THE LAW OF ONE PRICE: EVIDENCE FROM THE TRANSITIONAL ECONOMY OF CHINA

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Abstract—This paper applies the recently developed econometric methods of panel unit root tests and nonlinear mean reversion to investigate price convergence in China—the largest transitional economy in the world. We find that prices did converge to the law of one price in China for an overwhelming majority of goods and services, based on a large panel data set. The finding sheds light on the extent of the market economy in China, and casts doubt on Young's proposition that the economic reform has led to the fragmentation of Chinese domestic markets.

I. Introduction

RECENTLY, there has been a surge of economic literature about research on the law of one price (LOP) and purchasing power parity (PPP). In particular, utilizing the econometric methods of panel data unit root tests, a new wave of research has investigated the patterns of *intranational* price convergence. This new strand of the literature notes that the underlying theories of market segmentation can be applied not only to international markets but also to markets within a country, despite the fact that there is no exposure to exchange risk and no explicit trade barriers within a single domestic economy. Indeed, the issues of market integration and the LOP are central to the very foundation of the discipline of economics.

However, existing literature has so far focused attention mainly on OECD countries. This paper attempts to enrich the existing literature by examining convergence to the LOP in a major transitional economy—China. There are three further reasons why it is particularly important to study the issues of price convergence in transitional economies in general and in China in particular. First, the ongoing transition of former communist countries from planned to market economies has been one of the most important economic phenomena in the last few decades. It is therefore interesting to discern whether the liberalization of domestic trade prompts major shifts in price structures that were highly distorted under central planning. Second, among the transitional economies, China seems to have been the center of attention in the recent economic literature. In particular, as highlighted by two recent contributions by Young (2000) and Lau, Qian, and Roland (2000), whether China's "gradualist" reform has been successful is still a subject of great interest and intense debate. The current study will therefore provide direct empirical evidence on the extent of the market economy in China. Third, ever since China embarked on its economic reform and adopted an open door policy in the late 1970s, its economic development has been greatly fueled by its active participation in international trade. In recent years, China's major trading partners have strongly urged it to open its domestic markets further to the outside world, especially after it was admitted to the World Trade Organization. However, even if the Chinese central government removes the barriers to international trade significantly, the effectiveness of this policy might be greatly affected by regional trade barriers within China itself. By examining price movements across different regions in China, this study helps to reveal whether local protectionism has resulted in significant barriers to interregional trade.

Our empirical analysis investigates price movements in China with a large data set that consists of 93 products and services in 36 major cities over a maximum of 156 months. It shows that, based on the criteria of price convergence that are commonly used in the existing literature, there is overwhelming evidence in support of convergence toward the law of one price in Chinese domestic markets. Moreover, we find that both the pattern and the speed of price convergence in China's transitional economy are highly comparable with those in well-developed market economies, such as the U.S. and Canada. Thus, by showing that regional markets have performed quite efficiently in China, our study provides empirical support for the view that the economic reform implemented in China has been generally successful in transforming its economy into a market-oriented one.

The rest of this paper is organized as follows. The next section provides a brief review of the existing literature on the law of one price. Section III gives a sketch of the price reform process in China and summarizes some of the theoretical background. Section IV describes the data set used in this paper. The empirical methodologies we employ are discussed in section V. Section VI analyzes the main empirical findings. We conclude the paper in section VII.

II. A Brief Literature Review

In recent years, research on PPP and the LOP has received increasing attention in the economic literature. For example, Frankel and Rose (1996) examine deviations from PPP, using a panel of 150 countries and 45 annual post–World War II observations. They find that PPP deviations are eroded at a rate of approximately 15% annually. Engel and Rogers (1996) examine the nature of deviations from PPP, using price data for the United States and Canada.

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They find that the distance between cities explains a significant portion of the variation in the prices of similar goods in different cities, but the price variation is much higher for two cities located in different countries than for two cities that are the same distance apart in a single country. Rodrik (2000) provides a comprehensive analysis of why national borders have significantly depressing effects on international economic integration. Based on their detailed surveys of the recent literature, Froot and Rogoff (1995) and Taylor and Taylor (2004) conclude that the LOP has become the focus of substantial controversy and the subject of a growing body of literature.

The large volume of recent research on PPP and LOP was mainly fueled by newly developed econometric methods. In particular, two strands in the literature are closely related to our paper. First, based on panel unit root tests, a number of empirical studies have examined the intranational price movements in several OECD countries. This has shifted the focus from looking mainly at international markets to examining both international and domestic markets, and from using time series data to using panel data. A very partial list of some recent contributions to this focus includes Parsley and Wei (1996), Engel and Rogers (2001), Rogers (2001), Cecchetti, Mark, and Sonora (2002), Ceglowski (2003), and Goldberg and Verboven (2005).

Parsley and Wei (1996) estimate the rate of price convergence within the United States, using a panel of 51 prices from 48 cities. They find that the estimated speed of price convergence is substantially faster in the United States than that typically found in cross-country data. Engel and Rogers (2001) use new disaggregated data on consumer price indexes to determine why there is variability in the prices of similar goods across U.S. cities. In particular, they show that the distance between cities accounts for a significant amount of the variation in prices between pairs of cities, but nominal price stickiness plays an even more significant role. Rogers (2001) finds evidence of price convergence in the 1990s among countries in the euro zone. He notes that the price dispersion of traded goods across the euro zone is now close to that found across U.S. cities, but deviations from the LOP are still largely evident, despite the ongoing convergence. Cecchetti, Mark, and Sonora (2002) study the dynamics of price indexes for major U.S. cities and find that relative price levels revert at a very slow rate to the mean. Ceglowski (2003) investigates the price movements for 45 specific consumer goods across 25 Canadian cities and shows that the provincial border effect is of an order of magnitude smaller than that estimated for the Canada–U.S. border. Using a panel data set of car prices in Europe, Goldberg and Verboven (2005) find strong evidence of convergence toward the LOP at relatively high speeds.

Second, when it is considered that there are significant costs of transportation and transaction in international and interregional trade, it is likely that price adjustments undergo nonlinear dynamics toward PPP and LOP (for example, Benninga & Protopapadakis, 1988; Dumas, 1992; Taylor, 2001). The econometric methods for nonlinear price movements, which were developed by Granger and Terasvirta (1993) and Terasvirta (1994), have been utilized in a growing number of empirical studies.[1] For example, Michael, Nobay, and Peel (1997), Baum, Barkoulas, and Caglayan (2001), and Taylor, Peel, and Sarno (2001) test the price convergences to long-run PPP among several major OECD countries. O'Connell and Wei (2002) show that after allowing for possible nonlinear price convergence processes, prices tend to be more likely to converge to the LOP in the United States.

This paper aims to complement the existing literature by examining the implications of the LOP in a major transitional economy—China. In related existing literature on transitional economies, De Masi and Koen (1996), Conway (1999), and Young (2000) investigate relative price movements in Russia, Ukraine, and China, respectively. However, none of these studies utilize the econometric methods of panel unit root tests or nonlinear dynamics.

III. Institutional and Theoretical Backgrounds

China embarked upon economic reform in 1978 and has since followed the path of gradual transition from a planned economy toward a market economy. In an influential early book, Naughton (1995) identifies three chronological phases of economic reform in China, which coincide well with the phases of price reform. He describes the first phase (1979–1983) as the period when reform was still "the bird in the cage." Although a variety of piecemeal measures were implemented in this period, attempts to coordinate new reform policies into a coherent program failed, largely for political reasons. As a result, reformers did little to correct distorted price structures. During this period, price reforms emphasized adjustment rather than opening up the price control system under the planned economy. Controlled prices for major agricultural goods and industrial materials were repeatedly adjusted upward to bring them closer to the market price levels, while the controls on prices for many daily consumer goods were gradually loosened.

The second phase (1984–1988) is the period when reforms took off. The breakthrough arrived when reformers introduced the policy of a *dual-track* economic system in 1984, which permitted outputs of major industrial materials above certain target levels to be sold on free markets. At the same time, prices for many consumer goods, services, and agricultural goods were left to be determined by the market. The prices for the remaining controlled agricultural goods were allowed to adjust further upward to meet market equilibrium prices.

High inflation and the 1989 Tiananmen political incident ended the second phase of reform. However, this retreat was only temporary. China's commitment to the creation of a

[1] See Taylor and Taylor (2004) for a recent survey of this literature.

