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Spatial Market Integration of Livestock Products and Road Conditions in Mongolia

Eiichi KUSANO[1]* and Izuru SAIZEN[2]

[1] Research Strategy Office, Japan International Research Center for Agricultural Sciences (Tsukuba, Ibaraki 305-8686, Japan)
[2] Graduate School of Global Environmental Studies, Kyoto University (Kyoto, Kyoto 606-8501, Japan)

Abstract

This paper evaluates the spatial linkages between the livestock product markets in Mongolia and the effects of road conditions on market transactions. It is based on the Engle-Granger test, an error correction model, and a model of market integration using the monthly price datasets of livestock products in Mongolia during 2005-2009. Empirical analysis indicates that the most and least integrated markets are the cashmere and milk markets, respectively. Extending paved roads might tighten the integration of the livestock products markets.

Discipline: Agricultural economics
Additional key words: Engle-Granger test, Error Correction Model, price

Introduction

To address the questions of livelihood and meadow preservation in Mongolia, it is necessary to comprehend its livestock-based industry. In 2010, an estimated 217,000 households had livestock, comprising 29% of total households and 78% of rural households[25,26]. Mongolia began its transition from centrally planned to market-oriented economy in 1991. Privatization and price liberalization resulted in soaring livestock numbers. The total number of goats, sheep, cattle, camels, and horses grew from 25.9 million in 1990 to 44.0 million in 2009. Several studies have argued that this explosion in livestock numbers is a factor behind pastureland degradation[8,23,24].

Livestock is heavily concentrated in the area surrounding the capital, Ulaanbaatar, which has the biggest consumption market in Mongolia[35]. The insufficient transportation infrastructure may be a reason for this high livestock concentration. If livestock product transactions were efficient enough, herders in remote areas could profit and the excessive concentration of livestock around the capital could be eased. Improved transportation infrastructure may also increase domestic economic welfare by facilitating the transport of livestock products that are difficult to sell or circulate in remote areas due to high transaction costs. The issue of market integration is thus closely related to meadow preservation and social welfare in Mongolia.

Market integration is thought to be hindered by the poor transportation network. In 2009[1], there were 11,200 km of national roads, of which 6,240 km were natural tracks; there were only 2,180 km of paved roads. This vast natural track network can increase trader costs and risks for agricultural product transactions between markets. As Buccola[6] suggests, transaction costs and risks can be a primary influence on market integration. Many researchers have shown interest in the effect of spatial conditions on market integration. They have regressed the results of cointegration tests of market pairs on the spatial distance between markets and several market characteristics[4,18,19,30,36]. The major results of their studies have indicated that long distances prevent market integration. However, few studies have analyzed the effect of transport infrastructure elements such as road conditions. Furthermore, in these limited studies, road conditions are frequently substituted by dummy variables instead of qualitative data[9,36].

In this study, we attempted to measure the effect of transport infrastructure on the degree of market integration of mutton, beef, milk, and cashmere using a regression model for road paving rate data. Market integration was measured with the Engle-Granger (EG) test for cointegration and an error correction model (ECM). We do not give preference to the market pairs in limited areas[9,14,18,36] for these tests, but instead analyze all permutations of the capital and

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*Corresponding author: e-mail kusano11@affrc.go.jp
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every province. The resulting estimation of the degree of market integration is presented as a map. Although previous studies on market integration did not fully focus on the expression of their results, visually presented information on market integration can be easily compared with other spatial studies on Mongolia and may contribute to the discussion of livestock allocation, meadow preservation, and regional natural disasters affecting livestock[35,40].

Background

Since the 1990s, the price of livestock products has been determined by a free market economy. Before 1991 however, the government set the prices for all products. Price liberalization was implemented by a government resolution in January 1991 and was almost completely accomplished by March 1992[38]. In 2007, 75.1% of live animals, 67.1% of meat, and 61.7% of wool and cashmere were sold to intermediaries by herders[27]. Meat, milk, and cashmere have their own respective circulation routes. Meat is mainly sold to the agents of meat processing plants or to private merchants from the countryside who sell meat at wholesale markets[2]. Intermediaries drive live animals to slaughterhouses, grazing them along the way[20]. They then slaughter the livestock and transport the carcasses to wholesale markets by truck[20]. Large amounts of meat are shipped to wholesale meat markets in Ulaanbaatar[2] (namely, 22 UB; hereafter, province names will be numbered and abbreviated; see Fig. 1 for a list of abbreviations and provincial boundaries). The milk collection system collapsed with the cessation of state-owned dairy market operations following market liberalization in the 1990s[20]. Dairy farmers and herders near urban centers began selling their products to intermediaries or delivering it themselves in the suburbs of large cities such as 22 UB, Darkhan in 13 DA, and Erdenet in 9 OR[37]. Raw cashmere is mainly sold to intermediaries, who then sell it on to markets run by processors or international operators. Most traders are not established in central market trading places and have little direct access to cashmere production companies[43]. The largest cashmere market in Mongolia is the Tsaiz market in 22 UB, followed by Zamyn-Uud in 14 DO, on the Chinese border[43].

Russia and China are major trade partners for Mongolian livestock products. The export volume of beef from Mongolia to Russia was 3,039 t, accounting for 97.4% of total exports, on average, between 2005 and 2007[13]. Similarly, 3,192 t of cow's milk, 99.2% of total imports, came from Russia over the same period. The export volume of mutton was only 37 t, as almost all the mutton produced is consumed domestically[13,20]. Of 3,135 t of raw and combed cashmere, on average, 78.0% of total exports went to China between 2007 and 2009[10]. 17 SE, 14 DO, and 19 DD are connected to Russia and China by rail and are thought to play important roles in Mongolia's international trade.

