Dynamic analysis of the livestock inventory in Inner Mongolia[1]

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Abstract

This paper examines the factors affecting the livestock inventory based on the panel data from 12 prefectures (or cities) in Inner Mongolia from 1980 to 2010. Specially, attempt to understand the dynamic changing of the inventory. Based on the livestock products market, an inventory equation is conducted to combine an equilibrium displacement model (EDM) and the livestock inventory. The result is that Inner Mongolia is a large open economy in the cattle market but a small economy in the sheep and goats markets. The livestock inventory is affected by prices of the livestock products and weather conditions significantly when prices are exogenous. Since prices are affected by market shifters, the livestock inventory is affected by the population and transportation in China besides the weather conditions after endogenizing the prices. Our results suggest that it is more reasonable and efficient to implement policies to adjust the livestock market in order to control the livestock inventory than to implement policies directly on the grassland or the farm level. In addition livestock is an environment-sensitive industry so it is necessary to improve the environment in order to ensure its development.

Key words: inventory; livestock; Inner Mongolia

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1. Introduction

Inner Mongolia Autonomous Region (IMAR) is one of the five autonomous regions and the largest pasture in China, where the grazing is one of the most important industries. Because of the grassland, IMAR also plays an important role in maintaining the ecosystem. The research related to livestock inventory has interested economists for many decades. Compared to other agricultural commodities, livestock is special because it has a nature of the biological lags which delay the response to the market. As a result, both past and anticipated prices are important determinants of production plans. As mentioned, grazing has close correlation with ecosystem. For example, overgrazing is considered as the main cause of grassland degradation in northern China (Han et al., 2008; Zhao et al., 2006; Li and Ji 2004) which in turn threatens this industry. From both economic and ecologic perspective, it is meaningful to analyze the determinants of the livestock inventory in IMAR.

Research about livestock inventory is complex because the dynamic cycle is hard to be simulated by economic models. But still this area is of great interest to economists. Jarvis (1974); Melton (1980); Rucker, Burt, and LaFrance (1984); Trapp (1986); Chavas and Klemme (1986); and Schmitz (1997) investigated the dynamic behavior underlying the livestock inventory through analyzing the replacement and culling decisions. In their studies, cattle are treated as capital. The models are mainly based on biological factors. The economic and environmental influences are considered as they affect the probability of replacement and culling decisions.

Jarvis examined the inventory of cattle by treating cattle as capital goods and producers as portfolio managers. The managers sought the optimal combination of different categories of animals to complement their non-cattle assets and then to maximize profit. This process results in the expected inventory of cattle. Melton extended Jarvis's study by considering the role of genetic improvement which was done on the experimental herd. Chavas and Kleme investigated the milk supply and the change of dairy herd. They considered a model of population growth, where the replacement decision and the culling decision would be affected by the milk price, slaughter price, and feed cost. Similar to Chavas and Kleme's work, Schmitz set up a replacement probability to introduce the economic and environmental effect (interest rate, Palmer Drought Severity Index, etc.) into the age dynamics model. Trapp's model is different from those mentioned above. He employed financial thoughts in his work where replacement and culling were treated as investment and disinvestment respectively in a firm. The firm's cost curve and the discounted net revenue flows affected the firm size (inventory of the beef-breeding herds). And, instead of estimating the dynamic adjustment process underlying cattle inventory behavior (replacement and culling), Rucker, Burt, and LaFrance employed a rational lag function including cattle prices, feed cost, and weather variables as an approximation.

One of the similarities of the past research is that it focuses more on the change of the inventory through a biological process rather than a supply-demand chain in the industry, even though some market factors have been included through their impacts on the replacement decision. In fact, market and farm are separate and they interact by price. Therefore it is logical to analyze market and farm separately and then to examine their interaction in terms of prices. In the market, supply shifters and demand shifters can impact the price, and then the changes of price will impact the inventory in the farm. In other words, price is endogenous. Tryfos (1974) separated livestock supply and inventories in his work. The relationship between supply and inventory is that the supply is the changes of inventories in different periods. Price is still exogenous. It affected the inventory first and then the supply. Arzac and Wilkinson (1979) realized that feed grain prices were endogenous so that the dynamics of the interaction between the livestock and feed grain markets might be analyzed. They incorporated the endogenous variables by allowing individual structural equations to be estimated and to enter into the solution of the model with different periodicities.

Besides the ignorance of the activities in a market and the endogeneity of the prices, another limitation of previous research is that most research lacks the influence of the environment. Fortunately, some recent studies have noticed the environmental influence on the inventory. For example, Belasco (2013) analyzed the impact of droughts on ranchers' decision regarding herd size by using state-wide panel data series from 1945 to 2012 and a first-difference fixed effects panel estimator.

Most research tries to make the dynamics of the inventory more close to the reality by addressing different assumptions or introducing variables to the econometric model. The methodology developed in the previous studies provides both theoretical and econometrical bases for this research. However, most research ignores the logic underlying the inventory and the retail market, in particular their interaction. In this case, this paper attempts to make it clear by connecting the dynamics of livestock inventory and the effect of market through endogenizing the prices of the livestock products.

The organization of this paper is as follows. The second section specifies the model; the third explains the variables and data; the fourth discusses the estimation and results; and the fifth summarizes the main findings of the paper.

2. Model specification

2.1. Theoretical model

A static partial-equilibrium model is constructed to describe the situation of Inner Mongolia's livestock sector. Complexities such as product heterogeneity, price wedges due to subsidies or tariffs, imperfect competition, and demand and supply interrelationships are ignored. Because more than 70% of livestock products and 85% milk are exported to other areas of China, IMAR is treated as an open economy in the model.