TABLE 1.—SHARES OF THREE CATEGORIES OF PRICES IN DIFFERENT TYPES OF PRODUCTS

Type of Products	Category of Prices	Share (%)								
		1990	1991	1992	1993	1994	1995	1996	1997	1998
Consumer goods and services	Planned	30	21	6	5	7	9	6	6	4
	Guidance	17	10	1	1	2	2	1	1	1
	Market	53	69	93	94	91	89	93	93	95
Agricultural goods	Planned	25	22	13	10	17	17	17	16	9
	Guidance	23	20	6	2	4	4	4	3	7
	Market	52	58	82	88	79	79	79	81	84
Industrial materials	Planned	45	36	19	14	15	16	14	14	10
	Guidance	19	18	8	5	5	7	5	5	4
	Market	36	46	74	81	80	78	81	82	86

Source: China Statistics Year Book (various years).

market economy received new emphasis in the 8th National People's Congress in 1993. The Congress announced that China's ultimate goal was to develop a "socialist market economy," shifting decisively away from central planning. Meanwhile, shifts in administrative responsibility, particularly for the internal distribution of consumer goods and services, had been introduced in parallel to the changes in policy direction.

The development of the internal market was fostered by a series of mechanisms that were intended to reduce the scope of state intervention. A key element of the strategy was the progressive lifting of price controls, through the introduction of three categories of prices—planned prices, guidance prices, and market prices—and the gradual movement from more regulated to less regulated categories. Table 1 shows the extent of that movement, and indicates that by the late 1990s, the prices for approximately 90% of products were determined by the market.

However, despite the impressive performance of the Chinese economy in recent years, it is still far from clear whether economic reform has led to a more efficient and integrated market economy in China. For example, Murphy, Shleifer, and Vishny (1992) analyze the theoretical possibility that the partial liberalization of prices has a devastating effect on resource allocation and reduces the total output. Also, Young (2000) argues that the incremental reform adopted by China resulted in rent-seeking opportunities, which can be captured by local officials through the protection of local industries. Consequently, this led to the fragmentation of Chinese domestic markets. In fact, according to Young, different regions in China closely resemble different nations with regard to their trade flows.[2] Though these arguments are insightful, there are counterarguments that are equally convincing. For example, Lau, Qian, and Roland (2000) contend that the dual-track system was designed to compensate local officials for their losses under economic reform. Under the dual-track system, local officials can sell the rights to purchase a certain percentage of raw materials and final products at planned prices, which are lower than market prices. Because opening up the market to other regions may significantly increase the market price, local officials can demand a much larger bribe for these rights. Consequently, local officials may have an incentive to promote interregional trade during the gradual transformation of the Chinese economy.

In summary, there are competing arguments over the effects of the gradualist reform employed in China. In particular, they make opposite predictions about whether Chinese local officials have an incentive to promote or restrict interregional trade. Hence, it is interesting to see how the empirical evidence squares with these predictions. In the existing literature, Young (2000) seems to provide the only empirical study on price convergence and divergence in China. He finds that the standard deviations of log prices across different regions and cities in China fluctuate substantially over time, and then interprets the finding as evidence that "gradualism" resulted in market fragmentation in China's transitional economy. However, sizable price fluctuations in the short run do not necessarily rule out a long-term tendency toward price parity. Thus, this paper extends Young's study by applying the recently developed econometric methods of panel unit root tests and nonlinear convergence models to the examination of the trend of price movements in China.

IV. Data

The data set used in this empirical study is a panel data set of monthly prices for a group of industrial products, agricultural goods, other consumer goods, and services in

[2] In particular, Young (2000, pp. 1102–1103) states that "to protect their industrial interests, provincial, county and even city governments found it expedient to erect barriers to trade so as to maintain high local final industrial goods prices. Aside from tariff barriers (i.e. special charges levied at road blocks), non-tariff methods such as physical barriers, outright prohibition, low-interest loans, and other financial benefits for commercial establishments marketing local goods, fines for commercial establishments marketing non-local goods, local purchasing quotas, and administrative trivia were used to hamper trade. The legal system was also subverted. . . . [T]he courts ignored non-local pleas, rulings and fines were issued against non-local producers." These interregional trade barriers in China closely resemble the numerous possible means, recognized in the literature, by which national borders affect *international* trade [see Rodrik (2000) for a comprehensive review].

36 major Chinese cities, which are collected by the China Price Information Centre (CPIC)—a division of the State Planning Committee of the People's Republic of China. Young (2000) was the first to use this data source.[3] Using the information provided by CPIC, the current study expands Young's data in two aspects. First, Young's data cover only the period from 1990 to 1999, whereas we update the data to 2003. Second, Young's data set includes only information on 82 industrial products and agricultural goods. We acquired additional price data from CPIC on a number of other products, particularly durable goods and services.

The data used in this paper were sampled monthly in 36 major Chinese cities.[4] The initial data set contained monthly price information for 49 industrial products for the period March 1990 to February 2003, 33 agricultural products for the period June 1993 to February 2003, and 18 other consumer goods and 18 services for the period January 1997 to September 2003. However, the data had a fair amount of missing information, especially for earlier periods. For the purpose of our analysis, we have had to use continuous time series data for each product and city. We therefore chose the longest possible continuous time series for each product and city. To avoid the small-sample problem, we first excluded any product for which there were fewer than 30 continuous observations in all cities. Next, we excluded those cities for which there were fewer than 30 continuous observations for each product. The result was an unbalanced panel data set for a total of 93 products and services. Fortunately, as pointed out by Young, the missing information seems to be random, and hence our results are not affected by the data selection process. The names and sample sizes for all 93 items of products and services are listed in appendix table A1.

The quality of Chinese data is often criticized because data reporting in China is likely to be affected by political factors (see, for example, Rawski, 2001). However, we have the following reasons to believe that the data for specific product prices collected by local government agencies under strict central government mandates (see the appendix for the description of the rules governing the collection of these price data) are unlikely to be subject to manipulation. To start with, the central government specifies the collection of prices for these products at fixed dates and locations. Moreover, most of the data are published in *China Price,* which is in general circulation and readily available to the public. Hence, local officials would find it hard to report false data, as the data can easily be verified. In addition, unlike macroeconomic data such as GDP growth rates and unemployment rates, these microeconomic data for prices could hardly serve as indicators in assessing the performance of local officials, and hence local officials would have no incentive to falsify them.

Our data set also has other distinctive features. First, all the price data are spot prices regularly collected on a monthly interval (the 20th of each month) from local markets by government agencies.[5] This is in contrast with most of the empirical studies in related literature, which (a) use price indexes and/or (b) use data with lower frequency. We believe that the monthly frequency of our price data corresponds well to the time needed for domestic price arbitrage. Second, the panel data set we use is truly nationally representative, as it covers a variety of goods and services in all the major cities of mainland China.

It should be noted that the market prices collected by CPIC for goods and services are list prices.[6] To the extent that in some markets prices paid may be different from the list prices, the use of list prices may result in measurement error problems. However, according to the report of the CPIC, the prices for durable goods and for most nonperishable consumer goods and services in our data set were collected from large department stores and state-owned organizations, where price negotiations were generally not allowed. Thus, the potential measurement errors arising from the use of list prices mainly affect the perishable consumer goods in our data set. Furthermore, such measurement errors, if they exist, should be random across different cities, and hence their effects on price convergence are not serious.

For the convenience of presentation, we grouped the products into raw industrial materials (9), processed industrial materials (23), durable goods and vehicles (10), perishable consumer goods (20), nonperishable consumer goods (13), and services (18). The above categorization has taken into account the following factors. First, the production of raw industrial materials was to a large extent under the control of local monopolies, and their prices still face regulation by central government and should have low variations. We thus separated them from other industrial materials, which generally faced less regulatory control from the central government. Second, the markets for processed industrial materials, durable goods, and vehicles were likely to be under imperfect competition. If Young's (2000) proposition is correct, then we should observe more price variation across cities for processed industrial materials and durable goods in China, as they were more profitable and hence prone to local protection. Next, we separated

[3] Young (2000) also uses annual price index data in his empirical study. However, as explained by Taylor (2001), low-frequency (annual) price index data are not as appropriate as high-frequency (monthly) specific product price data for examining price convergence.

[4] The cities are Beijing, Changchun, Changsha, Chengdu, Dalian, Fuzhou, Guangzhou, Guizhou, Ha'erbin, Haikou, Hangzhou, Hefei, Huhehaote, Jinan, Kunming, Lasha, Lanzhou, Nanchang, Nanjing, Nanning, Ningbo, Qingdao, Shenzhen, Shenyang, Shijiazhuang, Taiyuan, Tianjin, Wulumuqi, Wuhan, Xi'an, Xining, Xiamen, Yinchuan, Zhengzhou, Chongqing, and Shanghai. They include four municipalities and all the capital cities for the 28 provinces and autonomous regions in mainland China.

[5] Since the implementation of the dual-track price system, market prices have been available even for products still under state controls.

[6] For raw and processed industrial materials, the CPIC requires local price bureaus to report the trading prices in major local markets.

