Why Does Cattle Price Fluctuate?: Structural Characteristics and Simulation Works

Nam-Hee Choi
(Professor, Korea National University of Transportation, Korea, drnhchoi@ut.ac.kr)

Won-Gyu Ha
(Principal Member, Electronics and Telecommunications Research Institute, Korea, wgha@etri.re.kr)

and

Man-Hyung Lee
(Professor, Chungbuk National University, Korea, manlee@chungbuk.ac.kr)

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Ⅰ. Introduction

The prices of Korea's agricultural and livestock products have fluctuated considerably over the past few decades, surging and plummeting periodically. Typical Korean agricultural products whose prices fluctuate significantly include radishes, cabbages, onions, Korean beef, and pork. Of these, Korean cattle price per head has in recent times fluctuated to a greater extent than any other product.

The Korean cattle price per head (based on a large 600kg large cow) fell from KRW 6.21 million in 2001 to KRW 3.38 million in 2008, but rose again to KRW 5.33 million in 2010. However, thereafter, the price continued to fall until it plummeted by 40% to KRW 3.19 million at the end of 2011. Meanwhile, the price of a calf plunged by 57%, from KRW 2.17 million in 2010 to KRW 920,000 at the end of 2011. Moreover, during this period, the price of a beef calf plummeted to just KRW 10,000 (Sisa Seoul, 2012). Due to this halving of cattle prices and surging feed prices, Korean cattle farmers and markets came close to collapsing, and the government had to devise effective countermeasures. Livestock farmers and the Korean Cattle Association, as well as political circles, all urged the stabilization of cattle prices, demanding that appropriate policy measures be put in place. However, all these groups and the government itself have recognized different causes of and responsibilities for the plunge in Korean cattle prices.

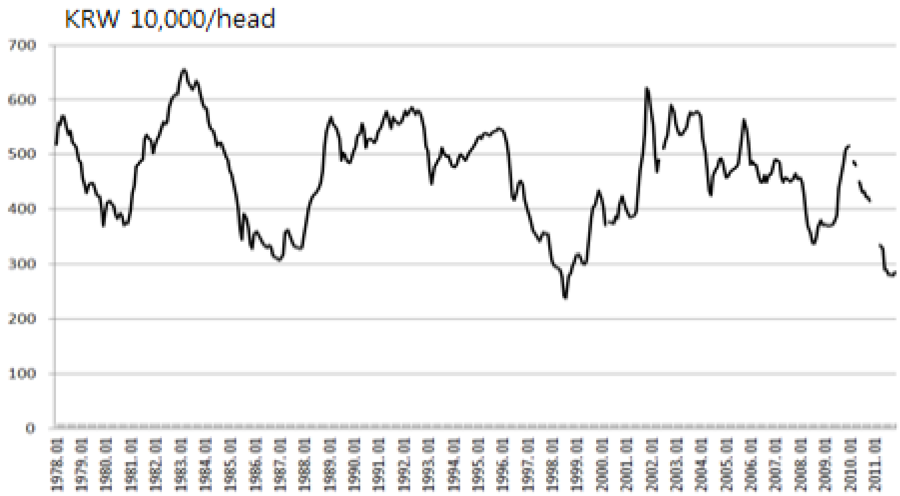
This study clearly defines the interaction of factors which causes Korean cattle price to fluctuate, because fluctuations have occurred periodically over the past thirty years. Such severe price changes are fundamentally influenced by supply and demand factors as functions of time. In other words, there is an interaction involving various factors--which influence the supply of and demand for Korean cattle--such as the size of the Korean cattle population, the volume of beef imports, beef prices, the amount of beef consumption, feed

prices, and farmers' demand for raising calves.
Specifically, this study aims to analyze the causal and circulatory structure of the problems pertaining to the price fluctuations in the Korean cattle market and to define the causes thereof. In addition, it simulates the results of policies for solving such problems in order to explore effective policy leverage aimed at stabilizing Korean cattle prices.

Ⅱ. Korean Cattle Price Fluctuations and Characteristics

1. Cattle Price Fluctuations and Changes in the Cattle Population: 1980-2012

Price fluctuations in the Korean cattle market can be examined in terms of the large ox price, large cow price, female calf price, and male calf price, but the typical cattle price is regarded as the price for a large, 600kg ox. Thus, such price fluctuations are most closely related to the Korean cattle population.

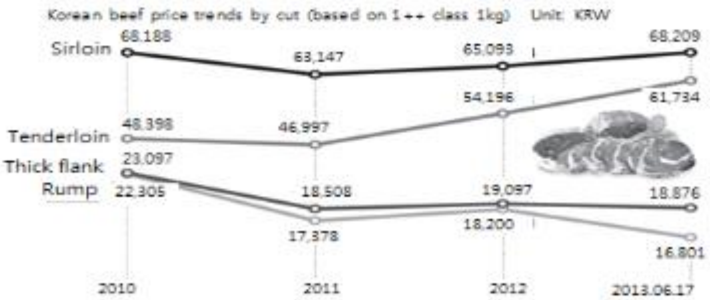


Source: Lee, Jeong-hwan, et al(2011). R&D of a Model for Establishing the Appropriate Korean Cattle Population, GS&J Institute.

[Figure 1] Changes in Large Korean Cattle Price

As shown in [Figure 1], Korean cattle price exhibits a periodical and repeated pattern of plunging and surging. In specific, Korean cattle price experienced a fluctuation crisis in the late 1970s, surged in the 1981-88 period, and plunged again in a price fluctuation cycle. The price of Korean cattle surged to KRW 6.5 million per head in 1983, and then immediately plummeted to a low of KRW 3 million per head in 1988. However, after just 1~2 years of a sharp price fall, Korean cattle prices surged again in 1989. Thereafter, Korean cattle price fluctuated, albeit slightly, for a long period.
Korean cattle price fluctuated slightly until 1998 when they fell more sharply than at any