The basic model consists of four equations

(1) $Q_s^* = \varepsilon_d(P^* + \alpha)$

(2) $Q_d^* = \eta_d(P^* - \beta)$

(3) $Q_x^* = \eta_x(P^* - \gamma)$

(4) $Q_s^* = k_d Q_d^* + k_x Q_x^*$

where Q_s^*, Q_d^*, and Q_x^* are proportionate changes in domestic production, consumption, and exports, respectively, (e.g., $Q_d^* = dQ_d/Q_d$ is proportionate change in domestic consumption); P^* is the proportionate change in the price of the livestock item in question; ε_d (> 0) is the domestic supply elasticity; $\eta_d(< 0)$ is the domestic demand elasticity; $\eta_x(< 0)$ is the export demand elasticity; α (> 0) is a parameter that represents the proportionate *downward* shift in the domestic supply curve due to some exogenous factor, i.e., the shift in the price direction holding quantity constant; β (> 0) is a parameter that indicates the proportionate *upward* shift in the domestic demand curve due to some exogenous factor; γ (> 0) is the proportionate *upward* shift in the export demand curve due to some exogenous factor; $k_d = Q_d/Q_s$ is the share of domestic production consumed within Inner Mongolia; and $k_x = Q_x/Q_s$ is the share of domestic production exported ($k_d + k_x = 1$).

The model contains four endogenous variables (Q_s^*, Q_d^*, Q_x^*, and P^*) and three exogenous variables or shift parameters (α, β, and γ). At issue is the effect of the supply and demand shifters on the *equilibrium* level of livestock production. The equilibrium level of production is the level that takes into account price changes induced by supply or demand shifts. To determine that, first solve the model for the price effect of the shift variables

(5) $P^* = -\left(\frac{\varepsilon_d}{D}\right)\alpha - \left(\frac{k_d\eta_d}{D}\right)\beta - \left(\frac{k_x\eta_x}{D}\right)\gamma$

where $D = (\varepsilon_d - k_d\eta_d - k_x\eta_x) > 0$. An increase in domestic supply ($\alpha > 0$) reduces equilibrium price, while an increase in domestic demand ($\beta > 0$) or export demand ($\gamma > 0$) increases equilibrium price.

Substituting equation (5) into equation (1) yields the reduced-form equation for domestic production:

(6) $Q_s^* = -\left(\frac{\varepsilon_d(k_d\eta_d + k_x\eta_x)}{D}\right)\alpha - \left(\frac{\varepsilon_d k_d \eta_d}{D}\right)\beta - \left(\frac{\varepsilon_d k_x \eta_x}{D}\right)\gamma$

An increase in domestic supply increases the equilibrium level of livestock production, as does an increase in domestic or export demand.

If Inner Mongolia is a small exporter such that it faces a perfectly elastic demand curve in the export market, equations (5) and (6) reduce to

(7) $P^* = \gamma \qquad (\eta_x = -\infty)$

(8) $Q_s^* = \varepsilon_d(\alpha + \gamma) \qquad (\eta_x = -\infty)$

In this instance, domestic demand shifters have no effect on the equilibrium level of livestock production. The reason is that with perfectly elastic export demand, shifts in domestic demand have no effect on equilibrium price, and without a price effect there is no production response. This is shown in figure 1 where a rightward shift in the domestic demand curve from *D* to *D*' causes offsetting changes in domestic consumption and exports, leaving domestic production unchanged at its initial equilibrium level Q_s.

2.2. Inventory Relation

The model is completed with an equation for livestock inventory. Following Rucker *et al*. (1984), the following structural relation is posited.

(9) $\tilde{I}_t = f(\tilde{P}_t, \tilde{F}_t, W_t) \qquad \frac{\partial \tilde{I}_t}{\partial \tilde{P}_t} \gtrless 0,\ \frac{\partial \tilde{I}_t}{\partial \tilde{F}_t} < 0,\ \frac{\partial \tilde{I}_t}{\partial W_t} > 0$

where $\tilde{I}_t$ is the desired herd size in period t, $\tilde{P}_t$ is the expected price for the livestock item in question (e.g., sheep), $\tilde{F}_t$ is the expected price of feed and/or feed availability, and W_t is weather conditions. Defining W_t as a weather index where larger values indicate more favorable conditions for grazing, an isolated increase in W_t is expected to increase the desired herd size. An isolated increase in expected feed cost (or a decrease in expected feed availability) is expected to decrease the desired herd size.

Importantly, expected livestock price has an ambiguous effect on desired herd size. The reason is that livestock properly is viewed as a capital good (Jarvis 1974). Consequently, an increase in the price of the livestock item has two opposing effects on producers' decisions. As noted by Rucker *et al*. (1984, p. 135), the price increase causes producers to expect higher prices in the future, which provides an incentive to increase breeding stock to take advantage of the higher future price.

Jarvis (1974) refers to this as the “investment demand” for livestock. On the other hand, the price increase encourages producers to sell livestock immediately to profit from the current high price. This is analogous to Jarvis’s “consumption demand” for livestock. Depending on which motive dominates (the investment motive or the consumption motive), equation (9) may be upward-sloping or downward-sloping with respect to expected price.

To implement equation (9) an equation must be found to represent desired herd size $\tilde{I}_t$, as this variable is unobservable. For this purpose, this study adopts the partial adjustment model.

(10) $$\frac{I_t}{I_{t-1}} = \left(\frac{\tilde{I}_t}{I_{t-1}}\right)^{\lambda} \qquad (0 < \lambda \leq 1)$$

where I is observed herd size, and λ is the “elasticity of adjustment” (Nerlove 1958). The relationship between observed and desired herd size may be found through proportionate differentiation of equation (10). Suppressing time subscripts and rearranging terms, the equation of interest is

(11) $$I^* = \lambda \tilde{I}^* + (1-\lambda) I^*_{t-1}$$

The proportionate change in desired herd size in any given period lies between the proportionate change in observed herd size in that period and the proportionate change in observed herd size in the previous period. If adjustment costs are low such that $\lambda \approx 1$, the observed adjustment in the current period is close to the desired adjustment, i.e., $I^* \approx \tilde{I}^*$. In this situation, producers are able to respond quickly to supply and demand shocks and the observed herd size in any given period is close to the desired herd size. The opposite is true if adjustment costs are high such that $\lambda \approx 0$. In this situation $I^* \approx I^*_{t-1}$ and the time required to achieve the desired herd size in response to a supply or demand shock can be quite lengthy.

Equations (11) and (9) may be linked by taking the total differential of the latter and converting partial derivatives to elasticities to yield (time subscripts suppressed)

(12) $$\tilde{I}^* = \delta_{\tilde{P}}\, \tilde{P}^* + \delta_{\tilde{F}}\, \tilde{F}^* + \delta_W W^*$$

where $\delta_{\tilde{P}} \left(\gtrless 0\right)$, $\delta_{\tilde{F}}(< 0)$, and δ_W (> 0) are partial elasticities of desired herd size with respect to expected price, expected costs, and weather, respectively.

