GIANNINI · FOUNDATION

OF AGRICULTURAL ECONOMICS

UNIVERSITY OF CALIFORNIA

Supply Response in the Cattle Industry: The Argentine Case

Lovell S. Jarvis

Giannini Foundation Special Report

Division of Agriculture and Natural Resources

PRINTED AUGUST 1986

Supply Response in the Cattle Industry: The Argentine Case

the author is:

Lovell S. Jarvis,
Associate Professor
Department of Agricultural Economics
University of California, Davis

PREFACE

This research was accomplished as Jarvis' dissertation in 1969. Part of the theoretical and empirical results was published in the *Journal of Political Economy* in May/June 1974. These findings have strongly influenced subsequent research on the livestock sector. The Gianinni Foundation is now publishing a revised version of the work as a special report because the dissertation, which has been difficult to access, contains additional methodologies and results which are still of interest: the links between the micromodels treating cattle as capital goods and the specification of the econometric model, the construction and validation of the disaggregated herd series needed to estimate the model, and the detailed interpretation of the empirical findings. The report also discusses technical change in the livestock sector, crop the livestock interrelationships, agricultural labor market developments, and the role of cattle cycles in Argentine macroeconomic fluctuations, all of which are of special interest to students of the Peron era.

The Giannini Foundation occasionally publishes research as a Special Report. This is in addition to its regular publications series, the Monograph, the Research Report, and the Information Series. Single copies of this special report may be requested from Publications, Division of Agriculture and Natural Resources, 6701 San Pablo Ave., Oakland, CA 94608.

TABLE OF CONTENTS

I. Introduction 1

II. Cattle as Capital Goods and Producers as Portfolio Managers 6

III. An Econometric Model of the Argentine Cattle Sector 17

IV. The Estimation of Disaggregated Cattle Herd Stocks for Argentina: An Example of the Use of Economic Models to Construct Unavailable Data Series 23

V. The Specification and Estimation of the Slaughter and Average-Slaughter-Weight Equations 45

VI. Estimation of the Slaughter and Average-Slaughter-Weight Equations by Instrumental Variables 64

VII. The Estimation of Domestic Consumption and Export Equations 74

VIII. Summary and Conclusions 81

Appendix I. The Burden of Discriminatory Agricultural Policies 88

Appendix II. A Simulation of Productivity Change in the Feed/Beef Conversion Process 90

Appendix III. Construction of the Climatic (Weather) Indexes 98

Appendix IV. "Production" Versus Slaughter as an Indicator of Output 103

Appendix V. Estimated Calving Rates in Argentina, 1937/38-1966/67 104

References 105

I. Introduction

The Argentine Pampas is an extraordinarily rich crescent-shaped agricultural area encompassing roughly 50 million hectares,[1] with a radius of roughly 400 miles to the north, west, and south of Buenos Aires. The soils of the region are broadly homogeneous, composed of sand and clay, extremely fertile and deep; rock and gravel are quite rare except in the southeast. The surface is largely composed of vast swells and gentle slopes. Drainage is often a problem and remains so in some areas even though a network of drainage canals has been constructed. Annual rainfall varies from 40 inches in the east to 20 in the west, and the climate is temperate with frost occurring only on the southern edges. Temperature, winds, and rainfall, along with drainage conditions, are the major determinants of cropping practices.

The two main agricultural activities are field crop and livestock production. The major crops are wheat, corn, grain sorghum, flax (linseed), sunflower seeds, barley, rye, and oats; livestock production includes cattle, sheep, hogs, poultry, and dairy products. Growing grain or oilseed and raising cattle are dominant and usually rival activities in production. Cattle are raised chiefly on natural or seeded pasture, forage crops, and some byproducts of grain production. Cattle are rarely fattened on harvested grains. Because 80 percent of Argentina's cattle production and 90 percent of the traditional field crop production takes place in the Pampas, conditions there can be taken as representative of those faced by cattle producers in the nation as a whole.[2]

The Argentine agricultural sector in 1965 contributed about 17 percent of the gross national product, employs about 20 percent of the labor force, and provides about 90 percent of Argentina's exports. Cattle production alone contributes about one-third the value of both total agricultural output and total exports, although it employs a smaller share of the labor force, being relatively land extensive and, considering the cattle value, capital intensive.

Nearly all major products of the Pampas are exported in large amounts, and domestic agricultural prices are largely determined by world prices and the exchange rate--except when the government directly interferes. Argentina's share of world trade in most traditionally exported commodities decreased steadily from 1940 to 1970; it is stretching the point to assume that Argentine agricultural exporters faced a perfectly elastic external demand for their products during the period of study.

Argentina suffered an increasingly severe foreign exchange constraint caused largely by the stagnation of total agricultural production and declining exports during the period 1945-1965. Although there have been large shifts among various crops and between crops and cattle during this period, total agricultural production in the Pampas has increased only slowly. The land frontier in the Pampas has been closed since 1930.

Most of this study represents an attempt to explain the economic behavior of Argentine cattle producers from the mid-1930s through the mid-1960s--in particular, to show whether they reacted significantly and in the expected manner to changes in economic incentives. If they did, there is no reason that the cattle sector cannot grow more dynamically in the future--provided that redirected government policies change the incentive structure facing producers.

Agriculture in the Argentine Pampas

Landholdings and farm operations show the influence of methods originally used to open and develop the Pampas. Although there are sizable regions in which large family farms are engaged in mixed agricultural activities, larger cattle ranches dominate the Argentine rural area, and both cropping and cattle-raising are characterized by land-extensive technology.

Producers have planted an increasing acreage of forage and dual purpose crops, which can be grazed or harvested depending on the pasture requirements of the herd. Within the Pampas, the percentage composition of agricultural land use during the study period has varied roughly as shown in

Table 1

Percentage Distribution of Crop and Pasture Land in the Argentine Pampas, 1935/39-1960/63

	Crop Land	Pasture Land Total	Seeded	Natural
		percent		
1935-39	37	63	12	51
1940-44	36	64	14	50
1945-49	33	67	16	51
1950-54	25	75	21	54
1955-59	26	74	24	50
1960-63	25	75	23	52

Source: CONADE, undated

Table 1. It appears that much of the decline in crop land is offset by an increase in seeded pastures, including forage crops. The amount of land in natural pastures has been much more constant, indicating that the technology necessary to convert these to seeded pastures has been slow to develop or that the need to do so has been slow to make itself felt.

Labor and nonagricultural capital inputs are minimal in cattle raising. The climate is mild and few structures are necessary. Although Argentine agriculture has been well mechanized for many years, the use of other nonagricultural inputs such as fertilizers, insecticides, better seeds, and improved cropping practices has been much lower than expected given the natural productivity of the land and the sophistication of producers. This is principally the result of: a traditionally weak Argentine agricultural research and extension program (although through the National Institute of Agricultural Technology (INTA), founded in 1957, improvements have begun) the long-standing prohibition of or duties on imports of needed new inputs, and the relatively low product prices received by producers. The marketing institutions and transportation facilities are well developed, although neglect has caused them to deteriorate during most of the study period. Only about 20 percent of producers have electricity, including those who generate their own. Thus, research and extension services, rural electrification, transportation facilities, and the general standard of living in rural areas, all need improvement.

Primary education is free and compulsory for seven years; many secondary schools and universities also are tuition-free. Literacy in Argentina in 1960 was 90 percent for those over 14 years old, and probably it is at least as high for cattle producers as a class. Cattle producers' wealth is usually above the national average, due in part to the relatively large size of most of their operations. Cattle producers have long been both politically and socially well organized. Many live in or frequently travel to Buenos Aires and other large cities.

