Welfare Implications of the Wool Act

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A model of the U.S. sheep industry is estimated and simulated to determine the impact of the wool incentive program on actors in U.S. sheep product markets. The simulation analysis indicates that U.S. sheep producers and lamb and wool consumers are the program's gainers while lamb and wool exporters and taxpayers are its losers. Net societal losses averaged $26.4 million per year during the 1980–85 period, considering U.S. as well as exporter interests. This loss is about 2.5% of average U.S. consumer expenditures on lamb and wool over the period.

Key words: policy, Wool Act, simulation, welfare.

The National Wool Act of 1954 established a program of direct payments to support the incomes of wool producers. The rationale for the support of wool rested on the premise that wool is "an essential and strategic commodity" which is not produced in sufficient quantities in the United States to meet domestic needs. Despite the wool incentive payments, wool production has continued to decline, from 283 million pounds in 1955 to 84 million pounds in 1986 (Government Accounting Office; American Sheep Producers' Council).

It has been argued that the incentive program has had little impact on wool production. In a 1982 study, Gardner used an econometric formulation to estimate the effects of the Wool Act. Gardner estimated that the incentive program increased wool production from 7–15% in 1980. This study concluded that maintaining wool production at 1950s levels was an impossible task due to the small percentage of revenue sheep producers receive from wool. Although a sound study, Gardner's model did not include adjustments in the lamb market in response to falling wool production.

It is the purpose of this article to present a theoretical framework for evaluating the effect of policy in the joint product case of lamb and wool and to empirically measure the impacts of the Wool Act on lamb and wool producers and consumers. To this end, consistent theoretical and empirical models are developed to model sheep producer and lamb and wool consumer response to the Wool Act. The empirical model is simulated and simulation results are compared to measure the effects of the Wool Act on wool market participants.

Economics of Wool and Lamb Markets

Wool and lamb are the joint products of sheep production and for the most part are complementary outputs. Any policy instrument which affects the price or production level of an output will impact its joint product. As a result, the wool incentive program impacts not only wool markets, but lamb markets as well.

Economic Model Illustrated

Domestic farm and retail markets for wool and lamb are illustrated in figure 1. The horizontal axis in figure 1 represents the quantity of sheep and associated outputs of wool (sheep × wool/sheep) and lamb (sheep × lamb/sheep). Price or revenue per sheep from lamb and wool is located on the vertical axis. Thus, price in figure 1 is defined as output-per-sheep times the price of the product considered. Interpretation is the same as the more traditional price/quantity graph, assuming output-per-sheep is unaffected by prices in the short run. Since price and quantity are adjusted for lamb and wool

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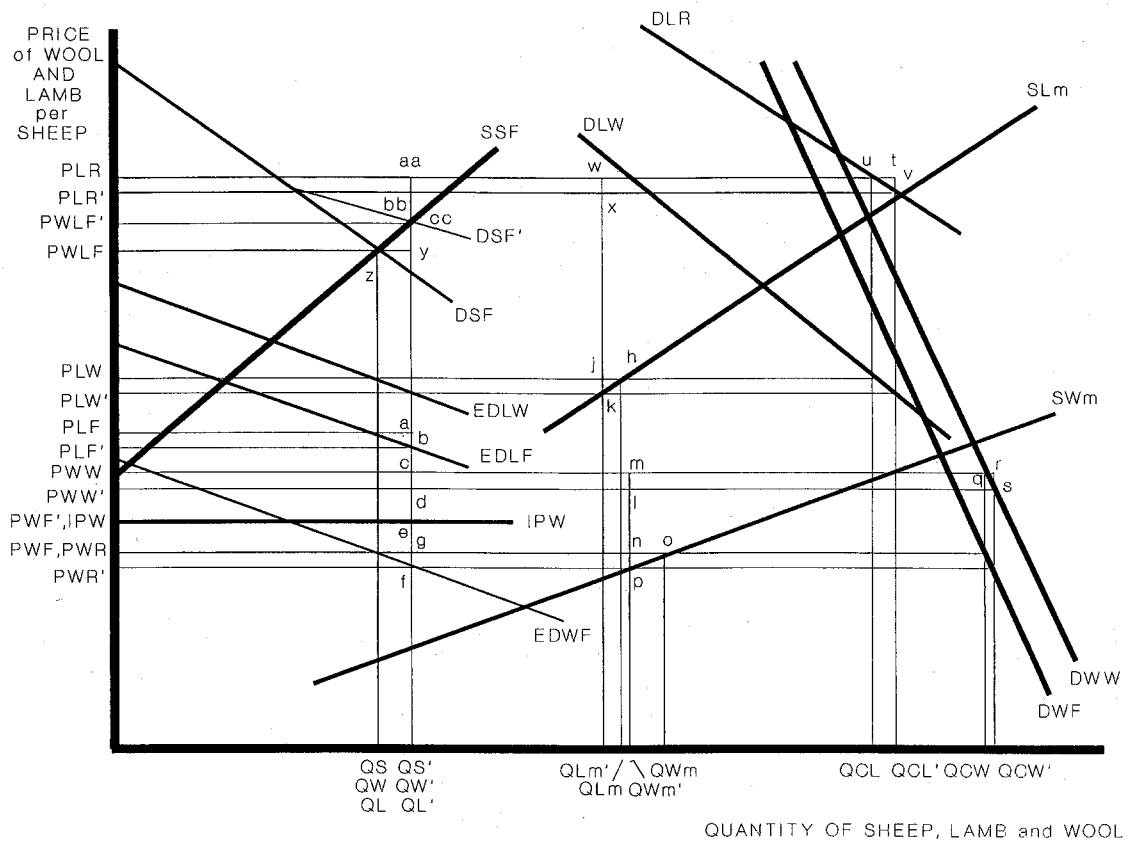

Figure 1. A graphic illustration of the U.S. market for sheep products including the welfare effects of the Wool Act

output-per-sheep, the same adjustment is implied for the supply or demand schedules represented in figure 1. This approach is necessary due to the jointness in lamb and wool production.