Substituting equation (12) into equation (11) yields

(13) $$I^* = \lambda\delta_{\tilde{P}}\,\tilde{P}^* + \lambda\delta_{\tilde{F}}\,\tilde{F}^* + \lambda\delta_W W^* + (1-\lambda)I_{t-1}^*.$$

Observed herd size is a function of expected price, expected costs, weather, and observed herd size in the previous period. The coefficients of $\tilde{P}^*$, $\tilde{F}^*$and W^* are short-run elasticities. The short-run elasticities approach their long-run counterparts as $\lambda \to 1$. If $\lambda = 1$ adjustment costs are zero and equation (13) reduces to equation (12), the static specification.

It remains to eliminate expected price and expected costs, as these variables are unobservable as well. For this purpose, this study assumes naïve expectations. Setting $\tilde{P}^*$ and $\tilde{F}^*$ equal to their observed values in the current period, equation (13) may be rewritten as

(14) $$I^* = \pi_0 + \pi_{\tilde{P}}\,P^* + \pi_{\tilde{F}}F^* + \pi_W W^* + \pi_{LDV}I_{t-1}^*$$

where $\pi_{\tilde{P}} = \lambda\delta_{\tilde{P}} \gtrless 0$, $\pi_{\tilde{F}} = \lambda\delta_{\tilde{F}} < 0$, $\pi_W = \lambda\delta_W > 0$, and $0 \leq \pi_{LDV} = (1-\lambda) < 1$. Observed herd size is a function of observed livestock price, observed inventory costs, weather conditions, and observed herd size in the previous period (lagged dependent variable or LDV). An intercept π_0 is included in equation (14) to account for autonomous shifts in the inventory relation due to factors that change gradually over time but that are not specified in the model.

2.3. Total Elasticities

Equation (14) is a structural equation. As such, the coefficients of $F^*$and W^* tell the effect of changes in inventory costs and weather on desired herd size when livestock price is held constant. In reality, livestock price will change in response to changes in market shifters. When Inner Mongolia is a small exporter, i.e., it faces a perfectly elastic demand curve in the export market, the price will change in response to the export demand shifters.

To account for the potential endogeneity in livestock price, and to incorporate demand shifters into the inventory relation, first rewrite equation (5) in the simpler form

(5') $P^* = \varphi_\alpha \alpha + \varphi_\beta \beta + \varphi_\gamma \gamma$

where $\varphi_\alpha = \frac{-\varepsilon_d}{D} < 0$, $\varphi_\beta = \frac{-k_d \eta_d}{D} > 0$, and $\varphi_\gamma = \frac{-k_x \eta_x}{D} > 0$. Substituting equation (5') into equation (14) yields

(15) $I^* = \pi_0 + \pi_S S^* + \pi_D D^* + \pi_X X^* + \pi_{\tilde{F}} F^* + \pi_W W^* + \pi_{LDV} I^*_{t-1}$

where S^* is a vector of domestic supply shifters associated with livestock *harvests* Q^*_S (as opposed to livestock inventory I^*) expressed as proportionate changes, D^* is a vector of domestic demand shifters, and X^* is a vector of export demand shifters. The parameters associated with these shift variables have indeterminate signs as follows

(15a) $\pi_S = \pi_{\tilde{P}} \varphi_\alpha \gtreqless 0$

(15b) $\pi_D = \pi_{\tilde{P}} \varphi_\beta \gtreqless 0$

(15c) $\pi_X = \pi_{\tilde{P}} \varphi_\gamma \gtreqless 0$

With the maintained hypothesis that feed and other costs associated with herd maintenance are exogenous to the livestock subsector under consideration (e.g., sheep), the coefficients of equation (15) can be interpreted as *reduced-form* elasticities. Specifically, $\pi_{\tilde{F}}$ tells the percentage change in herd size associated with an isolated 1 percent change in inventory costs, *letting livestock price adjust*. A similar interpretation applies to π_W. Because "total" elasticities that let price adjust in general are smaller than "partial" elasticities that hold price constant (Piggott 1992), the estimates of $\pi_{\tilde{F}}$ and π_W obtained from the reduced form (equation (15)) are expected to be smaller than the estimates obtained from the structural equation (equation (14)).

2.4. Small Exporter Hypothesis

If Inner Mongolia is a small exporter $\varphi_\alpha = \varphi_\beta = 0$ and domestic supply and demand shifters have no effect on price (see equation (7)). In this instance, equation (15) reduces to

(16) $I^* = \pi_0 + \pi_X X^* + \pi_{\tilde{F}} F^* + \pi_W W^* + a_{LDV} I^*_{t-1}$ $(\eta_x = -\infty)$.

If Inner Mongolia is too small a player in world markets to affect terms of trade, the only variables to affect herd size are export demand shifters, inventoryspecific costs, and weather. Since equation (15) nests equation (16), the small exporter hypothesis may be tested with a standard *F*- or *Wald*-statistic.

3. Variables and data

Table 1 identifies the variables. The data regarding the prices of sheep, goats and cattle in IMAR are less accessible so prices of respective products (e.g., beef) are used as the indicators of livestock prices. It is apparent, for example, the increase in the price of beef will cause the rancher to expect a higher price of cattle. The other variables are divided into three categories based on the models. The inventory shifters include the forage cost and the weather variables which are represented by temperature, precipitation and radiation. The increase in the forage cost will decrease the livestock inventory. The grazing depends on the weather conditions. The primary effects of the weather conditions are largely reflected through forage availability, such as pasture and range conditions and the production of hay (Rucker et al. 1984). The domestic supply shifters include the average annual income in the rural area of IMAR and two dummy variables reflecting dzud and the grassland protection policy respectively. Higher annual income in rural area will attract more labor force for grazing so the supply is assumed to increase. Dzud indicates the severe winter weather condition which has a direct impact on livestock inventory through death losses and reduced survival rates of newborn calves[2]. Therefore dzud will reduce the livestock inventory. The grassland protection policy was implemented in 2000 in order to make an efficient use of the grassland and recover the pasture. The livestock inventory is expected to decrease after the policy was implemented. The average annual income per capita and the total population in IMAR are the domestic demand shifters. As the income and the population increase, the demand for the livestock in the domestic market will increase. Similarly the increase in the income and population as well as the improvement of the transportation in China will spur

[2] Based on John (2013)'s study, dzud happened in Inner Mongolia in 1986, 1987, 1993, 1994, 1996, 1997, 1999, 2000, 2001, 2002, 2009, and 2010.

the external demand for the livestock products. Therefore the average annual income per capita, the total population, and the total road length in China represent the export demand shifters.