The quality of the Argentine cattle herd is superb: Purebred cattle of several types constitute a very high percentage of total herds and are the equal of cattle anywhere in the world. Nevertheless, compared to the United States, the calving rate is lower, animal disease and mortality rates are higher, natural pastures are used more frequently than seeded ones, there is almost no feed-lotting, storage facilities to meet feed emergencies are few, and general herd management is inferior. This reduces the efficiency and, therefore, the level of production and slaughter which might otherwise be achieved.[3] Both private and public bodies have acted to improve these conditions in recent years, but much remains to be done.

Government Policy and Argentine Agriculture

Rural production in the Pampas has been strongly affected by external events and government policy. Severe inflation, repeated devaluation, changing export taxes, and erratically administered price supports have wrenched prices discontinuously and unpredictably. Import prohibitions have excluded many urgently needed agricultural inputs. Industrially produced domestic intermediate and capital goods for use in agriculture have been insufficient and often of inferior quality. The government for a time exercised a monopsony position in purchasing agricultural products; in the 1960s, it simultaneously followed inconsistent policies designed (1) to hold down agricultural prices, because of their importance as wage goods and (2) to raise agricultural prices to spur production.

Perón came to power in 1943 representing two constituencies: (1) the growing number of urban industrial workers and (2) the nationalists interested in greater industrial development and economic "self-sufficiency," including a substantial part of the army. Many persons in the second category had seen Argentina suffer through World War I and the depression years of the 1930s cut off from many imports previously available, and through World War II when imports were again scarce and crops could not be exported because of a shortage of available shipping. Moreover, at the end of World War II, many expected war would soon break out again between the United States and Russia.

Given these experiences and expectations, rapid industrialization was called for and resources were needed to finance it. Despite the nation's economic difficulties during the 1930s and early 1940s, agriculture had continued to produce at a constant level of output. This convinced many that agricultural supply was inelastic and could be taxed without serious allocative effects. Further, they reasoned that if war broke out again and agricultural products, particularly grains, could not be exported, higher production would be of little use.

As a result, Perón imposed what were essentially high production taxes on traditional agricultural products; placed high tariffs on most imported goods, but particularly agricultural inputs; reduced expenditures on social overhead capital of nearly every variety in the rural sector; and began to accelerate industrialization.

As would be expected, the large landowners, who also tended to be the cattle producers, strongly opposed these policies. They composed a traditionally conservative, almost clubby class, not oriented toward social change, which made them naturally opposed to many of the new economic and social policies, even if their own incomes and wealth had not been directly threatened in the process.

Some of Perón's policies were directed specifically at his political enemies--in an attempt to reduce their income, wealth, and power.[4] But in many cases his other policies were harmed by such measures. Further, it can be shown that he discriminated more strongly against grain producers, who both were politically weaker and produced products with less potential export value, than he did against the cattle barons.

Perón's policies were also aimed at gaining popularity among the urban working class, for this was his major power base. Some of his policies had strong welfare justification, for Argentine society was badly in need of a social transformation which would redistribute income, health, education, and opportunity toward the lower classes. Also, reducing the prices of agricultural goods, particularly beef, increased the real income of urban workers substantially without increasing labor costs. Nevertheless, some of the policies used to improve the conditions of urban laborers were clearly contradictory to his goal of industrialization. Policies which raised the money wage of workers and radically increased their fringe benefits, although popular, did not make industrialization easier. And the higher tariffs or quotas, used to compensate industrialists for their higher labor costs, did not contribute to efficient industrialization.

As government expenditures increased, exports fell, imports fell, rapid inflation began, the government deficit grew, and the growth rate of the economy dropped. Perón recognized many of his errors by 1952 and attempted to change his economic policies to some degree, especially to relieve the discrimination against agriculture. But he could not or did not do so sufficiently to counteract the growing discontent, particularly among the military, who ousted him in 1955.

Since then, Argentina has had a series of governments, some elected, some selfappointed, but nearly all unable to make much headway toward providing for either economic or social progress. Evolution of both continues to be slow and painful to this day.

The Traditional Tenant Farming System and Its Demise

Traditionally, landowners of large ranches (estancias) contracted with tenants who grew grains for three to five years on one section and then were required to plant alfalfa or another forage crop on that section before moving on to another section of the ranch to plant grain. The owner would then pasture cattle on the alfalfa for several years while the cattle dung and legumes regenerated the soil for future grain crops. While owners received income from grain production and were guaranteed a good pasture for their cattle, they were spared the risk of investing large sums of capital in grain production because tenants were usually responsible for providing the seed and equipment.[5]

Landowners benefited greatly from the system because cheap labor increased land rents. Many impecunious immigrants also benefited, either eventually becoming small landowners or at least earning substantially better incomes than they could have at home. There was a strong element of social exploitation in this tenancy system, but only because there were so many who were willing to accept the prevailing tenancy terms.

When Perón came to power in 1943, he announced his intent to improve the condition of agricultural workers. First, he substantially increased the minimum money wage of the rural peon and helped agricultural workers, especially seasonal workers such as harvesters, to form strong labor unions. Although inflation reduced real wages faster than money wages could rise, the cost of labor relative to the prices of field crops rose. This severely reduced the net return from growing hand-harvested, labor intensive crops such as corn.

Second, Perón froze the rent contracts between tenants and farm owners and expropriated some property to distribute to tenants. The contract freeze prohibited owners from evicting their tenants and also fixed the rents paid. Severe inflation during this period reduced the fixed rents to very little in real value. More important, producers saw the freeze as the first step toward complete expropriation. As a result, farm owners tried to purchase rent contracts from their tenants--in essence bribing them to leave--and, if successful, managed the land themselves. They were, of course, reluctant to make contracts with new tenants.

Thus, the threat of the expropriation which was attached to tenant farming was extremely successful in reducing the labor used in agriculture. But it is less clear that this labor was well utilized by urban industry for, due to the increasing foreign exchange constraint, industrial growth had slowed so much that migrating labor went mainly into the service sector where it had relatively low productivity. And given the traditional pattern of production practiced in the Pampas, the increase in labor costs resulted in a further switch from grains to cattle.

The lot of the tenants could only be improved--that is, their standard of living raised to generally (and relatively) acceptable levels--by either redistributing land or removing many of them to other employment. It is not clear which method Perón originally intended, but he used mainly the latter.

Tenant removal was accomplished both by reducing the demand for their services in agriculture and by providing them with attractive employment elsewhere. The first Perón did by reducing grain prices, cutting off complementary capital inputs, and raising relative rural wage costs. The second he did by a massive program of industrialization and a legislated increase in urban wages. After a considerable lag, rural workers flocked to the large urban centers, especially Buenos Aires, in search of both higher income and other attractions of city life.

The Perón Era

Although Perón is justifiably accused of many things, he participated in a real transformation of Argentine life, one which had to be carried out eventually if Argentina wished to become a truly modern society. One mission was to transform the rural sector and another to urbanize and industrialize. Perón completed neither, but both processes were accelerated and carried through difficult phases without significant bloodshed.

Nevertheless, both processes were done very inefficiently, and the patterns established have not been corrected yet. In particular, Perón denied the agricultural sector needed inputs, thereby preventing the reasonably smooth transition from the tenant system to owner cultivation which might have occurred had new machines, seeds, fertilizers, and farming methods been introduced and had the labor exodus been slower. Instead, landowners found themselves short on labor, on capital and, often, on technical knowledge. Many owners had insufficient capital to purchase the equipment previously furnished by tenants and were even more hard-pressed to purchase additional equipment. Besides, new equipment was not on the permitted import list, so capital- labor substitution was long in coming.

However, the governments succeeding Perón were also very slow to increase the availability of agricultural inputs. Import tariffs on agricultural machinery, fertilizers, pesticides, and so forth, were maintained at high levels, ostensibly to save foreign exchange or to encourage domestic production of the same. A significant research and extension program did not begin until 1958, and little had been done by the late 1960s to rehabilitate the transportation system on which rural production depends, or to increase the telephone and electrical network. Thus, although Perón is directly responsible for initiating many damaging policies, these policies may have been the product of more general but misguided consensus. It has taken new policy makers a long time to reverse them.