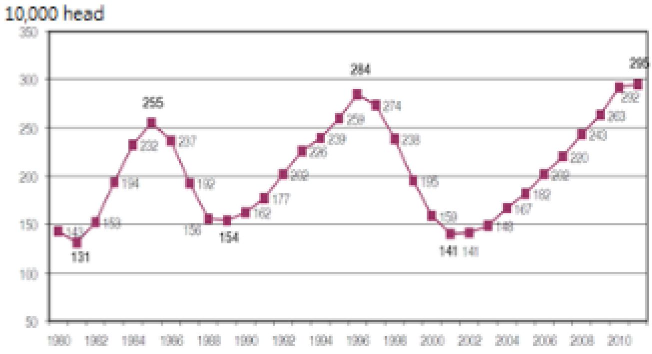
other time, causing the price per head of large cattle to fall to just KRW 2.38 million; however, just three years later, at the end of 2001, the price surged 2.6 times to KRW 6.21 million per head (Lee, Jeong-hwan et al., 2011). After 2001, Korean cattle price repeatedly fell and rose until 2008, when they plummeted to KRW 3.38 million. However, the price recovered to rise to KRW 5.15 million in 2010, but, two years later, at the end of 2011, it fell again to under KRW 3.19 million (Sisa Seoul, January 8, 2012).
In the course of these fluctuations in the price of Korean cattle, if large-cattle price in production sites increases, it will increase the demand for the raising of calves, which will in turn increase calf price. This suggests that calf price, influenced by and coupled with large cattle price, tends to change (Jeong, Min-guk, et al., 2012). In other words, when the prospects for raising Korean cattle are bright, calf price increases, with female calves being more expensive than males, whereas, when the prospects for raising Korean cattle are dim, cattle price falls, with female calves selling cheaper than male calves. This trend emerged in a case where the price of a female calf, amid a rise in Korean cattle price, was KRW 2.15 million on average in 2010, but fell to KRW 900,000 in 2011, when Korean cattle price fell sharply (Korean Rural Economic Institute, 2012). However, consumer price for Korean beef, which are closely related to prices determined at the production sites, almost did not change or even rose as in [Figure 2], suggesting that even when cattle price at production sites falls, a corresponding rise in consumption cannot be predicted.



Source: Nongmin Newspaper(2013). "Deepening Price Polarization according to Cuts of Korean Beef," June 21

[Figure 2] Trends in Korean Beef Consumer Price

Meanwhile, as shown in [Figure 3], the Korean cattle population, which is closely related to fluctuations in the price of Korean cattle, fluctuated regularly, and continued to increase significantly before the 2003~2011 period when there was a plunge in Korean cattle price. Compared with [Figure 1], this shows a pattern whereby, when the Korean cattle population increases to more than a certain level, Korean cattle price plunges, while when the Korean cattle population decreases, Korean cattle price plunges (Jeong, 2012; Jo, 2012; Lee, et al., 2011).



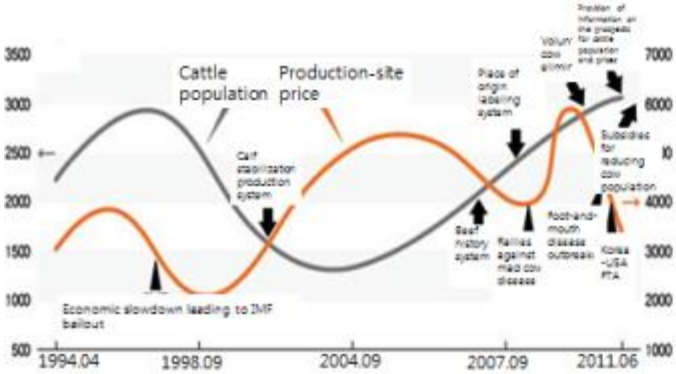
Source: Jeong, Min-guk, et al(2012). "Causes of the Recent Fall in Cattle Prices, and Solutions," KREI Agricultural Policy Focus, No. 8.

[Figure 3] Changes in the Korean Cattle Population

Conversely, however, when the price rises or the market prospects are bright, the Korean cattle population increases significantly. The gap in the Korean cattle population is almost double between the ongoing series of minimum and maximum levels: 1.31 million(1981) → 2.55 million(1985) → 1.54 million(1989) → 2.84 million(1996) → 1.41 million(2001) → 3.05 million(2011)). Furthermore, the fluctuation cycle shows a trend towards a gradual increase, as the 1980s saw a 4 to 5-year cycle, the 1990s a 6 to 7-year cycle, and the 2000s a 9 to 10-year cycle (Heo, et al., 2012). In the course of these fluctuations in the Korean cattle population, as indicated above, farmers, who produce fattening cattle, increase the demand for the raising of calves due to a rise in Korean cattle prices, and accordingly, their production of calves increases. Also, the producers of calves extend the female cattle breeding period in order to increase reproduction, thereby expanding the number of female cattle (i.e. slaughtering is decreased) and increasing the production of calves simultaneously. Thus, overall, the Korean cattle population rises sharply (Jeong, et al., 2012).

2. Interaction Characteristics between Korean Cattle Price and Population

Korean cattle market price is basically determined by the function of the supply of and demand for Korean cattle. Demand for Korean cattle, namely, demand for beef, however, is less influenced by the price, as seen in [Figure 2], which shows a change in beef consumer prices. Beef consumer prices have very little room to influence consumers' demand for beef due to the multi-stage distribution structure which responds insensitively to cattle prices at production sites or the supply amount (The Kyungnam Shinmun, May 27, 2011). Thus, any change in Korean cattle prices is not so much influenced by the demand factor as by the supply factor. Not only the price but also the supply, namely, the Korean cattle population (meaning the production volume of Korean cattle), have the problem of being structurally unstable.



Source: The Hankyoreh, GS&J(2012). "Concerns over Nine Rapid Turnarounds in Prices since 2008," January 5.

[Figure 4] Changes in Korean Cattle Price and Population

The interaction between Korean cattle price and population, as shown in [Figure 4], is characterized by a change in cattle population which causes a change in cattle price at production sites, which in turn influences the size of the cattle population. Such a fluctuation time cycle takes at least 4 years due to the long period of Korean cattle gestation and release. In addition, there is no single case wherein, in the process of interactions and changes of the Korean cattle population and prices, a long-time stable trend has continued. This is a counter-evidence that efforts by the government and Korean cattle organizations proved not very effective.