TABLE 2.—VARIABILITY OF PRICE DIFFERENTIALS AND ABSOLUTE PRICE DIFFERENTIALS

Product Group (Sample Size)	Variability of Price Differentials*		Mean Absolute Price Differentials†	
	Mean	Standard Deviation	Mean	Standard Deviation
Raw industrial materials (25,627)	0.0898	0.0360	0.0663	0.0265
Processed industrial materials (75,461)	0.1077	0.0551	0.0850	0.0471
Durable goods and vehicles (18,720)	0.1144	0.0342	0.1058	0.0402
Perishable consumer goods (65,857)	0.2297	0.1054	0.1691	0.0737
Other nonperishable consumer goods (29,005)	0.1422	0.0858	0.1271	0.0788
Services (29,688)	0.3720	0.1627	0.4600	0.3244

*Price differential variability is defined as the standard deviation over time of the percentage price difference $[p_{ijt} = \ln(g_{ijt} / \bar{g}_{jt})]$.
†Mean absolute price differential is defined as the mean absolute deviation of log prices between cities, that is, the mean over time of $|\ln(g_{ijt} / \bar{g}_{jt})|$.

agricultural goods and the remaining consumer goods into perishable consumer goods and nonperishable consumer goods. This division is based on the observation that perishable goods are more difficult to store and transport and hence their prices are more likely to experience large variations. The final category is services, which are to a large extent nontradable and therefore should display the largest variations in price.

We now turn to the basic statistics of our data. Similar to Cecchetti et al. (2002) and O'Connell and Wei (2002), we define price variation or relative price as $p_{ij,t} = \ln(g_{ij,t} / \bar{g}_{j,t})$, where *i, j,* and *t* stand for city, product, and time, respectively; $g_{ij,t}$ denotes the raw price of product *j* in city *i* at time *t*; and $\bar{g}_{j,t}$ denotes the mean of $g_{ij,t}$ over cities at time *t*.[7] Following Parsley and Wei (1996), we have calculated the variability of price differentials and mean absolute price differentials for those six categories of goods and services. The variability of price differentials is defined as the standard deviation over time of the price variations $[p_{ij,t} = \ln(g_{ij,t} / \bar{g}_{j,t})]$, and the mean absolute price differential is defined as the mean absolute deviation of the price variations, that is, the mean over time of $|\ln(g_{ij,t} / \bar{g}_{j,t})|$. Both of these measures, which are shown in table 2, intuitively illustrate how prices deviate from the mean over time and across cities.

From table 2, we can see, as expected, that services have the highest variability of price differentials and absolute price differentials, followed by perishable consumer goods, nonperishable consumer goods, durable goods and vehicles, processed industrial materials, and raw industrial materials. These results suggest that, as in any typical market economy, a product's price variation in China was mainly affected by the degree of tradability, market structure, and transportation costs.

Parsley and Wei (1996, p. 1216) provide similar statistics for their price data in the United States. Although the products covered by our study are somewhat different from those investigated by Parsley and Wei, it is still revealing to compare the corresponding statistics for the similar price data used in both studies. We have two observations. First, for services, the variability of price differentials and absolute price differentials is much greater in China than in the United States. This result is largely to be expected, because the service sector is much less developed in China (a developing country) than in the United States (a developed country). Second, we found that for both perishable and nonperishable consumer goods, the variability of price differentials and absolute price differentials was quite similar for China and the United States. This result suggests that the problem of fragmentation of the Chinese domestic goods markets might not be serious. In what follows, we provide a more rigorous empirical analysis.

V. Methodology

The LOP implies that the prices for the same product sold in different markets tend to converge to the same level due to profit incentives and market forces. In mathematical terms, the convergence to the law of one price for a product means that the time series of its relative prices is mean-reverting or stationary. However, there may be significant costs of transportation and transaction in interregional trade, which complicates the dynamics of price convergence. In the following, we describe the three empirical methodologies used in our study.

A. *Panel Unit Root Test*

A common approach to examine price convergence is to apply the unit root test to examine whether price differential series are stationary. The rejection of the unit root hypothesis implies that the time series of relative prices are stationary, so that relative prices will converge in the long run. However, if these tests fail to reject the hypothesis, then the relative prices follow a random walk. Hence, any deviation from the "one price" becomes permanent.

However, it has been noticed that the unit root test for a single time series, such as the augmented Dickey-Fuller (ADF) test, has low power in the sense that it tends to overly reject the stationarity hypothesis of a time series. Levin and Lin (1992) have shown that the use of a unit root test for a

[7] Though this is not shown, we have performed the same tests by using Shanghai as the benchmark city to define price variations. In other words, instead of examining whether prices in different cities converge to the cross-sectional mean, we also investigated whether prices in different cities converge to those in Shanghai. We find that this alternative method of defining price variations yields very similar results to the ones reported in this paper.

pooled time series and cross-sectional (panel) data can significantly increase the power of the test. They developed their method from a multivariate generalization of the ADF test, and provided statistical foundations for panel unit root tests. However, a limitation of the Levin-Lin test is that it imposes a cross-equation restriction on the first-order autocorrelation coefficients. Recognizing this problem, Im, Pesaran, and Shin (2003) and Maddala and Wu (1999), among others, put forward panel unit root tests that allow the autocorrelation coefficients to differ across panel members. Moreover, the Maddala-Wu test has the advantage of being applicable to both balanced and unbalanced panel data sets.

We started our empirical analyses by carrying out the ADF test for every product and over each city to examine whether its relative price series $[p_{ijt} = \ln(g_{ij,t} / \bar{g}_{j,t})]$ was stationary. The regression takes the form

$$\Delta p_{ij,t} = c_{ij} + \alpha_{ij} p_{ij,t-1} + \sum_{h=1}^{K} \beta_{ijh} \Delta p_{ij,t-h} + \varepsilon_{ij,t}, \qquad (1)$$

where Δ is the first-difference operator; ε is an identically independently distributed (i.i.d.) error term; and *i, j,* and *t* stand for city, product, and time. The test of price convergence (the ADF unit root test) is simply the test on whether α_{ij} is negative and statistically significant using some modified critical values for the t-test provided by McKinnon. The number of lags, *K,* to be included in equation (1) for each product and city series is determined individually by using the Akaiki information criterion (AIC) on a city-by-city and product-by-product basis.

All our ADF specifications include a constant term to capture city-specific fixed effects. Such effects may cover, for example, city-specific transportation cost and wage cost. Hence, the inclusion of the constant term captures whether prices converge to absolute price parity (zero mean) or relative price parity (nonzero mean).

Next, we applied the panel unit root test developed by Maddala and Wu (1999) (thereafter the MW test) to our unbalanced panel data as a whole. The MW test involves first testing the unit root for each time series for a certain product in each city separately. Then, for each product *j,* the MW unit root test statistic is $-2 \sum_{i=1}^{N} \log P_{ij}$, where *N* is the number of cities included for that product, and P_{ij} is the McKinnon *p*-value for the ADF test of the *i*th city. Maddala and Wu have shown that $-2 \sum_{i=1}^{N} \log P_{ij}$ has a χ^2 distribution with $2N$ degrees of freedom, based on a theorem developed by Fisher (1970).

The individual time series and panel unit root tests described above serve as our first step to check price convergence in China. Furthermore, these methods allow us to compare our results directly with those in OECD countries obtained in the existing literature, using similar models of linear convergence.

B. Nonlinear Mean Reversion

As shown in the theoretical literature (for example, Dumas, 1992; Taylor, 2001), the existence of significant transaction costs in interregional trade will result in a *band of inaction* within which interregional price differentials will be too small to cover the arbitrage costs. In other words, if interregional price differentials are inside the band of inaction, the activities of arbitrage are few and hence price differentials are likely to persist. Hence, only price differentials outside (larger than) the band induce arbitrage. In this case, price movements may experience nonlinear dynamics.

