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Reindeer husbandry, the Swedish market for reindeer meat, and the Chernobyl effects

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Abstract

Reindeer husbandry is a cornerstone in the culture of the Sami, northern Scandinavia's indigenous people. This paper presents a dynamic, theoretical model of the Swedish reindeer husbandry and the market for reindeer meat, as well as econometric results based on three-stage least squares regression on annual data. The most striking feature of the empirical results is a "backward-sloping" supply function, which is consistent with the theoretical model. The results also show effects of the Chernobyl accident. Prevailing winds at the time of the accident carried radioactive fallout over the grazing areas for the Swedish reindeer husbandry, causing effects on both supply and demand. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Reindeer husbandry in Sweden is an exclusive right for the Sami, northern Scandinavia's indigenous people. The reindeer (*Rangifer tarandus*) has been domesticated by the Sami for at least as long as there is written evidence (the oldest documents are from about 880 A.D.). Today (1998) there are around 230,000 reindeer in Sweden, owned by about 4600 reindeer herders (including approximately 1000 concession reindeer herders who, by special government permit, practice reindeer husbandry outside the traditional reindeer herding area) who all belong to one of the 51 Swedish Sami villages (Statistics Sweden, 1999; Riksdagens Revisorer, 1995–1996:8). Reindeer husbandry today is a modern business geared mainly towards meat production, and administered through family companies formed by the reindeer herders. However, even though the reindeer herders of today use modern equipment like snowmobiles and mobile slaughterhouses, the basics of reindeer husbandry have changed fairly little over the centuries. The reindeer are allowed, with some exceptions, to follow their yearly cycle and search around for natural grazing grounds, allowing grazing grounds to replenish themselves as the reindeer move from the high mountains to the coast and back again. This means that reindeer husbandry requires large areas. The Reindeer Husbandry Act gives the Sami the right to let their reindeer graze on, for instance, private forest land. In total, the Sami have grazing rights on about 40% of the Swedish land area.

Even if a minority of the about 20,000 Swedish Sami (the total number depends on how the ethnic group is defined) today are active reindeer herders, the importance of the reindeer husbandry for the Sami

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culture can hardly be overemphasized (Riksdagens Revisorer, 1995–1996:8). Most Sami have family members or other relatives who are reindeer owners, making the reindeer an integral part of the Sami way of life. Despite low profitability, many reindeer owners are also reluctant to give up reindeer husbandry altogether and maintain small herds that are compatible with other type of work. The Swedish government, both in statements and through different types of subsidies and compensations has also emphasized the importance of the reindeer husbandry as a cornerstone in the Sami culture.

This paper has two purposes. The first purpose is to present a dynamic economic model of a pastoralist such as a reindeer herder, who might have other objectives besides profit maximization, leading to testable hypotheses about the reindeer herder's supply of slaughtered reindeer. The second purpose is to test these hypotheses econometrically on a data set from 1973–1974 to 1995–1996 on prices, quantities and other variables connected to the Swedish reindeer herding industry with the ambition to identify demand and supply functions. In the theoretical section a dynamic model for the reindeer herder's supply of slaughtered reindeer is presented, which is based on the fact that most reindeer herders only receive part of their income from reindeer husbandry. The intrinsic utility of being an active reindeer herder here plays an important role in determining supply. In the econometric section the demand and supply functions that are relevant for the reindeer herding industry are identified, using three-stage least squares regression. The consequences of the meltdown of the nuclear reactor in Chernobyl, the Ukraine, play an important part in this market model. The reason is that after the accident large numbers of slaughtered reindeer had to be discarded because of excessive concentrations of Cesium 137 in the meat (caused by fallout carried by the prevailing winds at the time). This implies, among other things, that the number of slaughtered animals differs from the number that is actually cut up and sold on the market. The time period of the data set covers the main aftermath of the Chernobyl accident, and the empirical analysis shows how demand and supply shifted following this environmental catastrophe. The final section gives some concluding remarks.

2. Modelling demand and supply in the reindeer meat market

2.1. The supply side

The starting point for the theoretical supply model is that most reindeer herders only get part of their income from reindeer husbandry. According to the Swedish National Board of Agriculture (Jordbruksverket, 1998) a reindeer herding family company requires more than 400 reindeer for the family to be able to get their livelihood completely from their reindeer husbandry. With about 230,000 reindeer and about 930 reindeer herding companies (Statistics Sweden, 1999) the average number of reindeer per company is only 247. Furthermore, according to an income survey in a report by the Swedish Parliament Auditors (Riksdagens Revisorer, 1995–1996:8) the average household which included a reindeer herder received only 19% of their income from reindeer herding. This means that alternative sources of income is important for most reindeer herders and influences how much time that should be devoted to the reindeer herding company. A large reindeer herd takes a lot of time to manage (rounding up the animals for branding or slaughter, moving them from winter to summer grazing grounds, etc.). However, high prices on reindeer meat makes the trade-off between reindeer husbandry and other occupational alternatives more to the advantage of the former.

