Asian Economic and Financial Review
ISSN(e): 2222-6737
ISSN(p): 2305-2147
DOI: 10.18488/journal.aefr.2019.97.851.863
Vol. 9, No. 7, 851-863

URL: www.aessweb.com

HOW LARGE IS THE BORDER EFFECT BETWEEN THE UNITED STATES AND CHINA?

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Article History
Received: 1 May 2019
Revised: 4 June 2019
Accepted: 8 July 2019
Published: 26 July 2019

Keywords
Border effect
Price variation
Law of one price
Purchasing power parity
Indexed exchange rate
Geolocation

JEL Classification:
F30; F40; F41.

ABSTRACT

This study examines the border effect on price variation between the United States and China. A unique data set consisting of exchange rate, four different annual consumer price index series, and geographical position data was obtained for 14 metropolitan areas in the United States and 31 regions in China over the period 2004–2015. Three different regression models were employed to examine the border effect between the United States and China, which was shown to be statistically significant by all three. The distance needed to level the cross-border price dispersion was also estimated and revealed a substantial border effect. Further, to exclude the effect of the nominal exchange rate on cross-border price variation, the border effect was tested using the relative–relative price, but a large border effect remained. Finally, China's reform of its exchange rate regime in 2005, its entrance into the World Trade Organization in 2001, and both it and the United States' direct and indirect government interventions during the 2008 financial crisis proved to be possible influences on the border effect between the two countries during the sample period.

Contribution/Originality: This study is one of very few studies to investigate the border effect between the United States and China. It reports a statistically significant border effect between these countries.

1. INTRODUCTION

Over the last few decades, there have been numerous studies on whether, and why, different prices for the same product exist in different locations, contrary to the important theory of *Law of One Price* (LOP). One area on price dispersion that has grown in significance is that of border effect.

The reasoning behind border effect is based on the observation that LOP fails when products are traded across borders. LOP suggests that the same product should be charged the same price regardless of where it is sold, which implies that factors such as distance and border play no significant role in the process of product pricing. However, Engel and Rogers' (1996) groundbreaking study found strong evidence of systematic price dispersion between the United States and Canada, while Parsley and Wei (2001) later discovered evidence of the border effect between the United States and Japan.

Most border effect studies have depended heavily on data from developed countries to compare the variation in prices between them, and only a few have attempted the same between developing countries. Morshed (2003) examined and confirmed the border effect between Bangladesh and India, and then between Bangladesh and Pakistan Morshed (2007) where the border effect was not a significant cause of price variation.

Although the study of border effect has made substantial progress over the last decades, to our knowledge, there are none between developed and developing countries. It is becoming increasingly important to conduct such studies as emerging markets are beginning to play significant roles in the global economy. Inspired by previous studies, this study attempts to fill that gap by investigating the border effect between the United States and China, the largest developed and developing countries, respectively. The trade between these two economies is substantial, totaling around $648.2 billion in 2016 according to the Office of the United States Trade Representative. Moreover, due to current antiglobalization movements around the world and especially the recent trade dispute between the United States and China, it is time to study the border effect before the trade environment becomes more complex.

As there are significant economic, social, and political differences between the two countries, a border effect between the two countries is therefore posited. The data set of four Consumer Price Index (CPI) series for 14 metropolitan areas in the United States and 31 regions in China between 2004 and 2015, providing a total of 990 pairs of cities, were analyzed. The results confirmed a significant border effect between the United States and China: the price variation is much higher for two cities located in different countries than for equidistant cities within the same country. The influences on the border effect were also discussed: China reforming its exchange rate regime in 2005 and joining the World Trade Organization (WTO) in 2001, and both countries' direct and indirect government interventions during the 2008 financial crisis.

The paper is organized as follows: Sections 2 reviews the literature; Section 3 discusses the data; Section 4 summarizes the methodology; Section 5 discusses the results; Section 6 examines the major influences on border effect; and Section 7 presents the conclusions.