Our empirical study of nonlinear price movements is based on the econometric method developed by Granger and Terasvirta (1993) and Terasvirta (1994). This method has gained popularity in a number of recent empirical studies, such as Michael et al. (1997), Baum et al. (2001), and Taylor et al. (2001). Following these studies, the deviations from the LOP can be described in a standard exponential smooth threshold autoregressive (ESTAR) model, which takes the following form:

$$\begin{aligned} \Delta p_{ij,t} = {} & b_{ij} + \lambda_{ij} p_{ij,t-1} + \sum_{h=1}^{m-1} \phi_{ijh} \Delta p_{ij,t-h} \\ & + \left(b^*_{ij} + \lambda^*_{ij} p_{ij,t-1} + \sum_{h=1}^{m-1} \phi^*_{ijh} \Delta p_{ij,t-h} \right) F(p_{ij,t-d}) \\ & + \varepsilon_{ij,t}, \end{aligned} \qquad (2)$$

where

$$F(p_{ij,t-d}) = 1 - \exp[-\gamma(p_{ij,t-d} - a^*)^2]. \qquad (3)$$

Here γ is a positive coefficient, and a^* is the equilibrium value of price differentials. The ESTAR model is chosen because it allows for smooth and symmetric adjustments in response to both negative and positive deviations from the LOP. When $p_{ij,t-d} = a^*$, we have $F(\cdot) = 0$ and equation (2) reverts to a standard linear model (1) with $\alpha_{ij} = \lambda_{ij}$. When the gap between $p_{ij,t-d}$ and a^* gets very large so that $F(\cdot) \approx 1$, equation (2) becomes a new linear AR (*m*) model with $\alpha_{ij} = \lambda_{ij} + \lambda^*_{ij}$. Thus, the critical parameters are λ_{ij} and λ^*_{ij}. When deviations from the LOP are small, λ_{ij} mainly determines the movements of relative prices. When deviations from the LOP become greater and greater, λ^*_{ij} becomes more and more important in governing the adjustment process. Global stability is guaranteed if and only if $\lambda_{ij} + \lambda^*_{ij} < 0$. It should be noted that in nonlinear dynamics, it is admissible to have $\lambda_{ij} \geq 0$ as long as the condition, $\lambda_{ij} + \lambda^*_{ij} < 0$, is satisfied. In this case, prices experience a random-walk or even explosive behavior within the band of inaction, but will start to converge as soon as they deviate outside the band.

There are several standard steps for testing nonlinear convergence. The first step uses the following artificial regression to test if a price series conforms to a linear or an ESTAR specification:

$$p_{ij,t} = r_{ij} + \sum_{h=1}^{p} (\eta_{ijh}\, p_{ij,t-h} + \pi_{ijh}\, p_{ij,t-h}\, p_{ij,t-d} + \theta_{ijh}\, p_{ij,t-h}\, p_{ij,t-d}^2) + \varepsilon_{ij,t}. \quad (4)$$

In this regression, linearity is rejected if the null hypothesis, $\pi_{ijh} = \theta_{ijh} = 0$ (for all h), is rejected. The order of the autoregression, p, is chosen in such a way that it ensures the absence of residual autocorrelation up to the order of 12 lags. After selecting p, the delay length d is chosen such that it gives the smallest P-value in support of the test for nonlinearity. In the case that linearity is rejected, we then estimate equation (2) by nonlinear least squares. Based on the regression results, the hypotheses $\lambda_{ij} < 0$ and $\lambda_{ij} + \lambda_{ij}^{*} < 0$ are tested.

C. The Determinants of Price Dispersion

The methods of panel unit root tests and nonlinear mean reversion enable us to identify whether prices have a tendency to converge to the LOP. However, under some circumstances it will also be interesting to look at the determinants of price fluctuations over time. For this purpose, we employ a simple methodology similar to that of Parsley and Wei (2003).[8]

We first define log price differentials for product h at time t between any city pair i and j as

$$Q_{ij,h,t} = \ln g_{i,h,t} - \ln g_{j,h,t}$$

Then, we define

$$q_{ij,h,t} = Q_{ij,h,t} - Q_{h,t}^{*},$$

where $Q_{h,t}^{*}$ is the mean of $Q_{ij,h,t}$ over all city pairs. Next, we calculate the standard deviation of $q_{ij,h,t}$ across products at a point of time, which is denoted by $S_{ij,t}$. We then ran the simple regression of $S_{ij,t}$ on: (1) the time trend T and its square, (2) the log distance between the two cities, D_{ij}, and (3) a dummy $R(=1)$ indicating if the two cities are all located in the coastal region of China:[9]

$$S_{ij,t} = \rho_0 + \rho_1 T + \rho_2 T^2 + \rho_3 D_{ij} + \rho_4 R + \varepsilon_{ij,t}. \quad (5)$$

This regression (5) provides us with a simple method in examining how price fluctuations are affected by distance and location (coastal versus noncoastal) and how they change over time.

Ideally, we should run the above regression for each product separately, as the average trend of price dispersion for a group of products does not necessarily present a clear view on the trend of price dispersion for each individual product within the group. For example, an average of two negative figures and a positive figure can be either negative or positive. Hence from the sign of the average we cannot tell whether each of the underlying three figures is positive or negative. However, due to the large number of products studied in this paper, we simply run a regression with all products as well as separate regressions for each of our six categories of products. Because the products belonging to the same category are likely to be more homogeneous than a group of products from different categories, we believe that they are more likely to follow the same pattern of price dispersion over time. Hence, the separate regressions of six categories of products may suffer less from the aggregation bias discussed above.

VI. Results

Following the discussion in section V, we carried out linear and nonlinear unit root tests. We also ran a simple regression to see whether and to what extent price fluctuations followed a trend, if any, and are affected by distance and location. The results are presented in three corresponding subsections.

A. Panel Unit Root Test

We first look at the single time series unit root (ADF) test results, which are presented in table 3.

In column 2 of table 3, we report for each product the proportion of cities where the univariate ADF test rejects the unit root hypothesis at 5% significance levels. These range from 0 (for office rent) to 36 out of 36 (green peppers, first grade), with an average of 40% cities converging to the LOP (see column 2 of table 4, which summarizes table 3). Thus, these results reveal substantial evidence against the unit root hypothesis, and support the hypothesis of long-run price parity in the transitional economy of China. Furthermore, it should be noted that these numbers correspond very closely to the findings on Canadian prices by Ceglowski (2003), who also employed the MW test. Using a Canadian panel of prices with 45 specific consumer goods across 25 cities, Ceglowski found that the unit root null was rejected at the 5% level for 45% of the series of cities based on the ADF test. Hence, the extent of price convergence in China appears to be highly comparable with that in a developed country.

For the price convergence for different categories of product, we found that the percentage of cities that rejected

[8] It should be noted that this methodology is also similar to that of Young (see Young, 2000, pp. 1113–1114), except that the methodology we employ included the additional explanatory variables of distance and the coastal region dummy.

[9] The coastal cities are Beijing, Tianjing, Shijiazhuang, Dalian, Shanghai, Nanjing, Hangzhou, Ningbo, Fuzhou, Xiamen, Jinan, Qingdao, Guangzhou, Shenzhen, Haikou, and Nanning. These cities are located in China's coastal provinces: Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Haninan. [The definition of coastal provinces here is the same as in Young (2000).]