U.S. demands for wool at the farm and wholesale levels are labeled *DWF* and *DWW*, respectively. The wholesale and retail level demands for lamb are labeled *DLW* and *DLR*, respectively. These demands may be satisfied with domestically produced and/or imported products. The supply of wool imports (*SWm*) is on a raw or farm level basis. Lamb imports supply, labeled *SLm*, is on a wholesale or carcass basis. The demand for domestically produced wool, labeled *EDWF* in figure 1, is defined as the excess of demand (*DWF*) over import supply (*SWm*) at various prices. Thus, at a price P^*, $EDWF(P^*) = DWF(P^*) - SWm(P^*)$. As illustrated in figure 1, excess demand is zero at the intersection of *DWF* and *SWm* and positive at prices below that intersection. Similarly, the wholesale level demand for domestically produced lamb (*EDLW*) is the excess of demand (*DLW*) over import supply (*SLm*) at various prices. The demand for domestic lamb at the farm level (*EDLF*) is derived from the wholesale demand (*EDLW*).

The domestic supply schedule for sheep products, labeled *SSF*, relates breeding sheep numbers to annual revenue from the lamb and wool output of the sheep. Due to the jointness in production, lamb and wool are produced in fixed proportions. Thus, lamb and wool prices work jointly to determine breeding sheep population and related lamb and wool output. The demand for domestic sheep products, labeled *DSF*, is the vertical sum of the farm level domestic demands for lamb (*EDLF*) and wool (*EDWF*). It relates the quantity of breeding animals and related outputs to consumer expenditures for the outputs of a sheep.

Without a wool program, equilibrium in the domestic sheep products market is at the intersection of *SSF* and *DSF* with *QS* breeding animals in the flock. Revenue and expenditure

Table 1. Summary of Welfare Transfers and Losses Associated with the Wool Incentive Program

Figure 1 Welfare Area	Description
Wool Consumers	
PWW q s PWW'	Domestic wool consumers' surplus gain
q r s	Deadweight loss of economic surplus
Lamb Consumers	
PLR u v PLR'	Domestic lamb consumers' surplus gain
u t v	Deadweight loss of economic surplus
Lamb and Wool Producers	
PWLF' cc z PWLF	Domestic lamb and wool producers' surplus gain
PLF a b PLF'	Loss of revenue due to lower lamb prices/available to lamb consumers
PWF' e f PWR'	Incentive payment transfer from the government to domestic wool producers
PWR g f PWR'	Loss of revenue due to lower wool prices/available to wool consumers
cc y z	Deadweight loss of resources
Foreign Lamb and Wool Producers	
PLW h k PLW'	Foreign lamb producers' surplus loss
PLW j k PLW'	Loss of surplus available to U.S. lamb consumers
j h k	Deadweight loss of economic surplus
PWR o p PWR'	Foreign wool producers' surplus loss
PWR n p PWR'	Loss of surplus available to U.S. wool consumers
n o p	Deadweight loss of economic surplus

per sheep from lamb and wool sales is *PWLF*. A breeding flock of *QS* yields lamb and wool outputs of *QL* and *QW*, respectively. The raw wool price, *PWR*, is determined at the intersection of *QW* and *EDWF*. At *PWR*, *QCW* is consumed. This consumption is made up of *QWm* wool imports and *QW* domestic production. The wholesale wool price is *PWW* (from the intersection of *QCW* and *DWW*). Without the wool program, producers receive the market raw wool price for their wool.

Equilibrium in the domestic lamb market is at the intersection of *QL* and *EDLF* with lamb market price of *PLF*. A farm price of *PLF* corresponds to a carcass price of *PLW* (from the intersection of *QL* and *EDLW*). At *PLW*, consumption of *QCL* is made up of *QLm* imports (from the intersection of *PLW* and *SLm*) and *QL* domestic production. The retail price is *PLR* (from the intersection of *QCL* and *DLR*). Note that lamb and wool are produced in fixed proportions (*QS*, *QW*, and *QL* are at the same output point in figure 1) while lamb and wool can be imported and consumed in any proportion.

Economic Impact of the Wool Program Illustrated

Welfare transfers and losses resulting from the Wool Act are summarized in table 1.

Under the Wool Act, wool production is encouraged by a subsidy paid directly to producers. On average this subsidy is the difference between the wool incentive price (a parity-based target price) and the wool's value in the market. In figure 1 the incentive price is labeled *IPW*.

The incentive payment subsidy acts to insure domestic producers at least the incentive price for their wool. Thus, in effect, the demand for the wool of domestic producers is perfectly elastic at *IPW* for all quantities beyond the intersection of *IPW* and *EDWF*. This in turn lends a kink to the demand for domestic sheep production (*DSF'*). Incentive program equilibrium in the domestic sheep products market is at the intersection of *DSF'* and *SSF*, with a breeding flock of *QS'* and resulting wool and lamb outputs of *QW'* and *QL'*, respectively. Revenue per sheep from lamb and wool sales is *PWLF'*. With *QW'* production, the domestic wool market clears at price *PWR'* (intersection of *QW'* and *EDWF*). Foreign producers supply *QWm'* at *PWR'*. A lower wool price reduces foreign producers' surplus by area *PWR o p PWR'*. Area *PWR n p PWR'* is available to U.S. wool consumers due to lower wool prices. However, area *n o p* is a deadweight loss of producers' surplus. Lower raw (*PWR'*) and corresponding wholesale (*PWW'*) wool prices cause wool consumption to increase to *QCW'*. Due to a lower price and increased consumption, consumers capture

additional surplus of *PWW q s PWW'*. Area *PWW m l PWW'* is available from wool exporters, and area *m r s l* (equivalent of *PWW c d PWW'*) accrues from lost wool sales revenue of domestic wool producers.[1] Total producers' losses available to wool consumers exceed consumers' surplus captured by area *q r s*, an area of deadweight loss.

Domestic lamb and wool producers' wool revenue is increased due to the incentive programs by area *PWF' e g PWF*. Wool producers receive an incentive payment from the government of area *PWF' e f PWR'*, but a part of this, area *PWR g f PWR'*, is lost due to lower wool prices. In effect, area *PWR g f PWR'* is an indirect transfer to domestic wool consumers.

With the incentive program, equilibrium in the domestic lamb market is at the intersection of *QL'* and *EDLF* with a farm level lamb price of *PLF'*. At corresponding wholesale and retail prices of *PLW'* and *PLR'*, *QLm'* is imported and *QCL'* is consumed. A lower farm level lamb price implies a loss of revenue to domestic lamb producers of *PLF a b PLF'*. This loss is available to lamb consumers through lower prices. A lower wholesale lamb price reduces imports to *QLm'* and foreign lamb producers' surplus by area *PLW h k PLW'*. A portion of this loss is available to domestic lamb consumers (area *PLW j k PLW'*) but area *j h k* is a deadweight loss. Due to lower lamb prices, lamb consumers' surplus is increased by area *PLR u v PLR'*. However, the surplus losses of domestic and foreign lamb producers available to lamb consumers, *PLR aa bb PLR'* and *aa t v bb*, respectively (assuming a constant market margin, these equal *PLF a b PLF'* and *PLW j k PLW'*, respectively), exceed the surplus captured by lamb consumers by area *u t v*, an area of deadweight loss.

