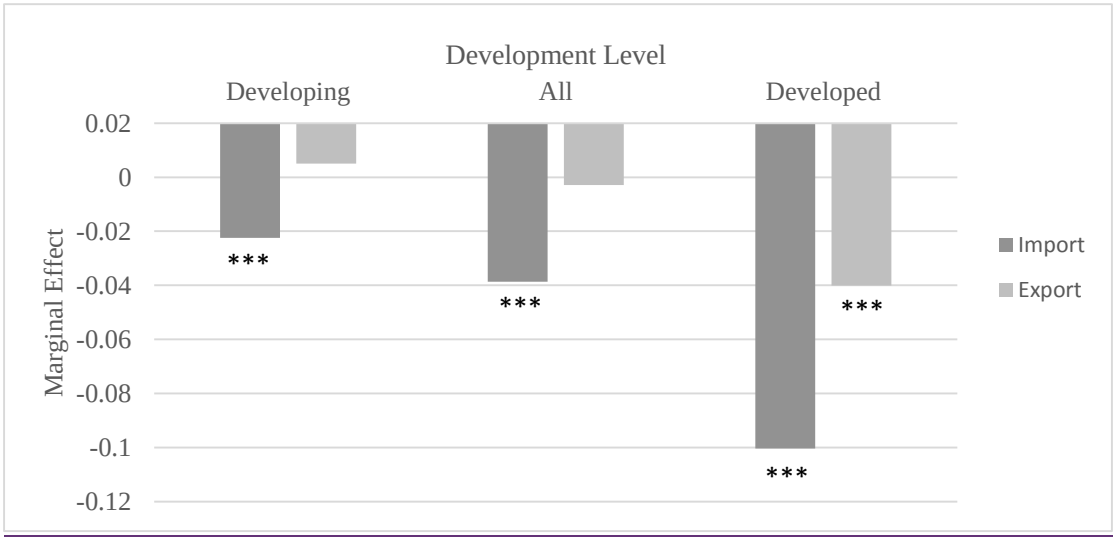


Fig. 1 Interactions between disasters and trade system. P_i denotes production of region i, D_i demand, I_i import value, and E_i export value. Solid arrows indicate flow between two components and dashed arrows indicate the impact.



*/**/*** indicates significance at 0.1/0.05/0.01 levels

Fig. 2 Marginal effects of natural disasters in partner countries on China's bilateral trade versus development levels

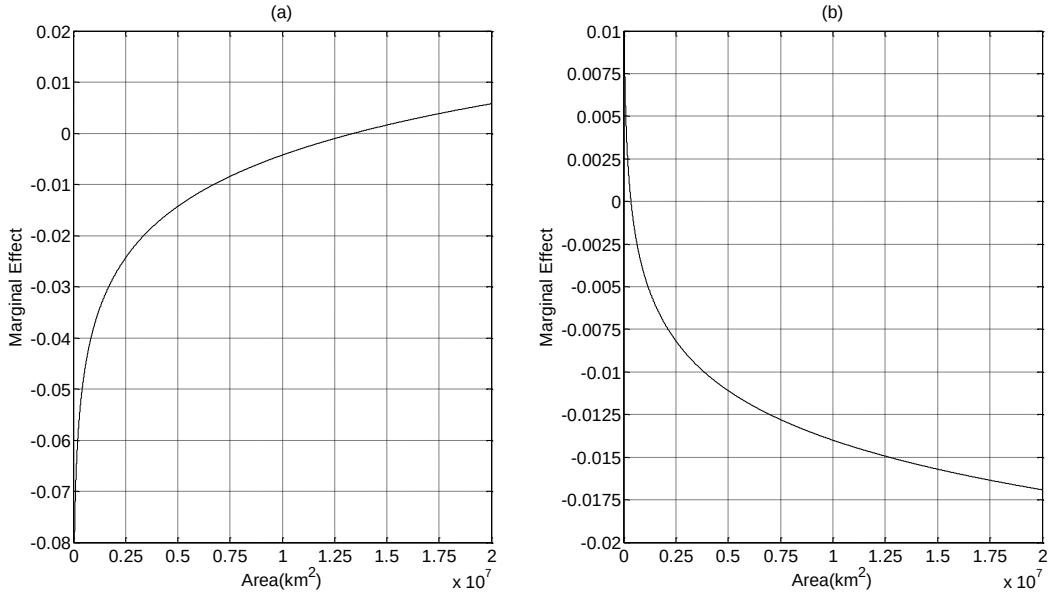


Fig. 3 Marginal effect of natural disasters in partner countries on China's bilateral trade as a function of land area. (a) is for ~~Chinese~~China's imports; (b) is for its exports.