TABLE 3.—LINEAR AND NONLINEAR UNIT ROOT TESTS

Product Name	Test of Linear Convergence				Test of Nonlinear Convergence			
	Prop. of Conver. Cities	No. of Sig. Const.	MW Test Stat. and Sig.	Half-Life (mo.)	Prop. of Cities that Reject Linearity Test	Prop. of Conver. Cities ($\lambda + \lambda^* < 0$)	Prop. of Cities with $\lambda < 0$	Prop. of Overall Conver. Cities
Raw Industrial Materials.								
Copper, electrolytic	22/35	9	370.804*	2.722	25/35	23/25	8/25	27/35
Aluminum, electrolytic	18/35	5	259.597*	2.898	25/35	24/25	3/25	29/35
Lead, electrolytic	17/35	12	270.666*	2.423	27/35	26/27	5/27	29/35
Zinc, refined	12/34	5	194.422*	2.9	21/34	21/21	5/21	23/24
Anthracite	7/27	5	108.903*	1.993	18/27	17/18	1/18	18/27
Pine logs, 4–5.8 m long, 18–28 cm diameter	8/29	5	118.310*	4.482	16/29	16/16	1/16	19/29
China fir logs, 5–5.8 m long, 14–28 cm diameter	9/21	6	108.966*	1.948	10/21	8/10	0/10	12/21
Nickel	4/25	3	67.185**	1.741	17/25	15/17	2/17	17/25
Tin	7/31	5	137.504*	2.228	17/31	17/17	0/17	18/31
Processed Industrial Materials								
Hot-rolled carbon-tied elemental steel	26/35	10	340.756*	2.735	29/35	29/29	6/29	32/35
Screwed steel	23/34	10	334.178*	1.927	24/34	23/24	2/24	31/34
Hot-rolled ordinary carbon angle steel	16/36	8	271.213*	2.454	26/36	26/26	5/26	31/36
Hot-rolled ordinary carbon wire rod	23/36	8	363.076*	2.364	31/36	29/31	3/31	31/36
Hot-rolled ordinary carbon medium plate	16/36	3	216.610*	3.52	23/36	22/23	1/23	25/36
Processed Industrial Materials								
Hot-rolled ordinary carbon sheet metal	18/34	9	249.012*	3.058	21/34	19/21	4/21	28/34
Cold-rolled ordinary carbon sheet metal	21/35	5	273.338*	2.614	23/35	23/23	5/23	30/35
Zinc-plated (galvanized) plate	18/36	8	280.205*	2.316	30/36	29/30	3/30	31/36
Cast pig iron, manganese	9/31	4	133.015*	3.966	22/31	20/22	5/22	23/31
Gasoline for cars	28/35	13	364.615*	1.38	24/35	23/24	6/24	31/35
Diesel oil, light	25/34	9	358.939*	2.261	27/34	27/27	4/27	30/34
Caustic soda, solid content $>$ 98%	14/36	19	235.102*	3.252	23/36	23/23	3/23	27/36
Caustic soda, solid content $>$ 30%	4/25	4	96.678*	2.538	10/25	9/10	0/10	12/25
Soda ash, first quality, content $>$ 98.5%	23/36	10	310.059*	2.883	27/36	26/27	2/27	31/36
Sulfuric acid, conc. $>$ 98%	6/35	7	152.167*	3.563	23/35	19/23	1/23	21/35
Polyethelene, high-pressure, industrial use	18/36	5	203.018*	2.042	24/36	23/24	5/24	30/36
Polypropylene, Equiv. to first quality	23/35	7	264.136*	2.544	23/35	23/23	2/23	30/35
Cement, ordinary	21/36	8	161.382*	4.258	24/36	18/24	0/24	19/36
Plate glass, Standard, 3 mm	15/36	8	248.667*	2.778	28/36	24/28	2/28	27/36
Pig iron (steelmaking)	6/26	6	100.245*	2.239	12/26	11/12	2/12	15/26
Heavy rail	6/21	3	139.695*	4.772	17/21	15/17	3/17	16/21
Billets	6/19	8	123.350*	2.431	9/19	6/9	0/9	9/19
Durable Goods and Vehicles								
Medium truck, 5 ton East Wind model	17/31	12	213.508*	2.64	17/31	17/17	1/17	22/31
Medium truck, 5 ton Liberty model	15/31	9	253.927*	2.11	14/31	12/14	4/14	19/31
Light truck, 1.75–2 ton, model 30	16/36	11	244.685*	2.175	25/36	24/25	5/25	30/36
Sedan, Santana	20/35	20	357.268*	3.667	24/35	22/24	0/24	28/35
Sedan, Xiali	11/31	6	153.729*	1.641	18/31	18/18	2/18	24/30
Sedan, Hongqi	10/34	8	217.414*	1.41	23/34	23/23	6/23	25/34
Washing machine, Little Swan, XQB50-95	7/33	5	138.926*	2.323	19/33	14/19	0/19	17/33
Microwave oven Galanz's, WD750BS	6/21	5	258.968*	0.924	15/21	15/15	2/15	17/21
Refrigerator, Haier, BCD-238WF62	2/23	3	67.356*	2.233	12/23	11/12	0/12	14/23
Air conditioner, Chun Lan, KFR-35GW	1/26	1	62.351		9/26	9/9	0/9	11/26
Perishable Consumer Goods								
Chinese cabbage, first grade	33/36	23	487.829*	1.063	18/36	17/18	6/18	35/36
Pork, deboned, fresh	22/36	17	296.658*	2.037	19/36	19/19	2/19	30/36
Potato, first grade	33/36	29	444.835*	1.044	19/36	18/19	3/19	35/36
Beef, deboned, fresh	17/36	9	237.317*	5.008	14/36	13/14	1/14	25/36
Mutton, deboned, fresh	16/31	14	261.635*	1.82	17/31	15/17	1/17	28/31
Perishable Consumer Goods								
Chicken	17/34	14	240.540*	2.318	14/34	10/14	1/14	22/34
Eggs, fresh, intact	28/34	27	407.745*	1.382	20/34	18/20	3/20	32/34

TABLE 3.—*(CONTINUED)*

Product Name	Test of Linear Convergence				Test of Nonlinear Convergence			
	Prop. of Conver. Cities	No. of Sig. Const.	MW Test Stat. and Sig.	Half-Life	Prop. of Cities that Reject Linearity Test	Prop. of Conver. Cities ($\lambda + \lambda^* < 0$)	Prop. of Cities with $\lambda < 0$	Prop. of Overall Conver. Cities
Fresh cutlass fish, < 0.5 kg	24/36	22	443.492*	1.628	20/36	19/20	1/20	29/36
Silver carp, > 0.5 kg	15/35	19	218.614*	2.206	22/35	19/22	3/22	27/35
Apples, first grade	23/34	19	301.757*	2.207	18/34	17/18	1/18	27/34
Watermelon, first grade	17/33	17	230.568*	1.337	10/33	9/10	1/10	24/33
Pork	13/33	10	189.375*	1.948	18/33	18/18	3/18	24/33
Soybeans, top grade	18/36	14	318.270*	2.407	18/36	18/18	4/18	25/36
Cucumber, first grade	35/36	25	679.402*	0.801	13/36	13/13	5/13	35/36
Tomato, first grade	31/36	26	689.960*	0.906	17/36	17/17	7/17	35/36
Eggplant, first grade	34/36	22	722.823*	1.036	17/36	15/17	7/17	33/36
Radishes, first grade	33/36	23	572.142*	1.114	13/36	13/13	2/13	33/36
Green peppers, first grade	36/36	30	888.386*	0.75	19/36	18/19	6/19	35/36
Pears	21/33	20	277.537*	1.208	11/33	10/11	0/11	26/33
Spinach	29/35	23	423.147*	0.82	11/35	11/11	3/11	31/35
Nonperishable Consumer Goods								
Cigarettes, Zhonghua, 84 mm	6/36	6	127.567*	2.930	28/36	25/28	1/28	26/36
Monosodium glutamate	11/36	13	213.207*	1.573	29/36	27/29	0/29	30/36
Toothpaste, Zhong Hua, 120 g, with calcium	5/34	5	149.407*	3.233	22/34	21/22	3/22	23/34
Flour, ordinary or standard grade	9/30	9	173.841*	1.341	16/30	15/16	0/16	22/30
Corn flour, top grade	5/32	8	112.965*	3.264	14/32	13/14	2/14	18/32
Polished rice	17/35	11	244.212*	2.142	17/35	16/17	1/17	23/35
Flour, top grade	14/36	17	200.878*	3.438	18/36	16/18	1/18	20/36
Peanut oil	8/26	11	129.477*	2.369	13/26	11/13	1/13	15/26
Rapeseed oil, second grade	8/25	7	139.469*	2.216	13/25	12/13	1/13	14/25
Soyabean oil, second grade	4/25	5	114.84*	2.664	15/25	15/15	1/15	16/25
Beer, Qingdao, 335 ml, 11%	6/32	5	135.41*	3.133	20/36	17/20	0/17	20/36
White wine, Wuliangye, 500 ml, 39%	6/36	6	157.23*	2.249	23/36	20/23	2/20	22/31
Man's shirt, Yi'ershuang	11/35	7	251.39*	1.738	30/36	30/30	5/30	32/36
Services								
Bus ticket, monthly pass	8/29	9	194.008*	3.735	22/29	21/22	0/22	22/29
Bus ticket, long distance, per kilometer	21/31	19	305.142*	1.478	14/31	13/14	3/14	24/31
Rent, public housing (m^2/month)	5/33	9	131.888*	1.959	17/33	16/17	1/17	19/33
Rent, private housing (m^2/month)	2/17	2	45.320**	1.338	8/17	6/8	0/8	7/17
Office rent, highest grade (m^2/month)	0/25	1	38.162		4/25	4/4	0/4	4/25
Hotel rate, 3 stars, standard room	7/35	7	205.566*	2.316	11/35	9/11	1/11	12/35
Water rate, household	3/36	3	84.711		22/36	18/22	0/22	18/36
Electricity rate, household	2/36	4	75.070		22/36	19/22	1/22	19/36
Gas rate, household	2/26	4	82.836*	2.271	15/26	8/15	0/15	8/26
Liquefied gas rate, household	9/36	11	153.895*	3.089	20/36	19/20	2/20	23/36
Telephone rate (per line per month)	6/36	8	165.804*	2.996	22/36	20/22	2/22	21/36
Public telephone (per 3 min)	5/36	6	98.641*	5.215	18/36	18/18	0/18	18/36
Mobile phone (per minute)	5/36	5	136.182*	3.354	18/36	17/18	1/18	18/36
Public hospital registration fee	5/36	7	82.141		22/36	21/22	0/22	21/36
Injection fee	4/36	4	118.973*	2.203	15/36	10/15	0/15	13/36
Operation fee for appendectomies	1/36	1	75.589		21/36	17/21	0/21	17/36
Dry cleaning, woolen suit	8/25	8	119.881*	1.524	10/25	7/10	0/10	13/25
Haircut, standard, wash, cut, and blow dry	26/26	25	586.374*	0.317	4/26	4/4	1/4	26/26

In column 4, * indicates significance at 5% level and ** indicates significance at 10% level.