Endnotes to I.

1. One hectare is about 2.5 acres.
2. There is no hard and fast line between cattle and crop producers. Some areas are quite specialized, but in most there is mixed production, and producers can switch between cattle and crops fairly easily. Sheep, hogs, and poultry are also produced, but in much smaller amounts and their production has not been a significant rival to cattle during the period studied.
3. A more detailed discussion of these and related matters is included in a separate section at the end of the introduction.
4. The evidence is that rural laborers bore much of the burden. Wealthy landowners complained about difficult times and doubtlessly suffered considerably, but their incomes appear to have fallen relatively less than those of year-round rural laborers. Tenants who acquired temporary free control of land benefited in the short run, but they later lost as well.
5. The system also resulted in a transient tenant class. Because tenants never stayed on one part of the ranch for longer than a few years and were responsible for removing any structures they had erected, their homes were simple and poor. Their primary goals were to accumulate enough capital to purchase their own land, to retire to the city, or to return to Europe. They therefore remained for many years a politically disenfranchised group (Scobie 1964b).

II. Cattle as Capital Goods and Producers as Portfolio Managers

In this section, several microeconomic models are developed to demonstrate why the short-run slaughter response to price of cattle slaughter should be negative, and why the degree of response should differ among different types of animals. Partial equilibrium capital-theoretic models are employed to show how producers in competitive markets ought to respond to the parameters they face, and the alteration of the partial equilibrium results within a general equilibrium context is explained. This is useful for the specification and interpretation of the econometric model to be estimated.

An Economic Model of Steer Production

To begin, micro-models are used to determine the optimum slaughter age and feed input for a steer, given growth functions for the animal and certain parameters faced by producers: the price of beef, the interest rate, and the cost of other inputs. To simplify the exposition, we begin with a model where the only input is the steer itself.

Let:

θ = age of the steer,

$w(\theta)$ = weight of the steer at age θ, $\frac{\partial w}{\partial \theta} > \theta$, $\frac{\partial^2 w}{\partial \theta^2} < 0$,

r = Interest rate,

$V(\theta)$ = the present discounted value of an animal allowed to live to age θ.

Thus if $V(\theta) = w(\theta)e^{-r\theta}$, where the price of beef is arbitrarily fixed at a constant value of unity, the steer will be slaughtered at age $\hat{\theta}$ which is chosen to maximize $V(\theta)$. The first-order condition for a maximum yields the requirement

$$\frac{\frac{\partial w}{\partial \theta}}{w} = r;$$

$\hat{\theta}$ occurs when the rate of growth of the animal is equal to the interest rate. The second-order condition,

$$\frac{\partial^2 V}{\partial \theta^2} < 0,$$

requires that the rate of gain be declining. In this model there is no opportunity cost to cattle production other than the interest foregone on invested capital. An increase in r will lower the optimal slaughter age, and vice-versa;

$$\frac{\partial \hat{\theta}}{\partial r} = -\frac{\frac{\partial^2 V}{\partial \theta \partial r}}{\frac{\partial^2 V}{\partial \theta^2}} < 0, \text{ because}$$

$$\frac{\partial^2 V}{\partial \theta \partial r} = e^{-re}(r\theta w - \frac{\theta \partial w}{\partial \theta} - w) < 0, \text{ at least as long as } r\theta < 1.$$

Although this model implies an important role for the interest rate, r actually plays a relatively unimportant role, as is discussed subsequently.

The model can be made more realistic by recognizing that a steer requires certain costly inputs throughout his life, which must be considered when choosing the optimal slaughter age. Although the slaughter decision still depends on the animal's rate of growth, the interest rate, and prices, it is conditional on the animal being fed the optimal ration. The criterion becomes maximization of the present discounted profit of the fattening process, which in perfect markets will be the value of the calf at birth:

(1) $\pi(\theta) = p(i, \theta)\, w(1, \theta)\, e^{-r\theta} - ci\int_0^\theta e^{-rt}dt.$

The new variables are

π = the present discounted profit of the fattening process;

i = a fixed bundle of daily inputs to the steer, independent of θ;

c = the cost of the fixed bundle, i;

p = the price per pound which may be obtained for the steer at age θ.

Both the weight and the price of the animal are assumed to be functions of i and θ, implying that the quality of the beef is reflected in the unit price received. The inputs required consist primarily of feed, but conceptually may include all inputs such as labor, shelter, fences, machinery, and veterinary care.[1] For the moment the process of determining market prices is ignored; these are taken as given to the individual producer.

The first-order conditions for a maximization of π require that the producer select both the optimal slaughter age and the optimal input stream:

(2a) $\frac{\partial \pi}{\partial \theta} = e^{-r\theta}(p\frac{\partial w}{\partial \theta} + w\frac{\partial p}{\partial \theta}) - re^{-r\theta}pw - cie^{-r\theta} = 0,$

(2b) $\frac{\partial \pi}{\partial i} = e^{-r\theta}(p\frac{\partial w}{\partial i} + w\frac{\partial p}{\partial i}) - c\int_0^\theta e^{-rt}\,dt = 0;$

which yield

(2a′) $p\,\frac{\partial w}{\partial \theta} + w\,\frac{\partial p}{\partial \theta} = r\,pw + c\hat{i}$, and

(2b′) $p\,\frac{\partial w}{\partial i} + w\,\frac{\partial p}{\partial i} = c\int_0^{\hat{\theta}} e^{-rt}\,dt = \frac{c}{r}(e^{r\hat{\theta}}-1)$.

At $\hat{\theta}$ the change in value due to changing weight and quality (unit price) is equal to the current interest foregone plus the cost of feeding. Alternatively, dividing through by pw, the rate of weight gain plus the rate of price change due to aging is equal to the interest rate plus the cost per day of feeding the animal as a percentage of its total value. Similarly, at $\hat{i}$ the present discounted value of the marginal net weight gain and price increase corresponding to the higher stream of inputs throughout the steer's life, less the percent discounted cost of feeding the animal these inputs, must be zero.

It is important to discover how the optimal $\hat{\theta}$ and $\hat{i}$ are affected by changes in the parameters faced by producers, i.e., the price of beef, the costs of inputs, and the interest rate. To determine this, the implicit function theorem may be used. The function for profitability is:

(3) $\pi = f(i, \theta, r, c, p)$,

where the variables i, θ satisfy the subsidiary conditions

(4) $\frac{\partial \pi}{\partial \theta} = \phi(i, \theta, r, c, p) = 0$, and

(5) $\frac{\partial \theta}{\partial i} = \Psi(i, \theta, r, c, p) = 0$.

After writing $\hat{i}$, $\hat{\theta}$ as functions of r, c, p:

(6) $\hat{i} = x(r, c, p)$ and

(7) $\hat{\theta} = \beta(r, c, p)$,

x and β may be substituted for i and θ in ϕ and Ψ. Using the chain rule for differentiation, we may then solve for the unknowns:

$$\frac{\partial \hat{\theta}}{\partial p}, \frac{\partial \hat{\theta}}{\partial c}, \frac{\partial \hat{\theta}}{\partial r}, \frac{\partial \hat{i}}{\partial p}, \frac{\partial \hat{i}}{\partial c}, \frac{\partial \hat{i}}{\partial r}.$$

In particular, these results indicate that a negative slaughter response for steers is expected in the short run. Temporarily, fewer steers are slaughtered because a higher price causes them to be withheld. This, of course, is a *ceteris paribus* result.