The data are from the Bureau of Statistics in both local and national China and include all the variables above. The data are panel data, where observations are yearly and span from 1980 through 2010 for the 12 prefecture-level regions in IMAR. The basic statistics of variables are shown in table 2, where prices have been adjusted by consumer price index (CPI). As shown in table 2, sheep and goats are the main livestock in IMAR. The differences of the variables among the cities are significant. The development of economy in IMAR is unbalanced. The largest average number of sheep, goats, and cattle is approximately 5.4 million, 2.6 million, and 0.9 million in Xilingol, Ordos, and Tongliao, respectively. The highest average annual income per capita is about US $3.61 in Baotou, which is higher than that of capital city in Inner Mongolia - Hohhot ($3.03). The largest population is 4.1 million in Chifeng. Figure 2 indicates the change of the relative prices. The relative price of cashmere was most obvious exhibiting variation 50 times from the early 1980s to 2010. The relative price of wool showed decreasing first and then increasing. The relative prices of beef and mutton decreased first and then increased. The livestock inventory in Inner Mongolia is illustrated in figure 3. Generally the livestock inventory increased from 1980 to 2010, in particular, the inventory of sheep, jumped in 2000. The inventory of cattle was relatively stable. Because the forage cost is just available from 1995 to 2010, the data used for estimation is from 1995 to 2010 and includes 192 observations.

4. Model estimation and results

4.1. Model estimation

The logarithmic first-difference forms of the structural equation (14) and reduced equation (15) are:

(14') $\mathrm{d}lnI_t = \pi_0 + \pi_{\tilde{P}}\, dlnP_t + \pi_{\tilde{F}}\, dlnF_t + \pi_W dlnW_t + \pi_{LDV} dlnI_{t-1}$

(15') $dlnI_t = \pi_0 + \pi_S dlnS_t + \pi_D dlnD_t + \pi_X dln\, X_t + \pi_{\tilde{F}} dlnF_t + \pi_W dlnW_t + \pi_{LDV} dlnI_{t-1}$

To simplify the notation, the additive error terms are omitted from the equations. P_t is the prices (adjusted by CPI) of beef, mutton, wool, and cashmere; F_t represent the forage cost; W_t includes the indicators of the temperature, precipitation, and radiation; I_{t-1} is one-year lagged livestock inventory; S_t, D_t, and X_t represent the domestic supply shifters, domestic demand shifters, and export demand shifters as introduced in the variable section.

As analyzed, the equation (14') represents the effect of the price, forage cost, weather, and previous livestock inventory on the present inventory. As introduced before, the effect of price is ambiguous and it depends on the herders' choice between "investment demand" and "consumption demand". If the herders choose "investment demand", they will hold the livestock and then the livestock inventory will increase. But if the herders choose "consumption demand", they will sell the livestock and then the livestock inventory will decrease. As assumed, the increase in the forage cost will decrease the livestock inventory, increase in the values of the weather index means good weather which benefits the pasture and then increases the inventory, and the adjustment indicator (π_{LDV}) will be positive but less than 1.

Reduced equation (15') is obtained by endogenizing prices. If Inner Mongolia is a large open economy, the prices of the livestock products will be affected by both domestic and export shifters in a market. If Inner Mongolia is a small open economy, the prices cannot be affected by the domestic market. No matter what kind of economy Inner Mongolia is, the prices are endogenous. It is of interest to investigate the effect of the market factors on the livestock inventory through endogenizing the prices. In addition, the effect of the forage cost and the weather will be in general weakened when let the prices adjust. Fixed effect regression is employed to analyze the panel data. There are four kinds of products: beef, mutton, wool and cashmere corresponding to three kinds of livestock cattle, sheep, and goats. The results are shown in table 3. The equations are also estimated by including the lagged prices but the results show that the prices in the previous period have no significant effect on the inventory in the current period (see appendix).

4.2. Results

Prices are assumed to be exogenous in structural models. The estimation of the structural models shows that the effect of the wool price on the inventory of sheep is significantly negative. But the price of beef, mutton, and cashmere has no effect on the inventory of cattle, sheep, and goats. 1% increase in the wool price will decrease the inventory of sheep by 0.42%. The result is consistent with the negative relationship between the price of wool and the inventory of sheep. According to figure 2 and figure 3, generally the price of wool decreased, and the inventory of sheep increased. Mutton and wool are joint products so the effects of their prices on the inventory of sheep should be the same. That the wool price is significant and the mutton price is not indicates that herders focus more on wool price as an indicator of sheep value than mutton. The decrease in the wool price signals that the value of sheep decrease. The associated decrease in the inventory of sheep indicates that herders prefer to sell rather than hold the sheep. The effect of the forage cost is not significant for all the three kinds of livestock. It means the forage cost is not an important consideration for the herders in Inner Mongolia. The effect of the weather conditions on the inventory of cattle, sheep and goats is different. Temperature has no significant effect on the livestock inventory. 1% increase in the precipitation will increase the inventory of cattle and sheep by 0.25%

and 0.23% respectively, but decrease the inventory of goats by 0.2%. Compared to the precipitation, the radiation affects the livestock inventory largely. 1% increase in the radiation will increase the inventory of cattle and sheep by 2.36% and 3.08% respectively, and decrease the inventory of goats by 1.88%. It means that different animals and their forage prefer different weather conditions. The effect of the inventory in the previous period is significant for all the animals. As expected, the coefficients of the lagged variables in the three equations are positive and less than 1. For cattle, sheep, and goats, the coefficients are 0.26, 0.18, and 0.24 respectively. It means the adjust cost for sheep, goats and cattle ascends. The cattle are the most valuable animal so the cost to adjust the inventory of cattle is the highest. Moreover the constant in the cattle inventory is significantly positive. It means the inventory of cattle has an increase trend.

