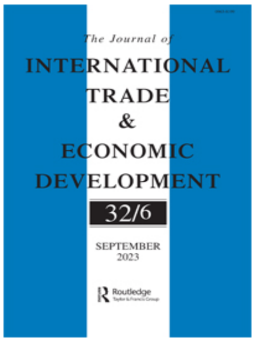

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Welfare effects of introducing quality certification system for developing countries: Evidence from the Chinese experience*

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ABSTRACT
This paper examines whether the quality-certification system might benefit developing economies while there is a widespread conjecture that the system might negatively affect technologically less developed economies. Based on a simple oligopoly model where a developing economy trades with an advanced economy that produces higher quality products, we demonstrate that the introduction of a quality certification system between technologically asymmetric countries might deteriorate the trade balance of the developing economy with the widened technology gap. In addition, we demonstrate that the empirical evidence from the Chinese experience of introducing a quality certification system for imported products from the EU supports the theoretical findings. That is, the imports from the EU to China have significantly increased with the increased quality gap after China introduced the quality certification system. The results implicate that the quality certification system might damage less developed economies when advanced economies hesitate technology transfer, and therefore, it is increasingly imperative to introduce an international coordination mechanism for active technology transfer when quality certification systems are introduced with respect to developing economies.

KEYWORDS Quality certification system; less developed economies; technology asymmetry; discriminatory measures against countries with lower technologies

JEL CLASSIFICATIONS O24, F13, F15

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1. Introduction

We examine whether a quality certification system might benefit less developed economies while there is a widespread perception that the system in fact damages countries with lower technologies in a discriminating fashion. As consumers' concerns about

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Table 1. Certification systems of major countries.[1]

Country	Certification	Number of items	The year of implementation
EU[2]	CE (European Conformity)	23	1993
China	CCC (China Compulsory Certification)	132	2003
USA	UL(Underwriters Laboratories) / FCC(Federal Communications Commission) / FDA(Food and Drug Administration)	19,000	1894 /1934 /1938
Japan	PSE/PSC (Product Safety Electirical/Certification)	457	2001

Source: Constructed by the author based on public websites of each government agency.[3]

the quality of imported goods are increasing globally, quality certification of imported goods became a grave issue in international trade recently.

There are two types of quality certification systems, voluntary quality certification system, and compulsory quality certification system. The voluntary quality certification system is not enforced on all products and firms obligatorily, but each firm might voluntarily choose to get the quality certificate from authorized institutions mainly for quality signaling purposes. The compulsory quality certification system requires all firms to get a quality certificate from authorized institutes to introduce and sell the products in the market.

This paper examines the impacts of introducing the compulsory quality certification system. Most advanced economies have introduced compulsory quality certification systems to protect the safety and health of domestic consumers, environmental protection, maintaining the minimum required quality for efficient industrial supply chains, and national security with respect to the majority of manufactured products and related services. Each country sets the standard for the minimum required quality level of each product, and all products of domestic firms and imported goods are allowed to be sold in the market only after each product is certified to satisfy the minimum required standard of quality by authorized institutions.

Meanwhile, consumers' demand for information on product quality has been increased in an effort to reduce uncertainty about whether the perceived quality and perceived risk of products will meet their expectations (Dowling 1986).[4] Driven by the increased demand for the reliable information on product qualities, most major trading countries have introduced the quality certification system to resolve the possible adverse selection problems due to the limited information on the product quality of imported goods.[5]

Although major trading countries have introduced quality certification systems as shown in Table 1, the introduction of quality certification systems by developing economies remains at a limited level in comparison to the advanced economies. For example, 28.1% of total imported goods to the EU were subject to the EU quality certification systems, whereas only 2.4% of the total imports to China were controlled by the quality certification system as noted in Table 2. In addition, the number of claims against Technical Barriers to Trade (TBT) including quality certification systems filed to the WTO's TBT committee has been increasing reflecting that quality certification systems might be abused against countries with lower technological capacities.[6]

Based on these backgrounds, we examine how quality certification systems affect less developed economies with lower technologies via international trade with advanced economies. Through a model analysis assuming that technologically asymmetric firms

Table 2. Import of certified goods (2017).

Country	Ratio	Import of certified goods	Total imports
EU	28.14%	1,444,188,636,000 (Euro)	5,131,463,202,000 (euro)
China	2.36%	42,217,922,000 (US $)	1,789,999,733,000 (US $)

Source: Constructed by the author based on the data at KITA.net.

compete in a Cournot fashion via international trade, we demonstrate that the introduction of a quality certification system in trade might negatively affect less developed economies with an increasing trade imbalance and a deepening technology gap.

In addition, the empirical evidence from the Chinese experience of introducing a quality certification system with respect to the products imported from the EU countries supports the theoretical findings in that the Chinese trade balance with the EU has been significantly deteriorated resulting in a widened quality gap after China introduced the quality certification system. The results implicate that developing economies with lower technologies might be negatively affected by the quality certification system, and therefore, it is increasingly imperative to introduce an international coordination mechanism to promote technology transfer especially when quality certification systems are introduced.

Reflecting the increasing importance of product quality in international trade, a vast literature considered the role of product quality in trade policies. The first group of the literature focused on strategic subsidy policies to improve product quality for firms facing quality competition with foreign firms (Fieler 2011; Flam and Helpman 1987; Hur 2006; Saggi and Sara 2008). Especially, Taba and Ishii (2016) showed that R&D subsidy policies might reduce the R&D investment of rival firms while increasing domestic firms' R&D investment, and consequently, the market share of the domestic firms supported by the R&D subsidy increases while the rival firm's share is decreased. The second group analyzed the impacts of strategic tariff and non-tariff policies assuming the quality asymmetry of traded goods as given (Helble 2007; Lewer and Van den Berg 2007; Linders et al. 2005). These studies showed how quality asymmetry and the related subsidy policies affect trade patterns, while quality certification systems that increase the quality-related costs of less developed economies remain unaddressed.

