Pork price transmission and efficiency in China

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Key words: China; vector error correction terms; efficiency; transaction costs; regional integration;

1. Introduction

Overall market performance may be indicated by spatial price behavior in regional markets and spatial market performance. The relationship between market proximity and integration is widely acknowledged. The shorter the geographic distance between two markets, the more they trade and the quicker their prices transmitted. The study of price transmission has usually tried to characterize the degree of co-movement of prices across spatially separated markets. Since prices are the most readily available and often the most reliable information on developing country marketing systems, market integration studies have almost exclusively referred to events resulting in price changes. Most specifically, market integration is restricted to the interdependence of price changes across spatially separated locations in a market. Vector error correction model can be used to capture the speed or strength of special price transmission.

However, the influence of trade flows between markets on the speed or strength of price transmission has not yet been documented in the literature. If proximity and trade flows influence price dispersion, then it presumably also influences price transmission. We therefore hypothesize that whether and how price signals are transmitted between markets depends on geographical and political proximity and also trade flows , and we propose an empirical test of this hypothesis based on an analysis of the determinants and efficiency of pork price transmission in China.

China has seen drastic nutrition transition and food structure change with rapid economic growth in the past three decades. Specifically, the traditional fiber-dominated food system is being replaced by a western-style meat-dominated diet. More than 60% of meat consumed in China is pork. Already the world's largest pork producer and consumer. Increasing local food supply is a central political goal in China, which has been affected severely by high pork import prices in recent years. Imported pork is becoming more competitive in China as Chinese pork production costs rise and animal disease outbreaks, environmental threats, and food safety concerns constrain growth of China's hog industry. Extensive policy intervention (the government macro-control and subsidy for hogs) by the Chinese government has contributed to consolidation in the country's pork industry but has not stabilized the market. However, most inter-regional shipments of pork within China are limited by lack of reliable transportation and temperature-controlled storage, which make the prices of piglet, hog and pork in different provinces vary in a large scale. Policy against this background, an improved understanding of price dynamics and market integration in the region can contribute to the formulation of welfare-enhancing policies.

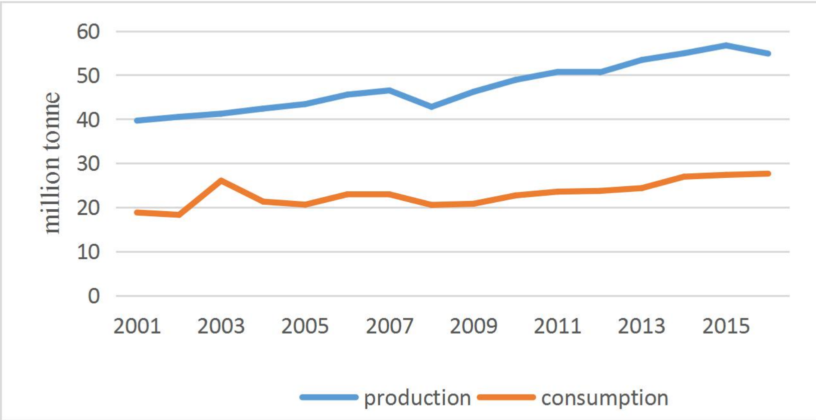
The objective of this research is to measure the speed and efficiency of spatial price adjustments in Chinese pork markets. The rest of this paper is structured as follows. In the following section we provide information on the Chinese pork market. In section 3 we review the literature and theory on the relationship between proximity, trade and price transmission. Sections 4 and 5 present our data and empirical approach respectively, and section 6 and 7 show our results and concludes specifically.

2. Chinese pork market

In this section we present an empirical description of the Chinese economy and Chinese pork market from 2000 to 2015, highlighting supply and demand, prices, domestic trade infrastructure and domestic trade practices of piglet , hog and pork. As we all know, China has 23 provinces, 4 municipalities and 5 autonomous regions, measuring more than 5500 kilometers from north to south, and 5200 km from east to west with the total land area of 9,634,057 square km. The population has increased from 1295.33 in 2000 million to 1374.62 million in 2015. The larger part of the population lived in rural areas around 63.78% in 2000 but decreased to 43.90% in the year of 2015 with the increase of urbanization.

Pork in China dominates both in meat production and consumption of households. According to official Chinese statistics in 2015, the total output of meat was 86.25 million tons, the pork production was 54.87 million tons, accounting for 65.1% of total meat production. The quantity of live pigs in China was 451.33 million, and the number of slaughtered pigs was 788.25 million, both are ranked in the world's first place, and almost accounting for half of the world's total amount. While pork consumption was 20.1 kg per capita per year accounting for 58.09% of total meat (pork, beef, mutton and poultry) consumption.

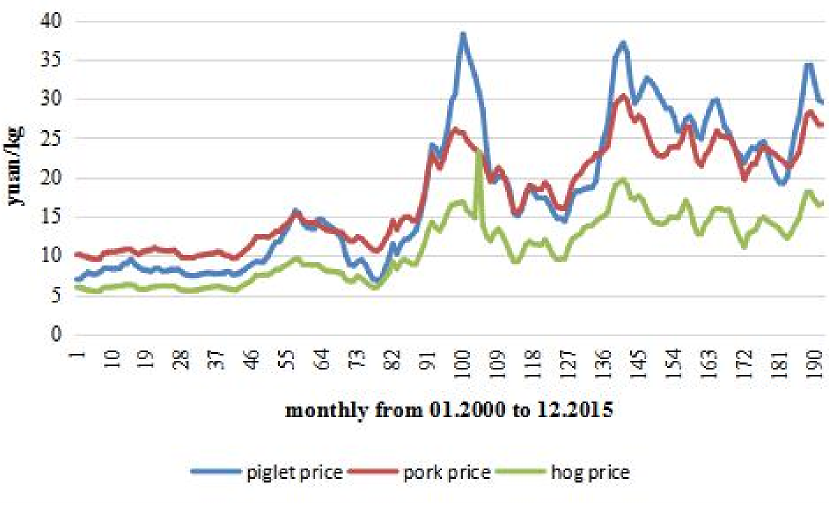
Figure 1 Annual pork production and consumption in China 2000 - 2015



Source: National Bureau of Statistics of China 2001-2016 (Annual pork consumption is calculated based on per capita consumption data)

Historically, China has been a mostly self-sufficient pork economy. Chinese pork markets are linked to international markets by trade and is pretty volatile now. Rising pork imports in China is contributed to the rising prices in domestic pork market. Increasing integration into international pork markets over the past decades has increased the regions' exposure to global price shocks and growing agricultural price volatility. High pork prices in China likely stem from the rising costs of hog production in China. Feed is the largest of the hog production expenses in China, accounting for about 60% of the total. Chinese officials use a variety of policy measures that are intended to reduce cyclical fluctuations in pork production. Measures include subsidies, tax breaks, and market interventions in hog farming and pork processing Government officials often play a coordinating role by recruiting farmers as suppliers, arranging access to land and bank loans, and brokering deals with investors or final customers.