Ⅲ. Review of Researches on the Causes of Korean Cattle Price Fluctuations, and Exploration of the Relevant Variables

Of the traditional approaches to fluctuations in the price of Korean cattle, results directly related to this study include previous researches that used historical data to examine the causation of Korean cattle price fluctuations. Of these, a major paper by Jeong and Heo (2000) attempted to prove the causational relationship between production-site price, wholesale price, consumer price, and calf price, all of which are determined with a time difference. However, this study has the limitation of being unable to consider other factors such as cattle population, except price. Gwon (2001), in his research with time-series models such as ARIMA, VAR, and the transfer function in predicting production-site cattle prices, used such variables as production-site ox price, male calf price, beef consumer price, and slaughter output. Lee and Son (2006) developed models of calculation intelligence theories combining fuzzy theory and the neural network algorithm, instead of using improved models such as the traditional regression analysis method, in an attempt to predict hog and cattle price. They claimed that the model's power to predict cattle price was excellent, with a prediction error factor of 4.62%, but they did not consider other variables except cattle population,

thereby failing to reflect the actual dynamics of Korean cattle markets.
Such Korean researches only used several variables related mainly to Korean cattle prices, and estimated and predicted how the price changes in a time series. These researches explain price fluctuation simply as a one-way directional and linear causation structure in which the independent variables uniformly influence the dependable variables. However, they fail to explain the interaction between the many variables leading to the cyclic fluctuations in the price of Korean cattle price and the dynamics thereof. Such a research trend can be found in many overseas researches which use time-series data in statistically estimating changes in (mainly) cattle or beef prices or in explaining or estimating the causation thereof (Kesavan et al., 1992; Ward, et al., 2002; Hahn, 2004; Hahn, 2010; Joseph et al., 2013).
Meanwhile, recent domestic researches have attempted to resolve the problem of Korean cattle price fluctuations by analyzing or predicting the causes thereof in a bid to explore diverse policies (Jeong and Heo, 2000; Gwon, 2001, Lee and Son, 2006; Lee, et al., 2008; Heo, et al., 2009; Heo, et al., 2011; Lee, et al., 2011; Jo, et al., 2012; Ministry of Agriculture, Food and Rural Affairs(MAFRA), 2012). Lee, et al. (2008) reported that whenever mad cow disease shocks occur, the demand for imported beef decreases to 50% due to health and safety concerns. Heo, et al. reported in their research (2011) on the prediction of cattle and hog prices following the onset of foot-and-mouth disease that, when foot-and-mouth disease breaks out, rather than the short-term killing of cattle leading to reduced supply, consumers' concerns about the safety of meat increase, thereby weakening the demand for Korean cattle and consequently leading to a fall in beef prices. Lee, et al. (2011) attempted to derive an appropriate cattle population that can simultaneously meet consumer demand, environment, and fodder constraint conditions. Jo, et al. (2012) warned that the fertile cow population will be reduced to below the appropriate population in 2013~14, leading to a significantly reduced calf breeding population, while the number of slaughtered cattle will expand significantly after December 2011, entering a full-blown period of reduced Korean cattle population. MAFRA (2012) pinpointed major problems of the Korean cattle industry such as the importation of beef, the limit on promoting the consumption amount, the shock of the large cow elimination rate, the ease of expanding the breeding population, and the serious fluctuations in the cattle population due to poor farming despite the large number of livestock farmers.
Meanwhile, major domestic and overseas researches on livestock price fluctuations, such as fluctuations in the prices of Korean cattle from the perspective of the system dynamics methodology, were reviewed to explore the possible major factors of this study. The first relevant paper is Meadows' thesis (1969), which analyzed the dynamic cycle theory of producing products, citing the cyclical fluctuations in the U.S. hog population and prices. He developed a dynamic pork fluctuation cycle model, using a wide range of variables such as pork stocks, hog price, farmers' expected price, the desirable number of breeding hogs, the time delay required for gestation and growth, the number of adult hogs, the adult hog slaughter rate, retail price, the desirable number of hogs to be raised, the slaughter rate, and the amount of pork consumption per person. Meadows simulated this model and defined how markets could be balanced. Some years later, Ford (2010) further refined this model, making it easier to understand for educational use, and experimented on how to derive a market balance. Conrad (2004) included not only cattle breeding-related variables, but also the production and prices of dairies (milk production and demand) and grains (feed) such as corn

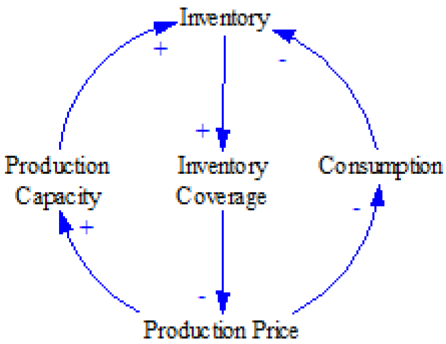
in the model in an effort to explain the price fluctuations of agricultural and livestock products. Dooley, et al. (2005) classified cattle into dairy cattle and fattening cattle, modeled the process of producing and releasing beef, considered scenarios about the innovation of New Zealand's livestock industry, and analyzed the value chain of beef products. Ross, et al. (2011) elaborately modeled the whole process--from calves in cows' wombs to beef production, including slaughtering--in a bid to analyze the beef supply network. He used various variables such as calves in cows' wombs, calf production, male calves, female calves, replacement heifers, un-castrated oxen, fertile cows, and the slaughter rate.

The aforementioned researches, all of which used the system dynamics method, share the following features: they combined the whole process of breeding cattle, production and release of beef, and market demand and price, and adopted an approach from the perspective of the supply chain or value chain. In addition, they considered all the diverse factors such as innovation of livestock category and production of grain, and used a feedback model involving the interaction of these factors as the basic structure.

Ⅳ. Analysis of the Causational and Circulatory Feedback Structure in Korean Cattle Price Fluctuations

1. Dynamics of the Korean Cattle Production Process

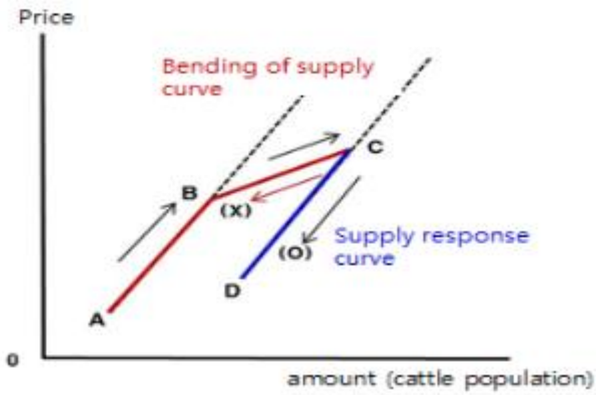
Beef, a commodity, is also subject to process of production and consumption. The basic structure, wherein cyclic fluctuation occurs in producing products, is that balance is not achieved between production capacity, production, product price, consumption, and inventory, but rather the flow of information or the flow of materials is cyclically delayed. In his research on the analysis of U.S. pork price fluctuations using the system dynamics methodology, Meadows (1969) explained the basic feedback structure as shown in [Figure 5], wherein fluctuations in product production and prices occur.