Domestic lamb and wool producers' wool revenue is increased by government transfers under the incentive program but lamb revenue is reduced. The net transfer is represented by area *PWLF' cc y PWLF* in figure 1. However, producers are able to capture additional surplus of only area *PWLF' cc z PWLF*. Thus, area *cc y z* is a deadweight loss.

The Simulation Model

An econometric model of the U.S. sheep producers' sector was developed to investigate the impacts of the wool incentive program. The model consists of four segments: a domestic sheep products supply segment, a lamb and wool import supply segment,[2] a wool demand segment, and a lamb demand segment. The model equations are listed in appendix 1. A diagram characterizing the relationships among simulation model equations and the correspondence between simulation model equations and the graphic model (figure 1) is shown in figure 2. Endogenous relationships within the simulation model are emphasized in figure 2. Market quantities and prices are the endogenous factors driving the simulation model. Equations characterized in figure 2 are numbered to correspond to simulation model equations listed in appendix 1. The labels in parentheses relate simulation model equations to the graphic model depicted in figure 1.

The domestic supply segment is modeled using a series of eight equations, four behavioral and four identities. (All behavioral equations are characterized in bold type.) In the aggregate case, historic retention of lambs for breeding purposes [equation (1)] along with the stock sheep slaughter decisions determine the size of the breeding flock [equation (2) labeled *SSF* in figure 1]. The breeding flock provides two valuable outputs, lamb and wool. Lambs may be slaughtered for meat or retained to enter the breeding flock during the next production period. Lamb slaughter [equation (7)] with live lamb weight [behavioral equation (3)] determines domestic lamb production [equation (8) or *QL* in figure 1]. Domestic lamb production and lamb imports [equation (9) or *QLm* in figure 1] combine for total lamb supply. Lamb market equilibrium is insured by equation (14) where supply is set equal to demand (as shown in figure 2, this is equivalent to setting *QL* equal to *EDLW* in figure 1). Consumption per capita determines retail lamb price [equation (11) and *PLR* in figure 1] which in turn determines wholesale lamb price [equation (12) or *PLW* in figure 1]. Wholesale lamb price in turn determines the farm price of lamb

[1] Areas *PWW c d PWW'* and *PWW m l PWW'* are equivalent to areas *PWR g f PWR'* and *PWR n p PWR'*, respectively, assuming that the wool marketing margin is constant.

[2] Live sheep imports and exports as well as lamb and wool exports historically have been negligible. Thus, they are ignored in this analysis.

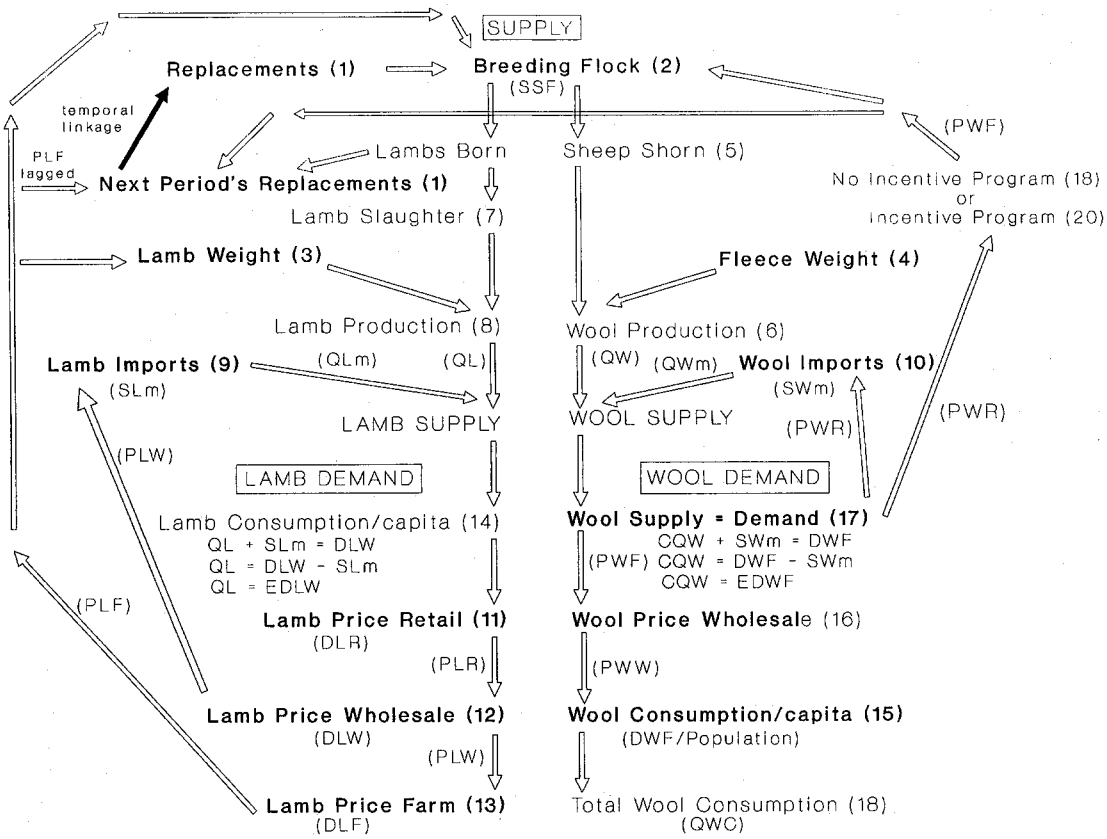

Figure 2. Illustration of the correspondence between the simulation and graphic models

(*PLF*) [equation (13) and *PLF* in figure 1]. Wholesale lamb price is the endogenous factor determining lamb imports (*QLm*), while the farm price of lamb impacts lamb weight (3), lamb slaughter, and breeding sheep slaughter.