The theoretical model presented here draws upon other models of agricultural households (e.g. Singh et al., 1986), but also includes the dynamics of reindeer growth. The basis for the analysis is a utility maximizing reindeer herder, who decides upon, private consumption (C), the size of his/her herd of reindeer (R) and the time devoted to work outside the reindeer herding company (l_2). Assume that the reindeer herder maximizes a utility function of the form, $U = CT(1+R)$, where C stands for private consumption, T for leisure time, and R is the herders' private reindeer stock, representing the fact that the herd of reindeer provides a intrinsic utility of its own for a Sami who is an active reindeer herder. Several government reports (e.g. Riksdagens Revisorer, 1995–1996:8; Ds, 1998:8) have pointed out the low profitability among the reindeer herding companies. The fact that the companies persist despite this is evidence for the earlier mentioned cultural importance of the reindeer husbandry that goes beyond being merely a source of income.

Essentially, the utility function states that the reindeer herder values private consumption, leisure time, and being an active reindeer herder. The quasilinear functional form is one of the simplest conceivable utility functions that makes C and T essential goods while allowing R to be a non-essential good, to permit the individual Sami to enter and leave active reindeer herding. Means for private consumption comes from two sources, profits from the reindeer herding company $(p - c_h)h - c_R R$ and labor income from work outside the reindeer herding company l_2, which is paid with the wage rate, w, i.e.

$$C = (p - c_h)h - c_R R + wl_2 \quad (1)$$

where p is the price (including price subsidies) per standardized reindeer (assuming a constant share of calves), c_h is the cost of slaughtering, h is the number of slaughtered animals, and c_R is the cost of managing a herd of a certain size (including the cost of supplementary fodder). Since most reindeer herding companies are small, price-taking behavior is a reasonable assumption.

A private reindeer stock not only entails management costs, it also takes time. Leisure time is therefore, defined as total time minus work managing the reindeer herd (including rounding up animals, branding and slaughtering) and work outside the reindeer herding company, i.e.

$$T = \bar{L} - l_1 R - l_2 \quad (2)$$

where $\bar{L}$ is total time, and l_1 is a coefficient denoting the average extra time it takes to manage one more reindeer. Inserting Eqs. (1) and (2) in the utility function, gives

$$U = [(p - c_h)h - c_R R + wl_2][\bar{L} - l_1 R - l_2][1 + R] \quad (3)$$

Reindeer growth is assumed to be a continuous function of the stock minus the number of slaughtered animals, i.e.

$$\dot{R} = f(R) - h \quad (4)$$

where $f(R)$ is the natural growth function for the reindeer stock. This function is assumed to have the usual features of a compensatory growth function, i.e. $f(R) = 0$ when $R = 0$ and at some carrying capacity stock, and $\partial f(R)/\partial R = f_R = 0$ at some maximum sustainable yield stock (e.g. Clark, 1990). The size of the carrying capacity stock is assumed to depend on available grazing resources, such as lichen and supplementary fodder.

Maximizing the present value of an infinite stream of utilities with respect to h and l_2 and where r is the discount rate, subject to the restriction given by Eq. (4), gives the following current-valued Hamiltonian

$$H = [(p - c_h)h - c_R R + wl_2] \times (\bar{L} - l_1 R - l_2)(1 + R) + \lambda[f(R) - h] \quad (5)$$

The first order condition with respect to h and the costate equation gives a steady-state equilibrium (where $\dot{\lambda} = 0$) which is defined by

$$(r - f_R)(p - c_h)T(1 + R) + T(1 + R)c_R + [l_1(1 + R) - T](\pi + wl_2) = 0 \quad (6)$$

where $\pi = (p - c_h)h - c_R R$. We can now solve Eq. (6) for h as

$$h = \frac{[r - f_R T(1 + R)]}{T - l_1(1 + R)} + \frac{c_R T(1 + R)}{[T - l_1(1 + R)](p - c_h)} + \frac{c_R R - wl_2}{p - c_h} \quad (7)$$

From this it is evident that

$$\frac{\partial h}{\partial p} = \frac{1}{(p - c_h)^2}\left[(wl_2 - c_R R) - \frac{c_R T(1 + R)}{[T - l_1(1 + R)]}\right] \quad (8)$$

The sign of $\partial h/\partial p$ will depend on $(wl_2 - c_R R) - c_R T(1 + R)/(T - l_1(1 + R))$. For a reindeer herder with a very small herd $\partial h/\partial p$ will be positive, since if $R \to 0$, $\partial h/\partial p \to [(wl_2 - c_R T)/(T - l_1)]/(p - c_h)^2$, which will be positive, since $c_R T/(T - l_1) \approx c_R$ (due to the fact that l_1 will be small relative to T), and $wl_2 > c_R$ (otherwise there would be no means for private consumption).