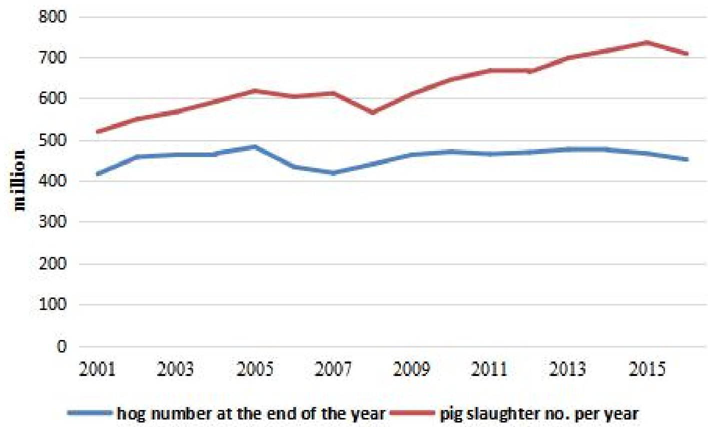
Figure 2 Piglet hog and pork prices in China Jan. 2000 - Dec. 2015



Source: China Livestock and veterinary Yearbook 2001-2016

Overall, production of pork in China is primarily undertaken by households. Most local supply of pork is consumed in the rural areas in which it was produced. Cross-province trade flows of pork are sometimes important in provinces such as Beijing and Shanghai because of the different hog raising structures and lower production. In coastal provinces, hog production is increasingly dominated by large-scale farms operated by companies. In some cities, hog production is banned due to environmental concerns. In western provinces, slaughter hogs are usually raised by individual small-scale farmers. These difference lead to trade diversions and cross-province trade are observed from main pork-producing regions to lower producing regions. There are three main hog raising regions according to rich natural resources and convenient transportation: (1) Sichuan province (with Guizhou province and Chongqing City); (2) Yellow and Huai river region(included Henan province, Hebei province and Shadong province) ; (3) Middle and lower reaches of Yangtzi river (included Hunan, Hubei, Jiangsu Anhui provinces and Shanghai City).

Figure 3 Hog keep no. at the year ending and pig slaughter no. Per year in China 2000-2015



The average distance between capital cities is 1724.602 km, and has a maximum of 4747 km and a minimum of 125 km. The density of the spatial network is not even. All districts in the west are typically remote and more dispersed. Prices in different provincial markets (spatial prices) within China differ from each other due to transaction costs. This is to some extent confirmed by the higher correlation of prices in different provincial markets the closer these provincial markets are located to each other. Beyond 2500 km the correlation decreases rapidly (see Figure 3, 4 and 5).