2. LITERATURE REVIEW

Both LOP and *Purchasing Power Parity* (PPP) suggest that national borders should not affect the price convergence process; however, recent studies suggest that they do play an important role in international trade, leading to greater price dispersion when goods cross borders. This is generally known as the *border effect*, which refers to the standard deviation of relative product prices in the cross-country city pairs being larger than that of in-country city pairs. The product pricing process is extremely complicated to measure owing to the many factors involved. Engel and Rogers (1996) used the regional CPI data from the United Stated and Canada to examine the significance of the border effect between the two countries and measure the distances required to level the price dispersion. Their findings contradicted LOP theory, revealing systematic price dispersion among different locations and a much higher price variation for city pairs located in different countries than for equidistant city pairs within the same country. They also discovered that frequent changes in the real exchange rate and distribution costs play a significant role in the product pricing process, which contribute to price dispersion and therefore exert an indirect impact on the border effect.

Using the models and methods introduced by Engel and Rogers (1996), Parsley and Wei (2001) examined the border effect between the United States and Japan, which proved to be statistically significant, and found strong evidence that price stickiness in local currency substantially contributes to movements in the CPI-based real exchange rate. Ceglowski (2003) also examined LOP theory in Canada, finding not only a significant border effect between the United States and Canada but also sizable provincial border effects within Canada.

Traditional thinking suggests that tariff–non-tariff barriers between countries may cause border effects. Over the last few decades, therefore, globalization has helped the free movement of goods and reduced restrictions across borders, while free-trade agreements, such as the North American Free Trade Agreement (NAFTA), reduce or even eliminate tariff–non-tariff barriers within regional trade blocs. Despite the general belief that international trade agreements reduce price dispersion across borders and therefore weaken or even eliminate border effects, Engefi and Rogers (2000) argued otherwise. They re-examined the border effect between the United States and Canada using different measurements and new data, paying particular attention to NAFTA and its impact. They found that removing the trade barriers did not reduce the border effect, since each country's market was highly segmented, in which each behaved like national markets. They concluded that the systematic heterogeneity across the markets may cause the huge border effect.

Morshed (2003) focused on the border effect between Bangladesh and India, separating the sample data into two sub-periods: the first from 1975 to 1984, and the second from 1985 to 1995. He concluded that both distance and border were important factors in the price dispersion between the two countries, and the border effect substantial. Morshed (2007) later studied the border effect between Bangladesh and Pakistan, which were both part of the same country until the former declared independence in 1971. Such a unique historical event provided the opportunity to directly examine the border effect at an intranational and international level followed by a direct cross-examination. He found no change in the price variation between the city pairs before and after Bangladeshi independence, inferring that the border effect may not cause the systematic high price variation between relative product prices in cross-border city pairs.

Although research into border effects has increased over the last two decades, some economists have criticized the methodologies used. Gorodnichenko and Tesar (2009) have argued that cross-country heterogeneity could cause price dispersion and, in turn, the huge border effect found in earlier studies. They showed that the border effect revealed by Engel and Rogers (1996) paper was driven mainly by the difference in the distribution of prices between the United States and Canada; therefore, it is almost impossible to separate the border effect from the trading effect.

While most border effect studies, in terms of product price variation, have focused on developed countries, such as the United States and other OECD nations, few have examined developing countries. This is the first, though, to study the border effect in relation to a unique and important pairing of the largest developed and developing countries: the United States and China.

3. DATA

3.1. CPI Series

The balanced panel data set consisted of four different annual CPI series from 14 metropolitan areas in the United States and 31 regions in China—all 45 areas and regions are listed in Appendix Table A—which represented the majority of business activities and transactions in the two countries. The lack of individual product and barcode price data is a common problem, especially with pricing systems in developing countries. As neither type of price data is available in China, CPI data was adopted as the best proxy for product price when estimating the border effect. This is consistent with previous research, such as the groundbreaking study conducted by Engel and Rogers (1996), who used the CPI from both the United States and Canada.

The Chinese CPI data were extracted from the National Bureau of Statistics of China's *Statistical Yearbook* database[1]. For the United States, pre-2010 CPI data were extracted from the United States Census Bureau's *Statistical Abstracts Series* database[2], while for post-2010, the Bureau of Labor Statistics' (BLS) *Archived Consumer Price Index Detailed Reports* database[3] was consulted.