Facing various informational barriers with respect to the quality of traded goods, quality certification systems are considered to be policy devices to secure the safety and security of consumers of importing countries. However, there are increasing concerns that the quality certification systems might be abused as another discriminatory measure against less developed economies as the cases of technical standards and sanitary and phytosanitary standard regulation.[7] To address these concerns, there have been several trials to introduce standardized quality certification systems that might benefit consumers and producers at the same time. One example is the quality certification system for Halal products for Islamic consumers, which was proven to have helped the producers too with the certified quality reputation (Noordin, Noor, and Samicho 2014; Ratanamaneichat and Rakkarn 2013). Moreover, the International Organization for Standardization (ISO) plays a role to reduce the possible discriminatory effects against countries with lower technologies via a standardized quality-assurance/certification system.[8]

The studies of Baldwin (1970), Das and Donnenfeld (1987), Essaji (2008), and Disdier, Fontagné, and Mimouni (2008) show the negative side of the quality certification system mainly due to the increased cost burdens and the complex regulatory processes of importing countries. Moreover, Petropoulou (2013) develops a model where quality standards are endogenously determined in an open market setting and shows that the global optimal quality standards are unattainable due to strategic adjustments in national quality standards for domestic firms under competition.

On the other hand, the benefits from quality certification have been demonstrated too focusing on enhanced consumer confidence on product quality and the resulting welfare improvement via quality certification systems (Wilson and Abiola 2003). Taking consideration of contradictory results, Bonroy and Constantatos (2015) provides a comprehensive literature review discussing why different results are derived focusing on the differences in the political economic frames of quality certification systems of varying countries. While the earlier literature has provided a wide range of discussions on the benefits and costs of the quality certification systems, the strategic aspects of the quality certification systems mainly damaging the less developed economies between countries with asymmetric technologies have not been explored as far as we understand. The contribution of this paper lies in addressing these loopholes in earlier literature such as analyzing the impacts on countries with lower technologies after strategic competition in international trade between countries with asymmetric technologies.

The paper is structured as follows. Section 2 explains the model structure and describes the market equilibrium before and after the quality certification system is introduced. Section 3 examines how the introduction of quality certification systems affects the welfare of developing and developed economies focusing on technology asymmetries. Section 4 shows that China's introduction of the quality certification system with respect to imports from the EU countries has increased the quality gap and aggravated the Chinese trade balance with the EU countries based on the data from 1998 to 2017. Section 5 concludes and discusses the policy implications for developing economies with lower technologies.

2. The model

The product quality certification system in this model is assumed to be an obligatory requirement that all domestic and foreign firms should comply with to access the market. The government i sets the minimum required quality level, q_{ci}, and if a firm's quality level is lower than the minimum required quality level set by the government, $(q_i < q_{ci})$, the firm has to make costly R&D investments to meet the minimum quality requirement.[9]

Representative firms from two countries compete a la Cournot fashion in both countries' markets.[10] We consider a three-stage game with the following structure:

Stage 1: Each government introduces the quality certification system, by setting the minimum required quality level to access the market.

Stage 2: A firm determines its costly choice of product quality after observing the government's decision on the quality certification system.

Stage 3: Each firm competes in two markets in a Cournot fashion.

We define a sub-game perfect equilibrium through backward induction in a non-cooperative environment. The representative firm from an advanced economy, the *North* country, produces high-quality products while the representative firm of a developing economy, the *South* country, produces low-quality goods.[11] The two markets are segmented, and consumer preferences are given with the following quadratic utility function:[12]

$$U_i = q_h x_{ii} + q_l x_{ji} - x_{ii}^2 - x_{ji}^2 - \theta_i x_{ii} x_{ji} + z$$

where x_{ii} and x_{ji} denote the quantity of consumed goods supplied by domestic production and imports from the other country.[13] q_h and q_l are the initial quality of each variety i and j respectively given exogenously. z is the expenditure on numeraire goods: $m - p_i x_i - p_j x_j$ with m as income. θ is the parameter representing the substitutability between two products. For the simplicity of discussion without loss of generality, we assume: $\theta \in [0, 2]$. When θ is 0, the two goods are independent, and if θ is 2, two goods are perfect substitutes.

The inverse demand function derived from the quadratic utility function is as follows, and the intercept of the demand curve is increasing in the product quality, which implies a rightward shift of the demand curve if the product quality is improved:

$$P_i = q_i - 2x_{ii} - \theta_i x_{ji}.$$

Firm i's profit function from both markets is given as follows:

$$\prod\nolimits_i = (P_i x_{ii} - \delta_{ii}/(\lambda_i R_i) - R_i) + (P_j x_{ij} - \delta_{ji}/(\lambda_i R_i) - R_i)$$

where δ_{ji} is the difference between the quality required by the certification system of country j and the actual quality of firm i, ($\delta_{ji} = q_{cj} - q_i$). λ is a parameter which denotes the efficiency of R&D investment ($0 < \lambda < 1$). R denotes the amount of R&D investment[14] to accommodate to the quality certification system. For the simplicity of the analysis, R is also assumed to be a fixed cost of R&D investment. Therefore, the R&D cost imposed by the quality certification system of the country j with the minimum quality standard imposed is given as $\delta_{ji}/(\lambda_i R_i)$. The government sets the minimum quality requirement, i.e. the marginal quality standard (MQS, q_c), at a higher level than the developing country's quality level, q_l.