The estimation results of the reduced form after endogenizing the prices are shown in the second column of table 3. Not all the “total” elasticities are smaller than the “partial” elasticities in the structural equations. The effect of the forage cost is still not significant for all the three kinds of livestock. The effects of the weather conditions are not as significant as that in the structural model. The inventory of cattle is affected by temperature and radiation significantly. 1% increase in the temperature will decrease the inventory of cattle by 0.26%. 1% increase in the radiation will increase the inventory of cattle by 0.17%. Higher temperature will cause drought in Inner Mongolia so it will decrease the inventory of cattle. The inventory of sheep is just affected by radiation. 1% increase in the radiation will increase the inventory of sheep by 2.19. The inventory of goats is just affected by precipitation. 1% increase in the precipitation will decrease the inventory of goats by 0.26%. The adjust cost changes after endogenizing the prices that the adjust cost for sheep is the highest. The adjust cost for goat is lower but similar to that for sheep. The adjust cost for cattle is the lowest. As the F-test indicates, Inn Mongolia is a large open economy in the cattle market but a small open economy in the sheep and goats markets. That Inner Mongolia is a large open economy in the cattle market means that the domestic market inside Inner Mongolia can affect the price of cattle products and then the inventory of cattle. Herders have power in the market so it is costless for them to adjust the inventory of cattle. But for sheep and goats, the supply and demand of their products are affected by the outside market. It is hard for the herders to estimate the conditions in a market and the adjust cost will be higher. Regarding the shifters in the market, some domestic supply shifters and export demand shifters are significant. None of the domestic demand shifters impacts the livestock inventory significantly. The dzud only decreases the inventory of cattle. The inventory of cattle and goats increased significantly after the implementation of the grassland protection policy. The reason why the livestock still increased after the policy was carried out is that the subsidy given to the herders is less than the increase of the price of the livestock products (Song et al. 2004). Another reason is that besides the grassland protection policy, series of policies were implemented in and after 2000. The dummy variable might include the effect of other policies. The population in China affects the inventory of cattle and goats significantly. 1% increase in the population increases the inventory of cattle and goats by 50.43% and 47.78% respectively. The large elasticities are because the inventory of cattle and goats changed a lot but the population in China did not change a lot from 1995 to 2010. Because of the large population in China, every one percent increase in the population will induce a huge demand in the livestock market. In addition, since changes in population are gradual, the variable probably measures a trend effect rather than population per se. The positive coefficients for cattle and goats might reflect trend growth in herd size over the period. The effect of the transportation is significantly negative for cattle and sheep. 1% increase in the road length will decrease the inventory of cattle by 0.21% and the inventory of sheep by 0.32%. The negative effect suggests herders liquidate inventory in response to increase in export demand.

5. Conclusions

This paper examines the factors affecting the inventory of livestock in IMAR. Specially, attempt to understand the effect of market on the inventory of livestock. Based on the livestock products market, an equilibrium displacement model (EDM) is constructed to describe the demand and supply of the beef, mutton, wool and cashmere which are the products of cattle, sheep and goats. Then based on Rucker et al. (1984)'s work, an inventory equation is established to combine the EDM and the inventory. In other words, the final equation includes not only the information from the market of beef, mutton, wool, and cashmere but also the information from the livestock farm level.

The estimation results from the structural model show that the herders prefer "consumption demand" for sheep, i.e. the increase in the wool price will decrease the sheep inventory in the current period. The prices of beef, mutton and cashmere have no significant on the inventory of cattle, sheep and goats. Different animals and forage need different weather conditions. More precipitation and radiation will increase the inventory of cattle and sheep but reduce the inventory of goats. It is costless to adjust the inventory of sheep, and then that of goats. The adjust cost is highest for cattle.

One of the contributions in this study is that it considers the influence of market shifters, i.e. income, population and transportation by endogenizing the prices. After endogenizing, the results show that IMAR is a large exporter in the cattle market but a small exporter in the sheep and goats market. That means the domestic shifters can affect the cattle products market but cannot affect the sheep and goats products market. It is the reason why the costs to adjust sheep and goats increase. In this case, the effects of the population and transportation are significant on the inventory of cattle and goats. The increase in the population increases the export demand and the increase in the road length allows the herders to liquidate the livestock inventory in response to increases in export demand. Based on the results, the dzud just reduced the inventory of cattle. The results also indicate that the inventory of cattle and goats increased after the implementation of the grassland protection policy. According to the previous studies, the reason is that the subsidy given to the herders is limited. In addition, series of policies were carried out in 2000 so the effect of policy in this study is actually mixed.

To summarize, the livestock inventory is more sensitive to the weather and the market factors than the policy. On one hand it is necessary to improve environment to ensure the development of the livestock industry. On the other hand herders adjust the inventory in response to the demand in both domestic and export markets. Therefore it is better to complement policies which can affect the price or demand in the market to control the livestock inventory and then reduce the grazing scale to protect the grassland.

References

Arzac, Enrique R. and Maurice Wilkinson. 1979. A quarterly econometric model of United States livestock and feed grain markets and some of its policy Implications. *Am. J. Ari. Econ.* 61(2):297-308.

Belasco, Eric J. 2013. The Spatio-temporal Impact of Drought on Local and Regional Feeder Cattle Inventories. Paper presented at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6.

Chavas, J.P. and R.M. Klemme. 1986. Aggregate milk supply response and investment behavior on U.S. dairy farms*. American Journal of Agricultural Economics*. 68: 55-56.

Han, J., Y. Zhang, C. Wang, W. Bai, Y. Wang, G. Han, and L. Li. 2008. Rangeland degradation and restoration management in China*. The Rangeland Journal* 30: 233–39.

Jarvis, L. S. 1974. Cattle as capital goods and ranchers as portfolio managers: an application to the argentine cattle sector. *Journal of Political Economy* 82:489-520.

John, Ranjeet et al. 2013. Vegetation response to extreme climate events on the Mongolian Plateau from 2000 to 2010. *Environmental Research Letters* 8(3):1-12.

Li, Yinpeng and Jingjun Ji. 2004. Assessment of the productivity and livestock carrying capacity of Inner Mongolia grassland by regional scale modeling. *Journal of Natural Resources*. 19(5): 610-16.