In the other extreme, for a reindeer herder with a herd so large that he is fully employed in reindeer herding (i.e. $l_2 = 0$) then, $\partial h/\partial p = [-1/(p - c_h)^2][c_R R + c_R T(1 + R)/(T - l_1(1 + R))]$. Here, the sign of $\partial h/\partial p$ will depend on the sign of

$T-l_1(1+R)=(1/C)\,[(\partial U/\partial R)+(\partial U/\partial T)\,(\partial T/\partial R)]$, which in turn depends on the relative importance of the marginal intrinsic utility of R, which will be positive, versus the marginal effect of R on the marginal utility of leisure time, which will be negative. If $\partial U/\partial R$, i.e. the marginal intrinsic utility of increasing the reindeer herd, is sufficiently large the sign of $\partial h/\partial p$ will be negative. Generally, we can expect to find reindeer herders with both positive and negative supply responses, depending the size of their reindeer herd, what other options are available in the labor market (i.e. w_i for an individual i), and their private marginal intrinsic utility of being an active reindeer herder.

It is interesting to examine other partial derivatives of the supply function as well. Consider the following partial derivative with respect to the private reindeer stock

$$\frac{\partial h}{\partial R}=\frac{T^2}{[T-l_1(1+R)]^2}\left[(r-f_R)+\frac{c_R}{(p-c_h)^2}\right]+\frac{c_R}{p-c_h} \tag{9}$$

A sufficient (but not necessary) condition for this expression to be positive, meaning that herder with a larger herd will also have a larger slaughter, is that $r > f_R$, i.e. the rate of interest on the alternative investment is greater than the growth rate of the reindeer stock. The derivative with respect to the wage rate in the alternative occupation is:

$$\frac{\partial h}{\partial w}=-\frac{l_2}{p-c_h}<0 \tag{10}$$

This sign depends on the fact that income from slaughtering and income from the alternative occupation are perfect substitutes.

2.2. *The Chernobyl effect*

On April 26, 1986, reactor 2 of the Chernobyl nuclear facility in the Ukraine had a meltdown. Due of the prevailing wind during the days after the accident sections of northern Sweden were relatively heavy affected by the fallout of Cesium 137, although, the contamination levels were nowhere near the levels incurred in the Ukraine. This meant that reindeer meat suffered from a relatively high level of contamination. As a direct consequence of the Chernobyl accident the slaughtered reindeer had to be tested for Cesium 137 concentration. Reindeer in which the meat is above a certain Bequerel level are discarded and not brought to the market. The reindeer herder can influence the share that is discarded to a certain extent by slaughtering earlier, giving non-contaminated fodder to the reindeer, etc. If the reindeer herders have taken such mitigative measures to try to reduce the contamination level in the meat, they receive compensation for reindeers that despite this are discarded.

More than 78% of the harvest was discarded during the year after the Chernobyl accident. Mitigative efforts and the relatively fast decay of the radioactive isotope Cesium 137 has since reduced the share of discarded reindeer to the extent that the Chernobyl effect today (2000) mostly is a bad memory. What effects did the Chernobyl accident have on the harvest behavior of the reindeer herder?

The Swedish National Board of Agriculture and the County Administrative Board pays several different compensations associated with the Chernobyl accident. The County Administrative Board compensates for mitigative measures while the Swedish National Board of Agriculture compensates for lost meat revenue. Since the latter compensation is based on the relevant market price plus the price subsidy the only supply effect that can be expected from the Chernobyl accident is perhaps a small reduction in supply due to the unpleasantness of having to bury slaughtered reindeer.

On the demand side it can be noted that while reindeer meat suffered from a relatively high level of contamination, other types of meat was less affected. Not surprisingly, the information about radioactively contaminated reindeer led to a preference shift among consumers away from reindeer meat towards other types of meat, causing a price drop. As the theoretical model allows, a lower price can induce some reindeer herders with large herds to make an increase in the harvest.