The breeding flock and replacement animals are shorn to provide the wool output. The number of animals shorn multiplied by the fleece weight [equation (4)] yields domestic wool production (*QW* in figure 1). Domestic wool production and wool imports [equation (10) and *QLm* in figure 1] combine for total wool supply. Wool market equilibrium is insured by equation (17) where wool supply is set equal to wool demand and solved for the raw wool price, *PWR*. As shown in figure 2, this is equivalent to setting *QW* equal to *EDWF* in figure 1. The raw wool price determines the wholesale price of wool [*PWW* in equation (15)] which in turn determines per capita wool consumption in the wool demand equation (15). Total wool consumption is simply per capita consumption times population (18).

The raw wool price (*PWR*) is the endogenous factor determining wool imports under the incentive program. The raw wool price equals the farm level wool price (*PWF*) if the market price is above the incentive price, otherwise, the farm price is equal to the incentive price [equation (20)]. Without the incentive program, the farm price of wool is equal to the raw wool market price. The farm price of wool is an endogenous factor which affects the slaughter of both breeding animals [equation (2)] and lambs [equation (1)].

Equations (1–19) in the "no policy" case and (1–18) and (20) (appendix 1) in the "Wool Act" case constitute a farm level model of the U.S. sheep industry with linkages to wholesale and retail level markets. As illustrated in figure 2, the empirical model listed in appendix 1 is consistent with the theoretical model graphically depicted in figure 1. Response parameters for the endogenous factors in the simulation model (appendix 1) are listed in table 2. These show the response of domestic lamb and wool

Table 2. Estimated Elasticities and Flexibilities Associated with Sheep Industry Simulation Model

Elasticity or Flexibility	Related to Simulation Model Equation(s) (appendix 1)	Related to Graphic Model Function (figure 1)	Estimate
$\frac{\% \Delta QL_t}{\% \Delta PLF_t}$	1–8	*SSF*	1.70[a]
$\frac{\% \Delta QL_t}{\% \Delta PWF_t}$	1–8	*SSF*	0.78[a]
$\frac{\% \Delta QW_t}{\% \Delta PWF_t}$	1–8	*SSF*	0.92[a]
$\frac{\% \Delta QW_t}{\% \Delta PLF_t}$	1–8	*SSF*	1.85[a]
$\frac{\% \Delta QLm_t}{\% \Delta PLW_t}$	9	*SLm*	1.47[b]
$\frac{\% \Delta QWm_t}{\% \Delta PWR_t}$	10	*SWm*	1.06[b]
$\frac{\% \Delta PLR_t}{\% \Delta CONLMB_t}$	11	*DLR*	−0.58[b]
$\frac{\% \Delta PLW_t}{\% \Delta CONLMB_t}$	11–12	*DLW*	−0.66[bc]
$\frac{\% \Delta PLF_t}{\% \Delta CONLMB_t}$	11–13	*EDLF*	−0.84[bc]
$\frac{\% \Delta CQWWC_t}{\% \Delta PWW_t}$	15	*DWW*	−0.15[b]
$\frac{\% \Delta CQWWC_t}{\% \Delta PRW_t}$	15–16	*DWF*	−0.09[bc]

[a] To estimate supply response parameters for the supply model, the model was dynamically simulated using the Newton method, initially with actual prices to yield a baseline solution and then resimulated for wool price, lamb price, hay price, and beef price assuming a sustained 10% increase in the value of the particular price factor while all other values were set to actual values. These increased price solutions were compared with the baseline solution to calculate supply response elasticities. The horizon reported here is five years.

[b] Calculated at the means of the data.

[c] Calculated using the elasticity or flexibility of price transmission concepts.

supplies to lamb price to be elastic over a five-year horizon. Both wool and lamb outputs are less responsive to wool price. The dynamic nature of the supply model allows supply elasticities to be inelastic in the short run with elasticity increasing as the horizon increases.

Wool and lamb import supply elasticities are estimated to be 1.06 and 1.47, respectively, evaluated at the data means. The lamb demand flexibilities at the retail, wholesale, and farm levels are estimated to be −.58, −.66 and −.84, respectively, evaluated at the means of the data. The estimated demand elasticity for wool is −.15 at the wholesale level and −.09 at the farm level. All of the response parameters in the simulation model are short run except in the case of the domestic supply model where the dynamic nature of the model allows the response to vary with time.

The sheep industry model was dynamically simulated on an annual basis using the Newton method (Judge et al., pp. 650–52). Using observed values for independent variables, the model was simulated assuming the incentive payment to be a part of the wool price and again assuming no incentive payment was made.[3] All tariffs were assumed in place for both simulations. The results of the two equilibrium simulations were compared to gauge the effects of the incentive payment program on the sheep industry.

Results

Changes in the stock sheep numbers and various output measures resulting from the incentive payment program are listed in table 3. The results of the model simulations indicate that the incentive program has had a major impact on the U.S. sheep industry. The size of the breeding flock (Stock Sheep) increased by over 26% between 1955 and 1985 as a result of the incentive program. Wool production follows stock sheep numbers closely. As the model formulation would suggest, lamb production increases due to the wool incentive payment; lag stock sheep and wool production increase because producers hold lambs from slaughter to build the breeding flock. Note that the Wool Act has had a minimal impact on wool consumption (table 4). Though prices were lowered, the inelastic nature of wool demand implied little consumption response. Increased wool production mostly was offset by reduced imports. It is also notable that the

[3] To validate the simulation model, the dynamically simulated equilibrium, assuming the incentive program in place, was compared to observed equilibrium conditions. The results of this comparison show the model to do an adequate job of simulating actual equilibrium. Mean percent simulation error was 8.9% for stock sheep, 17.6% for wool output, 4.4% for lamb output, −4.4% for farm price of lamb, −10.4% for lamb consumption, −2.8% for retail lamb price, −3.3% for wool consumption, 5.8% for lamb imports, and 6.2% for wool imports. The most serious error was a misestimation of lamb consumption and wool production during certain periods.

Table 3. Impact of the Wool Incentive Program on Sheep Population, Output, Revenue, and Imports

Year	Change In					
	Stock Sheep	Wool Production	Lamb Production	Producer's Lamb/Wool Revenue	Lamb Imports	Wool Imports
	(%)					
1960	1.5	1.8	1.0	1.5	−1.2	−0.9
1965	2.8	2.7	2.5	2.9	−2.5	−1.2
1970	11.7	12.9	6.8	15.6	−3.5	−5.4
1975	10.2	9.0	11.1	1.9	−8.7	−3.8
1980	5.7	6.1	3.9	7.4	−3.7	−1.7
1985	26.3	28.8	16.7	29.9	−22.8	−5.7

Wool Act has had a sizable impact on lamb consumption and imports through lower lamb prices. Consumption was increased nearly 14%, while imports fell over 22% in 1985.