Melton, B.E. 1980. Economics of beef cow culling and replacement decisions under genetic progress. *Western Journal of Agricultural Economics*. 5(2):137-47.

Rucker, R. R., O.R. Burt and J.T. LaFrance. 1984. An econometric model cattle inventories. *American Journal of Agricultural Economics*. 66: 131-44.

Schmitz, John D. 1997. Dynamics of beef cow herd size: an inventory approach. *American Journal of Agricultural Economics* 79: 532-42.

Song, Naiping et al. 2004. Prohibiting graze policy and its effect. *Journal of Natural Resources* 19(3): 316-23.

Trapp, J.N. 1986. Investment and disinvestment principles with nonconstant prices and varying firm size applied to beef-breeding herds. *American Journal of Agricultural Economics*. 68: 691-703.

Tryfos, Peter. 1974. Canadian supply functions for livestock and meat. *American Journal of Agricultural Economics*. 56(1):107-13.

Wu, Ruizi et al. 2012. Impact of ecological conservation program on lifestyle changes of households in Inner Mongolia. *Resource Science*. 34(6): 1049-1061.

Table 1. Variable Definitions

Variable	Definition	Mean	Std Dev
$\text{Price}_{\text{beef}}$	Real price index of beef	0.96	0.30
Price_{mutton}	Real price index of mutton	1.06	0.35
Price_{wool}	Real price index of wool	0.80	0.16
$\text{Price}_{\text{cashmere}}$	Real price index of cashmere	24.8	20.3
Inventory Shifters:			
Forage_{cost}	Price index of the forage cost	0.65	0.16
Temperature	Annual temperature in IMAR (^{o}C)	3.71	0.63
Precipitation	Annual precipitation in IMAR (mm)	252.6	32.97
Radiation	Annual radiation in IMAR (w.m^{-2})	78.82	0.99
Domestic Supply Shifters:			
Wage_{rural}	Rural average annual income per capita in IMAR(1000$)	0.84	0.53
Dzud	DV indicating the severe winter	--	--
Policy	DV for the grassland protection policy(2000)	--	--
Domestic Demand Shifters:			
Income_{IMAR}	Average annual income per capita in IMAR (1000$)	2.70	1.97
Population_{IMAR}	Total population in IMAR (Million)	1.84	1.09
Export Demand Shifters:			
Income_{China}	Average annual income per capita in China (1000$)	5.89	3.74
$\text{Population}_{China}$	Total population in China (Billion)	1.19	0.11
TransportationCH	Total road length in China (Million km)	1.66	1.02

Table 2. Basic statistics of variables for 12 cities in Inner Mongolia from 1980 through 2010.

City	Livestock Numbers (in 1,000)			Prices (Real relative price)				Income per capita (1,000 USD)		Population (million)	
	Cattle	Goat	Sheep	Beef	Mutton	Wool	Cashmere	Urban	Rural	Urban	Rural
Alxa	10.18	789.92	407.34	0.86	0.95	0.74	19.64	1.70	0.80	0.11	0.06
	(5.98)	(126.46)	(71.22)	(0.23)	(0.25)	(0.21)	(14.45)	(1.10)	(0.41)	(36.64)	(14.08)
Bayannur	75.85	1,519.87	2,856.68	1.02	1.14	0.84	23.58	1.81	1.07	0.45	1.15
	(40.73	(320.68)	(1,343.55)	(0.36)	(0.42)	(0.13)	(18.16)	(1.30)	(0.64)	(190.84)	(114.52)
Baotou	155.08	543.59	1,187.71	0.98	1.09	0.83	25.00	2.53	1.01	1.48	0.55
	(156.93)	(142.08)	(236.22)	(0.31)	(0.36)	(0.17)	(20.11)	(2.18)	(0.68)	(277.53)	(72.85)
Chifeng	762.28	1,743.51	2,565.73	0.98	1.09	0.82	23.83	1.75	0.70	1.43	2.68
	(141.91	(587.11)	(821.83	(0.31)	(0.36)	(0.15)	(18.44)	(1.08)	(0.35)	(447.42)	(302.69)
Hingan	365.47	813.63	1,680.39	1.00	1.11	0.83	24.23	1.51	0.61	0.45	1.09
	(59.24)	(703.53)	(929.26)	(0.33)	(0.38)	(0.15)	(18.97)	(1.00)	(0.27)	(104.09)	(64.66)
Hohhot	256.11	265.15	826.99	0.89	0.99	0.76	20.85	2.12	0.85	1.02	1.05
	(253.77)	(92.26)	(123.19)	(0.26)	(0.30)	(0.19)	(15.71)	(1.80)	(0.61)	(384.38)	(74.07)
Hulunbuir	597.43	534.84	2,604.08	0.98	1.09	0.82	23.78	1.75	0.84	1.35	1.20
	(203.06)	(415.37)	(1,772.45)	(0.32)	(0.38)	(0.14)	(18.76)	(1.22)	(0.43)	(259.57)	(213.41)
Ordos	98.32	2,607.31	2,394.00	0.88	0.98	0.75	20.67	1.96	0.84	0.49	0.78
	(78.47)	(1,115.46)	(443.50)	(0.25)	(0.29)	(0.17)	(15.53)	(1.74)	(0.58)	(367.33)	(237.83)

Tongliao	901.16	1,073.33	1,558.75	0.96	1.07	0.80	23.03	1.59	0.75	0.79	2.07
	(258.47)	(816.11)	(739.28)	(0.30)	(0.35)	(0.16)	(17.95)	(1.14)	(0.38)	(212.79)	(101.44)
Ulanqab	302.64	323.55	2,731.60	0.98	1.09	0.82	23.77	1.60	0.64	0.61	1.94
	(74.59)	(141.41)	(933.27)	(0.32)	(0.37)	(0.15)	(18.60)	(1.16)	(0.36)	(213.23)	(349.09)
Wuhai	1.35	31.03	21.00	0.98	1.10	0.83	23.71	1.98	0.99	0.33	0.03
	(1.36)	(12.07)	(14.65)	(0.32)	(0.37)	(0.16)	(18.52)	(1.68)	(0.75)	(99.00)	(11.95)
Xilingol	794.14	1,639.08	5,401.09	0.94	1.05	0.79	22.60	1.59	0.80	0.34	0.56
	(170.83)	(810.41)	(963.37)	(0.29)	(0.34)	(0.15)	(17.47)	(1.17)	(0.37)	(117.04)	(52.57)

Note: Mean and standard deviation (in parentheses).