2.3. *The demand side and the market model*

In general, reindeer meat is not an important food item in Sweden. The average quantity sold each year corresponds to about 0.6% of the total Swedish meat market. It is, however, locally more important in northern Sweden, and about eight percent is consumed by the reindeer herders themselves (Statistics Sweden, 1999). Although, no detailed statistics are available, it is possible to roughly divide the demand for reindeer meat into two groups, according to a 1983 report from a Swedish government commission on reindeer husbandry (SOU, 1983:67). The first group is the local consumers in the inner parts of northern Sweden. This group has an acquired taste for reindeer meat and have a relatively low price elasticity compared to the second group. This second group consists of the wholesalers and restaurants that provide customers in the larger cities in Sweden with reindeer meat. The export of reindeer meat, which is has increased from about 5–10% of the slaughter in the early 1980s (SOU, 1983:67) to about 20–30% in the mid-1990s (Statistics Sweden, 1999), can also be assigned to this group. The group is characterized by higher price elasticity and is prone to preference shifts, as for instance induced by the Chernobyl accident. The higher price elasticity gives this group a disproportionate influence on the total demand.

The relevant quantity variable for the demand side is not the number of slaughtered reindeer, but the quantity of reindeer meat on the market. For the studied period this quantity is highly influenced by the share of discarded reindeer due to the Chernobyl effect.

We are now ready to suggest some hypothesis about demand. Let $p_{R,t}$ be the deflated price to producers in Swedish crowns (SEK), and $p_{R,\mathrm{d}}(kh_N, p_\mathrm{B}, \alpha)$ be the inverse demand function, where k is a constant that we will use to switch from calculating in number of slaughtered reindeer to quantity of meat. This constant then represents the meat content in the average slaughtered reindeer. The variables h_N and p_B is the net slaughter, i.e. the number of slaughtered non-discarded reindeer, and the price of a substitute good (e.g. beef meat), respectively. The hypothesis is that $\partial p_{R,\mathrm{d}}(\cdot)/\partial h_N < 0$ and $\partial p_{R,\mathrm{d}}(\cdot)/\partial p_\mathrm{B} > 0$. The share of discarded slaughtered reindeer, α, is used as an indicator of the perceived severity of the Chernobyl problem, with $\partial p_{R,\mathrm{d}}(\cdot)/\partial \alpha < 0$. Similarly, $h_{\mathrm{G},s}(R, p, s, w)$ is the short-run gross supply function. The partial derivative $\partial h_{\mathrm{G},s}(\cdot)/\partial R$ can take both a positive or a negative sign, largely depending on the growth rate of the reindeer herd, as shown in Eq. (9). The variable p here indicates the price excluding subsidies, where the hypothesis is that $\partial h_{\mathrm{G},s}(\cdot)/\partial p_R < 0$ for reindeer herders with large herds (and vice versa), as shown by Eq. (8). The variable s is the price subsidy, where the hypothesis is the same as for p. Following Eq. (10) the hypothesis for the wage rate, w, is $\partial h_{\mathrm{G},s}(\cdot)/\partial w < 0$. Given the simultaneity of the model, ordinary least squares (OLS) estimation will yield biased estimates, and simultaneous-equation estimation techniques will be required.

3. Empirical analysis

3.1. The data

The data set that has been used in the econometric analysis below ranges from 1973–1974 to 1995–1996 and consists of the following variables

$h_{\mathrm{G},t}$	total number of slaughtered reindeer
$h_{N,t}$	number of slaughtered, non-discarded reindeer
$p_{\mathrm{B},t}$	price of beef meat deflated by consumer price index (base year = 1980), SEK
$p_{R,t}$	price of reindeer meat deflated by consumer price index (base year = 1980), SEK
Q_t	quantity of reindeer meat sold (metric tonnes)
R_t	total reindeer herd (winter herd)
s_t	government subsidy per slaughtered, non-discarded reindeer, deflated by consumer price index (base year = 1980), SEK
w_t	average male hourly earnings in agriculture, forestry, hunting and fishing deflated by consumer price index (base year = 1980), SEK
α_t	share of discarded reindeer: $\alpha_t = 1 - (h_{N,t}/h_{\mathrm{G},t})$

An ordinary least squares regression of the quantity of reindeer meat sold (Q_t) against the number of slaughtered, non-discarded reindeer ($h_{N,t}$) gives a coefficient of 0.031582 (t-statistic: 223.152, $\overline{R}^2$: 0.996, degrees of freedom: 22). No constant was used in this regression since, logically, if $h_{N,t} = 0$, then $Q_t = 0$, as well. A regression with a constant resulted in an insignificant constant very close to zero, and a slope coefficient almost identical to the above. The slope coefficient in the above regression can be interpreted as the meat content (metric tonnes) in a typical slaughtered reindeer, i.e. 31.582 kg/slaughtered reindeer. The regression statistics illustrate the stability of this average carcass weight, and the residuals can to a large extent be explained by changes in the proportion of