Equilibrium outputs are derived as follows:

(i) When $q_h > MQS'$ ($\theta = 1$),

Country i: $x_{ii}^* = \frac{1}{15}(-q_{ci} + 4q_i)$, $x_{ij}^* = \frac{1}{15}(-q_{cj} + 4q_i)$
Country j: $x_{jj}^* = \frac{1}{15}(4q_{cj} - q_i)$, $x_{ji}^* = \frac{1}{15}(4q_{ci} - q_i)$

(ii) When $MQS > q_h(\theta = 2)$,

$$x_{ii}^* = \frac{q_{ci}}{6},\ x_{ij}^* = \frac{q_{cj}}{6}$$

Each firm decides the optimal R&D investment to maximize the profits facing the minimum quality requirement, MQS, imposed by the importing country's quality certification systems. The optimal amount of R&D investment (R) is determined from the profit maximization after substituting the equilibrium outputs to the profit function via backward induction as follows:

$$R_i^* = \arg Max \Pi_i(x_{ii}, x_{ij})$$
$$R_i^* = 0\ (q_l > MQS), R_i^* = \infty\ (MQS > q_l)$$

The social-welfare function of each country is defined as the sum of consumer surplus and producer surplus as follows:

$$W_i = \sum_{q_h \neq q_l}^{2} \left[\frac{1}{2}(q_{ci} - P_i)(x_i + x_{ji})\right] + \Pi_i$$

The first term on the right-hand side in the social-welfare function is consumer surplus, which is derived from a linear inverse demand function. The second term is the producer surplus, which is the sum of the corporate profits from the domestic market and the export market.

3. Optimal strategies to introduce quality-certification systems

There are two types of quality certification systems: (i) a compulsory quality certification system that is legally binding, and (ii) a voluntary certification system that is not binding and therefore not enforceable. Compulsory certification systems are mainly adopted as safety standards; if a product fails to meet the compulsory certification standards throughout the production and distribution processes, the quality certificate is not issued, and therefore, is not allowed to access the market. Voluntary certification systems are not binding, and mainly used for quality signaling purposes.

Compulsory certification standards are usually adopted to improve product safety and credibility, while it is worried that the certification systems might be abused as a discriminatory means against the imported goods from countries with lower technologies.[15] This chapter analyzes the welfare effects of introducing a compulsory quality certification system between technically asymmetric countries. We examine the optimal policy of each government to introduce quality certification system, which sets the minimum quality required, (q_c), i.e. Marginal Quality Standard (MQS), considering the certification cost, $\delta/(\lambda R)$, and R&D efforts, R, required to satisfy the quality requirement. The MQS is set at a higher level than q_l, the quality level of a developing economy with a lower quality, and can be either lower or higher than the quality level of the advanced country ($q_h > q_c > q_l$ or $q_c \geq q_h > q_l$).

3.1. Government

The government of each country determines the minimum quality level of quality certification systems to maximize social welfare considering the cost of the domestic producers and the consumers' gains from improved quality levels of products.[16] In addition, the country with a higher product quality, i.e. *North* country, considers the possible strategic effects of the quality certification system against the firms from less developed countries.

For the country with a lower product quality, i.e. *South* country, the cost burden of the domestic firm is higher than the competing firm from the advanced country when a quality certification system is introduced. It is shown that the social welfare of the advanced economy, North country, is improved with the tougher quality certification

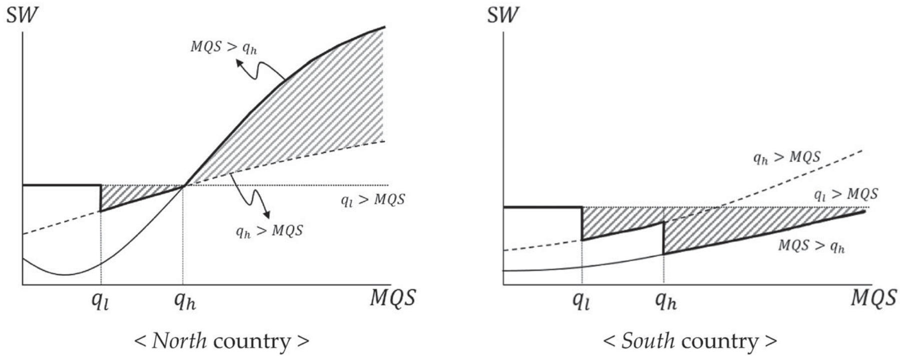

Figure 1. Social welfare with varying minimum quality required (MQS).

system, i.e. with a higher MQS, while the social welfare of a developing economy with a lower technology is deteriorated with the higher MQS as shown in Figure 1. Especially, facing the strategic competition with the firm from the advanced country, the government of the *South* country has little incentive to introduce the quality certification system with the required quality set higher than q_l.

3.2. Firm

Firms maximize profits via strategic variables such as R&D investment (R) and output levels. A firm's R&D investment (R) can reduce its cost to satisfy the quality regulation. When the *North* government introduces a quality certification system, the *North* firm with a higher quality level benefits from strategic advantages with respect to the *South* firm that has a lower product quality. In addition, the *North* firm has an incentive to increase the strategic advantage of higher quality level through R&D investment.

On the other hand, when the quality certification system is introduced, the producer surplus of the *South* firm is decreased due to the increased cost burdens to satisfy the requirements of the quality certification system. Nevertheless, *South* firm might reduce the additional cost burdens caused by the new system by R&D investment to reduce the additional costs for quality upgrading. However, even after the R&D efforts, the profit level of the South firm still remains lower than the case without the quality certification system as shown in Figure 2.[17]

Contrarily, even when the minimum required quality level by the new system is higher than the quality level of the *North* firm, the *North* firm benefits from the quality certification system due to the increased strategic advantages in the competition with the *South* firm via the R&D investment that deepens the quality difference between the *North* firm and the *South* firm. Furthermore, the introduction of the quality certification system increases the developing country's imports of higher quality products from the advanced economy due to the increased quality differences after the system is introduced.[18]

Empirical evidence can be found from the Chinese experiences of introducing a quality certification system, i.e. 'China Compulsory Certification (CCC) system' in 2003.[19] As shown in Figure 3, after CCC was introduced in 2003, the quality difference between Chinese products and OECD products has been increased, and the Chinese imports from the OECD have been increased, accordingly.