As well as the overall CPI that includes all consumer goods, the BLS and National Bureau of Statistics of China each list eight sub-CPI expenditure categories: the former presents (1) food and beverages, (2) housing, (3) apparel, (4) transportation, (5) medical care, (6) recreation, (7) education and communication, and (8) other goods and

[1] National Bureau of Statistics of China's *Statistical Yearbook* database: www.stats.gov.cn/tjsj/ndsj/

[2] United States Census Bureau's *Statistical Abstracts Series* database: www.census.gov/library/publications/time-series/statistical_abstracts.html

[3] Bureau of Labor Statistics' (BLS) *Archived Consumer Price Index Detailed Reports* database: www.bls.gov/cpi/tables/detailed-reports/home.htm

services; while the latter proposes (1) food, (2) tobacco, liquor and articles, (3) clothing, (4) household facilities and services, (5) healthcare and personal articles, (6) transportation and communication, (7) recreation, education and culture, (8) and residence. The analysis revealed that both countries coincided in three sub-CPI categories: food, clothing, and transportation. This study includes these three categories as well as the overall CPI.

Owing to restricted free access to the data and CPI category classification, the data sets range from 2004 to 2015, with 2003 as the base year for the CPI calculation. The balanced panel data set comprised 91 city pairs for the United States to United States (US–US) group, 465 city pairs for the China to China (CN–CN) group, and 434 city pairs for the United States to China (US–CN) group.

3.2. Other Data

The annual nominal exchange rate data between the US dollar (USD) and Chinese renminbi (RMB) was extracted from the Federal Reserve Economic Database[4]. For this study, the annual nominal exchange rate was converted into an index, using the 2003 as the base exchange rate, to then calculate the price dispersion for cross-border city pairs. The nominal coefficients of the indexed exchange rate may differ from those of the nominal exchange rate; however, it will not change either the significance of or conclusions drawn from those coefficients, as the indexed exchange rate is simply the annual nominal exchange rate deflated by the base exchange rate.

The geographical position data was extracted from the GeoNames Geographical Database[5], and the distance between city pairs calculated using STATA. For regions in China, the best estimation for the distance calculation was for each provincial capital city to act as the benchmark geolocation for calculating distance.

4. METHODOLOGY

This study adopted the with or without a border framework to estimate the border effect, employing the basic frameworks used by Engel and Rogers (1996), Parsley and Wei (2001), and Morshed (2003) and three different regression models.

In these three border effect regression models, $P_{j,k}^{i}$ is the log of the CPI of good i in location j relative to the price of the same good in location k. For the city pair j and k, $V(P_{j,k}^{i})$ is the standard deviation of $P_{j,k}^{i}(t) - P_{j,k}^{i}(t-1)$, which measures the price variation in the city pairs. The first border effect estimation model can be written as the following equation:

$$V(P_{j,k}^{i}) = \beta_1^i lndist_{j,k} + \beta_2^i CountryD_{j,k} + \sum_{m=1}^{n} \gamma_m^i CityD_m + u_{j,k} \qquad (1)$$

Regression Equation 1 estimates the price variation explained by the logarithmic form of the distance term, border dummy and city dummy variables, where $lndist_{j,k}$ is the distance between city pairs j and k. The country

[4] *Federal Reserve Economic Database*: www.research.stlouisfed.org

[5] GeoNames Geographical Database: www.geonames.org

dummy, $CountryD_{j,k}$, equals 0 if both j and k are located in the same country or 1 if in different countries. The city dummy, $CityD_m$, equals 1 if a city is located in either j or k, or 0 if not. There should be two city dummy variables for each city pair, meaning the sum of city dummy variables for each city pair, j and k, should be 2. To avoid the collinearity trap, the constant term was excluded from the regression model.

Coefficient β_2 in Equation 1 measures the border effect between two countries, which exists when it is statistically significant and differs from 0, since the price variation changes dramatically when products cross borders. The second border effect estimation model can be written as the following equation:

$$V(P^i_{j,k}/lndist) = \beta^i_1 + \beta^i_2(CountryD_{j,k}/lndist) + \sum_{m=1}^{n} \gamma^i_m(CityD_m/lndist) + u_{j,k} \quad (2)$$

Regression Equation 2 estimates the variables that are deflated by the logarithmic form of the distance term, as the log-distance between cities may be inflate the log-distance between cities may be inflate the standard deviation of the regression errors, resulting in a biased estimation. Therefore, regression Equation 2 tests whether the border effect remains statistically significant after deflating the logarithmic form of the distance term. In theory, the results from both Equations 1 and 2 should be consistent: coefficient β_2 in Equation 2 again measures the border effect between two countries, and proves it exists when β_2 is statistically significant and differs from 0.