Consider now the determination of the market price of different aged male animals, from calf to steer. (The calf has value as a "growing" machine.) We know $\pi(\hat{\theta})$ represents the calf's value at birth, i.e., $\hat{\pi}$ is the amount which if invested at interest rate r would have the same money value at time $\hat{\theta}$ as the finished steer, less the total feed costs compounded from their time of input to $\hat{\theta}$, at rate r:

(8) $\hat{\pi} = \pi(\hat{i}, \hat{\theta}) = p(\hat{i}, \hat{\theta})\,w(\hat{i}, \hat{\theta})\,e^{-r\hat{\theta}} - c\hat{i}\int_0^{\hat{\theta}} e^{-rt}dt$,

and $\hat{\pi}\,e^{r\hat{\theta}} = p(\hat{i}, \hat{\theta})\,w(\hat{i}, \theta) - \frac{c\hat{i}}{r}(e^{r\hat{\theta}} - 1)$.

Figure 1 illustrates (8) graphically while demonstrating another point as well. In deriving the optimal slaughter age and input stream, it was assumed that producers faced known functions for the rate of gain and the rate of change in price per unit for each animal. The product of these functions would, if graphed as a function of age, yield the locus shown as $p(\hat{i}, \theta)\,w(\hat{i}, \theta)$. Given our assumptions, slaughter occurs only at one age, $\hat{\theta}$, and because we assume perfect competition, the market value of the animal at $\hat{\theta}$ must equal the cost of producing the animal. This supply cost, reflecting the cost of feed inputs as well as the interest foregone on the value of the calf, can be easily obtained by rearranging Equation 8; supply cost (or market value) is graphed as VM(θ) in Figure 1. Slaughter occurs where VM(θ) is tangent to pw.[2]

In fact, however, animals are slaughtered at many different ages. This occurs both because some consumers are willing to pay a premium per unit weight for meat from either younger or older animals and because feed costs differ for different producers. For the moment we ignore the latter factor and consider only the implications of the former. Under our original assumption a calf's capital value dominates its slaughter value until age $\hat{\theta}$, so no calf will be slaughtered until this age. Any producer wishing to sell a calf will find a buyer who will continue to feed the calf until age $\hat{\theta}$. However, any consumer wishing to purchase an animal at a different age could do so if willing to pay a premium price per pound. That is, under the assumption of equal costs for all producers, the least cost per pound for beef is achieved by slaughtering animals at a unique age, $\hat{\theta}$. Meat from animals slaughtered at other ages must bring a premium price because consumer prices must vary directly with w(i, θ) to ensure that the producer is fully compensated for the original value of the calf and the value of the embodied feed inputs, including interest. To restate, if people are willing to pay $p(\hat{\theta})$ for meat from an animal aged $\hat{\theta}$, $p(\theta)$ must be greater than $p(\hat{\theta})$, $\theta \neq \hat{\theta}$.

To show this, we return to the model where no feed inputs are required and consider the cost per pound of producing animals of different ages. Take the case where $\theta < \hat{\theta}$.

Because $\frac{\dot{w}}{w} > r$ at this age $(\dot{w} = \frac{\partial w}{\partial t})$,

Figure 1

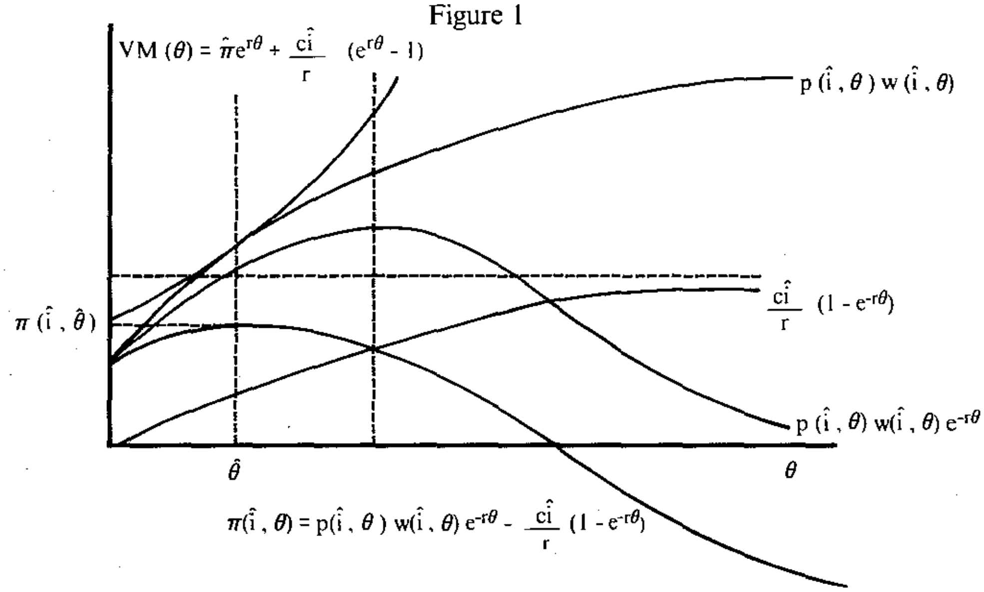


Figure 2

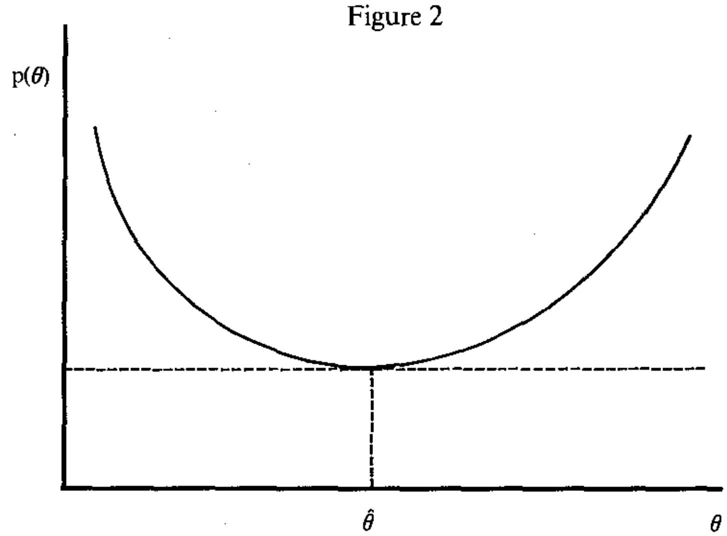
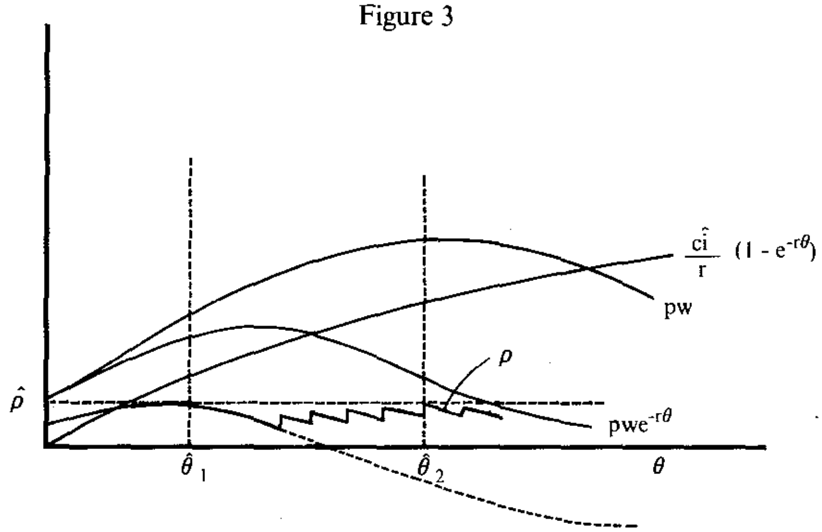


Figure 3



the animal must be worth more as a growing machine than as a consumption good. If the calf is purchased for consumption, it must be at the price determined by the capital value. This implies

(9) $p(\theta)\, w(\theta) = p(\hat{\theta})\, w(\hat{\theta})\, e^{-r(\hat{\theta} - \theta)}.$

Now let $w(\hat{\theta}) = e^{g(\hat{\theta} - \theta)}\, w(\theta)$, $g > r$.