Source: Meadows, Dennis Lynn(1969). The Dynamics of Commodity Production Cycles: A Dynamic Cobweb Theorem, MIT.

[Figure 5] Meadows' Basic Commodity Cycle Structure

When Kim's (2011) industrial economy circulation model, which expanded upon Meadows (1969), is applied to Korean cattle production and prices in the Korean cattle industry, the following circulatory process can be derived: rise in Korean cattle price (beef price) → increase in Korean cattle farmers' revenues → investment in raising Korean cattle → excessive expansion of production capacity (ex.: excessive production of calves, and breeding of fattening calves) → oversupply (excess of Korean cattle population and Korean cattle slaughtering) → fall in Korean cattle prices → drop in livestock farmers' revenues (dim prospects) → reduced investment in raising Korean cattle → excessively reduced investment in raising Korean cattle (elimination of fertile cows, and falling demand for breeding calves) → reduced Korean cattle population → reduced slaughter of Korean cattle (reduced supply of beef) → rising Korean cattle (beef) prices.



Source: Lee Byeong-o(2013). Improvement of the Korean Cattle Distribution Structure, and the Role of Agricultural Cooperatives, p.30.

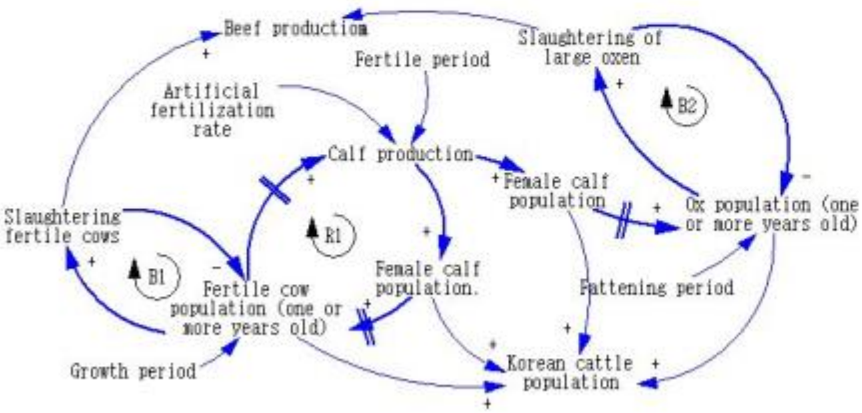
[Figure 6] Bending of the Supply Curve and Supply Response Curve in Korean Cattle Supply

The most fundamental reason for the fluctuations in the price of Korean cattle is that the Korean cattle population for beef production fails to achieve an appropriate balance, thereby preventing the price from changing stably. Thus, the basic structure, wherein the price of Korean cattle fluctuates, is that the control of the Korean cattle population in the industry and the market is not properly balanced. Moreover, in the Korean cattle industry, biological processes lasting over 40 months are involved in the breeding, fattening and slaughtering of Korean cattle, while supply control inevitably necessitates time differences, thereby increasing the possibility of such fluctuations (Lee, et al., 2012).

Notably, the relationship between the Korean cow population and price, as shown in [Figure 6], indicates that if the price increases, the supply curve is elastically bent to change from AB to BC, thereby increasing the population significantly and consequently causing oversupply and a contingent fall in price. Then, in this case, the supply (population) has to decrease, but it is inelastically reduced, thereby delaying the recovery of the price. Due to such bending of the supply curve and the supply response curve, the Korean cattle population exceeds the appropriate level, which is not easy to control (Lee, 2013).

The dynamic structure of the Korean cattle production process is shown in [Figure 7] in terms of a causation map. As shown in [Figure 7], the Korean cattle population is the sum total of female calves, male calves, fertile cows, and large oxen. The process of Korean cattle (beef) production is as follows: fertile cows give birth to calves, the newborn calves grow for over 14 months and become fertile cows, and the fertile cows give birth to calves for a certain period in farms before being slaughtered. Male calves, adopted by farmers, undergo about 30 months of fattening before being slaughtered and released onto the market. In this process of Korean cattle production, if the intention is to control the cattle population, as deemed necessary, it will cause a considerable delay which, eventually, will result in frequent fluctuations.

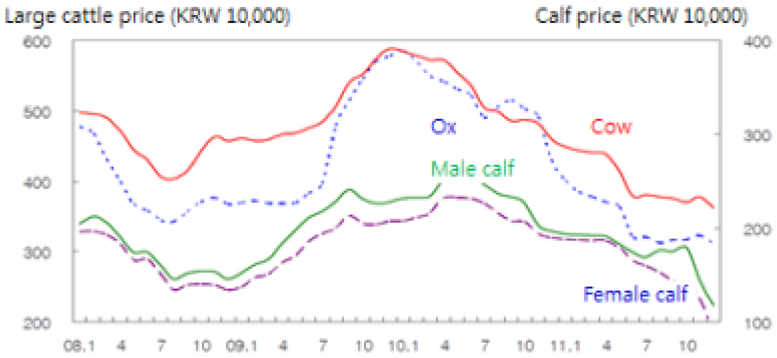
The figure shows a positive feedback loop wherein, in the process of Korean cattle production, if fertile cows increase in number, calf production will increase, which in turn will increase the number of female calves and fertile cows, again increasing calf production (R1). The fertile cow population shows a negative feedback loop wherein it is controlled by the slaughtering of large cows (B1). This suggests that the approach whereby the Korean cattle population can be controlled most effectively is the slaughtering of fertile cows, which directly influences not only the cattle population but also calf production. Male calves and oxen, i.e. the slaughtering thereof, influence the control of the Korean cattle population and beef output.