Both Equations 1 and 2 calculate all the distance terms in the logarithmic form, so that there is no need to test the fitness of the regression model because the regression curvature is already included. As the relationship between price volatility and distance is always concave, the logarithmic form of the distance terms does not influence the measurement of the border effect's significance level.

Previous studies have used the logarithmic form of the distance terms as the factor in their model because product prices may be sticky in terms of the local currency where they are sold. Those earlier studies focused mainly on major developed countries where price variation is not typically large; therefore, to obtain meaningful results from the regression model that reveal the changes in price variation, the sensitivity of the distance terms must be increased. However, consumer prices in developing countries are less sticky than those in developed ones. Furthermore, the annual GDP growth rate in China during the sample period, as well as price volatility, are significantly higher than in the United States, and a higher GDP growth rate is usually accompanied by higher inflation. It was not considered appropriate to use the logarithmic form of the distance terms in this border effect study because the estimation could be severely biased upward. Instead, to improve accuracy, a non-linear regression model with quadratic distance terms was employed to measure the border effect. The third border effect estimation model uses this alternative quadratic form of the distance terms, where $dist_{j,k}$ is the distance between city pairs j and k, and $dist^2_{j,k}$ is the squared distance. This model can be written as the following equation:

$$V(P^i_{j,k}) = \beta^i_1 dist_{j,k} + \beta^i_2 dist^2_{j,k} + \beta^i_3 CountryD_{j,k} + \sum_{m=1}^{n} \gamma^i_m CityD_m + u_{j,k} \quad (3)$$

Regression Equation 3 estimates the price variation with non-linear quadratic distance terms, and once more, excludes the constant term to avoid the collinearity trap. Theoretically, the change from the logarithmic to the quadratic form of the distance terms should not change the conclusions drawn from the border effect model but yield results consistent with those of Equations 1 and 2. In Equation 3, therefore, the border effect between two countries is measured by coefficient β_3, which reveals the existence of a border effect when it is statistically significant and differs from 0.

5. RESULTS

Table 1 reports the standard deviations for the log difference of the relative price index, can be used to observe and identify the systematic price dispersion in cross-border city pairs. These average standard deviations comprise: (i) both cities in the United States, (ii) both in China, and (iii) one in the United States and one in China.

Table-1. Average Relative Price Variations.

Category	US–US	CN–CN	US–CN
Food	0.0083	0.0162	0.0434
Clothing	0.051	0.021	0.0425
Transportation	0.0202	0.0118	0.0486
CPI	0.0089	0.0078	0.0322
No. of Pairs	91	465	434
Avg Distance (Miles)	1253.694	850.623	7200.861

Note: The entries represent the average (mean) value of the price variations across all city pairs within the United States, within China, and across the US–China border, respectively. Price variations are measured by the standard deviations of the relative CPI series. CPI is measured annually. The average distance between city pairs is given in the last row. The sample period is 2004–2015.

Table 1 shows that the lower price variations occur in the US–US group for the food sector and in the CN–CN group for the clothing and transportation sectors and overall CPI. Also, the average price variations are generally smaller when the city pairs are in the same rather than in different countries, except for the clothing sector. Finally, the price variations in the US–CN group is around 2–4 times higher than in either the US–US or CN–CN groups for the food and transportation sectors and overall CPI, while the price variations for the clothing sector is lower in the US–CN than in the US–US group. These results are consistent with those of Engel and Rogers (1996), who found that the price variations in their US–Canada group was typically higher than that in the US–US and Canada–Canada groups, except for men's and boys' and women's and girls' apparel, and footwear sectors. The results shown in Table 1 suggest that crossing a border significantly adds to price variations, revealing that national borders play an important role in price variation.

Table-2. Average Relative Price Variations—Log-Distance Adjusted.

Category	US–US	CN–CN	US–CN
Food/lndist	0.0012	0.0024	0.0049
Clothing/lndist	0.0075	0.0032	0.0048
Transportation/lndist	0.0029	0.0018	0.0055
CPI/lndist	0.0013	0.0012	0.0036
No. of Pairs	91	465	434
Avg Distance (Miles)	1253.694	850.623	7200.861

Note: The entries represent the average (mean) value of the log-distance adjusted price variations across all city pairs within the United States, within China, and across the US–China border, respectively. Price variations are measured by the standard deviations of the relative CPI series divided by the log-distance between the city pairs. CPI is measured annually. The average distance between city pairs is given in the last row. The sample period is 2004–2015.