Measures of the welfare implications of the Wool Act illustrated in figure 1 are listed in appendix 2 for selected years. Estimation formulas for the welfare effects are detailed in appendix 3. Measures of the net effects of the Wool Act on producers, consumers, marketers, and the government are provided in table 5.[4]

Sheep producers' benefits from the Wool Act have been modest. Producers' surplus was increased an average of about $23 million per year during the 1980s by the wool incentive program. This amounts to about 4% of sheep producers' total wool and lamb revenue. However, the effects of the program have been somewhat erratic. For example, in 1960 increased surplus accounted for less than 1% of producers' revenue whereas in 1983, it accounted for nearly 8% of producers' revenue.

Both lamb and wool consumers have benefited from the increased production stimulated by the wool incentive payment. Lamb consumers' surplus gains of $55.2 million accounted for nearly 8% of consumers' lamb expenditures in 1985, while wool consumers' gains of $31.8 million totaled over 9% of consumers' wool expenditures. The relatively greater impact on wool consumers is due primarily to the more inelastic demand for wool. Government transfers to sheep producers were about $100 million per year over the 1983–85 period. Note that the government costs reported in table 5 are simulated rather than actual incentive transfers. Simulated incentive program costs generally are somewhat greater than actual costs since not all producers request an incentive payment and simulated costs assume a payment on all wool production.

Table 4. Impact of Wool Incentive Program on Lamb and Wool Consumption and Price

Year	Change In			
	Retail Price of Lamb	Lamb Consumption	Wholesale Price of Wool	Wool Consumption
	(%)			
1960	−0.6	1.0	−0.8	0.1
1965	−1.4	2.4	−1.0	0.2
1970	−3.4	6.2	−4.0	0.8
1975	−5.4	10.1	−1.8	0.6
1980	−1.6	2.9	−0.7	0.3
1985	−7.2	13.9	−3.4	1.3

Lamb and wool exporters lose economic surplus as a result of the Wool Act. Lamb exporters' surplus losses were $3.2 million in 1985, nearly 10% of lamb exporters' revenue. Wool exporters' losses were $14.5 million in 1985, about 5% of wool exporters' revenue.

The social welfare effect of the incentive program is simply the sum of the deadweight losses resulting from the program's market distortions. If only the U.S. interest is considered, then transfers from lamb and wool exports accrue to internal interests and offset, somewhat, deadweight losses. In this case, the net social welfare effect of the program may be positive. The simulation analysis shows the Wool Act to cause $25.7 million in social losses in 1985 when only the U.S. interest is considered. Considering U.S. and exporter interests, social losses would necessarily occur during each year. These losses were $43.4 million in 1985, about 4% of consumers' lamb and wool expenditures.

[4] The sensitivity of the simulation model welfare results to changes in various key model parameters such as wool and lamb price coefficients of supply and demand was tested by reducing the value of the coefficient in question by 1% and resimulating the model. Results show the model to be modestly sensitive to changes in supply and demand price parameters. This sensitivity can be characterized by the mean percent change in the lamb and wool consumers' and producers' surplus effects due to a reduction in the wool price supply parameters (−2.3% and 15.6%, respectively); the lamb price supply parameters (−2.4% and 2.5%, respectively); the wool price demand parameters (−.9% and 3.8%, respectively); and the lamb quantity demand parameters (1.5% and −3.0%, respectively). Producers' effects are somewhat more sensitive to parameter adjustment than are consumers' effects.

Table 5. Net Effects of the Wool Incentive Program

Affected Group	1960	1970	1980	1981	1982	1983	1984	1985
	($ millions)							
U.S. Lamb and Wool Producers[a]	0.05	14.1	7.7	22.4	28.8	35.6	31.2	15.2
(*PWLF′ cc z PWLF*)	(0.01)	(3.7)	(1.7)	(4.8)	(6.4)	(7.9)	(6.7)	(3.2)
U.S. Wool Consumers[b]	8.0	26.0	5.4	6.1	9.8	15.2	22.8	31.8
(*PWW q s PWW′*)	(1.8)	(9.7)	(1.4)	(1.6)	(3.1)	(5.0)	(6.9)	(9.2)
U.S. Lamb Consumers[b]	2.5	18.0	10.3	6.9	11.2	22.3	37.0	55.2
(*PLR u v PLR′*)	(0.57)	(3.5)	(1.6)	(1.0)	(1.7)	(3.2)	(5.2)	(7.7)
U.S. Government								
(*IPW e f PWR′*)	5.5	53.7	27.8	−46.7	−66.9	−94.8	−114.6	−123.0
Wool Exporters[a]	−3.3	−11.2	−2.4	−2.8	−4.5	−7.0	−10.5	−14.5
(*PWR o p PWR′*)	(1.2)	(6.3)	(0.86)	(1.0)	(1.8)	(3.0)	(4.0)	(5.2)
Lamb Exporters[a]	−0.03	−0.95	−1.6	−0.7	−1.4	−2.3	−3.6	−3.2
(*PLW h k PLW′*)	(0.80)	(4.9)	(2.6)	(1.6)	(2.7)	(4.8)	(7.3)	(9.7)
Net Welfare Effects: U.S. Interest[c]	−2.7	−2.3	−2.5	−11.8	−17.3	−22.3	−24.4	−25.7
	(0.30)	(0.30)	(0.25)	(1.1)	(1.8)	(2.3)	(2.3)	(2.4)
Net Welfare Effects: U.S. and Exporter Interests[d]	−0.63	−14.5	−6.5	−15.4	−23.2	−31.6	−38.5	−43.4
	(0.01)	(1.9)	(0.65)	(1.5)	(2.4)	(3.2)	(3.7)	(4.1)

[a] The numbers in parentheses are producers' surplus change as a percentage of producers' revenue.
[b] The numbers in parentheses are consumers' surplus change as a percentage of consumers' expenditures.
[c] $PWR\ n\ p\ PWR' + PLW\ j\ k\ PLW' - cc\ y\ z - q\ r\ s - u\ t\ v$. The numbers in parentheses are welfare effects as a percentage of total consumer lamb and wool expenditures.
[d] $-cc\ y\ z - q\ r\ s - u\ t\ v - j\ h\ k - n\ o\ p$. The numbers in parentheses are welfare effects as a percentage of total consumer lamb and wool expenditures.