Then

$$(10) \quad \frac{p(\theta)}{p(\hat{\theta})} = \frac{w(\hat{\theta})\, c^{-r(\hat{\theta} - \theta)}}{w(\theta)} = \frac{w(\theta)}{w(\theta)}\; e^{g(\hat{\theta} - \theta)}\, e^{-r(\hat{\theta} - \theta)} = e^{(g - r)(\hat{\theta} - \theta)},$$

and $p(\theta) > p(\theta)$, $\theta < \hat{\theta}$. A similar proof can be used to show that $p(\theta) > p(\hat{\theta})$ for $\theta > \hat{\theta}$. Therefore, although the value of the animal itself, $VM(\theta)$, increases monotonically, the price per pound of the beef from the animal, $p(\theta)$, will have a U-shaped age profile, as shown in Figure 2. The inclusion of feed costs in the model, as long as costs are the same for all producers, will increase the bowness of this profile.

The derivation of the least-cost-per-pound age, and the premium paid for animals of all other ages, is useful for conceptualizing how consumer preferences can affect the age distribution of slaughter, both cyclically and over time. However, although consumers' preferences influence the age distribution of slaughtered animals by determining the premium consumers are willing to pay for beef from different-aged animals, these preferences have only an indirect effect on either the relative or absolute differences between the equilibrium market values of different-aged animals. These relative prices will vary only a little with changes in the price of beef, feed, and the interest rate, the changes depending on the specific growth function of the animal. A similar result holds for the absolute difference between the supply-determined market values of two steers of different ages. The supply-determined relative market values of different-aged steers, such as at ages θ_1 and θ_2, are found via

(11)
$$RP_{\theta_1\theta_2} = \frac{VM(\theta_1)}{VM(\theta_2)} = \frac{\hat{\pi}\, e^{r\theta_2} + ci/re^{r\theta_2} - 1)}{\hat{\pi}\, e^{r\theta_1} + ci/r(e^{r\theta_1} - 1)}, \quad \theta_2 > \theta_1.$$

Explicit numerical solutions for each of these unknowns can be obtained using data from farm management studies. However, as only qualitative results were needed for this study, rough estimates of the price data and the growth functions pertaining to Argentine steers were used. These results will be valid as long as the rate of gain is declining in the vicinity of $\hat{\theta}$ and if the marginal return to increased inputs diminishes monotonically.

$\frac{\partial \hat{i}}{\partial p} > 0$, $\frac{\partial \hat{\theta}}{\partial p} > 0$ An increase in p increases the marginal value product of each input, increasing the optimal feed ration and the optimal slaughter age.

$\frac{\partial \hat{i}}{\partial c} < 0$, $\frac{\partial \hat{\theta}}{\partial c} < 0$ An increase in the cost of inputs reduces both the daily input and the optimal slaughter age. Animals are not only fed less per day, but for a shorter period of time because they grow more slowly at any given age.

$\frac{\partial \hat{i}}{\partial r} < 0$, $\frac{\partial \hat{\theta}}{\partial r} < 0$ An increase in r reduces the daily feed inputs, because greater feed investment implies higher interest costs. The increase in r also reduces the optimal slaughter age as it increases the interest foregone at every age.

An Economic Model of Cow-Calf Production

In the previous subsection economic models were employed to analyze the impact of various parameter changes on the market value, input level, and slaughter age of steers. A similar analysis is now carried out of cows. From an economic viewpoint, the principal characteristic distinguishing cows from steers is the ability of the former to produce calves.[3] Cows may produce beef either directly, by being fattened for slaughter, or indirectly, by bearing calves which may be fattened for slaughter. This latter option is reflected by including an additional term in the profit equation. This term is the present value of the expected calf stream, $\sum_{t=1}^{\theta} \frac{C(i, t)}{(1 + r)^t}$,

where C (i, t) is the expected value of the calf born in year t, assuming the cow has been fed input stream i throughout her life. This expected value depends on the probability that the cow will have a calf in year t, the respective probabilty that the calf will be male or female, and the expected values of male and female calves in that year.

Equation 12, the profit equation for females, includes three terms—the present value of the beef available at the time of slaughter, the calf stream, and the inputs required to maintain the animal—whose sum is equal to the value of a female animal at birth:

(12)

$$\hat{\rho} = \sum_{t=1}^{\theta} \frac{C(\hat{i}, t)}{(1+r)^t} - c\hat{i} \int_0^{\theta} e^{-rt}dt + p(\hat{i}, \hat{\theta})\, w(\hat{i}, \hat{\theta})\, e^{-r\hat{\theta}}.$$

Equation (12) can be used to determine the optimal slaughter age and input stream for cows, as was done previously for steers. As is shown in Figure 3, female calves have a distinctly bimodal optimal slaughter age because more female calves are born than are needed for replacement purposes in the breeding herd. As a result, some female animals are slaughtered as fattened heifers at age $\hat{\theta}_1$, before they bear calves, and some are slaughtered only after their value as breeding animals has declined, at age $\hat{\theta}_2$.[4] Female calves are essentially homogeneous at birth, and producers are therefore indifferent at the margin between retaining an animal for the breeding herd or fattening it for slaughter. If the value of a female as a breeding animal rises relative to its value as a slaughter animal, some females formerly destined for slaughter will be withheld, and vice-versa. This switching will continue until an equilibrium is achieved.[5]

An analysis similar to that carried out for steers would show that the immediate response of both heifer slaughter and cow slaughter to an increase in the price of beef is negative. A higher beef price, or lower feed costs, makes it profitable to feed heifers to heavier weights and to retain cows for calf production.

Slaughter Response by Animal Type

The models presented in the two previous sections can be used to show that the magnitude of the slaughter response will differ for different types of animals. At any single point in time there is a fixed supply of animals in the herd for which there exist two types of demand: consumer and producer. As long as a producer is willing to outbid consumers to retain the animal as a productive asset, the animal remains in the herd. When the consumer wins, the animal is slaughtered. Our interest is to determine how the relative strength of the bidders' demands for different types of animals varies with exogenous shocks to the system, e.g., monetary devaluation, climatic variation.

Some insight is provided by the partial equilibrium models already developed. We examine first the *ceteris paribus* change in relative value between a steer ready for slaughter and a newly castrated calf after an "exogenous" increase of 10 percent in the price of beef. Assume that the slaughter age of the steer is unchanged and that the value components of the profit equation originally have the approximate relationships prevailing for a steer calf in Argentina:

(13) $pwe^{-r\hat{\theta}} = a = 5$, and

(14) $ci\int_0^{\hat{\theta}} e^{-r\theta}dt = b = 4.$

Then, a steer calf has value $\hat{\pi} = a - b = 5 - 4 = 1$, and a 10 percent increase in the price of beef produces a theoretical rise of 50 percent in $\hat{\pi}$:

(15) $\dfrac{\hat{\pi}_1}{\hat{\pi}_0} = \dfrac{1.1\,(5) - 4}{5\text{-}4} = 1.5$

where the subscripts, 0 and 1, indicate profit before and after the price change, respectively. The further away the age of expected slaughter, the greater is the change in the capital value of the animal.

The effect is even greater for female calves, or male calves which have not been castrated. In either case, the option exists to retain the animal to an older age, but, more importantly, an increase in the value of a calf increases the calf stream value of the female calf, or the stud value of the male calf, and the recursive effect of further calf price increases would be carried on indefinitely if there were no dampening force. Thus, the proportional "instantaneous" increase in the value of a "breeding" calf should be substantially greater than either the original increase in the price of steer beef or the increase in the value of a castrated male calf.