Roads and railways comprise a major portion of Mongolia's transportation infrastructure. The main railway line runs from north to south through Russia, 13 DA, 22

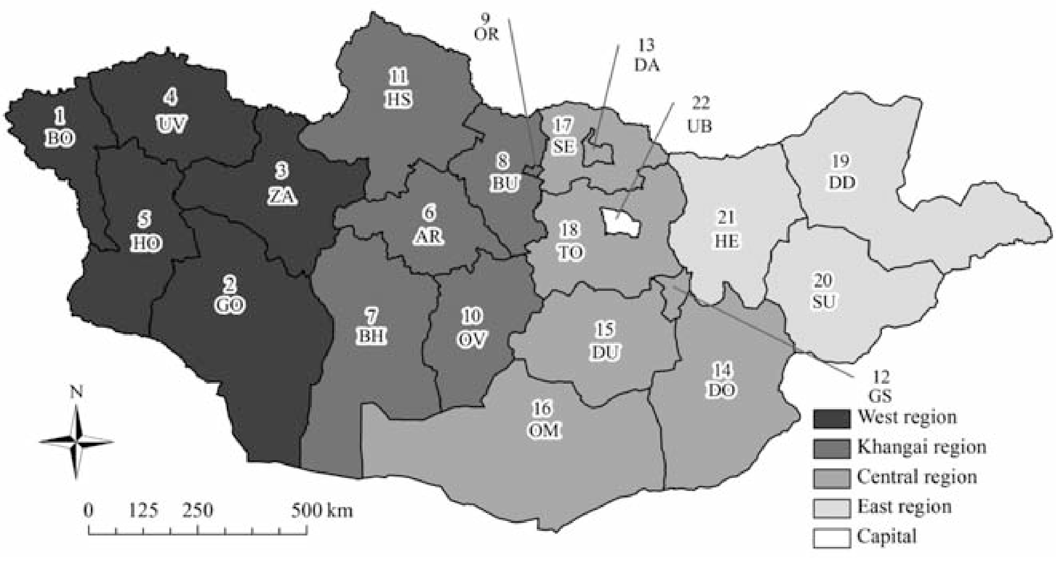

Fig. 1. Economic regions and provincial boundaries

West region: 1. BO (Bayan-Olgii), 2. GO (Govi-Altai), 3. ZA (Zavkhan), 4. UV (Uvs), 5. HO (Khovd). Khangai region: 6. AR (Arkhangai), 7. BH (Bayankhongor), 8. BU (Bulgan), 9. OR (Orkhon), 10. OV (Ovorkhangai), 11. HS (Khovsgol). Central region: 12. GS (Govisumber), 13. DA (Darkhan-Uul), 14. DO (Dornogovi), 15. DU (Dundgovi), 16. OM (Omnogovi), 17. SE (Selenge), 18. TO (Tov). East region: 19. DD (Dornod), 20. SU (Sukhbaatar), 21. HE (Khentii). Capital: 22. UB (Ulaanbaatar)

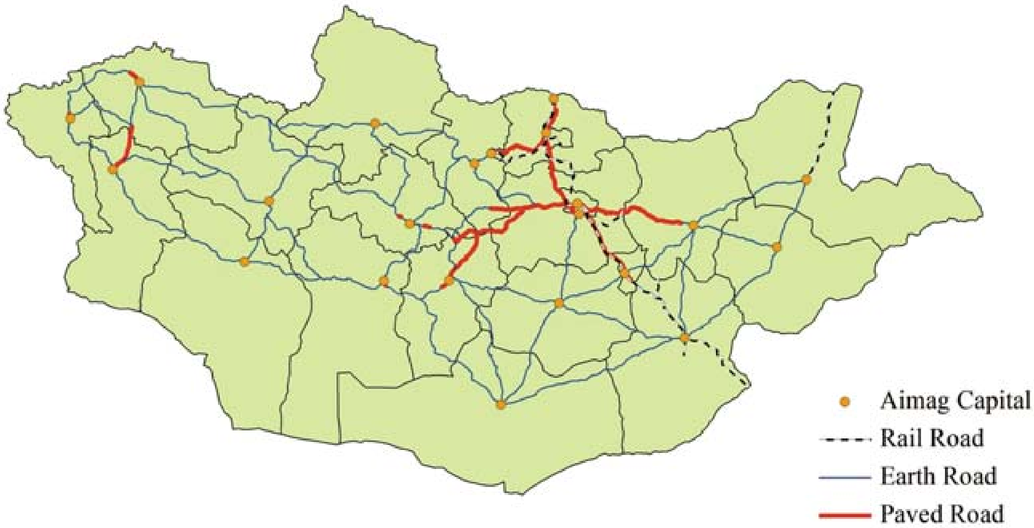

Fig. 2. Location of provincial capitals and highway network
"Aimag Capital" is the center of each province.
Source: GazrynZurag Co., Ltd.[15]

UB, 12 GS, 14 DO, and China, while another connects 19 DD and Russia (Fig. 2). Other areas are not included in the railway network, and domestic circulation largely depends on the road network. Although the total length of paved roads increased from 2004 to 2010[25,29], the road network comprises mainly natural tracks (Figs. 2, 3). Tracks allow for speeds of 15 to 50 km/h, and are prone to closures during winter or at times of high humidity[1]. The poor conditions presented by these natural roads can prevent active transactions in remote areas from the capital, where paved roads are concentrated. The Mongolian government aims to construct a paved road network of 11,000 km by 2021[1]. The paved roads are mainly planned to extend north-south and east-west from 22 UB, and connect the three eastern provinces with Russia and China[1,33].