Implications

These simulation results indicate that the Wool Act, with its incentive payment for wool, has had a substantial impact on the size and output of the U.S. sheep industry. Although in decline, the industry would have declined faster without the incentive payments. The welfare losses associated with the wool program have been modest (average $1,956,035 per year if only U.S. interests are considered) over its life, but the impacts on particular groups and during particular periods have been more substantial. Clearly, the government, responsible for the incentive transfer, has been the biggest loser. Lamb and wool consumers' gains have been substantial. It is notable that consumers' gains have exceeded sheep and lamb producers' gains during most years since the Wool Act's adoption. Consumers' gains exceeded those of producers substantially in some years, e.g., by a factor of over five in 1985. Lamb and wool exporters have suffered losses as a result of the incentive program, although lamb exporters' losses have been small. This result shows that a large portion of the incentive transfer is passed through to lamb and wool consumers. In addition, wool and lamb exporters' losses resulting from lower market prices with the incentive program largely pass through to consumers.

It should be noted that this is an *ex post* analysis of the wool program. Its results show the effects of the wool program over the recent past, given the structure and exogenous conditions of the past. Response parameter estimates reflect the behavior of market participants with the wool program in place. Even with this caveat, the relatively small social losses associated with the wool program and recognition of benefits captured by lamb and wool consumers, as well as the treasury costs of the program, would seem to be important considerations in future farm policy deliberations.

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References

American Sheep Producers' Council. *Situation Outlook Report: 86–87*. Denver CO: American Sheep Producers' Council, 1987.

Gallant, A. R., and J. J. Goebel. "Nonlinear Regression

with Autoregressive Errors." *J. Amer. Statist. Assoc.* 71(1976):961–67.
Gardner, B. *Effects of U.S. Wool Policy.* Government Accounting Office, Community Economic Development Division 82-86CR. June 1982.
Government Accounting Office. *Congressional Decisions Needed on Necessity of Federal Wool Program.* CED-82-86, August 2, 1982.
Hewlett, J. P., G. D. Whipple, and D. J. Menkhaus. "The Demand for U.S. Apparel Wool." *Sheep Ind. Develop. Res. J.* 5(Spring 1989):20–25.
Judge, G. G., R. C. Hill, W. Griffiths, H. Lütkepohl, and T.-C. Lee. *Introduction to the Theory and Practice of Econometrics.* New York: John Wiley & Sons, 1982.
U.S. Department of Agriculture. *Agricultural Statistics,* Washington DC. 1939–84.
———. *Cotton and Wool Situation and Outlook Report,* CWS47. Washington DC, November 1986.
———. *Livestock and Meat Statistics,* Statist. Bull. Washington DC. Various years, 1940–85.
———. *Wool Statistics and Related Data and Supplements,* Econ. Res. Serv. Statist. Bull. Nos. 250, 363, 455.
Whipple, G. D., and D. J. Menkhaus. "An Econometric Investigation of the Demand for Lamb." *Sheep Ind. Develop. Res. J.* 5(Winter 1989a):7–11.
———. "Supply Response in the U.S. Sheep Industry." *Amer. J. Agr. Econ.* 71(1989b):126–35.

Appendix 1

The Simulation Model

The econometric model of the U.S. sheep production sector used in this research consists of a domestic sheep products supply segment, a lamb and wool import supply segment, and a lamb and wool demand segment. All behavioral equations were estimated based on 1950–85 annual data. Data were collected from selected issues of *Livestock and Meat Statistics* [U.S. Department of Agriculture (USDA)], *Agricultural Statistics* (USDA), *Wool Statistics and Related Data and Supplements* (USDA), and *Cotton and Wool Situation and Outlook Report* (USDA). Supply and demand components of the model were estimated separately, using single-equation techniques. Data limitations and the size of the model precluded the use of a systems estimation procedure. Where autocorrelation was a problem, equations were corrected for autocorrelation using the Yule-Walker method (Gallant and Goebel), and ρ is reported. In those cases where autocorrelation was not a problem, least squares techniques were used, and the Durbin-Watson statistic is reported. The standard errors for coefficients are listed in parentheses beneath the respective coefficients. A more complete presentation of the domestic sheep supply model is contained in Whipple and Menkhaus (1989b). The lamb demand segment is discussed in Whipple and Menkhaus (1989a), and the wool demand segment is discussed in Hewlett, Whipple, and Menkhaus.

Domestic supply.

$$(1)\quad REPL_t = \sum_{j=1}^{8} SS_{jt-1}\cdot L\_\%_{t-1}\cdot(1 - D_{0t-1})$$
$$\cdot(7.620 + .1339PLF_{t-2}/PH_{t-2}$$
$$(4.54)\quad (.0731)$$
$$- .00391YEAR_{t-1}$$
$$(.0023)$$
$$+ 4.245PWF_{t-1}/PH_{t-1}$$
$$(1.479)$$
$$-.0000686PLB_{t-1} + .00122PB_{t-1})$$
$$(.000508)\qquad (.00160)$$

$$R^2 = .985\quad F = 328.3\quad \rho = .34,$$
$$(.17)$$

$$(2)\quad \sum_{j=1}^{8} SS_{jt} = REPL_t + \sum_{Y=2}^{8} REPL_{t-Y+2}\cdot\prod_{j=2}^{Y}$$
$$\cdot(.5691 + .4181PLF_{t+j-Y-1}/PH_{t+j-Y-1}$$
$$(.1034)\quad (.04259)$$
$$+ 5.8484PWF_{t+j-Y-1}/PH_{t+j-Y-1}$$
$$(1.0444)$$
$$- .7358PS_{t+j-Y-1}/PH_{t+j-Y-1}$$
$$(.06529)$$
$$-.0003957PB_{t+j-Y-1}$$
$$(.000853)$$
$$- .00000275PLB_{t+j-Y-1}$$
$$(.00002)$$
$$+ .00695AGE_{t+j-Y-1})$$
$$(.0224)$$

$$R^2 = .993\quad F = 600.1\quad DW = 1.3,$$

$$(3)\quad LVWT_t = 79.386 + .18291PLF_t$$
$$(.878)\quad (.058)$$
$$- .9703PCON_t + .5052YEAR_t$$
$$(.4103)\qquad (.0386)$$