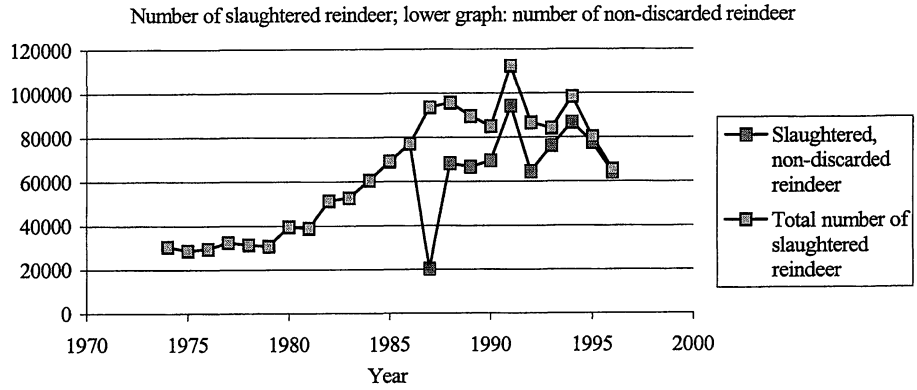

Fig. 1. Total number of slaughtered reindeer and the number of slaughtered non-discarded reindeer.

calves being slaughtered. In the following the number 0.031582 will be used to switch from counting in numbers of reindeer to quantity of meat (metric tonnes).

A few graphs should give a sense of the magnitude and changes in certain variables. The upper time series in Fig. 1 is the total number of slaughtered reindeer, $h_{G,t}$, whereas, the lower time series refers to the number of slaughtered, non-discarded reindeer, $h_{N,t}$. Note that $h_{N,t} = h_{G,t}$ before 1987, i.e. before the Chernobyl meltdown. As mentioned, after the Chernobyl accident more than 78% of the slaughtered reindeer were discarded due to the Cesium 137 content. The share of discarded reindeer has then declined, partly due to actions taken by the Sami to mitigate the effects, such as giving the reindeer non-contaminated fodder. No graph for Q_t is shown since it would be virtually identical to the graph for $h_{N,t}$ in shape.

The real price, $p_{R,t}$, decreased almost constantly from 1974 to 1993 and then climbed again slowly. Despite this, the gross supply in terms of total number of slaughtered reindeer each year increased almost constantly during the same period. However, as mentioned earlier, the reindeer herder does not only receive $p_{R,t}$. He/she also receives a price subsidy per slaughtered, non-discarded reindeer, here denoted s_t. This subsidy is similar to the subsidies awarded to other agricultural products in Sweden. However, the subsidy can also be seen as one way for the Swedish government to put money behind the statements about the cultural importance of the reindeer husbandry. It is worth noting that since s_t is paid per slaughtered, non-discarded reindeer regardless of weight it gives incentives to slaughter calves. However, despite this the average carcass weight has not decreased over the years, as evident from the previous regression of Q_t against $h_{N,t}$. We can now calculate the deflated total revenue per slaughtered, non-discarded reindeer, empirically defined as $I_t = 31.582 p_{R,t} + s_t$. Fig. 2 illustrates the development of I_t and s_t.

From Fig. 2 it is evident that the subsidy has more than doubled in real terms during the studied period. This fact combined with the drop in $p_{R,t}$ implies that the subsidy part of the revenue earned for every non-discarded reindeer has increased from about nine percent in the beginning of the studied period to about 28% in the end of it. This has, however, not been sufficient to prevent an almost constant drop in I_t from 1974 to 1993.

3.2. Empirical results

As mentioned earlier, the demand/supply system characterised by $p_{R,\mathrm{d}}\,(kh_N, p_\mathrm{B}, \alpha)$ and $h_{\mathrm{G,s}}\,(R, p, s, w)$ is assumed to be simultaneous. This assumption was tested using a variant of the Hausman specification test described in Spencer and Berk (1981). This test consists of first regressing the explanatory variable that is suspected to be simultaneous with the dependent variable against all exogenous variables (the reduced form equation), and then using the residuals as an independent variable when estimating the demand and supply equations separately. A t-test of the coefficient of the residuals with the null hypothesis of no simultaneity completes the test (cf.