[Figure 7] Feedback Structure in the Korean Cattle Production Process

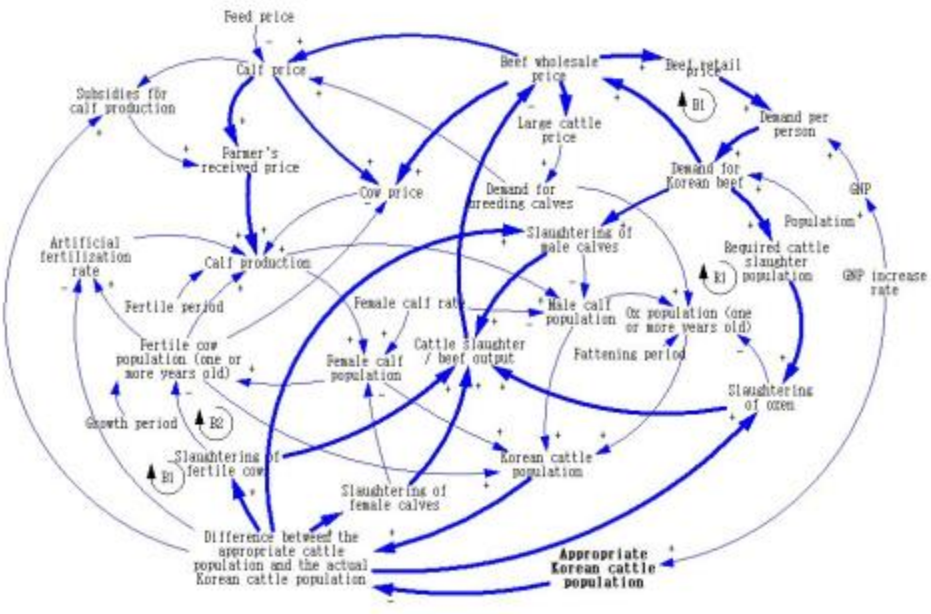
2. Dynamics of Changes in the Price of Korean Cattle

As shown in [Figure 8], for Korean cattle price, the price change patterns of oxen, male calves, cows, and female calves are very similar. This suggests that these price changes, especially the price of large oxen, are very similar according to the supply of Korean cattle. In other words, the price of large Korean oxen and the price of other Korean cattle are coupled with each other.



Source: Jeong, Min-guk et al(2012). Causes of the Recent Fall in Cattle Prices and Response Measures, KREI Agricultural Policy Focus, No. 8.

[Figure 8] Pattern of Changes in Korean Cattle Price

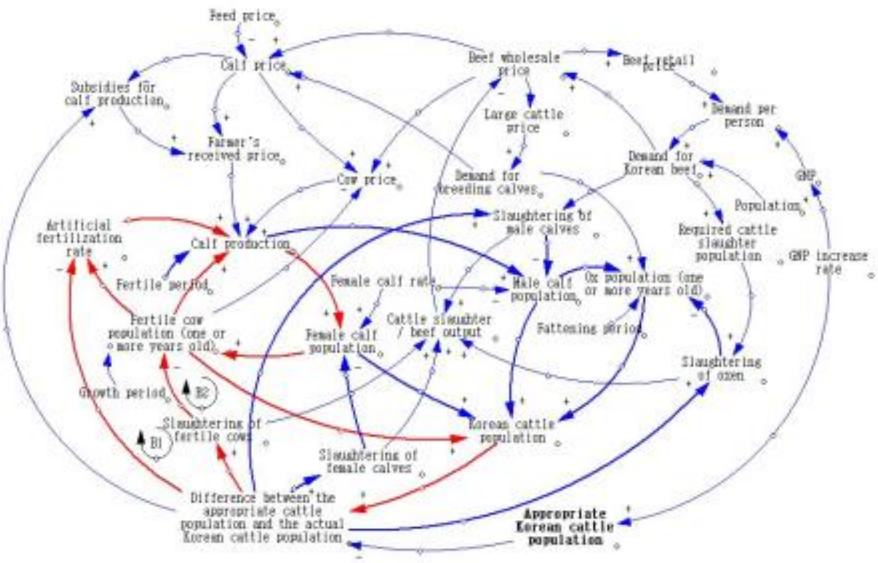


[Figure 9] Feedback Structure of Changes in Korean Cattle Price

The basic feedback structure wherein the price of Korean cattle fluctuates is as shown in [Figure 9] where, if the Korean cattle population exceeds an appropriate level, it will cause an increase in the slaughtering of Korean cattle, which in turn will increase beef output, eventually causing a fall in Korean cattle prices. A drop in Korean cattle prices, such as the calf price or cow price, will decrease the production of calves or the breeding of fattening cattle, thereby causing an overall drop in the Korean cattle population. In this case, a feedback structure is one in which the appropriate level of the Korean cattle population will be reduced, eventually causing a rise in Korean cattle prices (B1, R1).

3. The Risk Posed by the Adoption of a Policy for Controlling the Appropriate Cattle Population

[Figure 10] shows a feedback structure in which, although the Korean cattle population and price fluctuate in the long term, such problems cannot be solved.



[Figure 10] Policy for Controlling Korean Cattle Price and Its Embedded Risk

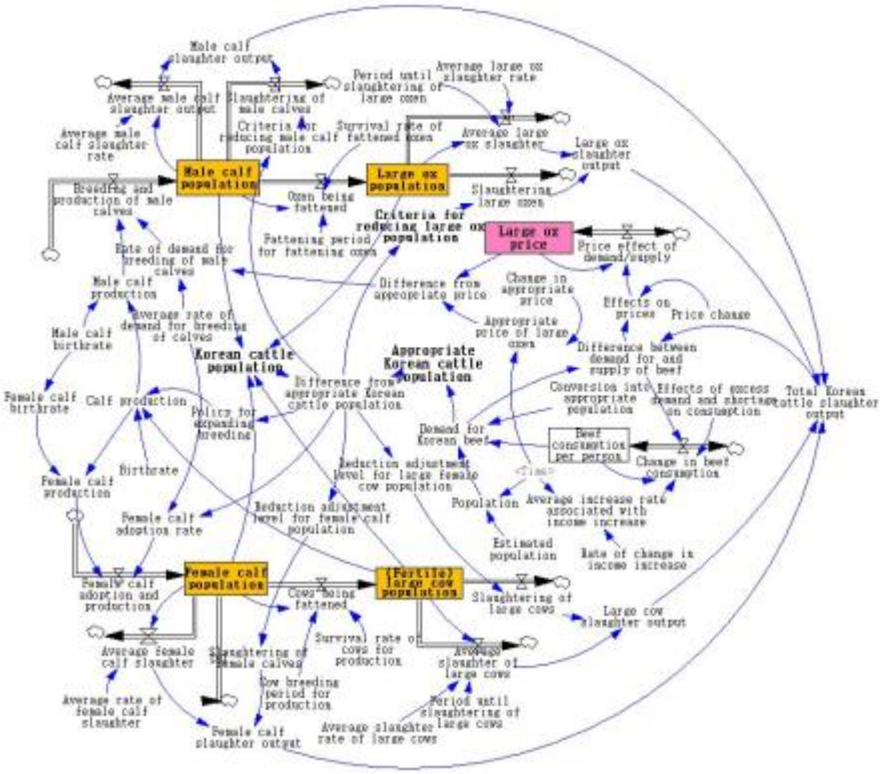
Korea's policy for responding to the problem of fluctuations in the Korean cattle population is such that, if the current Korean cattle population exceeds an appropriate level, it will cause a drop in the price, so, to reduce the cattle population, not only large oxen but also fertile cows have to be slaughtered. This is because if a drop in price leads to a rise in demand, it will reduce market shocks, but the demand for beef is inelastic to the price, and the beef supply is also inelastic to short-term demand changes, making it extremely difficult to resolve these problems.