The "instantaneous" increase in value which is reflected in these models is a partial equilibrium result. These models take no account of the fact that other adjustments will occur in response to a beef price increase, perhaps quite rapidly. For example, the change in the value of the steer calf discussed above reflects the change in the value of the animal as a capital good. As the value increses, producers will respond by retaining more such animals to be used for future production, and will reduce the number currently slaughtered. The resulting reduction of current slaughter will increase even more the current price of beef, but will also increase the future supply of beef, thereby lowering the expected future price of beef and perhaps increasing the cost of feed. As the capital value of an animal depends on expected, as opposed to current, prices the movement of expected prices will dampen, at least at some point, the tendency for the relative prices of animals to change.[6]

The process will be facilitated by the fact that beef from different animals is highly substitutable in consumption. Thus, as the relative prices of certain types of animals begin to increase, the consumption of these animals is reduced. Market prices are constrained by the high price elasticity of consumer demand across animal categories, and this constraint allows producers to bid away more easily those animals with more sensitive capital prices.[7]

This consumption constraint is important in two other respects as well. First, because it limits the relative price variation, the differential effect of a price increase indicated in the partial equilibrium models will tend to be reflected in the slaughter response of the different animal categories. The slaughter response also depends on the relative availability of the animals, but the consumption constraint plays an important role. Second, the limitation on the relative price variation allows the use of a single price, such as the price of two-year-old steers, as the price variable for all types of cattle in a disaggregated econometric model, without great loss of accuracy. This is helpful because it is difficult to identify the consumer demand for each type of animal.

The preceding discussion suggests an expected ranking of slaughter elasticities of the different categories. Although each category should exhibit a negative short-run response to a price increase, the elasticities will likely differ. This differenee will reflect both the sensitivity of the value terms in the profit equation, as shown in the partial equilibrium models, and also the relative availability of each animal category. The degree of instantaneous impact of a parameter change on the capital value of the animal depends on the expected time lapse before slaughter and on the presence of the breeding term with its recursive effect. The relative supply is also important, however, for the elasticity of slaughter response refers to the percentage change in the number slaughtered. The larger the number of animals of a given category relative to the number needed to satisfy the increased herd demands, the lower is the expected elasticity. This point, which may appear tautological at first, may be illustrated by considering again the role of the breeding term in the profit equation for male animals.

In principle, there is no difference in the equation for male and female calves at birth. A male calf also has a bimodal optimal slaughter age, for it too can be fattened to be slaughtered for beef or retained to enter the herd as a breeding animal. As each male calf theoretically has the potential to do either, each male profit equation should contain a breeding value term. Accordingly, the value of a male calf at birth may be as sensitive to a price change as that of a female calf; that of a male calf becomes less sensitive only after castration. Following castration male calves' values will be less sensitive because then their productive value depends only on their ability to convert feed into beef.[8]

The price elasticity of female slaughter, however, is normally greater than that of males because there are fewer females born relative to the replacement needs of the breeding herd. When the size of the breeding herd is to increase, the proportion of male animals switched from prospective slaughter to retention is generally much smaller than that for female animals, because there are many more male animals destined for slaughter and many fewer are required for the desired increase in the breeding herd. This differential results in different slaughter elasticities for the two types of animals.

It is therefore difficult to generalize the expected elasticity of slaughter response. One must consider the difference between the animal's actual and expected slaughter ages, its breeding potential, and the normal distribution of slaughter. A convenient rule of thumb suggests that female animals should have a higher slaughter elasticity than males, and younger animals higher than older. For example: Male calves, even before castration, should demonstrate a lower elasticity than females (because of their lower relative demand for the breeding herd, not their absolute lack of breeding potential); both male and female calves should have more elastic slaughter response than either steers or cows. Bulls should demonstrate a more elastic response than steers, despite the fact that they are generally older animals. But it is not strictly necessary that heifers exhibit a higher slaughter elasticity than yearling steers. Although some heifers may be switched from slaughter to the breeding herd, those which are not cannot profitably be withheld very long for further fattening because their rate of weight gain soon slows.

Beef Price and Feed Cost Response

The previous models suggest that the immediate slaughter response is negative for all categories. This does not necessarily imply that the estimated beef/feed relative price coefficients in the slaughter equations of an econometric model will be negative for all categories. First, an increase in the price of beef which is not expected to last could lead to increased rather than decreased slaughter in the very short run. It is necessary to differentiate between the response to an expected price and the estimated coefficient on a past or existing price variable—a well-known problem.[9]

Second, slaughter response is quite different from production response. The attempt by producers to increase production requires a reduction in slaughter in the short run and the stronger is this attempt, the sharper is the drop in slaughter. Production, however, will increase eventually to allow greater slaughter. As the period of observation grows larger, the (net) slaughter response becomes less negative, eventually becoming positive. The estimated sign of the beef/feed relative price coefficient in the slaughter equation therefore depends entirely on the observation, i.e., a quarterly model is more likely to exhibit a negative beef price slaughter elasticity than an annual model.[10] the rapidity with which the build-up in stocks is reflected in a higher slaughter flow is likely to vary across categories.

Third, the fact that animals can pass through several categories during one year means that "switching" caused by price changes can affect the estimated price coefficients. According to Argentine definition, an animal is a calf from birth to nine months, a yearling from nine to 18 months, and a steer from then until slaughter. A calf aged eight months at the beginning of the year theoretically could be slaughtered during the year in any of the three categories. Thus a price increase which causes all animals to be fed to heavier weights may cause some animals to be withheld just long enough to be slaughtered in a different category. This effect could make it incorrectly appear that the animals in older categories had a positive price-slaughter response. Further, the age distribution of the slaughtered animals within each category could be altered by the price increase. This implies a change in the weight and type of beef produced, and suggests the need for equations estimating the average slaughter-weight of the different categories for a good prediction of total beef production.

Fourth, some categories of animals, like older steers or sterile cows and heifers, have capital values which are relatively insensitive to changes in future expected prices. These animals will continue to be sold to slaughter even when other animals such as calves, breeding heifers, and cows are increasingly being withheld. Indeed, the slaughter response of these older animals could even be positive under the proper conditions. For example, if a current price increase is due to devaluation, and future inflation is expected to rapidly return the relative price of beef to its previous level, the slaughter response of steers could be positive.

Another plausible explanation, suggested by Yver (1971), focuses on the dynamic impact of changing beef prices on the cost of feed. He argues that if producers face a short-run feed constraint they will be unable to increase the herd in the short run as much as they would like to eventually. Their desire to retain animals of all ages will cause an increase in the opportunity cost of feed to such an extent that some animals, such as steers, will be slaughtered in greater numbers. The animals likely to be so affected are those nearing their time of slaughter, for the capital values of their animals with longer productive lives will be less sensitive to a short-run change in the cost of feed.

Regional Distribution of Production

Once the assumption of equal input costs for all producers is dropped, the micro models developed here can also help to explain the distribution of production activities among regions or among countries. For example, assume that the cost of transportation is neglibible for dressed beef, but considerable for live animals, and that consumers are willing to pay only very small premiums for beef from different aged animals. This makes the consumption value of the animal essentially a function of weight. Thus, in regions where feeding costs are relatively higher, the capital value of calves will tend to be lower, at least up to some age θ_1. Because $\hat{\pi} = pwe^{-r\theta} = ci \int_0^{\theta} c^{-rt}dt$, for any given p and r, a higher c will be associated with a lower $\hat{\pi}$. Further, as $VM(\theta) = \hat{\pi} e^{r\theta} + ci/r(e^{r\theta} - 1)$, a higher c results in a lower $VM(\theta)$ during the early part of the animal's life, $\theta > \theta_i$. This may be graphed as in Figure 4.