Figure 3 Distance between capital cities and correlation of piglet market prices

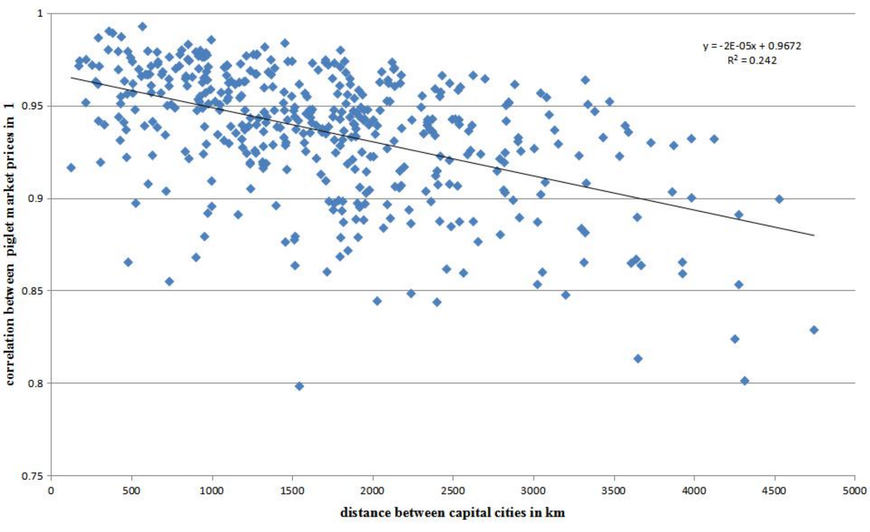


Figure 4 Distance between capital cities and correlation of hog market prices

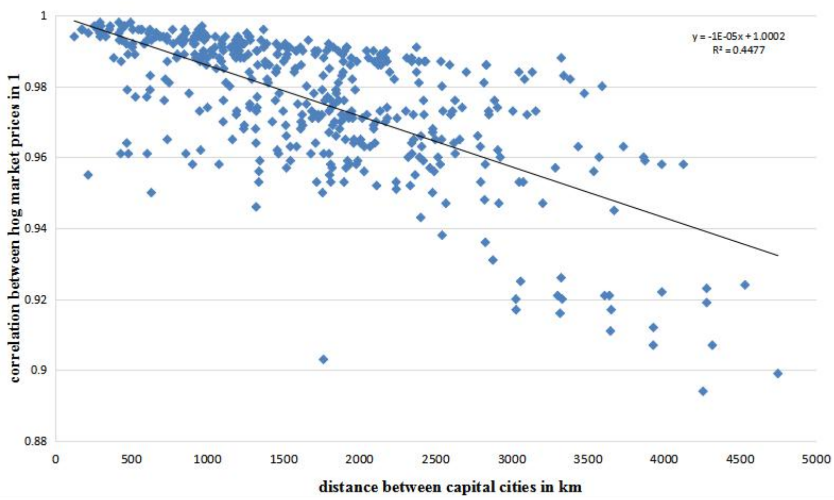
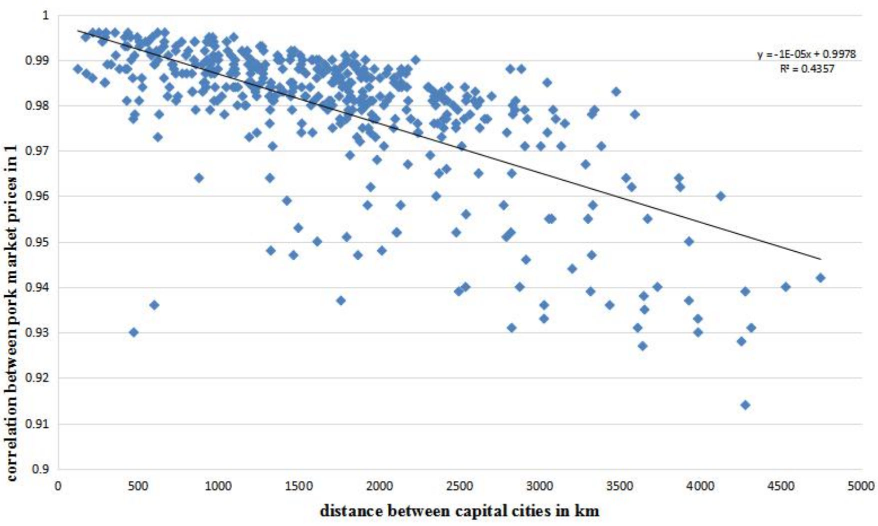


Figure 5 Distance between capital cities and correlation of pork market prices



Source: own calculated based on data from National Bureau of Statistics of China 2001-2016, China Livestock and veterinary Yearbook 2001-2016, http://map.baidu.com

Transport of piglet, pig and pork is mainly undertaken through highway network in China. Prior and green pass allowance are provided by traffic department for pork trading. Logistics companies for transporting service are developed well among different markets in recent years. As the economy of provinces varies and regional development is not balanced, the quantity and quality of roads between them varies. So there are reasons to suspect that spatial price efficiency in the Chinese pork market may be higher with good infrastructure .

3. Theory and literature

In recent studies, researchers have investigated spatial price transmission in markets of various agricultural output (Greb, von Cramon-Taubadel, Krivobokova, & Munk, 2013; Acosta, Ihla, & Robles, 2014; Tan & Zapata, 2014; Zhepeng Hu & B.Wade Brorsen, 2017).

Typically, agriculture economists use the law of one price (LOP) as the criterion for spatial price transmission. The LOP states that the price difference for the same product at different locations should be no more than the transaction costs of trading the product between the two markets. In this case, there is no incentive for trade and correspondingly no transmission of shocks. Otherwise, if prices differ by more than the costs of trade between two markets, an arbitrage opportunity occurs, trade is triggered and shocks are transmitted, which will decrease the price in the higher price market and increase the price in the lower price market until the LOP is met again, this is the price transmission procedure which take place either directly or via third spatially separated markets. Prices are consequently thought of as being connected by a stable long-run equilibrium, with attraction forces of this equilibrium resulting in the correction of temporal deviations that occur due to supply or demand shocks. Thus, the extent of spatial price adjustment could not only be measured by how often violations of LOP occur, but also by the speed with which such violations are corrected.

We use time series methods to determine the speed and direction of price adjustments. The vector error correction model (VECM), which only depends on price data, is a popular model to measure spatial price transmission. The VECM not only helps determine how fast violations of spatial equilibrium between two locations are corrected but also shows price dynamics. In a VECM, the transmission of supply and demand shocks between two markets depends on the difference between the prices in these markets. TVEM is based on price data alone and has been criticized because it neglects the role of transaction costs (Barrett, 2001; Meyer, 2004). While threshold vector error correction models (TVECMs) have been developed to incorporate effects of transaction costs into price transmission analysis. In a TVECM, transaction costs from one market to another market can be estimated by a threshold estimator. A large number of studies have used TVECM to analyze spatial price transmission (Meyer, 2004; Ben-Kaabia & Gil , 2007; Surathkal, Chung & Han , 2014). But if there is no threshold effects in the error correction terms after doing related tests, this model will fail to capture the relationship between transaction costs and market integration.

As whether and how prices in spatially separate markets co-move is closely related to the costs of trade and communication between these markets. The literature on spatial price transmission has dealt with various factors that constrain the pass-through of price signals from one market to another. In our research we are of great interest in price transmission efficiency between different provinces which share various distances between market pairs. Related study have been done for finding the determinants of market integration. In table 1 we collect six closely related papers to our research which address the question of the determinants of integration. Their common methodological feature is that they proceed in two stages. They first measure spatial market integration in their relevant geographical setting. Then, they regress the measure of market integration on a number of explanatory variables.

Table 1. Summary of the Literature

Authors	Date	Location	Product	Estimation methods	Factors affecting integration
Goodwin, et al.	1991	US	livestock	Co-integration tests	Distance between markets, the amount of market information reflected in prices at a particular market, the market volume and the degree of concentration in the packing market.
Goletti, et al.	1995	Bangladesh	Rice	Co-integration coefficients dynamic multipliers measures of the speed of adjustment	Road distance and density, railway density, communication, volatility of policy and the degree of dissimilarity in rice self-sufficiency
Ismet, et al.	1998	Indonesia	Rice	Multivariate Johansen approach	Government interventions, rice production, kilometers of roads and a dummy that controls for the periods of self-sufficiency
Gonzalo, et al.	2012	Indonesia	Rice,Soybean, Maize, Sugar &Cooking oil	Johansen's co-integration test	Remoteness, contiguity, infrastructure, income per capita and output of the relevant commodity normalized by the population of the province.
Carolin, et al.	2016	West African	Rice	Linear and threshold cointegration tests	Great circle distance, road distance , border, contiguity and same language
Zhepeng Hu,et al.	2017	US	Urea	VECM and Parity Bounds Model	Monthly urea prices and transportation costs