However, such policies as the policy of slaughtering fertile cows probably had some success in reducing the Korean cattle population to under the appropriate level in the short term, but, in the long term, it significantly weakened the Korean cattle production sites, which in turn drastically decreased the Korean cattle population, consequently leading to a surge in the price of Korean cattle. This, in turn, created a vicious cycle of using the price control policy again. Ultimately, the policy for controlling the Korean cattle population is tantamount to causing fluctuations in the price of Korean cattle.

Ⅳ. Simulation of the Dynamics of the Korean Cattle Population and Prices

1. Simulation Models

Based on the aforementioned causational circulation structure of Korean cattle price fluctuations, the characteristics of dynamic changes in the Korean cattle market were examined using a simulation model comprising such variables as calf production, Korean cattle population, appropriate cattle population, total of slaughtered cattle, beef consumption per person, demand for Korean beef, and the price of large oxen. [Figure 11] shows a stock and flow diagram model designed to simulate why the Korean cattle price and population fluctuate in Korean cattle markets, and what will happen to the Korean cattle population and prices in the future.



[Figure 11] Simulation Model for Korean Cattle Population and Price Fluctuation

This model classified production-site Korean cattle prices into the female calf price, male calf price, large cow price, and large ox price, but used only the large ox price as the representative price. This is because, as shown in [Figure 8], of Korean cattle prices, the large ox price is the highest and represents the prices of other types of cattle, while the changes in prices of other types of cattle are coupled with the large ox price. Thus, it was assumed that male calf adoption rates were influenced by the large ox price.

In addition, if the Korean cattle population exceeds an appropriate level in the Korean cattle markets, efforts will be made by cattle farmers, relevant organizations and the government to curb the excess population. The general available methods of solving the problem include the method of slaughtering male and female calves, large cows and large oxen in addition to the average slaughtering of Korean cattle, and that of adjusting the female calf adoption rate; so, with the reflection thereof, a simulation model was created. In this regard, it is noteworthy that, to adjust the total Korean cattle population, the most direct methods include reducing the number of large cows, which give birth to calves, and controlling the adoption rate of female calves, which will grow to become fertile adults; and these factors bring about a chain influence (Lee, et al., 2011; Jeong, et al., 2012).

Meanwhile, the proposed simulation model deleted exogenous variables such as beef importation, foot-and-mouth disease, international grain price and feeder price--which would influence fluctuations in the Korean cattle market as discussed in the review of literature--, as well as policy variables such as a policy for requiring the marking of the origin of production, the effects of which are expected to have been reflected in consumption levels in Korean cattle markets. In doing so, a model was created for this study using variables such as cattle population and cattle production-site Korean cattle prices, which are expected to have the most far-reaching effects on Korean cattle market fluctuations. The policy scenarios outlined in <Table 1> served to set up simulation models and to examine the function formulae of major variables and the effects of policies for stabilizing Korean cattle prices. In setting the model, the simulation period was set as the period from 2008, when Korean cattle prices plunged to their lowest level in recent years, to 2025.

In addition, because Korean beef consumption is inelastic to the price, and because it is difficult for Korean cattle prices to be immediately reflected in consumer prices due to the distribution structure, this study saw that, for the policy for adjusting Korean cattle prices and population, the policy scenario for controlling Korean cattle population is more appropriate than the policy for promoting Korean beef consumption. In other words, since fluctuations in the Korean cattle market are attributable chiefly to the cattle population, this study created a scenario by which to examine the effects of the policy for reducing the Korean cattle population, as an approach to resolving fundamental problems, namely, policy alternatives with a focus on the reduction of the large cow and large ox populations.

Three policy scenarios were designed. The basic policy scenario focused on considering the relevant stakeholders' policies and efforts when the Korean cattle population exceeds an appropriate level in the markets. Specifically, the scenario assumed that when the Korean cattle population exceeds an appropriate level, the government and relevant organizations will move to basically cull the excess cattle population by about 20%. The second policy scenario assumed that when the Korean cattle population exceeds an appropriate level in the markets, policies will be implemented to reduce the excess cattle population, and large cows in particular. Lastly, the third policy scenario assumed that likewise, when the Korean cattle population exceeds an appropriate level in the markets, policies will be implemented to reduce the excess cattle population, especially, large oxen. This study simulated the long-term effects of such policy scenarios on the Korean cattle markets.

<Table 1> Outline of the creation of the simulation model and the formulae of the major variables

Category	Major items	Outline of simulation equations
Model setting	Simulation period =	Start=2008, Final=2025, Year, DT= 0.5
Model setting	Simulation method=	Euler method
Formulae of major variables	Korean cattle population=	Male calves + female calves + large cows + large oxen, unit: 1,000 heads/year)
Formulae of major variables	Calf production=	(No. of large fertile cows*birth rate)+(policy for expanding breeding)
Formulae of major variables	Large cow population=	INTEG (fattening cows - slaughtering of large cows - the average no. of large cows slaughtered, 1,164)
Formulae of major variables	Demand for Korean beef=	(Population*"beef consumption amount per person")/converted value of appropriate number of cattle
Formulae of major variables	Effects on the price=	Effects of price change (difference between demand for and supply of beef)*0.75 ※ 0.75 shows a level of insensitivity to the difference between demand and supply
Formulae of major variables	Level of reducing the number of large cows =	((difference from appropriate Korean cattle population<=0), (difference from appropriate Korean cattle population),(0))
Formulae of major variables	Total of Korean cattle slaughtered=	Male calves slaughtered + female calves slaughtered + large cows slaughtered + large oxen slaughtered
Formulae of major variables	Average number of large oxen slaughtered =	(No. of large oxen*average slaughtering rate of large oxen)/ the period until the slaughtering of large oxen
Policy scenarios	Basic policy scenario	▶ If the Korean cattle population fails to reach an appropriate level, support will be provided to make up 20% of the shortfall. Also, if the population exceeds an appropriate level, the excess will be reduced by 20%.
Policy scenarios	Scenario for reducing the number of large oxen	▶ When appropriate level is exceeded, if the excess is set at 50% of the number of large oxen reduced
Policy scenarios	Scenario for reducing the number of large cows	▶ When appropriate level is exceeded, if the excess is set at 50% of the number of large cows reduced