$$R^2 = .986\quad F = 504.3\quad DW = 1.91,$$

$$(4)\quad FLCWT_t = 1.2675 + .8458FLCWT_{t-1}$$
$$(.531)\quad (.0698)$$

$$R^2 = .738\quad F = 61.21\quad DW = 2.58,$$

$$(5)\quad SSRN_t = SS_t + REPL_{t+1},$$

$$(6)\quad QW_t = SSRN_t\cdot FLCWT_t,$$

$$(7)\quad LBS_t = (SS_t\cdot(1 - D_{0t-1})\cdot L\_\%_t) - REPL_{t+1},$$

and

$$(8)\quad QL_t = LMBS_t\cdot LVWT_t,$$

where $REPL$ is the number of replacement lambs, $\sum_{j=1}^{8} SS_j$ is the number of stock sheep aged one through eight in the breeding flock, L __% is the lambs saved per stock sheep in the breeding flock, D_0 is the lamb death loss as a percentage of lambs saved, PLF is the farm price for lamb ($/lb.), PH is the alfalfa hay price ($/ton), $YEAR$ is a linear time trend variable (1950–85), PWF is the farm price of wool including incentive payments ($/lb.), PLB is the price of farm labor index, PB is the calf price ($/lb.), PS is the price of cull sheep ($/lb.), AGE is the age in years of a particular stock sheep cohort, $LVWT$ is the average live lamb weight (lbs.), $PCON$ is the price of 20% protein concentrate ($/ton), $FLCWT$ is annual wool output per animal (lbs.), $SSRN$ is number of sheep shorn (head), QW is total domestic wool production (lbs.), LBS is lambs slaughtered (head), and QL is lamb production (live weight, lbs.).

Import supply.

$$(9)\quad QLm_t = \underset{(5{,}570{,}045)}{-32{,}511{,}753.4} + \underset{(78{,}935)}{363{,}904.4}PLW_t + \underset{(.0053)}{.03309}NZAULP_t - \underset{(101{,}209)}{497{,}746.3}PEXP_t$$

$$R^2 = .819 \quad F = 36.2 \quad \rho = \underset{(.17)}{.19},$$

$$(10)\quad QWm_t = \underset{(134{,}873{,}800)}{434{,}234{,}200} + \underset{(11{,}069{,}600)}{303{,}151{,}600}PWR_t - \underset{(42{,}155{,}900)}{87{,}692{,}200}PWWD_t + \underset{(138{,}200)}{144{,}100}QAEXP_t - \underset{(2{,}835{,}294{,}200)}{1{,}106{,}820{,}000}TRSUS_t - \underset{(1{,}001{,}700)}{2{,}992{,}400}YEAR_t + \underset{(4{,}441{,}600)}{14{,}590{,}100}WD_t$$

$$R^2 = .723 \quad F = 12.61 \quad \rho = \underset{(.17)}{.37},$$

where QLm is annual lamb imports for the U.S. (lbs.), PLW is the U.S. wholesale carcass lamb price ($/lb.), $PEXP$ is the average price of New Zealand and Australian lamb exports weighted by share of U.S. lamb imports by origin ($/lb.), $NZAULP$ is lamb production in New Zealand and Australia (lbs.), QWm is total wool imports (clean lbs.), PWR is the U.S. raw wool price ($/lb.), $PWWD$ is the world market price of raw wool (U.S. $/clean lb.), $QAEXP$ is Australian wool exports (mill. greasy kg), $TRSUS$ is the U.S. tariff on raw imported wool ($/clean lb.), and WD is a binary variable for war ($WD = 1$ if $YEAR = 1951$–52; $WD = 0$ otherwise).

Demand for lamb.

$$(11)\quad PLR_t = \exp(\underset{(.470)}{2.201} - \underset{(.085)}{.5780}\ln(CONLMB_t) + \underset{(.096)}{.3011}\ln(PBR_t) + \underset{(.062)}{.1113}\ln(INC_t) + \underset{(.064)}{.0771}\ln(PCR_t) + \underset{(.091)}{.0645}\ln(PPR_t))$$

$$R^2 = .995 \quad F = 2{,}122.7 \quad \rho = \underset{(.17)}{-.35},$$

$$(12)\quad PLW_t = \exp(\underset{(1.839)}{-9.2098} + \underset{(.098)}{.6961}\ln(PLR_t) - \underset{(.044)}{.0346}\ln(RW_t) - \underset{(.074)}{.4117}\ln(QL_t))$$

$$R^2 = .998 \quad F = 2{,}189.0 \quad \rho = \underset{(.16)}{.45},$$

$$(13)\quad PLF_t = \exp(\underset{(.435)}{-1.608} - \underset{(.032)}{.1933}\ln(MPW_t) + \underset{(.047)}{1.2677}\ln(PLW_t) - \underset{(.019)}{.0054}\ln(LBS_t))$$

$$R^2 = .996 \quad F = 2{,}739.0 \quad \rho = \underset{(.17)}{.24},$$

where PLR is the retail price of lamb ($/lb.), $CONLMB$ is annual per capita consumption of lamb (lbs.), PBR is the retail price of beef ($/lb.), INC is annual per capita personal income in the U.S., PCR is the retail price of broilers ($/lb.), PPR is the retail price of pork ($/lb.), exp is the exponential operator, ln is the natural log operator, RW is the per-hour wage rate in food retailing ($/hr.), and MPW is the per-hour wage rate in meat packing ($/hr.).

Lamb market equilibrium. Equilibrium in the lamb market is insured by equation (14) which links the lamb demand system to domestic and imported lamb supplies:

$$(14)\quad CONLMB_t = (.845((QL_t \cdot .5) + QLm_t))/POP_t,$$

where POP is the U.S. population, the .5 constant is the live-lamb dressing percentage, and .845 is the carcass-to-retail yield (*Livestock and Meat Statistics*).

Demand for wool.

$$(15)\quad CQWWL = \underset{(.2915)}{3.6556} + \underset{(.0000608)}{.0001769}INC_t - \underset{(.1037)}{.11241}PWW_t - \underset{(.0086)}{.05413}YEAR_t + \underset{(.2143)}{.3586}WD_t$$

$$R^2 = .932 \quad F = 106.2 \quad \rho = .55, \ (.15)$$

$$(16) \quad PWW_t = \underset{(40.013)}{90.340} + \underset{(.243)}{2.514} + \underset{(.103)}{.3127}PTL_t - \underset{(.020)}{.0456}YEAR_t + \underset{(.000000001215)}{.000000002175}RAWWL$$

$$R^2 = .923 \quad F = 92.9 \quad \rho = .53, \ (.15)$$

where $CQWWL$ is annual U.S. per capita wool consumption (lbs.), PWW is the wholesale wool price ($/lb.), PTL is the price of textile labor in the U.S. ($/hr.), and $RAWWL$ is U.S. wool production plus raw wool imports (lbs./clean basis).