According to different countries and different type of agricultural product, factors affecting integration varies. Hernandez-Villafuerte (2011) finds road distance influence the long-run elasticity of price transmission between rice markets in Brazil significantly with a negative direction. Mengel (2016) tests for the presence of distance and border effects on the transmission of rice prices between markets in Western Africa and finds that the likelihood of cointegration falls with increasing distance between markets, positive effect of contiguity on cointegration is also robustly estimated. Goletti (1995) uses the degree of dissimilarity in rice production of various markets. He explains the more dissimilar the markets, the more incentive they have to trade with each other. Production affects market integration through the degree of dissimilarity in product self-sufficiency of various markets. If market i is a surplus market and market j is a deficit market, then the likelihood that i and j are linked by trade in a product is higher than if both markets were surplus or deficit, ceteris paribus. Verela(2013) also introduce infrastructure measures the quality of roads and real per capita income to analyze the determinants of price differences and market integration.

However, market integration and price transmission studies use different econometric specifications, estimation approaches and types of data (frequency, spatial aggregation). Hence, the results of different studies are not always directly comparable. Furthermore, as the common methodological feature of these studies is that they proceed in two stages. In the second step, the variance of the observations on the dependent variable (the measure of market integration) will induce heteroscedasticity.

Though distance between markets has been acknowledged as an important factor affecting market integration and inferences related to the drivers of revealed patterns of integration are very informative, formal empirical analysis of the links is pretty rare. Meanwhile, the effect of distance and potential trade flows on the speed of price adjustment has not been done in the literature. What is more, analysis of price transmission efficiency by using stochastic frontier model is a great innovation in our research.

4. Data

We employed 90 monthly price series for piglet, hog and pork in 30 Provinces (capital cities) in China. We considered only prices for domestic pork, piglet and hog because research has indicated that local product varieties are not close substitutes (Demont et al. 2013a; 2013b). For example, if we included prices for local pork varieties in our analysis we would risk confounding border and distance effects with the influence of product heterogeneity and imperfect substitution on price transmission. The price series are taken from China Livestock and veterinary Yearbook. Most of the series start in the early 2000s and end in 2015. The markets considered were retail markets. To ensure comparability, we converted all series to the Chinese yuan per kilogram (yuan/kg). Each series included at least 181 and at most 192 observations(16 years of monthly observations). Geographically, the series cover almost all over China. There are three types of price series for each city, namely piglet, hog and pork prices separately. All series were considered and numbered accordingly, e.g. Beipi (piglet price of Beijing), Beiho(hog price of Beijing), Beipo(pork price of Beijing). Tibet was not included in the estimation due to incomplete data. The means of the piglet/ hog/ pork price series in different provinces vary between 11.95/ 10.18 / 15.95 and 24.25/ 12.37/ 20.51 yuan per kg specifically (Table 2).

Table 2. Summary statistics of piglet, hog and pork prices

	Piglet prices				Hog prices				Pork prices			
Series label	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max
Bei	17.14	7.93	5.00	36.65	11.12	3.85	5.87	19.85	16.49	6.04	8.06	28.81
Tia	18.47	9.24	5.57	37.85	11.00	4.05	5.35	19.85	18.04	6.40	7.5	31.93
Heb	16.79	8.78	5.24	37.66	10.63	4.08	4.77	19.64	17.12	6.03	8.57	30.35
Shx	21.50	10.57	5.31	45.45	10.65	4.07	4.57	19.25	17.25	6.20	8.04	30.28
Inn	22.51	9.70	5.50	45.04	11.15	4.17	5.17	18.65	17.13	6.36	7.31	30.05
Lia	23.73	14.14	4.46	53.12	10.55	4.12	4.47	19.60	17.36	6.49	7.85	32.02
Jil	21.44	12.36	5.08	50.76	10.51	4.11	4.42	19.62	16.65	6.05	7.00	29.82
Hei	18.99	10.58	4.00	47.52	10.27	4.02	4.00	18.98	15.95	6.01	6.50	29.19
Shh	18.59	8.22	7.58	37.97	11.54	3.82	6.25	20.02	20.51	6.00	12.05	31.75
Jis	11.95	5.96	3.88	29.27	10.18	3.84	4.83	18.68	17.40	5.77	9.37	29.34
Zhe	14.01	6.08	5.56	29.08	11.25	3.97	5.61	20.07	17.14	6.21	6.95	30.06
Anh	14.95	7.22	5.29	33.98	10.99	4.07	4.98	19.88	18.01	5.84	9.47	30.25
Fuj	21.75	12.26	6.44	54.34	11.38	3.73	5.65	19.80	16.95	5.06	10.00	27.72
Jix	18.37	9.18	5.96	37.84	11.24	4.05	5.42	20.20	18.13	5.99	9.74	30.08
Shd	13.23	6.57	4.79	29.02	10.53	3.96	5.13	18.84	17.55	6.24	9.00	30.42
Hen	18.21	9.82	5.16	42.71	10.58	4.07	4.95	19.24	17.28	6.15	8.92	29.54
Hub	19.87	9.98	6.14	43.82	10.77	4.11	4.89	19.86	18.56	6.21	10.00	31.2
Hun	20.40	11.09	5.85	49.21	11.04	4.15	5.40	20.38	18.15	6.38	9.48	31.43
Gud	20.94	11.17	7.36	55.69	11.72	3.80	6.58	20.07	17.84	5.13	10.91	28.43
Gux	13.58	6.88	4.72	30.08	10.48	3.94	5.32	19.04	17.92	5.75	9.81	30.21
Hai	16.42	7.49	6.73	37.26	11.79	3.58	6.85	20.65	18.57	6.85	9.00	30.33
Cho	14.23	7.38	4.46	34.22	10.29	4.40	4.35	20.45	16.97	6.25	8.86	30.8
Sic	13.54	6.58	5.44	27.94	10.41	4.43	4.4	20.21	17.66	6.70	8.5	31.53
Gui	14.70	7.67	5.2	33.49	11.25	4.56	4.8	20.42	18.10	6.95	8.87	31.46
Yun	16.49	8.76	6.6	37.21	10.50	4.32	4.81	20.29	17.45	6.80	8.83	30.94
Sax	20.64	11.49	3.2	50.23	10.47	4.11	4.37	19.44	17.16	6.52	7.29	30.09
Gan	22.15	9.93	7.63	40.92	10.98	4.32	4.52	20.83	17.92	6.77	7.97	32
Qin	24.25	13.28	8.03	61.2	12.37	4.56	4.88	23.66	18.74	6.18	10	32.24
Nin	20.70	8.85	6.95	43.33	10.81	4.27	4	19.82	17.20	7.18	6	31.4
Xin	20.33	9.25	6.38	38.21	11.08	4.10	5.06	20.23	18.35	6.42	7.4	31.87
Chi	17.87	8.99	6.84	38.23	10.86	4.16	5.45	23.18	17.64	6.16	9.56	30.35