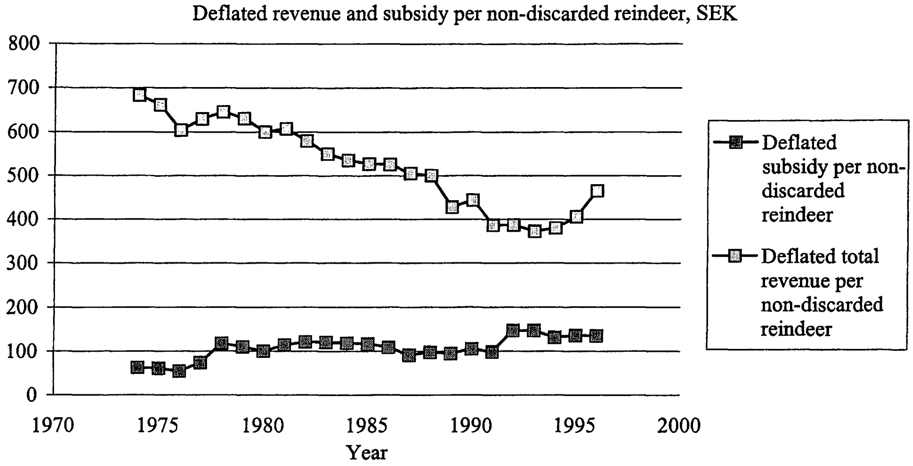

Fig. 2. Deflated total revenue to the reindeer herder per slaughtered, non-discarded reindeer and the deflated subsidy.

Pindyck and Rubinfeld, 1991). In the demand equation Q_t was used, since as noted above $Q_t \approx kh_{N,t}$ when $k = 0.031582$. The test of the simultaneity of $p_{R,t}$ and Q_t in the demand equation show that the null hypothesis of no simultaneity can not be rejected (t-statistic of the coefficient of the residuals was equal to -0.560, with 17 degrees of freedom). The corresponding test of the simultaneity of $h_{G,t}$ and $p_{R,t}$ in the supply equation show, however, that the null hypothesis of no simultaneity can be rejected at the one percent level (t-statistic of the coefficient of the residuals was equal to 2.638, with 15 degrees of freedom).

These tests show that simultaneous-equation estimation techniques are required. To this end three-stage least squares (3SLS) was applied (Greene, 1995). The 3SLS estimator was preferred before two-stage least squares (2SLS) since the former uses all of the available information and has a smaller asymptotic variance–covariance matrix than single-equation estimators, such as 2SLS. Also, under the usual assumption, that the disturbances are distributed multivariate normally, it is at least as efficient as any other estimator that uses the same amount of information. If the disturbances in the demand and supply equations are uncorrelated, 3SLS reduces to 2SLS (cf. Kennedy, 1998). Preliminary tests show a gain in efficiency from using 3SLS, compared with 2SLS. Two functional forms, a linear and a logarithmic, were tested. Following the inverse demand function in Section 2.3, α_t is used as an indicator of the perceived severity of the Chernobyl problem, i.e. as a demand shifter. Furthermore, since if $\alpha_t = 0$ (which was the case before the Chernobyl accident), $\ln(\alpha_t) = -\infty$, the share of non-discarded reindeer, $\ln(1 - \alpha_t)$, was used in the logarithmic case. Naturally, the expected sign of the coefficient then becomes reversed. To investigate any supply effect from the Chernobyl accident due to the unpleasantness of having to bury slaughtered reindeer, α_{t-1} and $\ln(1 - \alpha_{t-1})$ was added in the linear and logarithmic specifications, respectively. The results are presented in Table 1.

Most coefficients are significant and have the expected signs. A noteworthy feature in the linear model presented in columns 2 and 3 is the significant negative demand effect of α_t. Using the coefficient on Q_t and the coefficient on α_t as estimates on $\partial p_{R,t}/\partial Q_t$ and $\partial p_{R,t}/\partial \alpha_t$, respectively, the estimate of $\partial Q_t/\partial \alpha_t$ becomes -3884.92. Since α_t is a share the interpretation is that if the share of discarded reindeer increases by ten percentage points the quantity of reindeer meat demanded is reduced by about 388 metric tonnes due to the preference shift. This shows the strong negative demand effect caused by the publicity around the Chernobyl problem for the reindeer husbandry, and the subsequent preference shift. A feature in both models is the absence of a significant supply effect of α_{t-1} or, in the logarithmic model, $\ln(1 - \alpha_{t-1})$. Note also the negative coefficients on $p_{R,t}$ and s_t,

Table 1
Three-stage least squares estimates of demand and supply functions for the Swedish reindeer meat market during 1973–1974 to 1995–1996[a]