the unit root null was the highest for perishable consumer goods (71%), followed by processed industrial materials (48%), raw industrial materials (38%), durable goods and vehicles (33%), nonperishable consumer goods (27%), and services (22%). These findings are largely consistent with our expectations. First, due to their lack of tradability, services were least likely to experience price convergence across cities. Second, the finding that price convergence was more prevalent for perishable consumer goods than for processed industrial materials, raw industrial materials, and durable goods and vehicles conforms well to the view that the markets for the latter three types of products were under more imperfect competition, which led price differentials across different regions to be more persistent. The only seemingly counterintuitive finding here is that nonperishable consumer goods have the lowest rate of convergence amongst all categories of goods. Due to their relatively low costs of storage and transportation, one might expect that it

TABLE 4.—PERCENTAGE OF CONVERGENT CITIES, SIGNIFICANT CONSTANTS, AND HALF-LIFE BY PRODUCT CATEGORIES

	Test of Linear Convergence			Test of Nonlinear Convergence			
Product Category	% of Conver. Cities	%. of Sig. Const.	Half-Life (mo.)	% of Cities Rejecting Linearity Test	%. of Conver. Cities ($\lambda + \lambda^* < 0$)	% of Cities with $\lambda < 0$	% of Overall Conver. Cities
Raw industrial materials	38	42	2.59	63	94	12	67
Processed industrial materials	48	38	2.82	67	92	11	75
Durable goods and vehicles	33	45	2.18	52	94	12	69
Perishable consumer goods	71	72	1.66	47	94	19	84
Nonperishable consumer goods	27	53	2.41	60	91	7	63
Services	22	24	2.44	49	86	5	53
Overall	40	46	2.35	56	92	11	69

is easier for the prices of nonperishable goods to converge than for those of other goods, especially perishable goods.

Next, we look at the number of significant constant terms in equation (1) for all price series. The corresponding figures are shown in column 3 of table 4. Our results reveal that for 46% of the convergent individual relative price series, the constant term in equation (1) is significant at the 5% level. This means that for slightly less than half of cities prices converge to relative rather than absolute parity.

Price convergence to relative parity means that, despite long-run price convergence, fixed price gaps still exist across different cities due to city-specific heterogeneities. These heterogeneities may arise from differences in regional transportation, wage, and rental costs. However, they may also be caused by trade barriers, such as local tariffs imposed by municipal governments. To the extent that our data and methodology cannot properly identify the exact causes for such city-specific gaps, the question of whether or not local trade barriers resulted in the interregional fixed price gaps in China remains unsolved. However, the following three pieces of evidence may convince us that even if some local trade barriers might exist in China, the extent of market fragmentation should not be the major cause for the failure of the prices to converge to absolute parity. First, our finding of overall price convergence in China indicates that markets across different cities are indeed interrelated or integrated. Second, both Parsley and Wei (1996) and Ceglowski (2003) found that there were also a significant number of prices in their studies for the United States and Canada that followed relative price convergence rather than absolute price convergence.[10] Third, from column 3 of table 4, we note that processed industrial materials and durable goods and vehicles have a much smaller proportion of significant constants than perishable and nonperishable consumer goods. In other words, we find that, contrary to some prior expectation, the categories of products whose interregional trade was more likely to be restricted by local officials for rent-seeking purposes were actually more likely to converge to *absolute* price parity. This indicates that in reality local officials may have more incentive to promote rather than hinder trade, as suggested by Lau et al. (2000).

The univariate ADF test is commonly viewed as having low power to reject a unit root null, although it has the advantage of providing us with information regarding the minimum number of cities for which prices converge to the LOP for each product. Now, we turn to our panel unit root test result, which fully utilizes the information contained in the panel data and has proven to be far more powerful than the univariate ADF test. The calculated MW test statistics over all products, together with their significance levels, are listed in table 3. The results of the MW unit root test are quite striking. If we look at the panel price data for each product, we can reject the null of a unit root for all but two goods (nickel[11] and air conditioners) and five service items (office rent, public hospital registration fees, operation fees for appendectomies, water rates, and electricity rates) at the 5% significance level. This means that prices have a strong tendency to converge to the LOP for an overwhelming majority of the products in our data set.

Furthermore, it is interesting to look at how fast prices converge to the LOP in China. To do so, we calculated the half-lives for all the convergent log price differential series of each product. The average half-life for all products is shown in table 3 and is summarized in table 4. These results show that the half-lives range from 0.32 month to 5.21 months, with an overall average of 2.35 months and a median of 2.26 months. To make international comparisons, we focus on the median half-lives for the perishable consumer goods, nonperishable consumer goods, and services. The median half-lives for these three categories of products are 1.38, 2.369, and 2.27 (excluding the five types of nonconvergent services), respectively. This finding is quite

[10] Parsley and Wei find that 60% of their products' prices converge to relative parity (constant terms are jointly significant in their fixed-effect panel estimation results) in the United States. Ceglowski (2003) also shows that in Canada, in approximately 30% of cases, prices converge to relative price parity. However, neither of these studies specifies whether the calculations of the percentages are based on all convergent prices or on the whole set of price data (including both the nonconvergent and convergent prices). Thus, the comparison is only indicative. (It should be noted that a significant constant in a nonstationary time series implies neither absolute nor relative price parity.) Further, using a panel data set of car prices in Europe, Goldberg and Verboven (2005) find that car prices across the European countries exhibit large and persistent differences.

[11] Nickel just misses the 5% level but passes the 10% level with ease.

surprising, as our estimated median half-life is below the estimates of the median half-life found in corresponding studies of the United States and Canada.[12] For example, Parsley and Wei (1996) found that the median half-life for a panel of U.S. goods prices was approximately 4 to 5 quarters, and Ceglowski (2003) found a median half-life of 0.55 year for a panel of Canadian product prices. Parsley and Wei (1996) also found that the median half-life for services in their study is 15 quarters.

As it is hard to imagine that the Chinese domestic markets are more efficient than those in the United States and Canada, a more reasonable explanation for these findings can be sought from the methodologies. First, the much larger median half-life found by Parsley and Wei may be partially due to their use of the Levin-Lin panel unit root test. As discussed before, the Levin-Lin approach requires a uniform autocorrelation coefficient for all price series in the panel. This restriction may bias the estimated half-life upward because not all series are convergent. The MW approach allows the estimated autocorrelation coefficients to vary across series, and the estimated half-life is based only on those convergent coefficients. Therefore, from this point of view, our results should be more comparable with Ceglowski's. Furthermore, we noticed that the half-life of a product reported by Ceglowski is the median of both convergent and nonconvergent price series for the product [see table 2 of Ceglowski (2003)], whilst the half-life of a product or service reported by us is based on the mean of all convergent price series for that product or service. If we follow Ceglowski's approach to estimate half-lives, then the median half-life is 1.6 months for our perishable consumer goods and 4.5 months for our nonperishable consumer goods. The latter figure in particular is quite similar to Ceglowski's estimate of 0.55 years.

B. Nonlinear Mean Reversion

In the analysis of nonlinear price movements, we first conducted a test of linearity. The results are presented in table 3 and summarized in table 4. We have the following observations. First, the proportion of cities that reject the linearity hypothesis is 56%, that is, slightly more than half of the time series exhibit nonlinear dynamics. Second, processed industrial materials and raw industrial materials are significantly more likely to reject the linearity test, suggesting that there are more transaction costs in engaging in the trade of these two categories of goods.

Next, we examined the patterns of price adjustments of the time series that reject the linearity test. The analysis shows that, overall, 92% of those prices follow a nonlinear convergence to the LOP. Meanwhile, the variations among the six categories of goods and services are rather small. We then calculated the overall proportion of cities whose prices converge (whether in a linear or a nonlinear way), which turns out to be 69% and is a large increase from the case in which linear convergence is based on the univariate ADF test (40%). Thus, the results show that the incorporation of nonlinear dynamics into the analysis significantly increases the power for testing the LOP.

In addition, we investigated whether time series that follow the patterns of nonlinear convergence exhibit convergent behavior when the deviations from the LOP are small, by testing the hypothesis $\lambda_{ij} < 0$. We found that only 11% of them pass such a test. In other words, most of the price series that follow the patterns of nonlinear convergence exhibit random-walk or explosive behavior when the deviations from the LOP are small. We also found that the variations in passing this test among the six categories of goods and services were fairly large, namely, 19% for perishable consumer goods, 12% for durable goods and vehicles, 12% for raw industrial materials, 11% for processed industrial materials, 7% for nonperishable consumer goods, and 5% for services. Interestingly, we found this variation matches closely, in descending order, the proportions of overall convergent cities for these six categories of goods and services, which are 84% for perishable consumer goods, 75% for processed industrial materials, 69% for durable goods and vehicles, 67% for raw industrial materials, 63% for nonperishable consumer goods, and 53% for services.