5. Methods

5.1 Vector error correction model (VECM)

As a popular model for spatial price analysis, the VECM estimates price adjustment as the impact of a change in one price on another price. We use

P_t^i P_t^j

bivariate VECM between the price of *i* province and price of *j* province . In our setting, the VECM takes the following form:

$$\begin{bmatrix}\Delta P_t^i \\ \Delta P_t^j\end{bmatrix} = \begin{bmatrix}\varphi_1 \\ \varphi_2\end{bmatrix} + \begin{bmatrix}\alpha_1 \\ \alpha_2\end{bmatrix}\left[P_{t-1}^i - \beta_0 - \beta_1 P_{t-1}^j\right] + \sum_{m=1}^{k}\begin{bmatrix}\delta_{1m} & \rho_{1m} \\ \delta_{2m} & \rho_{2m}\end{bmatrix}\begin{bmatrix}\Delta P_{t-m}^i \\ \Delta P_{t-m}^j\end{bmatrix} + \begin{bmatrix}\varepsilon_{1t} \\ \varepsilon_{2t}\end{bmatrix} \qquad (1)$$

Where *t* is an index of time, $\alpha, \beta, \delta, \rho$ and φ are parameters to be estimated, and ε are white noise disturbances. $P_{t-1}^i - \beta_0 - \beta_1 P_{t-1}^j$ in Equation (1) refers to the error correction term (*ECT*), captures deviations from the long-run equilibrium relationship between P_t^i *and* P_t^j *. Hence* $ECT_{t-1} = P_{t-1}^i - \beta_0 - \beta_1 P_{t-1}^j$ *equals to zero* when these related prices are in equilibrium. We are particularly interested in the parameters α which measures the rate at which deviations from equilibrium are corrected, i.e., the speed of spatial price transmission.

Equation (1) is estimated by using the two-step method proposed by Engle and Granger (1987) . Firstly, estimate the long-run relationship between price pairs of i provinces and j provinces by using OLS to obtain an estimator of $u_{t\text{-}1}$ (residuals) from Equation (2):

$$P_t^i = \beta_0 + \beta_1 P_t^j + u_t \qquad (2)$$

and then using the estimated lagged residuals instead of the $ECT_{t\text{-}1}$ when estimating (1), again using OLS.

Before estimating, we check the data stationarity by using Augmented Dickey Fuller (ADF) unit root to test both in data levels and first differences. ADF test lag lengths are determined using the Akaike information criterion (AIC). If price level data are non-stationary, then the first differenced price data are tested. If first differences are stationary, the data are said to be I(1). Then cointegration test are conducted for I(1) data by conducting Johansen's cointegration test. If prices series are cointegrated, an error correction model needs to be used. After confirming cointegration, the null hypothesis of no threshold effects is tested. All these tests and estimation are performed in statistical software R.

5.2 Determinants of market integration

Until now, no matter researchers try to find factors that affecting market integration or evaluate the efficiency of price transmission (see literature review part), they commonly proceed their analysis in two stages. The dependent variable in their second step is estimated from the first step, this will generate a loss of inefficiency in the second-step measurement. What's more, if the sampling uncertainty in the dependent variable is not constant across observations, the regression errors will be heteroscedastic and ordinary least squares (OLS) will introduce further inefficiency and may produce inconsistent standard error estimates. If sampling error comprises a larger share of the variation in the dependent variable and this uncertainty varies greatly across observations, appreciable gains in efficiency can be achieved through the use of a pair of alternative feasible generalized least squares (FGLS) estimators that we describe below.

We use FGLS to estimate the determinants of market integration. Instead of using the cointegration test status of price pairs as the dependent variable in the second step, we add the absolute alpha values ($|\alpha_1|+|\alpha_2|$) for each pair of prices estimated from Equation (1), and use as dependent variables ,independent variables are chosen from Table 2 .

The 30 price series for each type of product were combined to form $[(30^2-30)/2] = 435$ price pairs separately for the subsequent analysis. In the empirical specification of transaction costs we have used several variables to approximate these cost components. A large component of transaction costs concerns transport costs. Transport costs, in turn, are determined for a substantial part by distance traveled. In order to account for transport costs we have included distance between capital cities of provinces, other costs, e.g. information costs, might also be related to distance.

A border dummy takes the value 1 if the cities in one pair share a common border. The covariate border was obtained from the geography of China. Keeping all other factors constant, we expected that shared borders between two provincial markets would create more impediments to trade, information flows and price co-movement.

In order to capture the effect of self-sufficiency of pork on price transmission , we consider both production and consumption in various market pairs. The degree of dissimilarity is measured by total pork production and consumption, and is denoted by prodctioni for province i , productionj for province j, etc. The more dissimilar the markets, the more incentive they have to trade with each other. Trade affects market integration through the degree of dissimilarity in product self-sufficiency of various markets. We also introduce the potential trade quantity variable which equals to total production minus total consumption If market i is a surplus market and market j is a deficit market, then the likelihood that i and j are linked by trade in a product is higher than if both markets were surplus or deficit. As the potential trade flows between two provinces are pretty difficult to get, we use the difference between the trade flows of two provinces to see if it is net surplus or net deficit.

We also introduce the highway distance per capita for market pairs as infrastructure variable to measure the quantity of roads and real per capita income difference between two markets to capture demand-push effects.