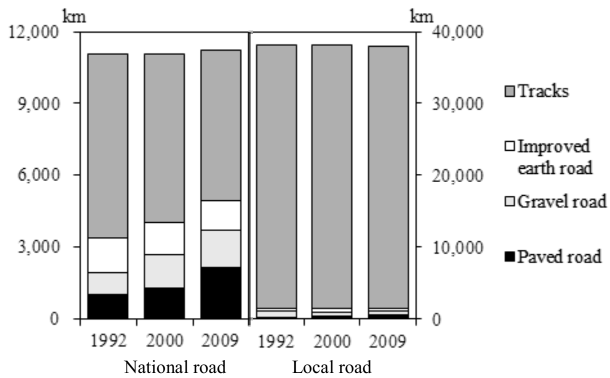

Fig. 3. Total length of national and local roads
National roads connect the centers of provinces. Local roads include other roads, both urban and rural.Source: ADB[1]

When looking at product prices by district, higher prices for mutton and beef can be observed in southern areas (14 DO and 15 OM), which may be due to a supply shortage, as implied by the comparatively scarce sheep and cattle there (Fig. 4). Higher meat prices in 16 UB, 15 TO, and 14 DA might imply the integration of those markets to the main market, 22 UB, where 39% of the total population of Mongolia is concentrated[29]. Milk prices are higher in broad areas of the south, where the number of cattle is smaller than in the northern areas. The price of cashmere is comparatively high in the southwest areas, which may indicate significant demand for cashmere from China.

This paper attempts to reveal the spatial characteristics of the market integration of livestock products and evaluate the effects of paved roads on this integration based on three hypotheses. First, the most and least integrated markets are those of cashmere and milk, respectively. Cashmere is thought to be easy to transport because it is light. In contrast, milk can be hard to transport because it is perishable and the collection system is thought to have collapsed after market liberalization. Second, the markets are more integrated in the districts surrounding 22 UB than in the west-east edge or southern areas, which are not directly connected to 22 UB by paved roads. The transaction of meat and milk might be active in areas near the capital, 22 UB, where the population is concentrated. Third, road paving can increase the degree of market integration. The transportation of perishable commodities such as milk can be dependent on road conditions, which affects transit times. Thus, the effect of road paving might be more significant for the milk trade than for other products.

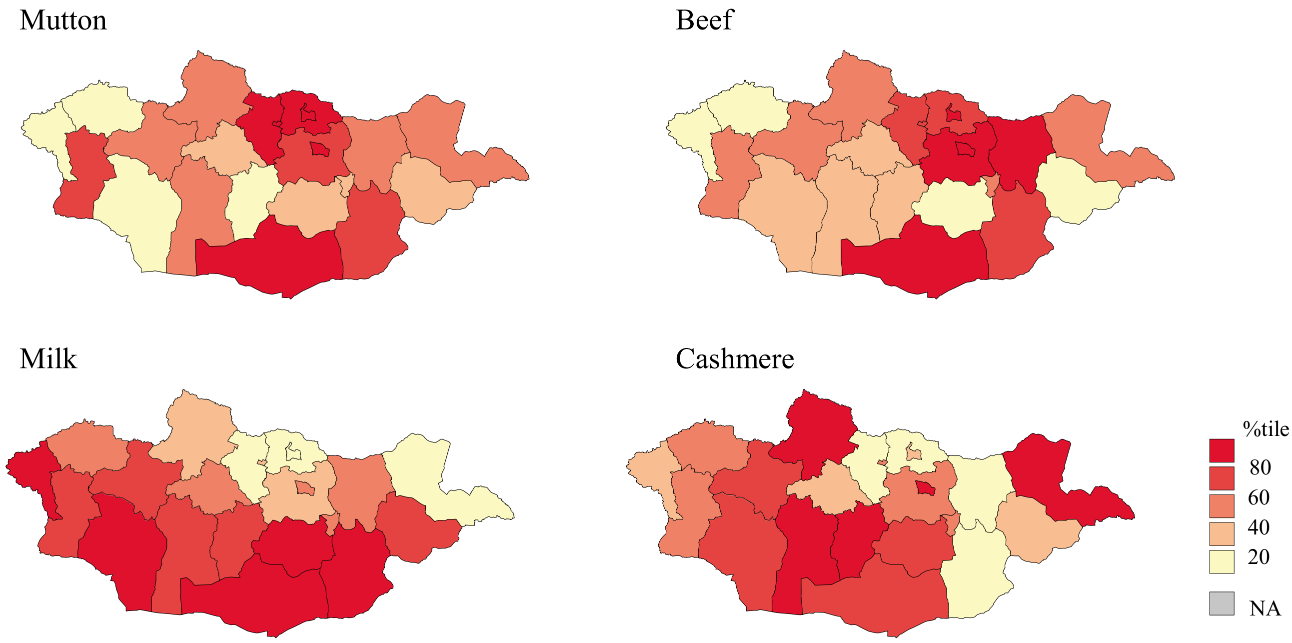

Fig. 4. Market prices (Jan. 2005 - Nov. 2009 average)

Monthly price data are deflated by the CPI into a constant based on 2010 prices in Mongolia and converted to USD by the exchange rate in 2010 (1USD = 1,356MNT). The price legend is divided into five quintiles for each commodity. The minimum and maximum for each commodity are as follows: Mutton: 2.12-2.73USD/kg. Beef: 2.05-3.01USD/kg. Milk: 0.49-1.12USD/l. Cashmere: 24.39-32.57USD/kg.
Source: Bank of Mongolia[3], National Statistical Office[26,28].

Methods and data

1. Cointegration test and error correction model

To test the above hypotheses, the proportions of integrated market pairs were compared between several commodities. We also tested the long-term stability of market prices using the EG test for cointegration, whereupon an ECM was used to gage the short-term price relationship. Previous studies have used the Ravallion test[21,34], cointegration tests, the parity bounds model (PBM)[4,5,9,42], and threshold autoregressive (TAR) models[17,30] to capture market integration. The Ravallion test faces criticism, as it does not take the stationarity of price data into account[32]. Recent models such as PBM or TAR require stronger assumptions and have elaborate theories, hence requiring data that is difficult to obtain in Mongolia. Thus, the EG test and ECM, which have the advantages of simplicity and lesser data requirements, were used in the present study.