Explanatory variables	Inverse demand function dependent variable ($p_{R,t}$)	Supply function dependent variable ($h_{G,t}$)	Inverse demand function dependent variable $\ln(p_{R,t})$	Supply function dependent variable $\ln(h_{G,t})$
Constant	9.0287 (3.123)**	40516 (0.602)	3.3781 (3.020)**	−6.8634 (−1.174)
Q_t	−0.17562E−02 (−2.753)**			
$\ln(Q_t)$			−0.29046 (−2.844)**	
$p_{B,t}$	0.56069 (4.248)***			
$\ln(p_{B,t})$			0.51869 (3.188)**	
α_t	−6.8227 (−5.000)***			
$\ln(1-\alpha_t)$			0.35646 (4.080)***	
R_t		0.32254 (3.497)**		
$\ln(R_t)$				1.6641 (5.203)***
$p_{R,t}$		−4475.9 (−3.199)**		
$\ln(p_{R,t})$				−0.76801 (−3.312)***
s_t		−285.46 (−4.397)***		
$\ln(s_t)$				−0.36876 (−4.698)***
w_t		1049.3 (1.091)		
$\ln(w_t)$				0.24589 (0.500)
α_{t-1}		12922 (1.924)		
$\ln(1-\alpha_{t-1})$				−0.08215 (−1.815)
$\overline{R}^2$	0.856	0.916	0.754	0.926
Degrees of freedom	18	16	18	16

[a] T-values are within parentheses.
** Significant at 1% level.
*** Significant at 0.1% level.

imply a "backward-sloping" supply curve. As indicated by the theoretical section, negative supply responses is a possibility for reindeer herders with large herds. This supply curve evokes questions about the stability of an equilibrium price. If $\partial h_s/\partial p_R < \partial h_d/\partial p_R$ at the equilibrium price the market adjustment will tend to diverge from the equilibrium, making it unstable. The coefficient on $p_{R,t}$ gives an estimate on $\partial h_s/\partial p_R$, and inverting the coefficient on Q_t gives an estimate on $\partial Q_d/\partial p_R$. Multiplying the latter figure with the average number of reindeer required to produce one metric tonne (31.664, which is the inverse of the coefficient for average carcass weight), gives an estimate of $-18{,}029.8$ for $\partial h_d/\partial p_R$. Since, this is less than the estimate on $\partial h_s/\partial p_R$ the market equilibrium appears to be stable.

A non-expected sign is found in the coefficients on w_t and $\ln(w_t)$, which contradict the theoretical prediction in Eq. (10). These coefficients are, however, not significant, which is most likely due to the lack of more specific empirical data on w_t. The coefficients in the logarithmic model presented in the two rightmost columns have the advantage of being able to interpret as elasticities. Note here, the strong supply elasticity from increases in the reindeer herd, indicating the stock-harvest relation. The apparent difference in the coefficients on $\ln(p_{R,t})$ and $\ln(s_t)$ may appear somewhat puzzling. There is no obvious reason why a one percent change in the real price should have a larger effect than a one percent change in the real price subsidy. To investigate this anomaly closer a t-test with the null hypothesis that the coefficients of $\ln(p_{R,t})$ and $\ln(s_t)$ are equal was conducted. To do the test the supply equation given by the rightmost column in Table 1 was reestimated replacing $\ln(p_{R,t})$ with $\ln(p_{R,t}) + \ln(s_t)$ (and keeping $\ln(s_t)$ as a separate variable, see Pindyck and Rubinfeld, 1991, p. 114, for details). Since in this estimation the coefficient on $\ln(s_t)$ is insignificant (t-statistic: 1.58) we have failed to reject the null hypothesis of no difference in the supply effect between $\ln(p_{R,t})$ and $\ln(s_t)$, i.e. the apparent difference in the coefficients in Table 1 is insignificant.

The demand and supply equations in Table 1 can be used to calculate the reduced form parameters, solving for either price or quantity. To illustrate the fit of the