In summary of the above two subsections, our econometric analysis shows strong evidence of price convergence and hence market integration in China. Such a finding is in favor of the view that China's transition to a market economy has been quite successful during the last two decades.

C. The Determinants of Price Dispersion

The previous two subsections examine price convergence based on the methods of panel unit root test and nonlinear dynamics, which try to detect if a time series of price differential has the tendency to revert to the mean. In this subsection, we examine the determinants for the price fluctuations in China. In particular, we test if price dispersion follows a declining trend, which can serve as another indicator for price convergence. The regression results based on this methodology are reported in table 5.

From the "Overall" column of table 5, we first observe that when price dispersion is measured over all products in our sample, it follows an increasing trend at a decreasing rate. This appears to contradict our early results based on the panel unit root test and nonlinear mean reversion. However, if we investigate the trend of price dispersion for different categories of products separately, then the results in the last six columns show that for five out of the six categories of

[12] The estimated median half-live for the six vehicle types in our data is approximately 3 months; the corresponding figure for the five European countries in Goldberg and Verboven's (2005) study is 1.3 to 1.6 years. Again, the estimated speed of convergence for China seemed to be much faster than that for the European countries. However, the comparison may be biased, as the two studies covered different models of cars and used different methodologies in estimation (Goldberg and Verboven used the Levin-Lin panel unit root test).

TABLE 5.—REGRESSIONS ON THE DETERMINANTS OF PRICE DISPERSION

Independent Variable	Overall	Raw Industrial Materials	Processed Industrial Materials	Durable Goods and Vehicles	Perishable Consumer Goods	Nonperishable Consumer Goods	Services
Log distance	.0274	.000243	.0088	.0070	.0327	.0160	.0149
	(47.45)*	(0.4)	(22.62)*	(11.16)*	(50.09)*	(26.91)*	(13.79)*
Time	.0026	−.0009	−0.00002	−.000009	−.0031	.0032	−.0014
	(70.55)*	(−22.88)*	(−0.79)	(−0.13)	(−34.2)*	(53.11)*	(−5.73)*
Time squared	−.000006	.000007	.000004	−.0000004	.00001	−.00002	.00001
	(26.80)*	(29.22)*	(25.24)*	(1.09)	(27.96)*	(−40.8)*	(10.22)*
Coastal dummy	.0033	−.0070	−.0078	−.0091	.0099	.0305	−.0198
	(3.16)*	(−7.11)*	(−11.2)*	(−7.61)*	(8.43)*	(28.48)*	(−10.2)*
Constant	−.0554	.1450	.0770	.0711	.3149	−.1613	.4269
	(13.07)*	(32.84)*	(26.89)*	(13.2)*	(50.24)*	(−27.1)*	(21.02)*
Sample size	86077	64722	79057	47706	66048	56930	50272
Adjusted R^2	.3127	.0223	.1296	.0055	.0719	.1040	.0313

Dependent variable: $S_{ij,t}$, defined in equation (5).
t-statistics are in parenthesis. *Significant at 1% level.
Cities in coastal region are Beijing, Tianjing, Shijiazhuang, Dalian, Shanghai, Nanjing, Hangzhou, Ningbo, Fuzhou, Xiamen, Jinan, Qingdao, Guangzhou, Shenzhen, Haikou, and Nanning. These cities are located in China's coastal provinces: Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Haninan [the same definition of coastal provinces in Young (2000, p. 1109)].

commodities (raw industrial materials, processed industrial materials, durable goods and vehicles, perishable consumer goods, and services), the time trend has a negative coefficient. Three out of these five negative coefficients are statistically significant at 1% level. Only one category of products, nonperishable consumer goods, had an increasing trend in average price dispersion.[13] Thus, the price dispersion for most categories of products decreased in the past decade. These results indicate that the aggregation bias discussed in section V C indeed exists. To the extent that the time trend of price dispersion is better measured at more disaggregated levels, our results here are largely consistent with the findings in sections VI A and VI B. Moreover, caution should be taken in interpreting an upward trend of price dispersion obtained by this simple method of regression, for an increase in a commodity's price dispersion within a certain band is not in contradiction with the LOP, in view of the existence of the nonlinear convergence (O'Connell & Wei, 2002; Taylor & Taylor, 2004).

Next, our regression analysis here shows that the coefficient on the distance between the markets is positive and significant for all categories of commodities. This is in line with the intuition that price convergence is negatively associated with transportation costs, and is also consistent with the findings of existing literature, such as Parsley and Wei (2003) and Ceglowiski (2003).

Finally, the results on the coastal dummy seem to be quite mixed. Whereas the coefficients for four categories of commodities (raw industrial materials, processed industrial materials, durable goods and vehicles, and services) are negative and significant, they are positive and significant for the remaining two categories (perishable and nonperishable consumer goods) and the overall products. Because the coastal dummy picks up the effect of all city pairs with both cities in the coastal region, one may expect that the price convergence should be more prevalent and hence price dispersion should be smaller (a negative coefficient), as their markets opened earlier and attracted more foreign investment than the rest of China. But our findings do not confirm this prior expectation for some categories of products.

[13] This result seems to be consistent with the finding in section VI A that nonperishable consumer goods have the lowest average rate of convergence amongst all categories of goods.

D. A Comparison with Young (2000)

Young (2000) constitutes a pioneering contribution to the study of Chinese market integration. This paper extends Young (2000) in two main aspects. First, as elaborated in section IV, the current study is based on a much larger and more comprehensive data set with more categories of products and covering a longer time span. Second, the econometric method employed in this paper is more rigorous than that used in Young (2000). Based on the panel unit root test and the nonlinear mean-revision model, we find that prices converged to the LOP in China for an overwhelming majority of goods and services. Moreover, in contrast to Young (2000), we find that price dispersion across city pairs generally tended to decline over time, once we divide the overall sample into several categories of products in a regression analysis similar to Young (2000). Hence, our results cast doubt on Young's (2000) claim that regional prices in China diverged and markets in China were increasingly fragmented.

The contradictions between our findings and Young's may arise from the following three aspects. Firstly, we use a more comprehensive data set than Young, in terms of both the number of products and the time span. Secondly, although our finding that the overall price dispersion followed an upward trend seems to be consistent with Young's, such an overall measure may suffer from an aggregation bias, and we have shown that the price dispersions for most subcategories of products generally followed a downward trend. So Young's finding may be plagued by such a bias. Finally, in testing whether the LOP holds, the methods of the panel unit root test and nonlinear mean reversion employed in our

paper have the following advantages over the simple method of looking at the trend of the standard deviations of log prices as in Young (2000).

First, even in a well-functioning market economy, product prices may experience many fluctuations or cycles due to short-run informational asymmetry among different regions of the economy and various shocks to the economy. In other words, the empirical implication of the LOP is that relative prices tend to converge, rather than that prices are the same across regions or that there is no price fluctuation. The method of simply looking at the trend of standard deviation of log prices as in Young (2000) is likely to overlook the cyclical price changes and hence tends to overreject the hypothesis of price convergence. Second, as highlighted by Parsley and Wei (2003) and Taylor and Taylor (2004) and also supported by the evidence obtained in section VI B, prices more often than not follow a nonlinear convergence pattern. Under this scenario, the nondecreasing trend of the standard deviations of log prices is consistent with the possibility that the band of inaction for arbitrage activities is constant or increasing,[14] and therefore is not necessarily in contradiction with price convergence. Therefore, the methods employed in this paper yield more accurate empirical results than Young's method.

VII. Conclusion

The economic transition of former communist countries from planned economies to market economies is one of the most important global phenomena of the last two decades. As price liberalization is the necessary means to establish a full market system, it is a key element of the transition. In China, prices have been gradually liberalized through the dual-track system. Under this system, government-regulated prices and market-determined prices for some products have coexisted for a period of time while the government gradually reduced the proportion of the output under its price control. From table 1, we can clearly see that prices have been increasingly liberalized since 1990 as the share of planned prices has been steadily declining.

By applying the econometric methods of panel unit root tests and nonlinear mean reversion, our empirical analysis investigated the price movements in China with a large data set that consists of 93 products in 36 cities over a maximum of 156 months. This provides the first rigorous empirical study on the convergence to the law of one price across Chinese domestic markets. In fact, to the best of our knowledge, our empirical study represents the first application of the methodology of nonlinear mean reversion of Granger and Terasvirta (1993) and Terasvirta (1994) to the study of intranational price movements. Such a study not only enriches the literature on price convergence by adding a new piece of evidence from a large transitional economy, but also sheds light on the recent debate over how successful the gradualist reform in China has been.