First, the stationarity of the price series was checked using the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The price series integrated of order 1 (I (1)) were used for the following cointegration test. Cointegration relationships between selected price series were tested using the EG test as per Goodwin and Schroeder[18] and Fafchamps and Gavian[12]. Residuals were obtained from

$$P_{i,t} = \alpha_0 + \alpha_1 P_{j,t} + e_t \tag{1}$$

where $P_{i,t}$ and $P_{j,t}$ are the respective prices in locations i and j at time t, e_t is the residuals, and α_0 and α_1 are the fixed parameters. The residuals were then tested using the ADF test for the integration of order 0 (I (0)):

$$\Delta e_t = \beta_0 + \beta_1 e_{t-1} + \sum_{m=1}^{3} \beta_{m+1} \Delta e_{t-m} + \beta_5 T + \varepsilon_t \tag{2}$$

where Δ represents the first difference, T is the time trend, ε_t is the residuals, and β_0 to β_5 are the fixed parameters. The number of lags was decided by the Schwarz information criterion using a maximum of 3 because of the small size of each district sample. When the τ-statistics for β_1 exceeded the critical value of the EG test[22], residuals were I (0) and prices were interpreted as cointegrated.

The ECM for equation (1) is specified as

$$\Delta P_{i,t} = \gamma_0 + \gamma_1 e_t + \sum_{m=0}^{3} \gamma_{m+2} \Delta P_{j,t-m} + \sum_{n=1}^{3} \gamma_{n+5} \Delta P_{i,t-n} + \sum_{n=1}^{3} \gamma_{n+8} S_n + u_t \tag{3}$$

where S_n is a dummy for seasonality, u_t is the residuals, and γ_0 to γ_{11} are the fixed parameters. γ_1 ($-1 < \gamma_1 < 0$) is interpreted as the proportion of the adjustment of the short-term disequilibrium from the long-term stable relationships of prices. γ_2, the parameter of $\Delta P_{j,t}$, represents the short-term price influence from market *j* to *i*.

2. Relationship between spatial characteristics and market integration

The regional characteristics of transactions and the effect of road conditions were measured using a regression model on the cointegration test statistics as per previous studies[12,18]. A characteristic of this study is the use of road paving rates between every market pair to evaluate the effect of road conditions on market integration. In addition to the cointegration test statistics, the t-test statistics of a coefficient estimated by ECM representing short-term price transmission were regressed by the road paving rate and distance. The equation is given as follows:

$$log\left|Y_{i,j}\right| = \delta_1 logD_{i,j} + \delta_2\left(\frac{V_{i,j}}{D_{i,j}}\right) + \delta_3 + \sum_{k=1}^{21} \delta_{k+3}Z_k + v \qquad (4)$$

where $Y_{i,j}$ represents the EG test statistics estimated with equation (2) or t-test statistics for γ_2 in equation (3) between markets *i* and *j*. $D_{i,j}$ is the road distance and $V_{i,j}$ is the length of paved roads. Z_k is a dummy variable of combination *k* of markets representing the regional distinction effect on market integration.

In this study, intra- and inter-regional dummies are prepared. The intra-regional dummies take the value 1 when both markets *i* and *j* are in a specific area; the inter-regional dummies take the value 1 when either market *i* or *j* is in a specific area, and 0 otherwise. The intra-regional dummies include $Z_{UB\ Surround}$ and $Z_{Railroad}$, which are used to respectively measure the characteristics of market integration in the area surrounding 22 UB and the provinces connected by the railway. The inter-regional dummies, including Z_{China}, Z_{Russia}, $Z_{Mt\ Khangai}$, Z_{Forest}, and Z_{UB} are used to test the transaction effects on market integration for, respectively, a border area to China, a border area to Russia, a western area separated by the Khangai Mountains, a forest area, and 22 UB.

Test statistics obtained from equations (2) and (3) did not follow a normal distribution; thus, the bootstrap method[11], which does not require normality of population distribution, was undertaken to estimate equation (4). Bootstrapped coefficient estimates and standard errors can be used for the consistent inference for the variables influencing cointegration[18]. The bootstrap estimates were obtained from 10,000 replications.

3. Data

The market price data used in this paper were collected on a monthly basis by the National Statistical Office of Mongolia[28]. The data cover all 21 provinces and the capital, 22 UB (see Fig. 1). To test the usual market conditions, data from March 2005 to November 2009 were selected as a base period, avoiding the effect of livestock mortalities caused by natural conditions before 2003 and after December 2009. Monthly price data are deflated by the CPI into a constant based on 2010 prices in Mongolia and converted to USD based on the 2010 exchange rate. Regional differences in CPI are not taken into account in this study.

Serial data for cashmere prices were not obtained in many districts, hence we prepared two series of cashmere prices, hereafter referred to as cashmere (1) and cashmere (2). Cashmere (1) was prepared to encompass information from a broad area in Mongolia from p-values estimated with the EG test and t-test. Test statistics for the maximum number for a market pair could be estimated, but the sample period differed for each market pair depending on the availability of serial data. Cashmere (2) was prepared to estimate the effect of road paving (equation (4)), and the sample period was uniform: March 2005 to June 2007.

The market prices of livestock products in 22 UB are presented in Fig. 5. The price of livestock products is affected by the annual reproduction cycle[41]. Livestock are mainly fed grass during the summer in Mongolia and slaughtered from August to November before the weight loss caused by the shortage of grass in winter[39]. Cattle calve in March and April, and the milk supply is plentiful from May to October[39]. Fig. 5 indicates that meat and milk prices decline during their main production period. Although cashmere prices have no obvious seasonality, cashmere is gathered from March to May just before the goats shed their hair to adjust their body temperature. Enhanced production, storage, and transportation technology can also affect seasonality. The price peaks might flatten out if off-season transactions increase due to improved road conditions.

Three seasonality dummy variables were prepared for equation (3) to capture the influences of the seasonality of prices such as the downward tendency for mutton and beef from July to November, for milk from May to July, and for cashmere from April to May; the upward tendency for mutton and beef from February to May and for milk from September to November; the sudden rise for mutton and beef in April and for cashmere in March; and the sudden drop for milk in June.