The log-distance adjusted results in Table 2 are consistent with those in Table 1, also implying that national borders may be a determinant in the size of the relative price variation. However, price variations in the US–CN group are almost 2–3 times higher than those in the other two groups, except for the clothing sector.

Table-3. Regression Results Explaining Relative Price Variations.

Model 1				
	Constant	**lndist**	**BorderDummy**	**Adjusted R²**
Food		0.0026***	0.0256***	0.9868
		(9.99)	(40.95)	
Clothing		0.0011**	0.0042***	0.9755
		(2.52)	(4.14)	
Transportation		0.0016***	0.0291***	0.9875
		(5.71)	(43.62)	
CPI		0.0009***	0.0219***	0.9942
		(7.16)	(74.13)	
Model 2				
	Constant	**lndist**	**BorderDummy**	**Adjusted R²**
Food	0.0024***		0.0260***	0.8997
	(11.1)		(46.38)	
Clothing	0.0011***		0.0043***	0.8550
	(2.97)		(4.54)	
Transportation	0.0012***		0.0301***	0.9323
	(5.28)		(50.38)	
CPI	0.0009***		0.0218***	0.9656
	(8.84)		(80.24)	
Model 3				
	Constant	**lndist**	**BorderDummy**	**Adjusted R²**
Food	$4.56*10^{-6}$***	$-4.52*10^{-10}$***	0.0256***	0.9872
	(11.11)	(-10.55)	(18.21)	
Clothing	$1.88*10^{-6}$***	$-2.41*10^{-10}$***	0.0072***	0.9756
	(2.72)	(-3.41)	(3.11)	
Transportation	$2.98*10^{-6}$***	$-1.45*10^{-10}$***	0.0216***	0.9879
	(6.68)	(-3.18)	(14.43)	
CPI	$1.35*10^{-6}$***	$-1.24*10^{-10}$***	0.0218***	0.9941
	(6.72)	(-6.01)	(32.24)	

Note: The dependent variable is relative price variation. In Model 1, the log-distance, and border and city dummy variables are included. In Model 2, every variable in Model 1 is deflated by the log-distance. In Model 3, the border and city dummy variables, log-distance, distance squared are treated as independent variables. There are 990 observations in each regression. The sample period is 2004–2015. The t-statistics are given in parentheses.
* Significance at 10%; ** Significance at 5%; *** Significance at 1%.

Table 3 reports the regression results for the three border effect models, in all of which the border dummy coefficient is significant at the 1% level, revealing that the border effect is highly significant. The $lndist$ coefficient is also significant in all models in which it is included as an independent variable, showing that distance is important for explaining price variations in different cities, although the border dummy variable is also significant. Consistent with the findings of Engel and Rogers (1996) and Parsley and Wei (2001), the price variations for city pairs in different countries is much higher than for equidistant city pairs within the same country. The quadratic form of the distance terms is used in Model 3, and as all the coefficients are significant at the 1% level, this form appears to be suitable for examining price variation. The $Adjusted\ R^2$ in all three models is consistent with earlier border effect studies, suggesting that distance terms have strong explanatory power. Table 4 lists the results of the distance required to level the price variation, calculated using the three models with both the logarithmic and quadratic forms.

It is interesting that the border dummy coefficients in Table 3 are almost the same for the food and transportation sectors and overall CPI in all the regression models; however, those for the clothing sector changed dramatically in the non-linear regression model with the quadratic distance terms (Model 3), probably because of the different pricing structures in this sector. Engel and Rogers (1996) and Parsley and Wei (2001) provided two explanations for these price variation patterns in the clothing sector, which can be applied to the comparison of the clothing sectors between the United States and China. These explanations are: first, seasonal price changes in the clothing sector may contribute to price dispersion, meaning price variation is more volatile in the Unites States than China; second, a large proportion of clothing sold in the United States is imported while the majority is produced domestically in China. Mandel (2013) concluded that because Chinese exporters concentrate mainly on low-cost, low-quality clothes, other exporters are forced to focus on higher-quality alternatives. The authors expect the strange clothing sector pattern to significantly affect the estimated distances needed to level the price dispersion as well, which is discussed next.

Table-4. Distances Needed to Level the Price Dispersion.