Table 3 Summary statistics of market pair variables

Variable	Mean	Std Dev	Minimum	Maximum
Distance (km)	1724.60	912.46	125	4747
Common-border (yes=1,otherwise 0)	0.15	0.36	0	1
Highway quantity per capita (km)	7625.12	3218.74	1554.44	20409.47
Production i(million tons)	1.79	1.33	0.07	5.12
Production j(million tons)	1.87	1.54	0.07	5.12
Consumption i (million tons)	0.88	0.63	0.047	3.22
Consumption j (million tons)	0.96	0.83	0.047	3.22
Trade i (million tons)	0.90	0.99	-0.48	3.61
Trade j (million tons)	0.91	1.02	-0.48	3.61
Surplus (million tons)	-0.01	1.45	-3.94	4.09
Income per capita (yuan/year)	13266.68	16709.51	11	65987

Instead of assuming the structure of heteroskedasticity, we could estimate the structure of heteroskedasticity from OLS. First we estimate $\hat{\Omega}$ from OLS, and then we use $\hat{\Omega}$ replace of Ω.

$$\hat{\beta}_{FGLS} = (X'\hat{\Omega}^{-1}X)^{-1}X'\hat{\Omega}^{-1}y \tag{3}$$

There are many ways to estimate FGLS. But one flexible method is to assume that

$$\mathrm{var}(u|X) = u^2 = \sigma^2 \exp(\delta_0 + \delta_1 x_1 + \delta_2 x_2 + \ldots + \delta_k x_k) \tag{4}$$

By taking log of the both sides and using $\hat{u}^2$ instead of u^2, we could estimate

$$\log(\hat{u}^2) = \alpha_0 + \delta_1 x_1 + \delta_2 x_2 + \ldots + \delta_k x_k + e \tag{5}$$

The predicted value from this model is

$$\hat{g}_i = \mathrm{lo\hat{g}}(\hat{u}^2) \tag{6}$$

then we convert it by taking the exponential into.

$$\hat{\omega}_i = \exp(\hat{g}_i) = \exp(\mathrm{lo\hat{g}}(\hat{u}^2)) = \hat{\hat{u}}^2 \tag{7}$$

We now use WLS with weights $1/\hat{\omega}_i$ or $1/\hat{\hat{u}}^2$

5.3 Stochastic frontier spatial price transmission efficiency

We use a stochastic frontier analysis approach to investigate the differences in efficiency and the impact of potential determinants of efficiency in Chinese pork markets. When we look at the graphs of the distances between capital cities and the adjustment speed (alpha summations), we see that price pairs that are equally proximate can have very different alpha sums. So that make we think of a statistic frontier model, where the frontier is the benchmark (the highest possible alpha summation for a given distance), and different pairs that are separated by that distance are more or less "efficient" (close to the frontier). So in this part of our analysis we estimate a frontier regression in which the dependent variable was a error correction term (the sum of the two absolute value of error correction terms for one pair of prices) of a price pairs as estimated above, and the independent variables were measures of between the prices in questions to model why some pairs are more efficient with faster transmission than others that are equally proximate. The basic stochastic frontier model can be defined as follows:

$$y_{it} = f(x_{jit}; \beta_j) * \exp\{v_{it}, u_{it}\} \qquad (8)$$

where the adjustment parameter sums y is a function $f(\cdot)$ of the j different variables x described in table 2 for province i and j in period t. The functional form $f(\cdot)$ is specified as the appropriate function. β represents a vector of parameters to be estimated, and wit is the composed error $w_{it} = v_{it} - u_{it}$. The first component v_i is defined as a pure random error (white noise) independently and identically distributed as N(0, σ_{it}^2) (Aigner et al., 1977). The second error-term u_{it} is a systematic and non-negative random variable (Schmidt and Sickles, 1984), which is assumed to be under the province's control. We assume a half normal distribution for the inefficiency term. As there are a large volume of literature introducing stochastic frontier description, we omitted the related details description here. For us, adjustment parameter sums stand for our "output", determinants of market integration showed in table 2 are our "input". We expect the shorter the distance between two markets, the more efficient of the price transmission between markets.

6. Results

6.1 Results of unit root tests , cointegration tests and VECM

The ADF test (Dickey & Fuller 1979) is used to test for unit roots. The lag lengths for the ADF tests are determined using AIC. The ADF test fails to reject the null hypothesis of a unit root in all of the price series in levels, but rejects this null hypothesis for all of the series in first differences (Table 4).