Equation (4) was estimated using cross-sectional data, while EG- and t-test statistics as explained variables were estimated using equations (2) and (3), respectively. For geographic and road data, we digitized a printed road map[15] and calculated the road distances and the rate of paved roads between each district using ArcGIS 9.3 (ESRI). In this study, the paved road network is assumed to be fixed in a specific year, although statistics show that it has been extending continuously[25,29].

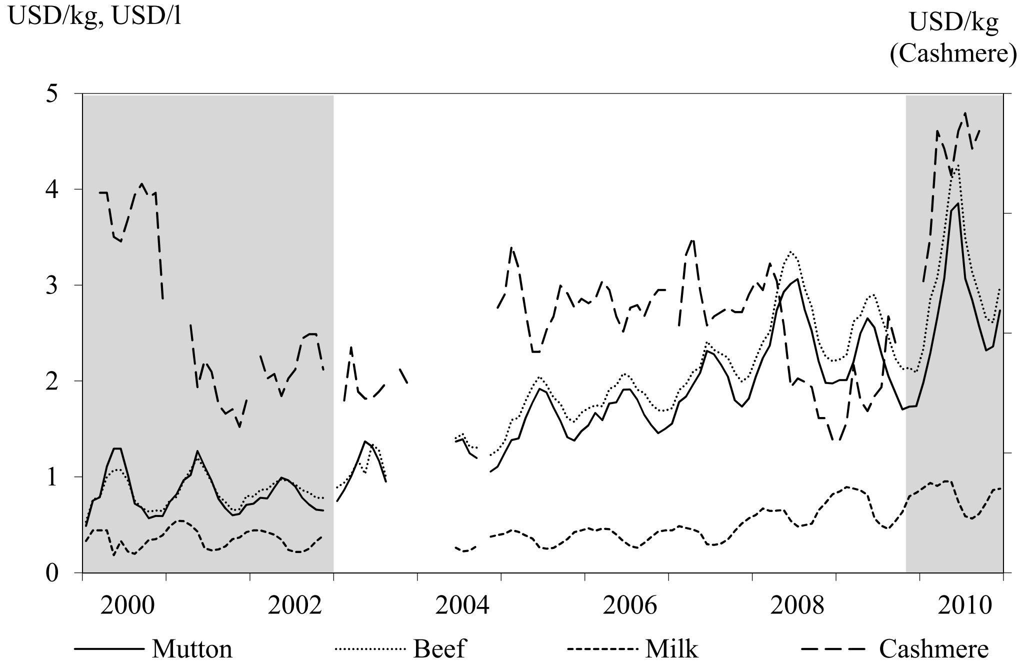

Fig. 5. Nominal monthly prices in Ulaanbaatar

The gray background indicates periods of high livestock mortality due to natural disasters.

Source: Bank of Mongolia[3], National Statistical Office[28]

Results

1. Degree of market integration of each livestock product

The results of the unit root tests are shown in Table 1. The table includes the average values for test statistics, the proportion of sample districts rejecting the null at the 1% level, the number of sample districts for the ADF and PP tests of each level, and the initial differences in price data. The results of the ADF and PP tests on level data respectively show that 5-23 and 0-5% of the sample districts have no unit root. The test results for the data of the first differences indicate that 82-100% of the sample districts have no unit root. Although we cannot deny the possibility that a specific commodity in several districts might be I (0), we interpreted all commodities in all districts as I (1) and used them for the next cointegration test.

The first hypothesis regarding the strength of market integration by commodity was verified through the following results of the EG test and ECM. Table 2 shows the results of the EG cointegration test. The results for Cashmere (2) are not included, to avoid any bias due to the limited sample size. The table shows that 35-51% of all permutations of sample districts were cointegrated at 1% significance. Cointegration indicates that two series follow a common stochastic process and implies the long-term integration of the markets[12,18,32]. The proportion of integrated markets for cashmere is almost the same as that for mutton ($p < .01$), while the integrated market pair for milk is lower than that for other commodities.

Table 1. Results of the unit root tests

	Levels						First differences					
	τ-stat		N(p<.01)(%)		N		τ-stat		N(p<.01)(%)		N	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP
Mutton	-3.08	-2.75	22.73	0.00	22	22	-5.79	-5.94	90.91	100.00	22	22
Beef	-2.66	-2.64	9.09	4.55	22	22	-6.48	-6.23	100.00	90.91	22	22
Milk	-1.17	-2.03	9.09	0.00	22	22	-5.73	-5.98	81.82	100.00	22	22
Cashmere	-2.32	-2.23	5.00	0.00	20	22	-7.64	-9.13	95.00	100.00	20	21

N: The number of sample districts (equal to the number of equations). N ($p < .01$) (%): Proportion of N rejecting the null at a significance of 0.01. The p-value was calculated based on MacKinnon[22]. The sample period for all commodities is Mar. 2005 - Nov. 2009. The number of lags was decided using the Schwarz information criterion in a maximum lag 3.

Table 3 summarizes the ECM results. The mean of the error correction term is theoretically a consistent negative, while the adjusted coefficients of the determination range and Q-statistics of the Ljung-Box test for the serial correlation suggest reasonably good statistical performance. The proportion of the coefficients at 1% significance indicates that the error correction term and the price of other markets at time *t* have a broader impact on the short-term price formation than the other coefficients. The average coefficients of the error correction terms put the markets in the following (ascending) order: cashmere, beef, mutton, and milk. This implies that the speed of the short-term adjustment process toward long-term equilibrium is faster in cashmere and slower in milk respectively. The coefficient of $\Delta P_{i,t}$ in cashmere is relatively large, while that of beef is the smallest.

Table 2. Results of the Engle-Granger test for cointegration

	τ-stat	p-value	N(p<.01) (%)	N
Mutton	-4.70	0.04	48.27	462
Beef	-4.58	0.05	44.47	380
Milk	-4.39	0.07	35.28	462
Cashmere(1)	-4.57	0.09	50.55	364

N: The number of district pairs (equal to the number of equations). N (p < .01) (%): Proportions of N rejecting the null at a significance of 0.01. The p-value was calculated based on MacKinnon[22].