Based on the criteria of price convergence that are commonly used in the existing literature, we found that prices did converge to the law of one price in China for an overwhelming majority of the goods and services in our data set. Moreover, we discovered that the patterns of price convergence in the transitional economy of China were highly comparable to those in the United States, Canada, and European countries. This supports the view that China's gradualist reform has been quite successful in effecting the transformation from a planned to a market-oriented economy, and this casts doubt on Young's (2000) proposition that China's economic reform has led to the fragmentation of its domestic markets. Furthermore, we also studied the factors affecting the overall variations of price differentials between city pairs in China, and found that for most products the variations of price differentials between city pairs appeared to decrease over time and were positively associated with the distance between two cities. These results are in line with our main finding that prices in different regions in China converged to the law of one price in the long run. In sum, our empirical study provides strong evidence in favor of the view that regional markets have been increasingly integrated in China.

[14] For example, the band of inaction could be widened by increases in wages and transportation costs, both of which have increased a lot during the past decade in China.

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APPENDIX

Data

As mentioned in the text, the price data used in this study were collected by the China Price Information Center of the State Planning Committee. Price data were collected to provide price information to the central and local governments for macroeconomic management. According to State law, the local price bureaus in 36 major Chinese cities are obliged to report price information for a specified list of products to the Price Information Center. The information must be collected from fixed local markets. For consumer goods and services, the information is collected once a month, on the 20th day of the month. For industrial materials and agricultural products, the information is collected three times a month, on the 5th, the 15th, and the 25th day of the month. The product names are uniform across all cities, and all prices must be market prices. The detailed product and service names and sample coverage are shown in table A1.

TABLE A1.—PRODUCT NAMES AND SAMPLE SIZES

Product Name	Time Range	No. of Cities	Sample Size
	Raw Industrial Materials		
Copper (electrolytic)	03/90–02/03	35	4334
Aluminum (electrolytic)	03/90–02/03	35	4157
Lead (electrolytic)	03/90–02/03	35	3945
Zinc (refined)	03/90–02/03	34	3817
Anthracite	05/93–02/03	27	1967
Pine logs (4–5.8 m long, 18–28 cm diameter)	03/90–02/03	29	2981
China fir logs (5–5.8 m long, 14–28 cm diameter)	03/90–02/03	21	1207
Nickel	02/98–02/03	25	1380
Tin	02/98–02/03	31	1839
	Processed Industrial Materials		
Hot-rolled carbon tied elemental steel	03/90–02/03	35	4101
Screwed steel	03/90–02/03	34	2761
Hot-rolled ordinary carbon angle steel	05/93–02/03	36	3521
Hot-rolled ordinary carbon wire rod	03/90–02/03	36	4704
Hot-rolled ordinary carbon medium plate	03/90–02/03	36	4403
Hot-rolled ordinary carbon sheet metal	03/90–02/03	34	3766
Cold-rolled ordinary carbon sheet metal	03/90–02/03	35	4206
Zinc-plated (galvanized) plate	05/93–02/03	36	3632
Cast pig iron (manganese)	03/90–02/03	31	3275
Gasoline (for cars)	03/90–02/03	35	2435
Diesel oil (light)	03/90–02/03	34	4395
Caustic soda (solid content $>$ 98%)	03/90–02/03	36	4362
Caustic soda (solid content $>$ 30%)	05/93–02/03	25	1559
Soda ash (first quality, content $>$98.5%)	03/90–02/03	36	4273
Sulfuric acid (Conc. $>$ 98%)	03/90–02/03	35	3682
Polythelene (high-pressure industrial use)	05/93–02/03	36	3035
Polypropylene (equal to first quality)	07/91–02/03	35	3585
Cement (ordinary)	03/90–02/03	36	4607
Cement	05/93–02/03	27	1955
Plate glass (standard 3 mm)	03/90–02/03	36	3906
Pig iron (steelmaking)	04/94–02/03	26	1138
Heavy rail	04/94–05/00	21	1077
Billet	04/94–02/03	19	1083
	Durable Goods and Vehicles		
Medium trucks (5 ton East Wind model)	03/90–02/03	31	2863
Medium trucks (5 ton Liberty model)	03/90–02/03	31	2811
Light trucks (1.75–2 ton, model 130)	10/90–02/03	36	2936
Sedan (Santana)	04/94–05/00	35	2196
Sedan (Xiali)	04/94–05/00	31	1867
Sedan (Hongqi)	02/98–02/03	34	1865
Washing machine (Little Swan, XQB50-95)	01/97–03/03	33	1669
Microwave Oven (Galanz's, WD750BS)	07/97–03/03	21	809
Refrigerator (Haier, BCD-238WF62)	06/00–03/03	23	801
Air conditioner (Chun Lan, KFR-35GW)	06/00–03/03	26	903
	Perishable Consumer Goods		
Chinese cabbage (first grade)	06/93–02/03	36	3647
Pork (Deboned, fresh)	06/93–02/03	36	3904
Potato (first grade)	06/93–02/03	36	3925
Beef (deboned, fresh)	06/93–02/03	36	3787
Mutton (deboned, fresh)	06/93–02/03	31	2587
Chicken	06/93–02/03	34	3495
Eggs (fresh, intact)	06/93–02/03	34	3705
Fresh cutlass fish ($<$ 0.5 kg)	06/93–02/03	36	3642
Silver carp ($>$ 0.5 kg)	06/93–02/03	35	3171
Apples (first grade)	06/93–02/03	34	3281
Watermelon (first grade)	06/93–02/03	33	1667
Pork	01/97–02/03	33	2277
Soybeans (top grade)	06/93–02/03	36	3531
Cucumber (first grade)	06/93–02/03	36	3870
Tomato (first grade)	06/93–02/03	36	3903
Eggplant (first grade)	06/93–02/03	36	3887
Radishes (first grade)	06/93–02/03	36	3844
Green peppers (first grade)	06/93–02/03	36	3864
Pears	01/98–02/03	33	1911
Spinach	02/98–02/03	35	1959

TABLE A1.—*(CONTINUED)*

Product Name	Time Range	No. of Cities	Sample Size
	Nonperishable Consumer Goods		
Cigarettes (Zhonghua, 84 mm)	07/97–08/03	36	2265
Monosodium glutamate	05/98–03/03	36	1669
Toothpaste (Zhonghua, 120 g, with calcium)	03/99–03/03	34	1669
Flour (ordinary or standard grade)	06/93–02/03	30	1487
Corn flour (top grade)	06/93–02/03	32	2655
Polished rice	06/93–02/03	35	3048
Flour (top grade)	01/97–02/03	36	2530
Peanut oil (first grade)	02/94–03/03	26	2018
Rapeseed oil (first grade)	01/91–09/03	25	2502
Soybean oil (first grade)	01/91–09/03	25	2520
Beer (qingdao, 335 ml, 11%)	05/98–03/03	32	1772
White wine (Wuliangye, 500 ml, 39%)	07/97–03/03	36	2330
Man's shirt (Yi'ershuang)	01/97–08/03	35	2540
	Services		
Bus ticket (monthly pass)	01/97–09/03	29	2310
Bus ticket (long distance, per kilometer)	07/97–09/03	31	2190
Rent, public housing (m^2/month)	01/97–03/03	33	2149
Rent, private housing (m^2/month)	06/00–09/03	17	698
Office rent (highest grade, m^2/month)	03/99–03/03	25	1201
Hotel room rate (3 stars, standard room)	07/97–03/03	35	2119
Water rate (household)	01/97–09/03	36	2874
Electricity rate (household)	01/97–09/03	36	2716
Gas rate (household)	01/97–09/03	26	2089
Liquid gas rate (household)	01/97–03/03	36	2531
Telephone line (per line per month)	07/97–03/03	36	2449
Public telephone (per 3 minutes)	07/97–03/03	36	2183
Mobile phone (per minute)	07/97–09/03	36	2516
Public hospital registration fee	01/97–09/03	36	2819
Injection fee	01/97–09/03	36	2752
Operation fee for appendectomies	01/97–09/03	36	2875
Haircut (standard, wash, cut, and blow dry)	01/97–09/03	26	845
Dry cleaning (woolen suit)	07/97–05/00	25	920

The descriptions in parentheses are product brand names and specifications.

The 36 cities are Beijing, Changchun, Changsha, Chengdu, Dalian, Fuzhou, Guangzhou, Guizhou, Ha'erbin, Haikou, Hangzhou, Hefei, Huhehaote, Jinan, Kunming, Lasha, Lanzhou, Nanchang, Nanjing, Nanning, Ningbo, Qingdao, Shenzhen, Shenyang, Shijiazhuang, Taiyuan, Tianjin, Wulumuqi, Wuhan, Xi'an, Xining, Xiamen, Yinchuan, Zhengzhou, Chongqing, and Shanghai. They include four municipalities and all the capital cities for the 28 provinces and autonomous regions in mainland China.