Table 4 unit-root tests of piglet, hog and pork prices

Series label	ADF statistics (price level)	ADF Statistics (price difference)	Series lable	ADF statistics (price level)	ADF Statistics (price difference)	Series lable	ADF statistics (price level)	ADF Statistics (price difference)
Beipi	-2.61	-7.71	Beiho	-2.19	-9.30	Beipo	-1.73	-9.41
Tiapi	-1.97	-8.76	Tiaho	-1.88	-9.26	Tiapo	-1.55	-9.02
Hebpi	-2.70	-7.54	Hebho	-2.01	-9.46	Hebpo	-2.08	-9.49
Shxpi	-2.40	-7.68	Shxho	-2.00	-8.85	Shxpo	-2.00	-8.87
Innpi	-1.73	-7.89	Innho	-1.44	-8.10	Innpo	-1.71	-8.01
Liapi	-2.45	-7.74	Liaho	-2.09	-9.32	Liapo	-2.13	-9.06
Jilpi	-2.57	-8.65	Jilho	-2.20	-9.17	Jilpo	-2.30	-9.08
Heipi	-2.35	-7.33	Heiho	-2.26	-9.58	Heipo	-2.19	-9.51
Shhpi	-1.50	-8.37	Shhho	-2.07	-9.32	Shhpo	-1.44	-8.48
Jispi	-2.38	-8.14	Jisho	-2.16	-9.52	Jispo	-1.84	-8.66
Zhepi	-1.96	-6.89	Zheho	-2.06	-9.11	Zhepo	-1.11	-7.83
Anhpi	-1.64	-7.38	Anhho	-2.11	-9.01	Anhpo	-1.61	-8.84
Fujpi	-2.26	-7.97	Fujho	-1.94	-9.89	Fujpo	-1.12	-7.90
Jixpi	-1.63	-8.37	Jixho	-2.17	-9.57	Jixpo	-1.48	-8.58
Shdpi	-2.27	-7.39	Shdho	-1.98	-9.30	Shdpo	-1.89	-9.33
Henpi	-2.19	-7.56	Henho	-1.98	-9.08	Henpo	-1.63	-8.42
Hubpi	-2.25	-8.80	Hubho	-1.95	-9.00	Hubpo	-1.44	-9.08
Hunpi	-2.11	-7.61	Hunho	-1.91	-8.52	Hunpo	-1.74	-8.68
Gudpi	-2.26	-7.73	Gudho	-2.02	-9.11	Gudpo	-1.50	-8.30
Guxpi	-1.96	-8.02	Guxho	-1.80	-8.23	Guxpo	-2.01	-11.52
Haipi	-2.05	-7.44	Haiho	-1.43	-9.00	Haipo	-0.64	-9.14
Chopi	-2.30	-8.28	Choho	-1.82	-8.84	Chopo	-1.82	-8.70
Sicpi	-2.17	-8.65	Sicho	-1.53	-8.02	Sicpo	-1.81	-8.19
Guipi	-2.24	-8.10	Guiho	-1.48	-8.27	Guipo	-1.31	-9.12
Yunpi	-1.91	-7.01	Yunho	-1.60	-7.94	Yunpo	-1.02	-7.51
Saxpi	-2.46	-8.41	Saxho	-1.94	-9.05	Saxpo	-1.55	-8.68
Ganpi	-1.69	-6.86	Ganho	-1.81	-8.72	Ganpo	-1.60	-8.18
Qinpi	-1.74	-6.70	Qinho	-1.75	-8.92	Qinpo	-1.44	-8.86
Ninpi	-2.33	-9.51	Ninho	-1.60	-7.80	Ninpo	-1.61	-9.42
Xinpi	-1.67	-8.83	Xinho	-1.39	-7.78	Xinpo	-1.68	-8.23
Chipi	-2.29	-7.65	Chiho	-1.64	-10.26	Chipo	-1.81	-9.04

The results of the Johansen's test indicate that there is strong evidence to reject the null hypothesis of no cointegration between P_t^i and P_t^j, suggesting that a long-run cointegration relationship exists between the price of i province and prices of j province in terms of pork, piglet and hog. As we have 435 price pairs for piglet, hog and pork separately. It is difficult to show in a table like ADF test results. If readers are interested , please feel free to contact authors to check. Both tests are conducted using the statistical software R in the "tsDyn" library.

After estimate the VECMs in equations for each of the 435 piglet, hog and pork price in province i with the prices in province j, we sum the adjustment parameter alphas of each price pair to get the alpha sums, results are presented in Table 4. Turning to the results for VECMs we see that the average adjustment parameter estimated for pork prices (0.36) and hog prices (0.38) is higher than piglet prices(0.20). The minimum and maximum figures also experience this trend.The lager the alpha sums , the quicker the price in province i react to the adjustment of price in province j. For example, the largest alpha sums are from the VECM estimation of Sichuan Province and Chongqing municipality, which are in right next to each other. Chongqing city are independent from Sichuan in 1997.

The proposed approach VECM to assess market integration makes it possible to exactly locate market failures and to compare regions according to the speed of price adjustment. The degree of market integration in the Chinese market is shown to be higher in developed districts and the evidence suggests that this is caused by closer distance and lower transaction costs. The western region also shows notoriously low levels of market integration which are likely to be due to high transaction costs.

Table 5. Evaluated parameters of price transmission speed

Variable	Obs	Mean	Std. Dev.	Min	Max
alphapo	435	0.36	0.15	0.07	1.13
alphapi	435	0.20	0.09	0.02	0.60
alphaho	435	0.38	0.16	0.09	1.19

6.2 Determinants of price transmission

We compare the results estimated from OLS and FGLS in table 5. In the second and third columns we try to capture the characteristics of production and consumption in i and j provinces separately. In the fourth and fifth columns we use trade in i and j to see the effect of trade flows. Overall, the standard errors are smaller when estimate using FGLS than OLS, here we just describe the results of FGLS. Distance seems to affect price transmission negatively in pork market, given that we decrease 1 km of the distance between two markets, the speed of price adjustment increase 8.54%. So, for a given degree of distance, two contiguous provinces are more likely to be integrated, given that transportation is less costly.

From column 3, we could find that the coefficient of differences of income per capita is negative, this means the larger gap of the income per capita between two markets, the slower the price adjust. We do not find any significant influence of common borders on the speed of price transmission. One interesting finding is that related to the self-sufficiency hypothesis. The results for the market for pork suggest that market integration is related to production and consumption. More production or less consumption leads to more market integration. The quantity of highway of market pairs owned has a positive effect on the speed of price transmission which is consistent with our expectation. When we take a look at column 5, some different results could be found, e.g. trade flows of market pairs have opposite direction of effects.

Table 6. Determinants of pork price transmission speed in China

	OLS	FGLS	OLS	FGLS
VARIABLES	alphapo	walphapo	alphapo	w1alphapo
lnd/wlnd	-0.0933***	-0.0854***	-0.0928***	-0.108***
	(0.0144)	(0.0134)	(0.0143)	(0.0220)
lndpci/wlndpci	-0.0127**	-0.0123**	-0.0118**	0.0144***
	(0.00523)	(0.00518)	(0.00521)	(0.00486)
commonborder/wcommonborder	-0.0199	-0.0328	-0.0243	0.0248
	(0.0238)	(0.0264)	(0.0237)	(0.0245)
productioni/wproductioni	0.0174**	0.0169**		
	(0.00708)	(0.00682)		
productionj/wproductionj	0.0303***	0.0235***		
	(0.00711)	(0.00697)		
cvpi/wcvpi	-0.0372**	-0.0355**		
	(0.0146)	(0.0150)		
cvpj/wcvpj	-0.0275**	-0.0188		
	(0.0134)	(0.0120)		
tradei/wtradei			0.0143**	-0.00104
			(0.00680)	(0.00789)
tradej/wtradej			0.0316***	0.0218***
			(0.00667)	(0.00763)
lnpchd/wlnpchd	0.0459**	0.0499***	0.0431**	0.185***
	(0.0200)	(0.0178)	(0.0185)	(0.0292)
w		0.627***		-0.668***
		(0.184)		(0.157)
Constant	0.719***		0.720***	
	(0.201)		(0.191)	
Observations	435	435	435	435
R-squared	0.227	0.889	0.221	0.878

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

6.3 Price transmission efficiency

Table 7 shows that distance, consumption and differences of income per capita are negatively related to price transmission efficiency while common border, production and highway quantity are positively related , as expected. The estimated parameters are (partial) elasticities, which measure the contribution (%) of each variable to the pork price transmission speed change (%). The distance makes the highest contribution to pork price transmission efficiency, i.e., a 1 % change in distance between two markets, a 9.33% growth in price transmission speed.