2. Spatial characteristics of market integration: Interpretation of maps

The second hypothesis concerning the effect of spatial characteristics on market integration was verified by the maps and equation (4). Figs. 6 and 7 show the proportions of cointegrated districts at 1% significance as determined by EG- and t-tests on the ECM parameters. The red color indicates districts affected by prices elsewhere. These figures clarify the regional differences in the degree of market integration rather than the difference by commodity, which is

Table 3. Results of the error correction model

		Mutton	Beef	Milk	Cashmere(1)
Coefficients	*Constant*	15.95	21.98	33.71	-168.51
	ε_t	-0.41	-0.43	-0.35	-0.50
	$\Delta P_{j,t}$	0.32	0.25	0.34	0.49
	$\Delta P_{j,t-1}$	0.02	-0.01	0.01	0.05
	$\Delta P_{j,t-2}$	0.01	0.00	0.02	-0.01
	$\Delta P_{i,t-1}$	0.01	0.04	0.06	0.01
	$\Delta P_{i,t-2}$	-0.02	0.02	0.06	0.02
	$S_{downward}$	-124.13	-117.15	-70.38	-611.89
	S_{upward}	100.19	80.29	10.86	NA
	$S_{sudden\ change}$	126.89	139.77	-126.59	2,490.80
Proportion of coefficients (p<.01) (%)	*Constant*	1.08	1.32	10.17	2.24
	ε_t	47.84	53.68	44.37	57.84
	$\Delta P_{j,t}$	37.01	24.21	34.85	74.25
	$\Delta P_{j,t-1}$	1.73	2.37	3.46	1.49
	$\Delta P_{j,t-2}$	1.52	2.11	1.95	0.00
	$\Delta P_{i,t-1}$	2.38	0.00	3.68	0.37
	$\Delta P_{i,t-2}$	0.43	0.00	3.03	0.37
	$S_{downward}$	19.05	14.21	14.07	10.07
	S_{upward}	4.11	8.42	9.31	NA
	$S_{sudden\ change}$	14.72	20.26	25.54	38.81
Adjusted R^2		0.56	0.49	0.52	0.49
Ljung-Box test	Q-stat	9.75	10.22	10.74	8.44
	p-value	0.65	0.61	0.58	0.72
Observations	Mean	56.00	56.00	56.00	49.82
	SD	0.00	0.00	0.00	5.10
Number of eauations		462	380	462	268

The lag of the Ljung-Box test is 12.

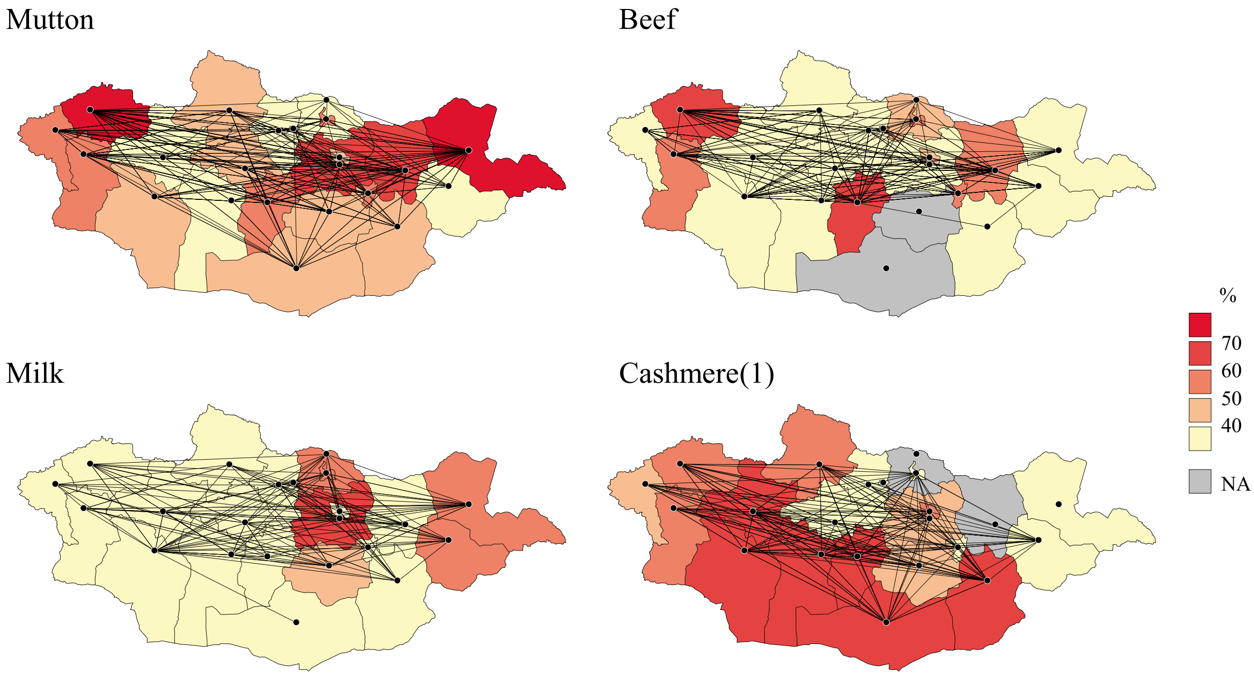

Fig. 6. Proportions of cointegrated districts at 1% significance (Engle-Granger test)
Red indicates a district cointegrated with other areas. Lines denote cointegrated pairs at 1% significance.