Considering relative conditions in Europe and Argentina, we can see why veal in Europe is absolutely cheaper per pound than in Argentina, even though mature beef is much cheaper in Argentina. If transportation costs were zero, calves born in Europe would be worth $\hat{\pi}_1$ at birth and be shipped to Argentina to be fattened to age $\hat{\theta}_1$. Since transportation costs are not zero, their value is $\hat{\pi}_2$, and they are fattened until slaughter in Europe. But they will not be fattened past θ_1, because after this age imported beef of the same quality is cheaper. The variation with respect to age in the market value of an animal in Europe therefore should have the shape of the envelope in Figure 5. As can be seen, the existence of many producers located in regions with different feed costs implies that the observed relative costs per pound of beef aged θ_i will vary less than if there were only one producer. Further, the absolute cost of beef from younger animals is cheapest in the higher feed cost regions, implying that part of the observed European "preference" for veal is due to its relatively lower price there. This relationship is shown in Figure 6, where it is

Figure 4

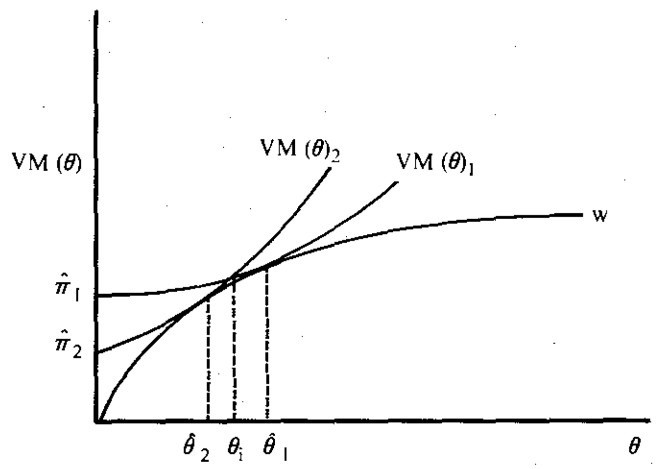


Figure 5

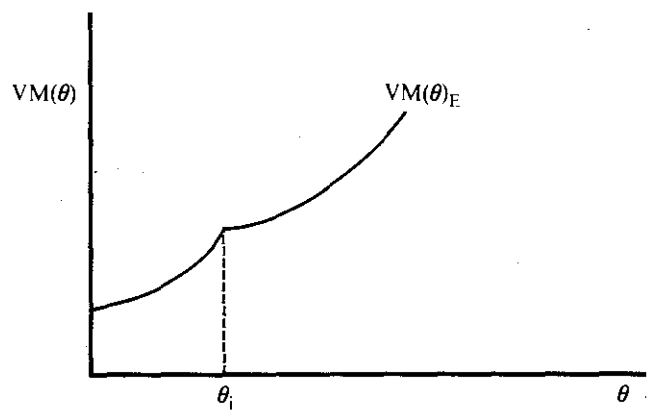
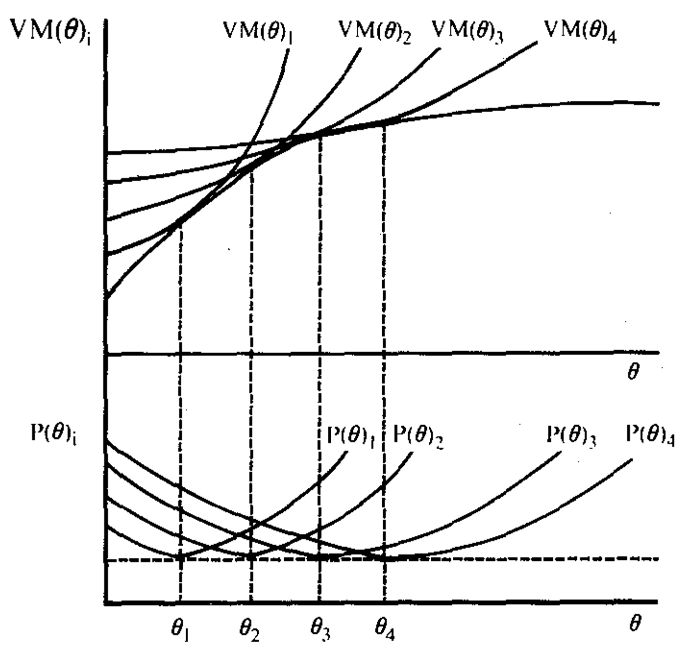


Figure 6



assumed that there is strict consumer indifference among beef from animals aged θ_1, θ_2, θ_3, and θ_4. Each country is shown to be relatively more efficient in the production of beef from a certain range of animal ages.

The regional location of production activities within a country may be determined similarly. Producers with differing feed costs will choose different parts of the production process. For example, breeding operations will usually take place in areas where feed is cheap, that is, where the cost of maintaining the cow year-round is less than the value of the calf at birth. Because all calves will have the same value at birth in a unified market, it will not be profitable to maintain breeding herds in high-cost feed areas unless producers there are more efficient, i.e., unless their herds have higher calving rates and lower mortality rates than herds elsewhere.[11]

Breeding may also take place as a complementary activity in areas where cows are maintained primarily for milk production. In this case the profit equation would include a component reflecting the present discounted value of the future milk stream: $P_m \int_{\theta}^{\theta} m(i, t)\, e^{-rt} dt$, where m(i, t) is the quantity of milk produced by a cow aged t, fed inputs i, and P_m is the price at which this milk can be sold. The milk component must compensate for the lower net value of the calf stream, implied by the (usually) much higher feed costs.[12]

The fattening process may also become geographically specialized, depending on the relative cost to feed across regions and the length of time it is available in each. On weaning, calves are usually sent to fattening regions where there is feed suitable for fattening. After some period the animals may be sent to market or sent to better grazing lands for finishing. Whether an individual animal is sold to slaughter or to further fattening depends on the current market price for slaughtered beef, whether feed is available at a cost low enough to continue profitable feeding, and transaction and transport costs. If current prices for feeder animals and expected future prices for finished animals are in the correct ratio, producers who have low-cost feed will purchase animals to feed and sell later either to other producers for further fattening or to slaughter. In many areas cheap feed will be available during a particular part of the year, e.g., winter wheat that can be grazed for several months without damaging the crop or the wheat stubble that can be grazed following harvest. Hence, even though wheat and cattle are competitive in many situations, they are also at time complimentary.

Changes in the Argentine Cattle Slaughter Age

Steers are now slaughtered at younger ages in Argentina than some years ago. New breeds of cattle and better pasture management have permitted higher growth-conversion rates at younger ages, and an earlier "leveling-off." But there are several other reasons as well. First, the effective interest rate (rate of discount) faced by farmers has increased, for farmers have become more sensitive to alternative investment opportunities. This should reduce $\hat{\theta}$, the least-cost-per-pound age, although the effect would likely be small. Second, the relative cost of feed inputs has also risen, i.e., the cost of pasture and forage has risen relative to the price of beef, especially as the grain yields for land have risen. Because younger animals convert feed into beef more efficiently than older animals, an increase in the relative price of feed will tend to reduce the slaughter age. Thus, both cost factors considered by this model have tended to reduce the slaughter age of animals in Argentina.

The slaughter age also depends on the premium consumers will pay for beef of various ages. Here too the trend in recent years seems to have favored the slaughter of younger animals. Many consumers now actually prefer the leaner beef from a young animal and are quite unwilling to pay the premium once received for older, fatter beef.[13]

Endnotes to II.

1. The assumption that the input bundle is fixed is unrealistic. The input bundle varies over the animal's life and the animal's response to current inputs depends on the amount and timing of past inputs. This becomes complicated mathematically, however, and has not been included in this analysis even though such effects are sometimes important.