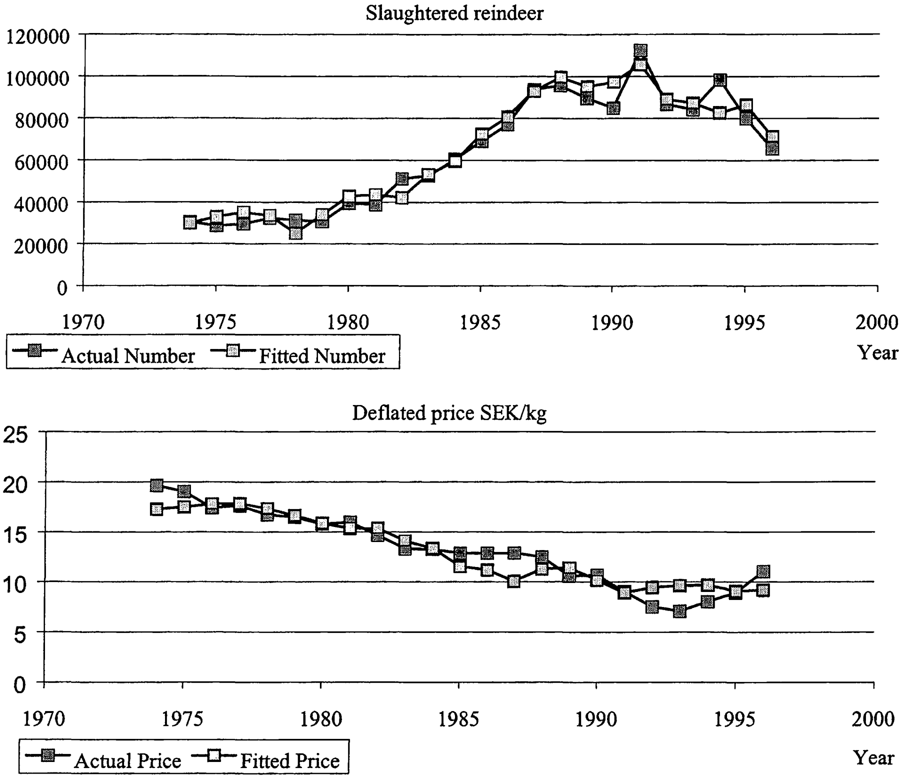

Fig. 3. Actual and predicted total slaughter of reindeer (top) and deflated price of reindeer meat (bottom).

model, the reduced form equations for $h_{G,t}$ and $p_{R,t}$ in the linear model were used to obtain fitted values $\hat{h}_{G,t}$ and $\hat{p}_{G,t}$. The actual and fitted values are illustrated in Fig. 3.

The model satisfactorily describes the fluctuations in quantities and prices, with a mean absolute deviation of 8.3 and 9.3% for $\hat{h}_{G,t}$ and $\hat{p}_{G,t}$, respectively. The model correctly picks up the sharp increase in slaughter in 1990–1991. However, it overestimates the price in the beginning of the 1990s.

4. Concluding remarks

Reindeer husbandry in Sweden has during the latest decades been under significant pressure from falling prices, partly caused by the effects of the Chernobyl meltdown. This paper has attempted to analyze the reindeer meat market based on a dynamic, theoretical model of the reindeer herder's decision problem. As the theoretical model shows, the intrinsic utility of the Sami way of life, i.e. being an active reindeer herder, plays an important role for the supply response. Such intrinsic utility arguments are likely to be common also for other types of pastoralists. Acknowledging the existence of such arguments is a crucial element in understanding pastoralist cultures and decisions.

The subsequent econometric analysis used three-stage least squares to analyze a data set covering the period from 1973–1974 to 1995–1996, a period which covers the main aftermath of the Chernobyl accident. The analysis reveals that the supply function for slaughtered reindeer is "backward-sloping", which is in accordance with the theoretical model outlined earlier. The backward slope is, however, not so large as to make the market equilibrium unstable. When using the share of discarded reindeer (due to Cesium 137 content) as a proxy for the intensity of the Chernobyl problem the econometric results show a strong negative demand effect.

The presented results have few predecessors. In a report to the Swedish Ministry of Finance (Ds, 1998:8) the authors present an OLS estimation of the supply function with $\ln(h_{G,t})$ as a function of $\ln(s_t)$, $\ln(R_t)$, and $\ln(p_{R,t})$. However, the report does not mention the econometric problem of identifying demand and supply functions in simultaneous equation systems, and the fact that OLS will yield biased estimates when used to estimate the supply function in such a setting. Despite this, it is interesting to note that, the estimates in the report are fairly close to the ones presented above.

It is clearly possible to model the reindeer herder's decision problem in the theoretical section in a more detailed manner. One such avenue would be to make the time cost of managing the reindeer herd dependent on the amount of fixed costs (i.e. using more machines, like motorcycles, makes it possible to manage a larger herd in the same amount of time). These types of theoretical refinements would, however, be more interesting should there exist data on the firm level on time usage and fixed costs. Data on factors that influence the grazing conditions would also improve the empirical estimates. Finding and utilizing data on the effects of forestry on the grazing conditions will be the subject for future research.

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