Table 3. First-difference fixed effect estimaiton

Variable	Structural equation (14')			Reduced-form equation (15')		
	ΔCattle	ΔSheep	ΔGoat	ΔCattle	ΔSheep	ΔGoat
$\Delta \text{Price}_{beef}$	-0.26	--	--	--	--	--
$\Delta \text{Price}_{mutton}$	--	-0.09	--	--	--	--
$\Delta \text{Price}_{wool}$	--	-0.42***	--	--	--	--
$\Delta \text{Price}_{cashmere}$	--	--	0.01	--	--	--
$\Delta \text{Forage}_{cost}$	0.17	0.10	0.12	0.13	0.24	0.05
ΔTemperature	-0.12	0.002	0.11	-0.26***	-0.14	-0.01
ΔPrecipitation	0.25**	0.23***	-0.20**	0.03	0.03	-0.26*
ΔRadiation	2.36***	3.08***	-1.88**	2.36*	2.19*	-1.39
$\Delta \text{Cattle}_{t-1}$	0.26***	--	--	0.17**	--	--
$\Delta \text{Sheep}_{t-1}$	--	0.18**	--	--	0.26***	--
ΔGoat_{t-1}	--	--	0.24***	--	--	0.23***
$\Delta \text{Wage}_{rural}$	--	--	--	0.04	0.10	-0.04
Dzud	--	--	--	-0.09***	-0.01	-0.02
Policy	--	--	--	0.22***	0.10	0.20*
$\Delta \text{Population}_{IMAR}$	--	--	--	0.18	0.04	0.06
$\Delta \text{Income}_{IMAR}$	--	--	--	0.47	0.27	0.21
$\Delta \text{Income}_{CH}$	--	--	--	-1.13	-2.03	0.24
$\Delta \text{Population}_{CH}$	--	--	--	50.43**	15.42	47.78*
$\Delta \text{Tranportation}_{CH}$	--	--	--	-0.21*	-0.32***	-0.19
Constant	0.10**	0.02	0.02	-0.32	-0.02	-0.44
F value	2.65***	2.48***	2.51***	2.73***	1.92***	2.05***
Adjusted R-sq	0.13	0.12	0.13	0.18	0.10	0.12
D.W.	1.97	2.0	2.04	1.98	2.09	2.02
F-test for SOE	--	--	--	3.78***	1.15	1.16

* Significant at 10% level;

** Significant at 5% level;

***Significant at 1% level;

Variables are expressed in logarithms.

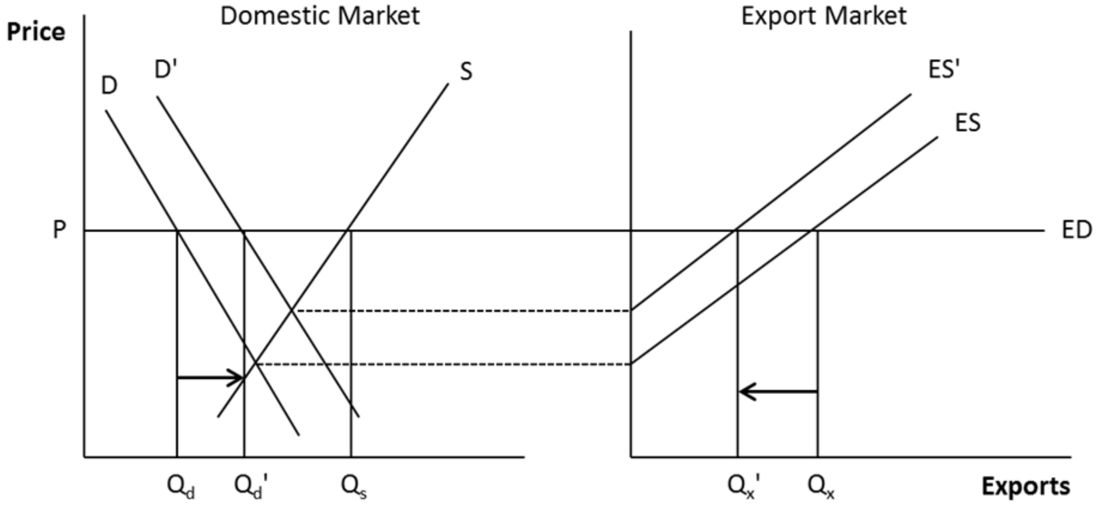

Figure 1. Effects of an increase in domestic demand on domestic production for a small exporter.