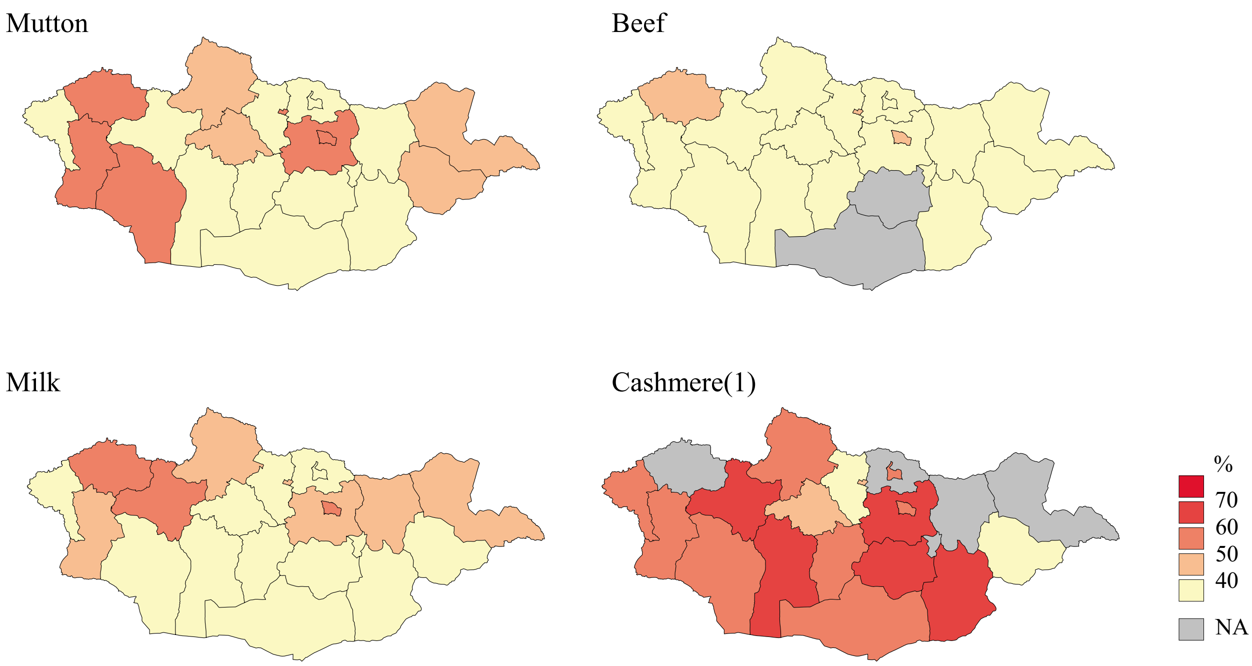

Fig. 7. Proportions of districts $\Delta P_{j,t}$ that are significant at 1% (t-test, ECM)
Red indicates a district cointegrated with other areas.

represented by spatially aggregated statistics in Tables 2 and 3.

Fig. 6 shows mutton prices in 18 TO, the area surrounding the capital, 22 UB, and 10 OV, 12 GS, 13 DA, and 21 HE, which are connected to 22 UB by paved roads and have long-term relationships with many other districts. Eastern and western edge regions such as 1 BO, 4 UV, 5 HO, and 19 DD are also broadly integrated. Beef prices in 4 UV and 10 OV are more sensitive than in other districts, although data for 15 DU and 16 OM were unavailable, and their effects are not obvious. Milk prices near 18 TO and the eastern edge provinces, including 19 DD and 20 SU, are

Table 4. Results of regressions on EG- and t-test statistics

	τ-statistic, Engle-Granger Test				t-statistic of $\Delta P_{j,t}$, Error Correction Model			
	Mutton	Beef	Milk	Cashmere(2)	Mutton	Beef	Milk	Cashmere(2)
Constant	1.40 **	1.47 **	1.67 **	1.56 **	1.84 **	0.23	1.67 **	2.12 **
	(12.96)	(11.2)	(15.26)	(10.48)	(4.59)	(0.45)	(4.78)	(4.53)
$logD_{i,j}$	0.03 *	0.02	-0.06 **	-0.01	-0.18 **	-0.01	-0.17 **	-0.17 **
	(1.86)	(0.76)	(-3.46)	(-0.56)	(-2.78)	(-0.1)	(-3.12)	(-2.23)
$V_{i,j} / D_{i,j}$	0.01	0.07	0.09 **	-0.04	0.38 **	0.26	-0.22	0.30 *
	(0.35)	(1.3)	(2.36)	(-0.73)	(3.08)	(1.5)	(-1.47)	(1.95)
Intra-regional dummy								
$Z_{UB\ Surround}$	0.02	0.09 **	0.07 **	0.01	-0.21	0.44 **	0.46 **	-0.29 **
	(0.52)	(2.11)	(2.22)	(0.17)	(-1.57)	(3.18)	(3.8)	(-2.17)
$Z_{Railroad}$	0.05	-0.14 **	0.09 **	0.09	0.08	-0.09	0.18	0.04
	(1.53)	(-4.58)	(2.79)	(1.55)	(0.89)	(-0.77)	(1.58)	(0.3)
Inter-regional dummy								
Z_{China}	-0.05 *	-0.04	0.07 **	0.02	-0.20 **	-0.04	0.01	0.20 **
	(-1.87)	(-1.33)	(3.06)	(0.49)	(-2.49)	(-0.36)	(0.08)	(2.08)
Z_{Russia}	0.07 **	-0.05 *	0.04 *	-0.08 **	-0.14 **	0.15	0.06	0.36 **
	(3.05)	(-1.92)	(1.71)	(-2.07)	(-1.97)	(1.51)	(0.84)	(3.21)
$Z_{Mt\ Khangai}$	-0.10 **	-0.05	0.13 **	-0.03	0.29 **	0.14	0.27 **	-0.24 **
	(-3.82)	(-1.51)	(5.12)	(-0.65)	(2.99)	(0.97)	(3.52)	(-2.06)
Z_{Forest}	-0.16 **	-0.04 *	0.04 **	-0.18 **	-0.05	-0.15	-0.13	-0.24 **
	(-7.35)	(-1.69)	(2.06)	(-3.54)	(-0.62)	(-1.5)	(-1.59)	(-2.63)
Z_{UB}	-0.14 **	-0.05	-0.03	-0.08 **	0.11	0.40 **	0.20 **	-0.61 **
	(-3.88)	(-1.25)	(-0.85)	(-2.04)	(0.75)	(4.4)	(2.01)	(-5.04)
Adjusted R^2	0.13	0.06	0.11	0.18	0.05	0.07	0.11	0.14
F-stats	8.51 **	3.79 **	7.10 **	5.45 **	3.83 **	3.92 **	6.99 **	4.64 **
Observations	462	380	462	188	452	351	436	209