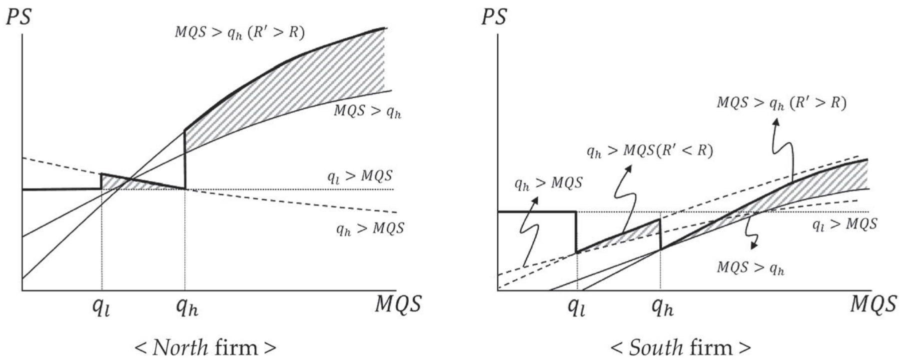

Figure 2. Firms' profits with varying level of minimum quality required (MQS).

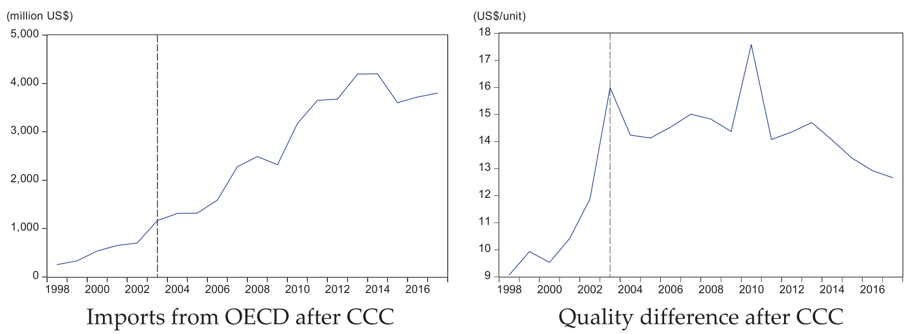

Figure 3. Chinese imports from OECD countries and the quality difference after CCC.[20] Data source: Computed by the authors using database from Korea International Trade Association.

4. Empirical analysis

4.1. Model

We examine the impacts of introducing the quality-certification system based on the panel data of the Chinese imports from OECD countries[21], GDP and population of trading countries, distance between trading countries, the quality difference between China and OECD countries and CCC dummy variables from 1998 to 2017. As well known, pooled OLS estimation of the panel data might provide an inconsistent estimation when there are unobserved individual effects that are time-invariant. Therefore, facing unobserved individual-specific effects, random-effect model is adopted when there is no correlation between the explanatory variables and unobserved individual effects. However, when unobserved individual-specific effects are correlated with the independent variables, only the fixed-effect model can provide consistent estimation as is the case with panel data of international trade. We find that the fixed effect estimation should be adopted via Hausman-Taylor test.

The regression equation is defined as follows:

$$Y_{it} = \beta X_{it} + \gamma Z_i + \alpha_i + \eta_{it} \; (i = 1, \cdots N; t, \cdots T)$$

Table 3. Summary statistics.[22]

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
log of imports	36,747	6.2321	3.9632	0	20.6139
log of $[GDP_i \times GDP_j]$	104,260	55.7740	1.7365	51.2510	60.4315
log of $[(GDP_i \times GDP_j)/(POP_i \times POP_j)]$	104,260	18.4476	0.8895	16.0888	20.4882
log of distance	104,260	8.9058	0.4628	6.8602	9.8553
log of quality difference	33,679	5.1847	2.8515	−8.1886	15.0648
CCC dummy	104,260	0.7	0.4582	0	1

Source: Estimated by authors.

Table 4. Correlation between variables.

Variable	log of import	log of $[GDP_i \times GDP_j]$	log of $[(GDP_i \times GDP_j)/(POP_i \times POP_j)]$	log of distance	log of quality difference	CCC dummy
log of import	1.0000					
log of $[GDP_i \times GDP_j]$	0.2294	1.0000				
log of $[(GDP_i \times GDP_j)/(POP_i \times POP_j)]$	0.1515	0.3990	1.0000			
log of distance	−0.0924	−0.0483	0.1012	1.0000		
log of quality difference	0.0590	0.0801	0.1647	0.0283	1.0000	
CCC dummy	0.0461	0.2801	0.5639	0.0219	0.0413	1.0000

Source: Estimated by authors.

where i and t represent the individual country and the time period. The dependent variable, Y_{it} represents China's imports from an OECD country i in period t. The independent variables, X_{it}, are time-varying while observable country specific variables, Z_i, are not time-varying, i.e. fixed over time. α_i represents the unmeasured characteristics of the individual country i, and η_{it} is a general error term.

4.2. Data

We use the annual data of China's imports from OECD countries[23] that are controlled by the Chinese quality certification system (CCC) during 1998–2017 to assess the impacts of introducing the quality-certification system by a country with a lower technological level. The summary of the data is given in Table 3, and all variables except 'CCC dummy' are in logarithm. China introduced CCC in 2003. Products classified under 146 HS codes at 8-digit level are imported through CCC, as shown in Table A1 in the Appendix.

The correlations between dependent and independent variables in Table 4 show that the China's imports from OECD are positively correlated with CCC dummy variable and quality difference between Chinese products and OECD products.[24]

For a pooled OLS estimation to be consistent, there should be no correlation between error term and explanatory variables (i.e. exogeneity of explanatory variable), and the variance of the error term should not change depending on the panel entity and time (i.e. homoscedasticity). The Breusch–Pagan Lagrangian Multiplier (LM) test was used to check the endogeneity of explanatory variables, and the Modified Wald test was tried to test the heteroscedasticity. Breusch–Pagan LM test and F-test are used to check the suitability of the random effect and fixed effect model, and the Modified Wald test is used to analyze the reliability of the F-test result. Table 5 shows that there is a positive correlation between error-term and explanatory variables and heteroscedasticity between

Table 5. Result of the Breusch-Pagan LM test and Modified Wald test.