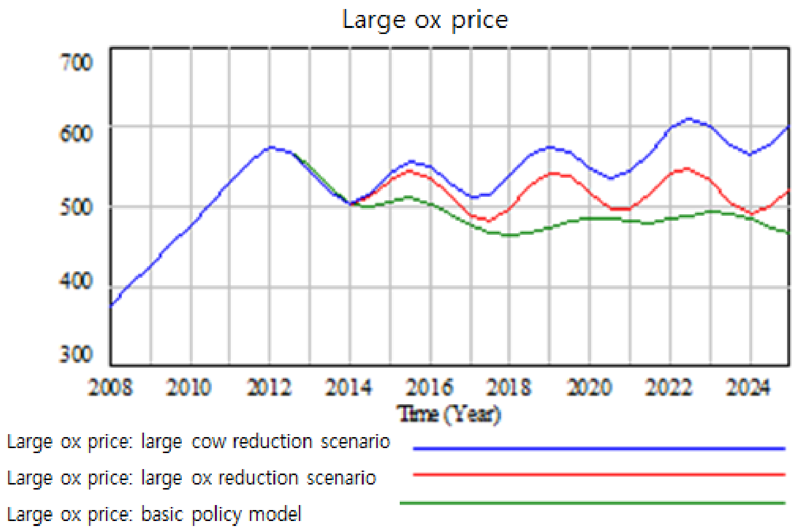
2. Simulation Results: Dominant Structure of Fluctuation, and Discovery of Policy Leverage

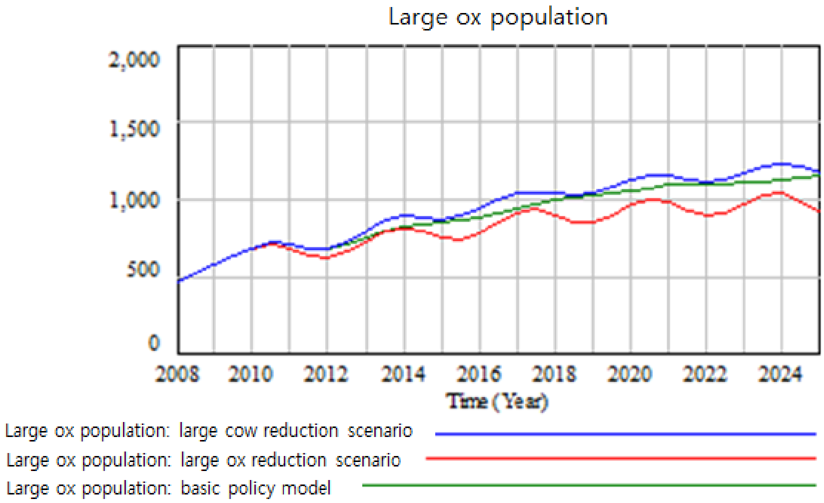
With the reflection of the aforementioned model setting and scenarios, the Korean cattle market simulation model was crafted and run, showing the simulation results of the individual scenarios in [Figure 12]. Simulation for the period 2008-2025 revealed that in all three scenarios, the Korean cattle population and the prices in the Korean cattle markets experienced fluctuations despite efforts to stabilize the markets. This suggests that the beef cycle essentially exists according to the effects of biological and policy delays in the process of raising Korean cattle.

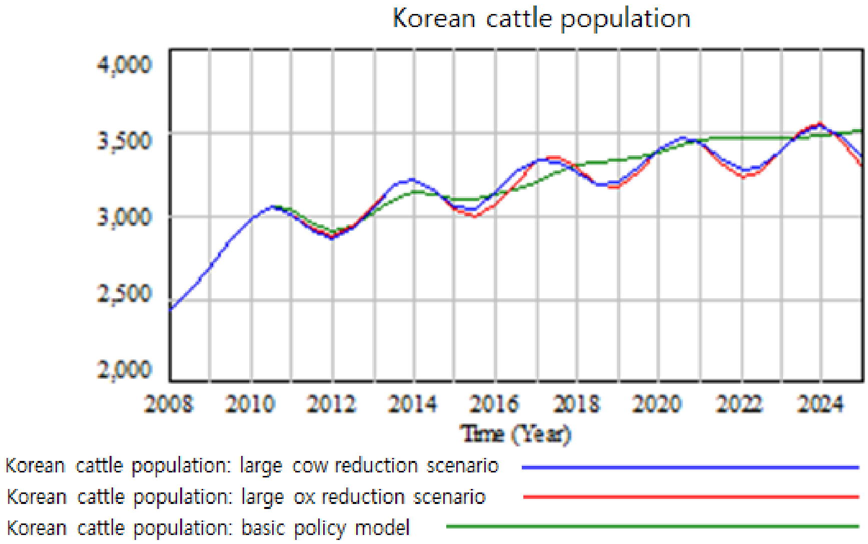
As shown in [Figure 12], the Korean cattle population in the period 2008-2025 shows a repetitive pattern of fluctuation consisting of an increase followed by a decrease nearly every three years in most of the scenarios. In the period 2008-2012, due to a rise in Korean cattle prices, the Korean cattle population steadily increased, but thereafter, it exceeded an appropriate level, causing Korean cattle prices to sharply decrease until the end of 2014; moreover, coupled with this trend, the Korean cattle population sharply decreased. However, the Korean cattle population after 2014 was forecast to increase again due to a rally in Korean cattle prices associated with a fall in the cattle population in the previous period. This pattern appeared until 2025 in the long term.

These simulation results suggest that the fluctuations in the Korean cattle market are attributable to the dominant structure wherein there are delays in the adjustment of the cattle population due to an excess or shortfall of the appropriate level of cattle population. Meanwhile, [Figure 12] was examined according to the individual policy scenarios from the perspective of the long-term effects on Korean cattle markets, revealing that when the Korean cattle population exceeded an appropriate level in the markets, of all the policy alternatives, the basic policy model, which adjusts the cattle population in all stages, would bring about the most stable policy effects.