Wool market equilibrium. The total U.S. consumption of wool (QCW), can be defined as per capita consumption times population ($CQWWL \cdot POP$). Setting the total U.S. demand for wool equal to domestic production (adjusted for clean yield: $QCW_t = QW_t \cdot WLYLD_t$, where $WLYLD$ is clean yield of raw wool) plus wool imports (QWm), substituting equation (16) for PWW in equation (15) and solving for PWR yields an equilibrium equation which insures a wool market price where total wool consumption (QCW) equals wool production (CQW) plus imports (QWm):

$$(17) \quad PWR_t = [((POP_t(3.6556 + .0001769INC_t - .11241 \cdot (90.340 + .3127PTL_t - .0456YEAR_t + .000000002175RAWWL_t) - .05413YEAR_t + .3586WD_t)) - (QWm_t + CQW_t))/(.11241 \cdot 2.514 \cdot POP_t)].$$

Defining total wool consumption as in equation (18) and reconciling the farm and wool market raw wool prices completes the simulation system.

In the case of no incentive payment, the farm price equals the market price and equation (19) completes the model:

$$(18) \quad QCW_t = CQW_t + QWm_t = CQWWL_t \cdot POP_t,$$

and

$$(19) \quad PWF_t = PWR_t.$$

In the incentive program case, equation (20) completes the model:

$$(20) \quad \text{if } PWR_t > IPW_t \text{ then } PWF_t = PWR_t; \text{ otherwise, } PWF_t = IPW_t,$$

where IPW_t is the wool incentive price for period t. Equation (20) insures that wool producers receive IPW for their wool without directly impacting the U.S. raw wool market.

Appendix 2. Estimated Welfare Transfers and Losses Associated with the Wool Incentive Program: Selected Years

Figure 1 Welfare Area	1960	1970	1980	1981	1982	1983	1984	1985
Wool Consumers	($ millions)							
PWW q s PWW'	80.0	26.0	5.4	6.1	9.8	15.2	22.9	31.8
q r s	0.00	0.10	0.09	0.01	0.02	0.06	0.12	0.20
Lamb Consumers								
PLR u v PLR'	2.6	18.0	10.3	6.9	11.2	22.3	37.0	55.2
u t v	0.01	0.54	0.01	0.06	0.16	0.62	1.64	3.58
Lamb and Wool Producers								
PWLF' cc z PWLF	0.05	14.2	17.7	22.4	28.8	35.6	31.2	15.2
PLF a b PLF'	2.7	19.3	12.9	8.1	113.7	26.2	43.6	64.2
PWF' e f PWR'	5.5	53.7	27.8	46.7	66.9	94.9	114.6	123.0
PWR g f PWR'	2.2	6.7	0.91	1.0	1.5	2.3	3.6	4.9
cc y z	9.06	13.5	6.3	15.3	22.9	30.7	36.3	38.8
Foreign Lamb and Wool Producers								
PLW h k PLW'	0.3	0.96	1.6	0.7	1.4	2.3	3.6	3.2
PLW j k PLW'	0.03	0.94	1.5	0.7	1.4	2.2	3.4	2.8
j h k	0.00	0.02	0.03	0.01	0.03	0.09	0.23	0.04
PWR o p PWR'	3.3	11.2	2.4	2.8	4.5	7.0	10.5	14.5
PWR n p PWR'	3.3	10.9	2.4	2.8	4.5	6.9	10.2	14.0
n o p	0.02	0.32	0.02	0.02	0.06	0.13	0.26	0.42

Appendix 3. Estimation Method for the Welfare Effects Associated with the Wool Incentive Program

Figure 1 Welfare Area		Estimating Equation
Wool Consumers[a]		
$PWW\ q\ s\ PWW'$	=	$(PWW - PWW')\cdot(QCW + ((QCW' - QCW)/2))$
$q\ r\ s$	=	$(((PWW - PWW')\cdot(QCW' - QCW))/2)$
Lamb Consumers[a]		
$PLR\ u\ v\ PLR'$	=	$(PLR - PLR')\cdot(QCL + ((QCL' - QCL)/2))$
$u\ t\ v$	=	$(PLR - PLR')\cdot((QCL' - QCL)/2)$
Lamb and Wool Producers[a]		
$PWLF\ cc\ z\ PWLF$	=	$(((PWF'\cdot QW' + PLF'\cdot QL')/\sum_{j=1}^{8} SS_j') - ((PWF\cdot QW + PLF\cdot QL)/\sum_{j=1}^{8} SS_j))\cdot(\sum_{j=1}^{8} SS_j + ((\sum_{j=1}^{8} SS_j' - \sum_{j=1}^{8} SS_j)/2))$
$PLF\ a\ b\ PLF'$	=	$((PLF - PLF')\cdot QL')$
$PWF'\ e\ f\ PWR'$	=	$((PWF' - PWR')\cdot QW')$
$PWR\ g\ f\ PWR'$	=	$((PWR - PWR')\cdot QW')$
$cc\ y\ z$	=	$(((PWF'\cdot QW' + PLF'\cdot QL')/\sum_{j=1}^{8} SS_j') - ((PWF\cdot QW + PLF'\cdot QL)/\sum_{j=1}^{8} SS_j))((\sum_{j=1}^{8} SS_j' - \sum_{j=1}^{8} SS_j)/2)$
Foreign Lamb and Wool Producers[a]		
$PLW\ h\ k\ PLW'$	=	$(PLW - PLW')\cdot(QLm' + ((QLm - QLm')/2))$
$PLW\ j\ k\ PLW'$	=	$(PLW - PLW')\cdot(QLm')$
$j\ h\ k$	=	$(PLW - PLW')\cdot((QLm - QLm')/2)$
$PWR\ o\ p\ PWR'$	=	$(PWR - PWR')\cdot(QWm' + ((QWm - QWm')/2))$
$PWR\ n\ p\ PWR'$	=	$(PWR - PWR')\cdot(QWm')$
$n\ o\ p$	=	$(PWR - PWR')\cdot((QWm - QWm')/2)$

[a] Under the wool incentive program equilibrium, variables are identified with a prime (').