Breusch-Pagan LM test	Modified Wald test
160,000***	11,000,000***

Note: ***, **, * mean significance within 1%, 5%, 10%.

Table 6. Result of estimation.[25]

Variable	Pooled OLS	Panel OLS	FE	RE	IV
log of [$GDP_i \times GDP_j$]	0.5438***	0.5965***	3.1011***	0.5965***	0.4972***
	(0.0164)	(0.0424)	(0.3277)	(0.0424)	(0.1053)
log of [$(GDP_i \times GDP_j)/(POP_i \times POP_j)$]	0.6690***	0.2672***	4.3686***	0.2672***	0.0688
	(0.0386)	(0.0531)	(0.3678)	(0.0531)	(0.2068)
log of distance	−0.6732***	−1.0518***	–	−1.0518***	−1.3534***
	(0.0389)	(0.1124)		(0.1124)	(0.2918)
log of quality difference	0.0405***	0.1130***	0.1239***	0.1130***	1.0137***
	(0.0076)	(0.0062)	(0.0064)	(0.0062)	(0.3642)
CCC dummy	−0.6831***	0.0624*	0.0984***	0.0624*	–
	(0.0589)	(0.0325)	(0.0331)	(0.0325)	
cons	−30.9269***	−24.9171***	99.8072***	−24.9171***	−17.8600***
	(1.0281)	(1.9771)	(11.7539)	(1.9771)	(4.6345)
F value (Wald χ^2)	481.5	4,126.46	989.40	4,126.46	2,313.34
R^2	0.0701	0.0621	0.8593	0.1147	0.0463
Number of observations	31,946	31,946	31,946	31,946	31,946
Number of groups	–	3,440	3,440	3,440	3,440

Note: 1. () is std. error, ***, **, * mean significance within 1%, 5%, 10%.
2. Instrumented variable is 'log of quality difference', Instrument is 'CCC dummy' in IV estimation.

panel entities at 1% level of significance. Therefore, pooled OLS produces inconsistent estimations, and the panel analysis should be adopted.

4.3. Results of estimation

We examine how introducing a quality-certification system and quality difference affects the trade balance of China by panel analysis. Panel analysis has both time-series and cross-section characteristics and can observe time-series variations and panel object variations at the same time.

The results from analyzing the panel OLS and pooled OLS are given in Table 6. All estimated parameters are statistically significant, while the coefficients of the 'CCC dummy' variable show significant difference between the panel OLS and pooled OLS.[26,27] The 'log of quality difference' and 'CCC dummy', the core variable in this study, have positive effects on China's imports of certified goods from the OECD countries. Estimated parameters for country size and distance variables are consistent with the general results of the gravity model analysis.

Next, we examine the impacts of introducing the quality certification system, CCC, considering the country specific time invariant factors via the fixed effect analysis. The estimation results in Table 6 show that the introduction of CCC increases the Chinese imports from OECD countries with the estimated parameters from the fixed effect model being higher than the random effect model in addition to the higher statistical significance.[28] Moreover, it is estimated that the quality difference between the Chinese and

Table 7. Hausman-Taylor estimation.

Variable	Hausman-Taylor
Time-variant exogenous	
log of [GDPi × GDPj]	0.2959**
	(0.1264)
log of [(GDPi × GDPj)/(popi × popj)]	0.5720***
	(0.1427)
CCC dummy	0.1037***
	(0.0315)
Time-variant endogenous	
log of quality difference	0.1239***
	(0.0061)
Time-invariant exogenous	
log of distance	−09,820***
	(0.3347)
cons	−14.3970**
	(6.0488)
Wald χ^2	4,263.99***
Number of observations	31,946
Number of groups	3,440

Note: () is std. error, ***, **, * mean to be significant within 1%, 5%, 10% significance level.

OECD products has caused significant increase of the Chinese imports from OECD countries. The theoretical analysis in Section 3 shows that the introduction of the quality certification system widens the quality difference between technologically asymmetric countries, showing the endogeneity between the quality certification system and the quality differences. Motivated by the findings, we introduce IV estimations to handle the endogeneity problem between the 'CCC dummy' and 'log of quality difference'. The IV estimation results show that the introduction of CCC increases the quality difference between Chinese products and OECD products, and the quality difference increases the Chinese imports from OECD countries.[29]

When control variables (x_{it}) and the unobserved time-invariant individual effect (α_i) are uncorrelated ($\text{cov}(x_{it}, \alpha_i) = 0$), both random and fixed effect estimations are consistent, while only the result from random effect estimation is efficient. However, when independent variables and individual effect are correlated ($\text{cov}(x_{it}, \alpha_i) \neq 0$), only the fixed effect estimation is consistent while the random effect estimation results are not consistent. Results of the Hausman-Test show that the null hypothesis for no correlation is rejected at 1% significance level. Therefore, the fixed-effect model is more appropriate than the random-effect model.

The Hausman test results show that the fixed effect model is more appropriate than random effect model in our analysis. However, we need to estimate the impact of time-invariant exogenous variables, which cannot be handled by a fixed effect model. Therefore, we adopt Hausman-Taylor model, which can produce consistent estimation about the coefficients of time-invariant regressors as the coefficients for distance between China and OECD countries and the constant. To estimate the impact of the introducing the CCC system in China on quality difference between the Chinese products and the OECD products, the quality difference is endogenized, while exogenous variables are categorized to time variant exogenous variables (denoted as TV exogenous variables) and time invariant exogenous variables (TI exogenous variables) as suggested by Hausman and Taylor (1981) and Amemiya and MaCurdy (1986).[30] As reported in Table 7, the Hausman-Taylor model estimation results show that all estimated coefficients are significant at the 5% significance level. In addition, 'CCC dummy variable' as an exogenous variable (TV exogenous) increases 'quality difference' as an endogenous variable (TV endogenous), and the quality difference has increased China's import of certified goods from OECD countries.