Category	Distance (Miles)
Food	
Method 1	17287.5
Method 2	$1.24*10^{8}$
Method 3	47016.27
Clothing	
Method 1	49.91
Method 2	352221.7
Method 3	63744.38
Transportation	
Method 1	$7.95*10^{7}$
Method 2	$5.72*10^{11}$
Method 3	83178.7
CPI	
Method 1	$4.94*10^{10}$
Method 2	$3.56*10^{14}$
Method 3	89702.66

Note: Method 1 uses the border effect equation from Engel and Rogers (1996), Method 2 uses the one from Parsley and Wei (2001), and Method 3 uses the non-linear regression model with quadratic distance terms. Please see Appendix B for details of the calculation for the distance needed to level the price dispersion.

From Table 4[6], it can be seen that the three methods produce different distances needed to level the price dispersion across the border. However, all the estimated values are statistically significant and demonstrate that the price variation across the border is substantial.

As suggested by Engel and Rogers (1996), this study used the relative–relative price variation to examine the border effect to exclude the effect of the nominal exchange rate on cross-border prices, as well as on the relative price measurements. In the tests, we defined the initial price as the price of each category at each place relative to its overall CPI at that place in the same period: the new relative price of food in Chicago is defined as $[Food_{t,Chicago}/CPI_{t,Chicago}]$. Table 5 reports the average variations of the relative prices using the new definition.

[6] Details for the distance calculation are listed in Appendix B.

Table-5. Average of Relative–Relative Price Variations.

Category	US–US	CN–CN	US–CN
Food/CPI	0.0106	0.0120	0.0223
Clothing/CPI	0.0492	0.0209	0.0490
Transportation/CPI	0.0187	0.0124	0.0767
No. of Pairs	91	465	434
Avg Distance (Miles)	1253.694	850.623	7200.861

Note: The results represent the average (mean) value of the relative—relative price variations across all city pairs within the United States, within China, and across the US–China border, respectively. Relative—relative price variations are measured by the standard deviations of the prices of each category at each place relative to their overall CPI at that place in the same period. The average distance between city pairs is given in the last row. The sample period is 2004–2015.

Table 5 reveals the exchange rate-adjusted relative–relative price variations in the three country groups. While the price variation remains relatively unchanged in-country city pairs, it does in cross-country ones, which implies that the nominal exchange rate is an important determinant for the relative price variation. Compared with the results in Table 1, the relative–relative price variations in the cross-country city pairs are reduced by nearly half for the food sector, slightly increase for the clothing sector, and increases dramatically for the transportation sector. Furthermore, the relative–relative price variations in the cross-country city pairs remain much higher than in the in-country ones, except for the clothing sector. This suggests that there may still be a large border effect between the United States and China even after eliminating the effect of the nominal exchange rate.

Table-6. Regression Results Explaining Relative—Relative Price Variations.

Model 1				
	Constant	**lndist**	**Border Dummy**	**Adjusted R^2**
Food/CPI		0.0022***	0.0064***	0.9748
		(10.67)	(13.13)	
Clothing/CPI		0.0016***	0.0106***	0.9731
		(3.12)	(8.90)	
Transportation/CPI		0.0019***	0.0570***	0.9916
		(5.55)	(68.46)	
Model 2				
	Constant	**lndist**	**Border Dummy**	**Adjusted R^2**
Food/CPI	0.0018***		0.0070***	0.6350
	(11.18)		(16.12)	
Clothing/CPI	0.0013***		0.0111***	0.8604
	(3.26)		(10.41)	
Transportation/CPI	0.0013***		0.0584***	0.9664
	(4.80)		(79.92)	
Model 3				
	Constant	**lndist**	**Border Dummy**	**Adjusted R^2**
Food/CPI	$4.10*10^{-6}$***	$-3.94*10^{-10}$***	0.0058**	0.9760
	(12.76)	(-11.97)	(5.42)	
Clothing/CPI	$1.68*10^{-6}$**	$-2.69*10^{-11}$	0.0050*	0.9731
	(2.09)	(-0.33)	(1.83)	
Transportation/CPI	$4.43*10^{-6}$***	$-3.62*10^{-10}$***	0.0524***	0.9919
	(7.96)	(-6.36)	(28.03)	

Note: The dependent variable is relative—relative price variation. In Model 1, the log-distance, and border and city dummy variables are included. In Model 2, every variable in Model 1 is deflated by the log-distance. In Model 3, the border and city dummy variables, log-distance, and distance squared are treated as independent variables. There are 990 observations in each regression. The sample period is 2004–2015. The t-statistics are given in parentheses.
* Significance at 10%; ** Significance at 5%; *** Significance at 1%.