Table 7. Determinants of pork price transmission efficiency by using Stochastic Frontier

VARIABLES	Frontier1	Frontier2	Frontier3
lnd	-0.0933***	-0.0928***	-0.102***
	(0.0143)	(0.0142)	(0.0144)
commonborder	-0.0199	-0.0243	-0.0281
	(0.0236)	(0.0235)	(0.0241)
productioni	0.0174**		
	(0.00701)		
productionj	0.0303***		
	(0.00704)		
cvpi	-0.0372**		
	(0.0145)		
cvpj	-0.0275**		
	(0.0133)		
lndpci	-0.0127**	-0.0118**	-0.0183***
	(0.00518)	(0.00517)	(0.00512)
lnpchd	0.0459**	0.0431**	0.0377**
	(0.0198)	(0.0184)	(0.0188)
tradei		0.0143**	
		(0.00674)	
tradej		0.0316***	
		(0.00661)	
sur			-0.00913*
			(0.00478)
lnsig2v	-4.045***	-4.037***	-3.985***
	(0.0679)	(0.0679)	(0.0679)
lnsig2u	-13.55	-13.52	-13.03
	(101.9)	(157.2)	(90.41)
Constant	0.720***	0.721***	0.937***
	(0.204)	(0.203)	(0.197)
Observations	435	435	435

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

We also use data envelopment analysis (DEA) to get the efficiency score of price transmission and then estimate the factors that affect the efficiency. As the largest efficiency value is 1, a Tobit regression is more feasible than OLS when we determine the factors of efficiency.

Table 8. Determinants of pork price transmission efficiency by using DEA

VARIABLES	DEA-OLS				DEA-Tobit			
lndpci	-0.000937	-0.000501	-0.00106	-0.000755	-0.000953	-0.000513	-0.00114	-0.000822
	(0.00212)	(0.00212)	(0.00237)	(0.00237)	(0.00211)	(0.00212)	(0.00238)	(0.00238)
commonborder	0.130***	0.130***			0.131***	0.131***		
	(0.00736)	(0.00735)			(0.00735)	(0.00735)		
productioni	0.00118		0.00126		0.00113		0.00113	
	(0.00287)		(0.00321)		(0.00286)		(0.00322)	
productionj	0.0175***		0.0207***		0.0175***		0.0209***	
	(0.00279)		(0.00311)		(0.00278)		(0.00313)	
cvpi	-0.00529		-0.00273		-0.00535		-0.00282	
	(0.00592)		(0.00659)		(0.00590)		(0.00662)	
cvpj	-0.0284***		-0.0324***		-0.0285***		-0.0326***	
	(0.00528)		(0.00590)		(0.00527)		(0.00593)	
lnpchd	-0.0444***	-0.0363***	-0.0481***	-0.0393***	-0.0446***	-0.0364***	-0.0485***	-0.0397***
	(0.00769)	(0.00724)	(0.00860)	(0.00809)	(0.00768)	(0.00724)	(0.00866)	(0.00815)
tradei		-0.000375		0.000113		-0.000448		-5.62e-05
		(0.00277)		(0.00309)		(0.00277)		(0.00312)
tradej		0.0148***		0.0178***		0.0149***		0.0180***
		(0.00266)		(0.00296)		(0.00266)		(0.00299)
Constant	1.059***	0.972***	1.224***	1.135***	1.061***	0.974***	1.229***	1.139***
	(0.0782)	(0.0738)	(0.0875)	(0.0823)	(0.0781)	(0.0738)	(0.0880)	(0.0830)
sigma					0.0540***	0.0546***	0.0609***	0.0614***
					(0.00184)	(0.00186)	(0.00209)	(0.00211)
R2/Pseudo R2		0.498	0.486	0.159	-0.3027	-0.2927	-0.0772	-0.0697
Observations	435	435	435	435	435	435	435	435

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

7. Conclusion

This study measures spatial price transmission and efficiency in the Chinese provincial pork markets which cover all the main geographic links of the pork supply chain in China. The results presented here confirm that various dimensions of proximity and trade flows affect not only spatial price transmission, but also price transmission efficiency. Cointegration is found in all price pairs. This implies Chines domestic markets are closely integrated. The coefficients on the error correction terms show how the Chines pork price adjusts between different provincial price pairs. Consistent with competitive spatial market equilibrium, we assess market integration by estimating the speed of price adjustment between market differentials using VECM. The required data on determinants of price transmission and efficiency are obtained from summed absolute parameters estimated from VECM.

Geographic distance, common borders and trade flows have systematic and expected effects on the adjustment parameter sums between prices in two spatially separate provincial markets. The closer two markets are in terms of distance, the more likely it is that price are transmitted between them. Both shared common borders and higher potential trade flows have positive effect on market integration. The proposed approach to assess market integration makes it possible to exactly locate market failures and to compare regions. The degree of market integration in the Chinese market is shown to be lower in deficit districts and the evidence suggests that this is caused by higher transaction costs. The western region also shows notoriously low levels of market integration which are likely to be due to high transaction costs.

In the estimations of price transmission efficiency on the basis of data from the Chines market all key explanatory variables are statistically significant. Stochastic frontier efficiency tests indicate price spreads between closer markets are higher. Overall we conclude that lower price transmission speed between different provinces suggest that trading infrastructure is not sufficiently developed and trade flows are not enough. The results contribute to an improved understanding of the determinants of price and market integration in the region. Based on this, welfare-enhancing policies may address investments in infrastructure and measures to facilitate trade. In addition, policies addressing pork prices in the region may take into account their effect on neighbouring markets and, to a much lesser extent, on adjacent provinces.

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