5. Concluding remarks

Considering the increasing concerns on the product quality of imported goods and the wide-spread adoption of compulsory quality certification regulation in advanced economies and developing economies as well, this paper examined the impacts of the adopting quality certification systems between asymmetric countries in terms technologies and quality levels.

Based on a simple model assuming Cournot competition between technologically asymmetric countries, it is found that a developing country might be negatively affected by the quality certification system in her trade with technologically advanced economies, since the quality certification system works as another discriminatory measures imposing higher costs to developing economies. Once a quality certification system is introduced, the quality gap between the firm from the advanced economy and the firm from the less developed economy is widened due to the asymmetric costs to satisfy the minimum quality requirement of the certification system. As a result, the imports of less developed economies from the advanced economies are supposed to be increased after the adoption of the quality certification system by a less developed economy with the increased quality difference.

These theoretical findings are supported by the empirical observation of the Chinese experience to introduce the quality certification system, i.e. CCC, with respect to OECD countries. The Hausman-Taylor model estimation results show that the Chinese introduction of the certification system widened the quality gap and increased the imports from OECD countries. These results implicate that the quality certification system between technologically asymmetric countries can be abused as a discriminatory measure against countries with lower technologies. In the same context, the introduction of a certification system by a less developed economy can expand quality gap and deteriorate the trade balance with advanced economies.

The possible trade distortion effects that might be caused by quality certification systems as found in this study provide a rationale to introduce an international coordination mechanism for a harmonized quality certification systems to minimize the possible distortion effects by the discriminatory abuse of the quality certification systems. In addition, to provide the global consumer benefits from increased qualities, further future studies are required on how to promote inclusive approaches on technology transfers satisfying incentive compatibility conditions for participating countries and firms with higher technologies.[31]

Notes

1. The number of items may differ based on the digit of the HS code.
2. The EU is not a country, but a supranational political and economic union.

3. The quality certification system has been introduced mainly in developed economies, and some developing countries are operating quality certification system for limited items. Developing countries such as Brazil (NMETRO: National Institute of Metrology, ANVISA: Agencia Naciona Vigilancia Sanitaria), Mexico (NOM: Normas Oficiales Mexicanas), Argentina (IRAM: Instituto Argentino de Normalizacióny Certificación) and Republic of South Africa (SABS: South African Bureau of Standards) have introduced quality certification systems for specific fields of the products.
4. Perceived quality is subjective assessment of the quality that consumers expect, and the expectation is based on the experience of the person or other persons (Dodds, Monroe, and Grewal 1991).
5. Lately, the consumers' quality concerns have been expanded to include concerns about the way of production along the supply chains such as workers' labor conditions and the environmental impacts of the production process. In the usual cases, these new issues of expanded quality concerns are not directly handled by quality certification agencies, but are managed by different regulations such as environmental regulation as the carbon border adjustment mechanism for example.
6. The details of the notified cases of TBT including quality certification systems reported to the WTO TBT committee can be found at http://tbtims.wto.org/en/PredefinedReports/NotificationReport.
7. See UNCTAD (2018) 'Non-Tariff Measures: Economic Assessment and Policy Options for Development (https://unctad.org/en/PublicationsLibrary/ditctab2018d3_en.pdf)' for the detailed discussions on the quality certification systems working as non-tariff barriers.
8. The International Organization for Standardization (ISO) has published quality-assurance and quality-management standards (the ISO 9000 series is part of quality certification). Details can be found at https://www.iso.org/iso-9001-quality-management.html.
9. The quality level of each firm, q_i, is an observable variable in this model, and therefore, the quality certification system does work as a screening mechanism to resolve informational barriers. If informational barriers are considered in the future extension, the information update about the quality level via signaling or screening should be the critical part of the analysis, which is beyond the scope of the analysis in this model.
10. Some studies including Ishii (2014) investigated a Bertrand duopoly where firms determine endogenously their product qualities as well as their product prices. Since Bertrand model analysis does not show the essential difference in the results from Cournot model about firms competing with technologies asymmetries, the replication of the analysis through Bertrand model is skipped in this paper.
11. The goods x are the tradeable goods. If x is the non-tradeable goods, the equilibrium output and quality are determined by each market's monopolist supplier.
12. Our main results hold with other types of quadratic utility functions such as, $U_i = x_1 + x_2 - x_1^2/q_2^2 - x_2^2/q_2^2 - \theta(x_1x_2/q_1q_2) + z$ as in Sutton (1996, 1997) and Symeonidis (1999, 2000).
13. The consumer utility function defined in Page 7 is based on the amount of consumption, which is equivalent to the amount supplied by the domestic production and imports from foreign suppliers in equilibrium.
14. Taba and Ishii (2016) analyzed how these governments' R&D policies affect firms' quality and quantity rivalry and found that while an increase in the R&D investment subsidy of each country raises the R&D investment level and product quality of its firm, it decreases the R&D investment level and product quality of its rival's firm and vice versa.
15. WTO's Agreements on Technical Barriers to Trade (TBTA) says that quality certification systems should not work as barriers in international trade except in national health and safety related cases. However, there is increasing concerns that certification systems might be used as strategic tools for domestic market protection.
16. Firm's initial quality level is assumed to be determined exogenously. Therefore, both countries have no incentive to consider the other country's strategy when introducing quality certification system. Hence, social welfare is affected only by domestic quality certification system, and there is no strategic interaction between two countries' policies in this model.
17. Firm i and Firm j are representative firms from country i and j competing in both markets a la Cournot fashion. In addition, two firms have differentiated qualities, q_h and q_l, as exogenously given. Therefore, the cost burden to meet a high quality standard (MQS) set by the importing country is heavier for a firm with low quality level, q_l, and therefore the equilibrium profits for a firm with high quality, q_h, are increased with a higher quality standard (MQS), as shown in Figure 2. Although the initial levels of firms' qualities are exogenously given, the quality standard regulation (MQS) requires the firm with low quality to meet the minimum quality required with costly investment.