** < .01, * < .05. t-statistics in parentheses. Adjusted R^2 and F-statistics obtained by OLS are reported for reference purposes. The numbers of provinces included in each dummy are as follows: $Z_{UB\ Surround}$ (8, 9, 12, 13, 15, 17, 18, 21, 22: Markets within 400km of 22 UB), $Z_{Railroad}$ (9, 12, 13, 14, 17, 18, 19, 22), Z_{China} (2, 5, 7, 14, 16, 19, 20), Z_{Russia} (1, 3, 4, 8, 11, 17, 19, 21), $Z_{Mt\ Khangai}$ (1, 2, 3, 4, 5, 7), Z_{Forest} (8, 11, 13, 17) and Z_{UB} (22).

affected by many other areas. Cashmere prices in broad areas of the southwest are highly integrated. Fig. 7 shows the proportion of districts $\Delta P_{j,t}$ that are significant in equation (3). The short-term price variations of mutton in the capital 22 UB, 10 OV, and regions in the west and east edges are synchronized with many other districts. Similarly, beef prices in 22 UB and 4 UV, milk prices in the capital and the east and west edges, and cashmere prices in many districts of the southwest area are broadly integrated with other districts.

These figures imply that transactions for mutton and cashmere would be more active in broad areas. Milk markets near the capital and the east region can be interpreted as more integrated in the long term. Stronger integration in 17 SE and 19 DD is also reasonable, since those provinces are connected with Russia by rail and active trade can be expected there. The transactions for cashmere can be active in broad areas in the south that share borders with China.

3. Spatial characteristics of market integration: Results of regressions on test statistics

The second and third hypotheses regarding the effect of spatial characteristics, including paved roads, on market integration were tested by the regression model. Table 4 shows the coefficients of equation (4), which imply the effects of distance, paved roads, and other regional characteristics on the degree of market integration. The larger τ-statistics from the ADF test indicate the greater possibility of rejection of the null that a variable has a unit root, and imply a more stable relationship between two variables in the long term. Similarly, the larger t-statistics of $\Delta P_{j,t}$ estimated with the ECM can imply greater coefficients or smaller standard errors and a more stable relationship between two variables in the short term.

The signs of the significant coefficients on distance and road paving rates are negative and positive, respectively, for almost all commodities in the table, while the degree of price integration between markets should be negatively influenced by spatial distances. Conversely, the coefficients of τ-statistics of milk and t-statistics of mutton and cashmere may imply that higher proportions of paved roads tighten their market integration. In other words, the comparatively limited transactions for milk could be affected by poor road conditions, especially in long-term relationships between markets.

The results of the intra-regional dummies indicate significantly positive and large effects of regional characteristics on market integration. Transactions surrounding 22 UB can be active, not only by the high paving rate but by other regional factors. The dummy of the railroad of milk is significantly positive in the long term, but many other commodities are insignificant. Inter-regional dummies for border areas of cashmere are positive, while those of mutton are negative in the short term. Dummies for the Khangai Mountains, the forest area, and 22 UB of mutton, beef, and cashmere are negative in the long term. Transactions in a specific area can weaken the market integration of those commodities. Conversely, the spatial characteristics can strengthen the market integration of milk in the long term. Furthermore, transactions from the Khangai Mountains with the western areas in sheep and beef and with UB in beef and milk can strengthen market integration.

Conclusions

There has been little study on the market integration of livestock products in Mongolia. This paper attempts to fill this gap by focusing on the market integration of livestock products and evaluating the effect of spatial characteristics on such integration. We first examined the hypothesis that the most and least integrated markets are those of cashmere and milk, respectively. This is supported by the results of the ECM, which imply a comparatively strong integration of cashmere markets in the short term. Furthermore, the results of the EG test and ECM indicate limited integration and milk prices that are slow to adjust. These results are consistent with the generalization that cashmere is easy to transport, whereas it is difficult to transport milk because it is perishable and its collection system is poor[20,35].

Next, we verified the hypothesis that markets are more integrated in the districts surrounding 22 UB than in those on the east-west edge or southern areas. This hypothesis is partially supported by test results indicating the broad integration of the capital, 22 UB, and its surrounding districts in both the long- and short-term. Transactions for meat and milk are thought to be active in the area around 22 UB. However, it is not necessarily appropriate to suggest that such transactions are active only in the area surrounding the capital. The test results indicate broad market integration in many districts, including the east-west edge and southern areas.

Finally, we tested the effect of road paving on the degree of market integration. The results of the regression analysis imply that higher proportions of paved roads tighten the integration of milk in the long term and of sheep and cashmere in the short term. The total length of paved roads has continuously increased[25,29], while plans have been made to extend the north-south and east-west roads from 22 UB and connect eastern provinces with Russia and China[1,33]. Further road paving might activate domestic transactions for livestock products in these areas.

There are several limitations to this study. First, strong market price correlations do not always indicate the existence of transactions. There is a possibility of accidental correlation[19], although this is also interpreted as evidence of inter-market transactions. Second, in many practical analyses, models to measure the degree of market integration often require strong assumptions concerning transaction costs[2,4,16,18]. The EG test and ECM in this paper also assume a linear relationship between prices in integrated markets. However, the stable price relationship in integrated markets might be affected by opportunistic behavior by intermediaries. These two problems are caused by limitations of the statistical data for transaction costs and trade volume. Third, this paper describes only part of the relationship between the livestock product market and road paving. We did not discuss the population movement and its effect on the market caused by the improvement in road infrastructure[1,44]. Our findings must be carefully interpreted within these limitations. Notwithstanding its limitations, this study will help improve understanding of the regional characteristics of livestock product markets in Mongolia.

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