Table 6 shows the regression results of applying the three border effect models using the relative–relative price variation and in particular, since the value of the border dummy variable is lower than in Table 3, that the nominal exchange rate is an important determinant in cross-border price variations. The clothing sector again differs from the food and transportation sectors, for the same reasons discussed earlier. Even when the effect of the nominal exchange rate on price variation is controlled, the $Border\ Dummy$ coefficients are still significant for relative–

relative price variations. These results support the hypothesis in this study that a border effect does exist between the United States and China.

6. MAJOR INFLUENCES ON BORDER EFFECT

As can be seen from Section 5, when products cross borders, price dispersion increases significantly. This section attempts to explain the US–CN border effect.

First, there is the reform of the currency exchange rate regime in China. O'Connell (1998) examined the persistent he deviation of the retail price from PPP across borders and found that exchange rate fluctuations was the main influence. The Chinese government began reforming its exchange rate regime on July 21, 2005, before which the exchange rate between the RMB and USD had remained stable around 8.28 RMB/USD for over a decade, owing to the Chinese central bank's strict control of the exchange rate and flow. Since 2005, greater flexibility has been allowed in the capital and foreign exchange markets, and the RMB has been appreciating against the dollar up to 2013, which is believed to have contributed to the cross-border price dispersion over that period.

Second, there is the rapid integration of China's economy into the global trade network over the last decade. Officially becoming a member of the WTO on December 11, 2001, China reduced tariff rates on most imported goods and removed many restrictions on foreign investments in local sectors. Since 2001, investments by foreign multinational corporations have increased dramatically, while the improved investment environment has also attracted more foreign companies to set up their business in China. Labor-intensive industries, such as clothing and electronic assembly, were quickly outsourced to China; in fact, American corporations have gradually started to produce high-end products in China to sell back to the United States. Hence, WTO membership has given China greater access to foreign direct investment (FDI) and foreign technology. Whalley and Xian (2010) examined the relationship between FDI and non-FDI in China, and the potential long-term impact on future economic growth. They argued that joint foreign and Chinese ventures were an important contributor to GDP growth in China, accounting for 40% of China's economic growth in 2003 and 2004 and bestowing significant benefits. For example, the General Motors Company started to manufacture its Buick Envision compact SUV through its joint venture with SAIC Motor Corporation Limited (SAIC-GM) for resale to the United States. This integration process exerts a huge impact on the price dispersion of daily consumer products between these two countries.

Third, there is the direct and indirect government intervention during the sample period, especially during the 2008 financial crisis. Yanga *et al.* (2008) studied domestic and international food prices and discovered that the Chinese government's direct intervention ensured the domestic prices of major grains were significantly lower than the international ones. Similarly, Oehmke and Yao (1990) examined the wheat market and large government subsidies in the United States, which led to American wheat being more competitive on the international market. Intervention became more intense during the 2008 financial crisis, with governments and central banks worldwide implemented strict fiscal and monetary policies to stabilize the global economy. The Chinese government injected a large amount of liquidity into its financial system and economy to both stabilize it and boost domestic consumption. The US government, on the other hand, allowed the Federal Reserve Bank to introduce quantitative easing to prevent the collapse of its financial system. Other supranational organizations, such as the International Monetary Fund and World Bank, simultaneously introduced their own plans to safeguard the global economy; however, the huge amount of money injected into the global financial system greatly distorted the consumer pricing system. Joyce *et al.* (2011) examined the impact of quantitative easing on the financial market in the United Kingdom and found that although the short-term impact was muted, in the long-term, it was potentially much larger than expected, by the collateral damage was difficult to measure. A few years after the financial crisis, higher inflation rates in developing countries, such as China, and lower inflation in developed countries, such as the United States, due to the lack of demand, have severely skewed the consumer pricing system and created more volatility.

These three reasons are only some of the major contributors to the changes in price dispersion during the sample period. Their impact, though, has increased the difficulty of separating issues of pricing heterogeneity from true border effects. Therefore, in future border effect analyses, it is recommended that more variables be included in the regression model to determine the sources of cross-border price variations more accurately.