Due to the current heterogeneity between two firms, two firms will end up with asymmetric equilibrium profits levels when quality choices are endogenously determined leading to the asymmetry in two countries' welfare levels, basically in the same line as the current results.

18. Zhou, Spencer, and Vertinsky (2002) examines strategic incentives for investment policies towards quality improvements based on Bertrand and Cournot competition. Under Bertrand competition, the low-quality country subsidizes investment to raise export quality, while the high-quality country imposes a tax reduce too intensive competition. Under Cournot competition, the results are reversed with a tax in the low-quality country and a subsidy in the high-quality country.
19. China's CCC (China Compulsory Certification) system is a compulsory safety mark system for 54 product categories not only for imported products but for the Chinese products sold or used in the Chinese market introduced in 2003. CCC covers the majority of electrical and electronic products, machinery, automobiles and telecommunication products including toys for examples. The CCC mark is administered by the CNCA (Certification and Accreditation Administration of the People's Republic of China), while CQC (The China Quality Certification Center) is designated to process CCC mark system.
20. The vertical axis of Figure 3 about 'Quality difference after CCC' represents the difference between the average unit price of the imported OECD products and Chinese products under CCC regulation. The label of the vertical axis is based on the widely adopted approach as Saggi and Sara (2008) notes that all consumers prefer high quality for a given price implying the equilibrium price to be equivalent to the preference for the quality of the product.
21. We examine the empirical evidence of the theoretical modelling focusing on Chinese case since Chinese products show significant quality difference from the OECD countries' products while trade volume is big enough. In addition, the introduction of Chinese quality certification system, i.e., CCC, in 2003 might demonstrate the effects of introducing a quality certification system with detailed HS code data from 1998 over 20 years..
22. The units of raw data before taken logarithm are as follows. imports: thousand US Dollars, GDP: constant 2010 US Dollars, population: persons, distance: km, quality difference: US Dollars/unit.
23. As of 2017, the data of OECD countries include 36 countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom, United States.
24. As pointed out by an anonymous reviewer, the correlation coefficients between the Chinese imports from OECD and the CCC dummy variable and quality difference between Chinese products and OECD products are relatively low. This feature is consistent with the general findings from the gravity model analysis showing that the volumes of international trade are mainly affected by the changes in exchange rates and economic growth rates of trading countries, while the coefficients of other variables remain in a relatively limited scale.
25. IV estimation (2-stage LS) shows that the coefficient of CCC dummy is 0.1121 with the 1% significance level.
26. The Breusch-Pagan LM and Modified Wald test results show that the results of Panel OLS are more accurate, and the results of Pooled OLS might be biased.
27. The panel data is the same as the pooled data in that cross-section data and time-series data are combined. However, panel data is different from pooled data in that each object is observed over time, while pooled data survey different objects over time. Pooled OLS assumes that coefficient values and constants for each variable are the same for all objects, while panel OLS analyzes time-series variation of each object, i.e., 'within variation,' and variation between panel objects, i.e., 'between variation' at the same time.
28. The fixed effect model assumes that the object specific time invariant factor is fixed for each panel object, while the random effect model assumes the object specific factor to be a random variable.
29. An anonymous reviewer suggested trying the Pseudo Poisson Maximum Likelihood (PPML) estimation considering the structural features of the gravity model. PPML estimation proposed by Silva and Tenreyro (2006) can address the possible selection bias and the heteroscedasticity bias that might be caused when the bilateral trade data are missing due to the zero trade volume. Our PPML estimation results, reported in Appendix part, show basically the same estimation results as the fixed effect and random effect model analysis in terms of the sign and direction of each control variable's

impact, while there are minor differences in the size of the estimated parameters, which implicates that our estimations are not significantly biased.

30. The panel OLS model has a bias and inconsistency problem. The fixed-effect model can obtain a consistent estimator but could not measure γ_i because of the disappearing Z_i. On the other hand, the random-effect model has a bias problem but produces a consistent coefficient (regression coefficient) by ignoring endogeneity.
31. The findings from the theoretical model analysis and the empirical study of this paper show that the introduction of quality certification systems might damage developing economies if the system imposes asymmetrically heavier cost burdens on domestic firms of developing economies. Therefore, it is recommended for developing economies to set the standard of the minimum required quality to be equivalent to the average quality level of domestic firms of developing economies at the initial stage of introducing the certification system. Dynamically, the standard for the minimum required quality might be increased reflecting the technology and quality improvement of domestic firms. R&D subsidies would contribute to improving the quality levels of domestic firms as long as the subsidies take the form of non-specific subsidies satisfying WTO rules.

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Appendices

Appendix 1. Derivation of the market equilibrium and comparative statics

In the corporate profit function, the first term on the right-hand side is profit from the domestic market, and the second term is the producer’s profit from exports. The firm’s profit maximization problem is considered first to define the market equilibrium via backward induction as follows:

$$Max \prod_i (x_{ii}, x_{ij}) = (P_i x_{ii} - \delta_{ii}/(\lambda_i R_i) - R_i) + (P_j x_{ij} - \delta_{ji}/(\lambda_i R_i) - R_i)$$
$$F.O.C: \frac{\partial \Pi_i}{\partial x_{ii}} = 0, \frac{\partial \Pi_i}{\partial x_{ij}} = 0$$

From the profit maximization problem described above, the equilibrium outputs are given as follows.

(i) When the quality-certification system is not introduced, $(\delta = 0, \theta = 1)$, the equilibrium outputs are given as follows from the above profit maximization problem:

$$x^*_{ii} = x^*_{ij} = 1/15(4q_i - q_j).$$

‘$\delta = 0$’ implies that there is no difference between the minimum required quality level and the current quality level of the firm, and ‘$\theta = 1$’ assumes that the level of substitutability between two competing products is in the intermediate range, not an extreme case.