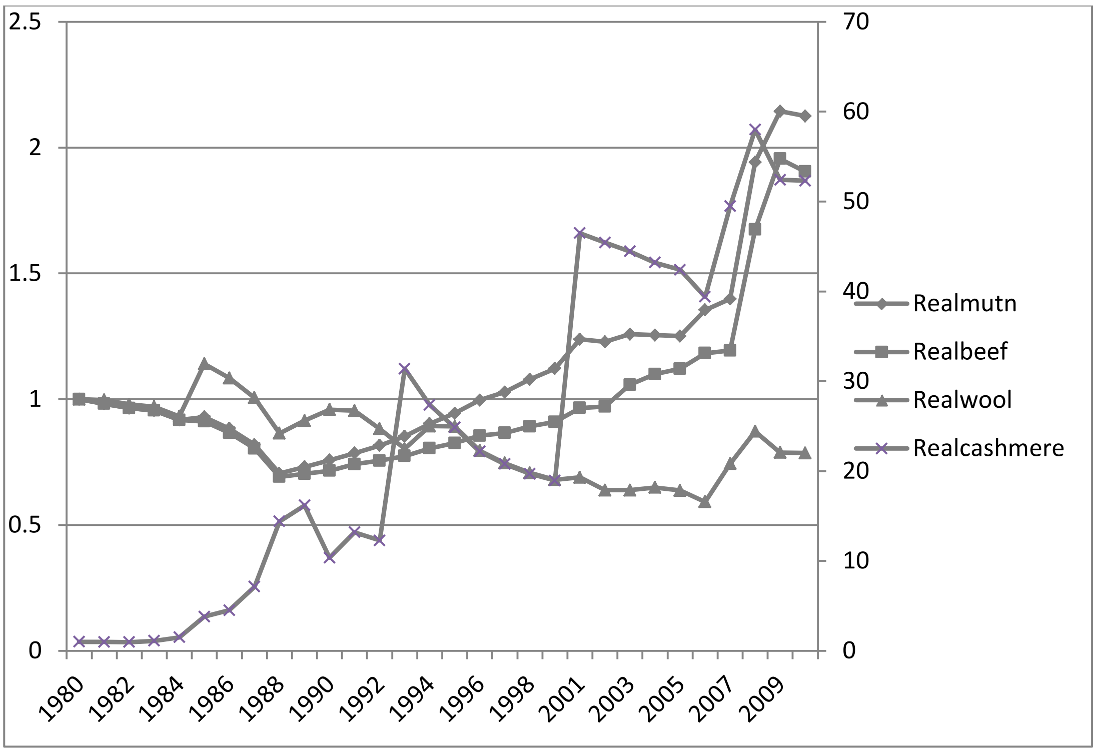

Figure 2. The relative price of livestock products in Inner Mongolia (1980-2010)

Note: The prices are deflated using 1980 as baseline. The right side scale is only for Cashmere

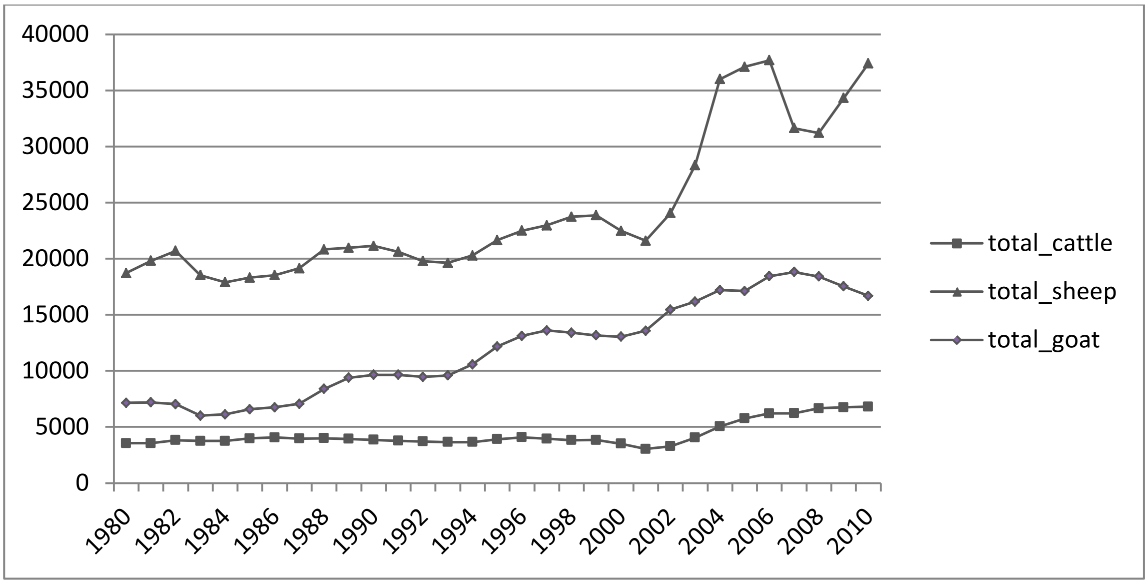

Figure 3. Total number of livestock in Inner Mongolia (1980-2010).

Note: Arrows represent the years of the implementation of government policies.

Data Source: Inner Mongolia Statistic Yearbook, 2010.

Appendix Table 1. First-difference fixed effect estimation results with prices in the previous period

Variable	Structural equation (14')			Reduced-form equation (15')		
	ΔCattle	ΔSheep	ΔGoat	ΔCattle	ΔSheep	ΔGoat
$\Delta Price_{beef}$	-0.25	--	--	--	--	--
$\Delta Price_{beef\_1}$	-0.25					
$\Delta Price_{mutton}$	--	-0.18	--	--	--	--
$\Delta Price_{mutton\_1}$		-0.25				
$\Delta Price_{wool}$	--	-0.45***	--	--	--	--
$\Delta Price_{wool\_1}$		0.15				
$\Delta Price_{cashmere}$	--	--	-0.09	--	--	--
$\Delta Price_{cashmere\_1}$			-0.05			
$\Delta Forage_{cost}$	0.18	0.05	0.11	0.13	0.24	0.05
ΔTemperature	-0.15*	-0.004	0.12	-0.26***	-0.14	-0.01
ΔPrecipitation	0.26***	0.24***	-0.19**	0.03	0.03	-0.26*
ΔRadiation	2.88***	3.35***	-1.69**	2.36*	2.19*	-1.39
$\Delta Cattle_{t-1}$	0.26***	--	--	0.17**	--	--
$\Delta Sheep_{t-1}$	--	0.16**	--	--	0.26***	--
$\Delta Goat_{t-1}$	--	--	0.24***	--	--	0.23***
$\Delta Wage_{rural}$	--	--	--	0.04	0.10	-0.04
Dzud	--	--	--	-0.09***	-0.01	-0.02
Policy	--	--	--	0.22***	0.10	0.20**
$\Delta Population_{IMAR}$	--	--	--	0.18	0.04	0.06
$\Delta Income_{IMAR}$	--	--	--	0.47	0.27	0.21
$\Delta Income_{CH}$	--	--	--	-1.13	-2.03	0.24
$\Delta Population_{CH}$	--	--	--	50.43**	15.42	45.78*
$\Delta Tranportation_{CH}$	--	--	--	-0.21*	-0.32***	-0.19
Constant	0.11**	0.04	0.02	-0.32	-0.02	-0.44
F value	2.64***	2.34***	2.46***	2.73***	1.92***	2.05***
Adjusted R-sq	0.13	0.12	0.13	0.18	0.10	0.12
D.W.	1.99	1.98	2.04	1.98	2.09	2.02
F-test for SOE	--	--	--	3.78***	1.15	1.16

* Significant at 10% level;

** Significant at 5% level;

***Significant at 1% level;

Variables are expressed in logarithms.