7. CONCLUSION

This study examined a unique data set comprising four different CPI series, from 2004 to 2015, for 45 metropolitan areas and regions in the United States and China, respectively. Statistical evidence revealed that a border effect exists between the United States and China, with price variation being generally higher in the cross-border group. Moreover, the distance needed to level cross-border price dispersion shows that the border effect is large. The relative–relative price variation was also employed to examine the border effect, remained large even after controlling the effect of the nominal exchange rate on price variation. This paper further discussed the major contributors to the change in price variation during the sample period.

Two contributions are made to the existing literature. This is the first study of the border effect on price variation between the United States and China. To our knowledge, most studies have previously focused on developed-to-developed countries and only a few on developing-to-developing ones, whereas this study extends border effect research to examine developed-to-developing countries. In addition, this study confirms the existence of a border effect between the United States and China. It is hypothesized that multiple factors, such as reform of foreign exchange regime in China, its WTO membership, and both countries' economic policies for dealing with the financial crisis and economic recession, have contributed to the price dispersion.

Finally, there are at least two possible subjects for future research arising from this study. First, it would be not only interesting but also important to study the clothing sector in detail. The clothing sector operates differently from other sectors, as found in this and earlier studies, but the specific reasons have not yet been investigated. Second, further studies focused on developed-to-developing countries would complete the picture of border effects.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: All authors contributed equally to the conception and design of the study.

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APPENDIX

Appendix A. Areas and Regions Included in the Panel Data

Table-A. Areas and Regions.

United States	China
Atlanta	Beijing
Boston	Tianjin
Chicago	Hebei
Cleveland	Shanxi
Dallas	Inner Mongolia
Detroit	Liaoning
Houston	Jilin
Los Angeles	Heilongjiang
Miami	Shanghai
New York City	Jiangsu
Philadelphia	Zhejiang
San Francisco	Anhui
Seattle	Fujian
Washington DC	Jiangxi
	Shandong
	Henan
	Hubei
	Hunan
	Guangdong
	Guangxi
	Hainan
	Chongqing
	Sichuan
	Guizhou
	Yunnan
	Tibet
	Shaanxi
	Gansu
	Qinghai
	Ningxia
	Xinjiang

Appendix B. Border Effect Distance Measurements

Three different methods were employed to calculate the distance needed to level the price dispersion: the first from Engel and Rogers (1996), the second from Parsley and Wei (2001), and the third from Morshed (2003) and based on the non-linear regression model with the quadratic form of the distance terms, as shown in the regression model (Model 3).

The first distance estimation equation from Engel and Rogers (1996) is:

$$V(P^i_{j,k}) = \beta^i_1 lndist_{j,k} + \beta^i_2 CountryD_{j,k}$$

When estimating the distance needed to compensate for the border effect, $V(P^i_{j,k})$ is set to 0. The assumption is that the estimated distance should reduce the price dispersion to zero, and thus quantify the magnitude of the border effect. The final distance estimation equation is:

Equation B1 estimates the distance needed to level the price dispersion to 0 in Engel and Rogers' (1996) study, the results of which are listed in Table 4 as Method 1. The second distance estimation equation from Parsley and Wei (2001) is:

$$\beta_1 ln(dist + Z) = \beta_1 ln(dist) + \beta_2$$

where Z represents the distance needed to reduce the price dispersion to 0. The final distance estimation equation is:

$$Z = dist * (exp^{\frac{\beta_2}{\beta_1}} - 1) \qquad (2)$$

Equation B2 estimates Z in Parsley and Wei's (2001) study, the results of which are listed in Table 4 as Method 2.

The third distance estimation equation is based on Model 3 with the quadratic form of the distance terms. When estimating the distance needed to compensate for the border effect, $V(P^i_{j,k})$ is set to 0. The distance estimation equation with quadratic distance terms is:

$$\beta_1 dist + \beta_2 dist^2 + \beta_3 = 0$$

From which the distance needed to level the price dispersion can be estimated by:

$$dist = \frac{1}{2} * \left(\left| \frac{-\beta_1 + \sqrt{\beta_1^2 - 4\beta_2\beta_3}}{2\beta_2} \right| + \left| \frac{-\beta_1 - \sqrt{\beta_1^2 - 4\beta_2\beta_3}}{2\beta_2} \right| \right) \qquad (3)$$

Equation B3 estimates the distance needed to level the price dispersion to 0 in Morshed's (2003) study, the results of which are listed in Table 4 as Method 3. The distance needed should be the mean of the two absolute values.