In case the quality certification system is not introduced, each firm's output level is determined by the quality level of each competing firm as defined in the above equilibrium output level. A firm's equilibrium output is increased if its own quality level is increased $\left(\frac{\partial x_{ii}^*}{\partial q_i} = \frac{\partial x_{ij}^*}{\partial q_i} = 4/15 > 0\right)$, and its competitor's quality level is decreased $\left(\frac{\partial x_{ii}^*}{\partial q_j} = \frac{\partial x_{ij}^*}{\partial q_j} = -1/15 < 0\right)$.

(ii) When the quality certification system is introduced with the minimum quality required at '$q_h > MQS$' ($\theta = 1$), the equilibrium outputs are given as follows:

Country i: $x_{ii}^* = \frac{1}{15}(-q_{ci} + 4q_i)$, $x_{ij}^* = \frac{1}{15}(-q_{cj} + 4q_i)$
Country j: $x_{jj}^* = \frac{1}{15}(4q_{cj} - q_i)$, $x_{ji}^* = \frac{1}{15}(4q_{ci} - q_i)$

Simple comparative statics show that firm i's equilibrium output is increased with her own quality level $\left(\frac{\partial x_{ii}^*}{\partial q_i} = \frac{\partial x_{ij}^*}{\partial q_i} = \frac{4}{15} > 0\right)$ and decreased with the minimum quality requirement level, i.e. MQS, $\left(\frac{\partial x_{ii}^*}{\partial q_{ci}} = \frac{\partial x_{ij}^*}{\partial q_{cj}} = -\frac{1}{15} < 0\right)$. Contrarily, the firm j's equilibrium output is increased if competitor's quality level is decreased $(\frac{\partial x_{jj}^*}{\partial q_i} = \frac{\partial x_{ji}^*}{\partial q_i} = -\frac{1}{15} < 0)$ and MQS is increased $\left(\frac{\partial x_{jj}^*}{\partial q_{cj}} = \frac{\partial x_{ji}^*}{\partial q_{ci}} = \frac{4}{15} > 0\right)$.

(iii) When the quality certification system imposes a higher minimum required quality level, ($MQS > q_h$ ($\theta = 2$)), equilibrium outputs are given as follows:

$$x_{ii}^* = \frac{q_{ci}}{6},\ x_{ij}^* = \frac{q_{cj}}{6}.$$

A firm's equilibrium output can be increased when MQS is increased: $\left(\frac{\partial x_{ii}^*}{\partial q_{ci}} = \frac{\partial x_{ij}^*}{\partial q_{cj}} = \frac{1}{6} > 0\right)$.

Appendix 2. Estimation results of the Pseudo Poisson Maximum Likelihood (PPML) estimator

Table A1. Estimation results of the Pseudo Poisson Maximum Likelihood estimator.

Variable	FE	RE	PPML
log of [$GDP_i \times GDP_j$]	3.1011***	0.5965***	0.0873***
	(0.3277)	(0.0424)	(0.0017)
log of [$(GDP_i \times GDP_j)/(POP_i \times POP_j)$]	4.3686***	0.2672***	0.1168***
	(0.3678)	(0.0531)	(0.0042)
log of distance	–	−1.0518***	−0.1026***
		(0.1124)	(0.0038)
log of quality difference	0.1239***	0.1130***	0.0068***
	(0.0064)	(0.0062)	(0.0007)
CCC dummy	0.0984***	0.0624*	0.0605***
	(0.0331)	(0.0325)	(0.0304)
cons	99.8072***	−24.9171***	−4.3692***
	(11.7539)	(1.9771)	(0.1085)
F value (Wald χ^2)	989.40	4,126.46	
R^2	0.8593	0.1147	
Number of observations	31,946	31,946	31,946
Number of groups	3,440	3,440	2

Appendix 3

Table A2. HS codes Products governed by CCC.

Item	HS code	Item	HS code
Insulated wire, cable	85444910, 85446019, 85445910	IT equipment	84714140, 84716010, 84433212, 84433214, 84433219, 84433213, 84433211, 84716039, 84716050, 85044013, 85044019, 95041000, 84721000, 84705010, 54705090, 84729090, 90082000, 90283010, 90291020, 84714190
Electrical apparatus for switching or protecting electrical circuits	85369000, 85366900, 85361000, 85365000		
Low-tension electric equipment	85371090, 85352100, 85362000, 85351000, 85353000, 85363000, 85364100, 85364900, 85365000, 85359000		
		Lamps and lighting fittings	94051000, 94052000, 94054090, 85041010, 85041090
Electric motors and generators	85011099, 85013100, 85013200, 85014000, 85015100, 85015200		
		Electric communication apparatus terminal	85176234, 84433290, 85171990, 85171100, 85176229, 85171210, 85275039, 85175033, 85175034, 85171910
Tools for working in the hand with a self-contained electric motor	84672100, 84672910, 84672290, 84672210, 84672920, 84672990		
Electric welding machines	85153190, 85153900, 85152900, 85151100	Vehicle and safety items	87012000, 87019000, 87111000, 87112000, 84073100, 84073200, 84073300, 84073410, 87082100
Home appliance	84181020, 84145110, 84151021, 84798920, 84143011, 84211210, 85161000, 85162990, 85081100, 85164000, 85166010, 85167200, 85094000, 85165000, 85098090, 85167190, 85197990, 84198100, 85166030		
		Tires	40111000, 40119900, 40112000, 40114000
		Safety glass	70071190, 70072190, 70071900, 70072900, 70080000
Audio and visual apparatus	85182100, 85182200, 85182900, 85184000, 85185000, 82249900, 85273200, 85273900, 85279090, 85199910, 85199990, 85219010, 85219090, 85281210, 85282200, 85252100, 85284990, 85284910, 85285910, 85401100, 85401200, 85404020, 85404010, 85406090, 85283010, 85291020, 92071000, 85438920, 85251010, 85252091	Farming equipment	84248100
		Latex	40141000
		Medical device	90221200, 90221300, 90221400, 90189040, 90189090, 90181100, 90215000
		Firefighting equipment	85319010, 59090000, 84241000
		Security alarm system	85311090