Contrary to this, the method of reducing the number of large oxen to control the excess of Korean cattle population, and the method of reducing the number of large cows, which have huge effects on calf production may all cause continuous fluctuations in the Korean cattle population and prices. In particular, the approach of reducing the large cow population all at once may further increase fluctuations in both the large oxen population and prices, thus influencing Korean cattle prices the most significantly.

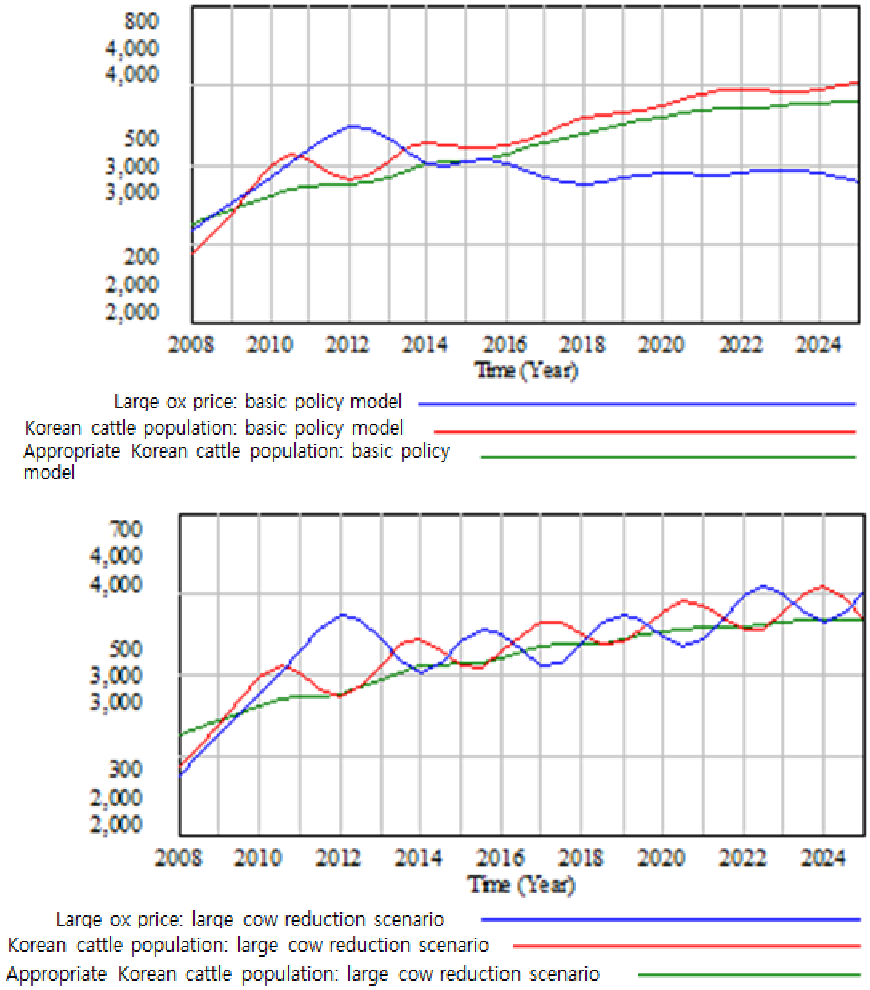






[Figure 12] Korean Cattle Population and Price Simulation Works(Base)

As discussed above, the dominant fluctuation structure in Korean cattle markets is one in which the balance between the Korean cattle population and an appropriate level of cattle population, and the balance between Korean cattle prices, the amount of Korean beef consumption, and the amount of Korean cattle slaughtered cannot be achieved due to a delay of the process. In addition, the basic policy model--which simultaneously controls all types of cattle population, as shown in [Figure 13]-- proved to be the most stable as an effective policy means of stabilizing such fluctuation. Meanwhile, if large cows are temporarily reduced in large numbers, it will reduce calf production and, consequently, after a certain period, will decrease the entire cattle population and increase Korean cattle prices accordingly, which will bring about a chain as well as having the unbalanced result of increasing the Korean cattle population.



[Figure 13] Analysis of Effects of Policy for Stabilizing Korean Cattle Market Fluctuation

Ⅴ. Conclusion

Several researches have been conducted to predict Korean cattle price and population in Korean cattle markets. However, due to the feedback structure involving various factors and delays of the process in Korean cattle markets, they failed to define long-term fluctuations in cattle population and price. The findings of this study have revealed the following: as disclosed in the analysis of the causal circulation structure, the dynamic characteristics of Korean cattle markets are defined by the feedback structure involving various factors such as cattle population, appropriate level of cattle population, production-site price, beef production price, consumer price, feed price, beef importation amount and import price, foot-and-mouth disease, the release and supply amount of beef, demand and consumption amount, demand for breeding calves, and the number of fertile cows slaughtered.

Meanwhile, a simulation of Korean market fluctuations with the focus on the Korean cattle population and price revealed the following: such fluctuations occurred due to an imbalance between the Korean cattle population and the appropriate level of Korean cattle population, and an imbalance between the Korean cattle price, Korean beef consumption amount, and the number of Korean cattle slaughtered, which further intensified and continued to be repeated due to delays in the process. The results of the simulation, which was aimed at analyzing long-term changes in Korean cattle markets, predicted that only the basic policy model, which proved to be the most successful policy alternative, would show a strong fluctuation in the price of Korean cattle until 2018 due to such a feedback structure, and thereafter a somewhat weak fluctuation pattern until 2025. In addition, the findings of this study revealed that if the Korean cattle population exceeded the appropriate level, the method of simultaneously reducing the population of all types of Korean cattle in all stages of breeding would prove to be more desirable than the method of reducing the number of large fertile cows.

Lastly, the findings of this study revealed the following point: in Korean cattle markets, due to the complexity of the distribution structure, there is a very inelastic relationship between the production-site Korean cattle price, the Korean cattle slaughter amount, and the amount of Korean beef consumption; thus, there is a structure wherein it is difficult to resolve problems of imbalance such as an abnormal increase or decrease in the cattle population in the short term according to market principles. Thus, to resolve the problems with the cattle population and prices in Korean cattle markets, the government's efforts should focus on improving the beef distribution structure to flexibly connect the Korean cattle supply and prices, and beef consumption, rather than pursuing a strategy with the focus on supply aspects such as reduction of the cattle population and encouragement of calf-breeding.

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