   Other factors can be more simply incorporated. For example, marketing costs paid by the producer at the time of sale will tend to lengthen the slaughter age. If these costs are fixed, and denoted by z, we have

   $$\pi\ (\theta) = pwe^{-r\theta} - ci\int_0^{\theta} e^{-rt}\, dt - ze^{-r\theta} \text{ and}$$

   $$\frac{\partial\theta}{\partial z} = -\frac{\dfrac{\partial^2\pi}{\partial\theta\partial z}}{\dfrac{\partial^2\pi}{\partial\theta^2}} > 0, \text{ for } \frac{\partial^2\pi}{\partial\theta\partial z} = e^{-r\theta}(r) > 0.$$

The producer reduces the present discounted value of the marketing costs by prolonging the time of sale. During any period fewer cattle are slaughtered, holding each to an older age.

Price expectations can be introduced by letting the price vector vary with time, $p(i, \theta, t)$, and the effect of climatic variation or disease on the animal's ability to convert feed into beef can be recognized by allowing shifts in the growth function, $w(i, \theta, \gamma)$.

2. As is clear in the mathematical formulation, the optimum slaughter age is a function of the relative beef/feed price, p/c, not the absolute price of beef.

3. Biologically, male animals are as essential as cows to the breeding process. Therefore, the profit equation for male animals ought to include a breeding term as well. This term was deleted in the previous section to simplify the analysis, but it does play an important role in some situations, and will be discussed in the next subscetion.

4. Although cows may conceive until age 13, they are rarely retained in the breeding herd beyond age nine because their teeth wear down, making it increasingly difficult to feed. This lowers the probability of conception, which is sensitive to the cow's level of nutrition, and also makes it increasingly difficult for the cow to suckle a calf. Both factors decrease the expected value of the calf stream, prompting slaughter.

5. The models discussed here focus on the partial equilibrium behavior of producers facing exogenous changes in prices, although clearly such prices are endogenous to the economic system as a whole. Without an endogenous solution, many relationships such as the biomodal slaughter distribution would not hold.

6. The capital values of certain animals may be decreasing even at a moment when their current slaughter value is increasing. This inverse movement, which prevents any price movement from being cumulatively destabilizing, requires that price expectations take into account future supply and demand, rather than naively extrapolating current prices. The models employed above assume a naive extrapolation, but only for expositional purposes.

7. Only when no more cows and heifers can be withdrawn from slaughter will the "tie" via consumer demand between their prices and those of other animals be broken. Under normal conditions, given the number of cows and heifers sent to market each year and the cost of making large sudden changes in the size of the breeding herd, this does not occur.

8. The male profit equation may be written

$$\pi = pwe^{-r} - ci\int_0^{\theta} e^{-rt}dt + \sum_{t_b=1}^{\theta} \frac{\frac{\partial T(i_b, t_b, V_j)}{\partial B} \cdot \sum_{k=1}^{j} T_k(i_c, t_c)}{(1+r)^{t_b}}$$

This is the present discounted value of a calf at birth where $\partial T/\partial B$ is the proportional increase in the expected value of a calf provided by adding one bull fed i_b inputs, aged t_b, and given V_j cows in the herd. T_k is the expected value of each calf produced by a cow in the herd, fed inputs i_c and aged t_c, before the addition of the new bull. The sum of the bull's impact each year is then discounted back to its time of birth.

The decision to fatten or to retain for breeding is generally made quite early in the case of males, because very few males are needed for breeding and also because the costs of castration are lower the younger the calf. Castration sacrifices the value of breeding component, and generally inhibits growth, but it does make the animal more docile, thus reducing management costs and the likelihood of future injury.

9. The sensitivity of an animal's capital value may depend on the length as well as the magnitude of the change in price expectations. This factor is difficult to include in an econometric model unless the specific cause affecting the duration of price expectations is quantifiable in a simple fashion. This is not always the case. However, the issue can be important. For example, the capital values of both cows and breeding heifers depend on the future price of calves, but the value of an older cow near slaughter age should be more sensitive to a temporary price change, as when climatic variation causes a shift in slaughter plans, than would be the value of a young breeding heifer. Similarly, if producers expect devaluation to result in higher inflation and a rapid return to the pre-devaluation relative prices, they might be hesitant to build up their herds by investing in young breeding animals, preferring instead to retain older animals for an additional period.

10. Work by Nores (1972) confirms this.

11. In Argentina the major breeding area is the Salada River basin where drainage and land quality are relatively poor. Sufficient pasture for the cows and calves is usually available during the crucial periods of the year, but grain and/or forage crops for year-round fattening normally cannot be grown here. Breeding herds are maintained elsewhere, however, and there is evidence that these producers achieve higher calving rates. See Jarvis (1969, Chapter 8).

12. For dairy animals, capital values of female calves will be substantially greater than those for male calves.

13. In a personal conversation, Lucio Reco, then director of the Department of Agricultural Economics, Ministry of Agriculture, Argentina, suggested that this was due not only to a change in taste for beef, but also to the growth of the vegetable oil industry. Vegetable oil has become an attractive and preferred substitute for animal oils. Thus, the demand for fat from fatty beef as a complementary product has decreased.

III. An Econometric Model of the Argentine Cattle Sector

From the theoretical results of the previous section, we specify an econometric model. This model may be used to explain the historical reaction of the cattle sector to exogenous shocks such as those caused by climatic variation and by changes in the domestic demand for beef or for other related agricultural products. The annual variation in herd size and slaughter response are emphasized as indicators of producer behavior, but the model also explains domestic consumption, exports, and the relative beef/grain price. Similarly, although the emphasis here is on short-run behavior via the structural equations, the long-run impact response can be determined as well.

In many studies of the price response of various agricultural commodities, single-equation estimates are deemed appropriate because of the type of production process. Because there is usually a considerable time lag between the commitment of resources and marketing the product, and because the growing season rigidly constrains the timing of production, it is assumed that producers' current production decisions have no recursive impact.[1] But this assumption is not justifiable for cattle production, because producers' current decisions to increase or decrease their herds have immediate impact on market prices and hence on future price expectations and associated decisions.[2] That is, resources are, in one sense at least, less rigidly committed than for planted crops, so a strong recursive effect should be expected. While there is a market for cattle of every age, the profitability of the enterprise, given the opportunity cost of land and other resources, usually depends on holding the animal to a particular predetermined age and condition. But if conditions change, producers may choose to sell animals any time before or after their original target marketing dates--or they may choose to retain them to increase the herd. These options are generally not available for most cropping activities.[3]

A Short-run Model of the Cattle Sector

To begin, assume that the supply of animals is fixed at any point in time, i.e., there is a given stock for disposal which cannot be increased momentarily. There are three sources of demand for the herd: domestic beef consumption (CN_t), beef export (EX_t), and animal production (H_t). Thus, the existing stock is allocated by the competitive bidding of the rival demanders; the herd total must equal the sum of the animals demanded for each purpose, i.e, the market clears. This particular formulation explicitly shows the short-run interdependence of the three types of demand. The three corresponding equations and their sum:

$$CN_t = g(P_B, \ldots)$$

$$EX_t = h(P_B, \ldots)$$

$$H_t^* = f(P_B, \ldots)$$

where P_B is the price of beef, may be graphed as in Figure 7. The intersection of their aggregate with the existing stock, H_t, determines the market price and the number of animals which, at this price, will be demanded for each use. Note that in this short-run scenario the herd demand slope is negative.

If any of the demand functions shifts up, while the other two remain fixed, the market price will increase, and vice versa. Because of the identity, an increase in one component entails a decrease in one or both of the other two at the new price. For example, increased demand for animals by producers must, in the short run, increase the market price and reduce the number of animals going to foreign and/or domestic consumption.

This short-run picture is useful in emphasizing the competitive nature of the three different groups which demand cattle: The number of cattle destined to a particular use cannot increase without a decrease in the number going to at least one of the other two uses. The simultaneity of the relationships is captured through the competitive bidding process between consumers and producers without the need for a structural slaughter equation. The number of animals slaughtered is simply the number of animals

Figure 7

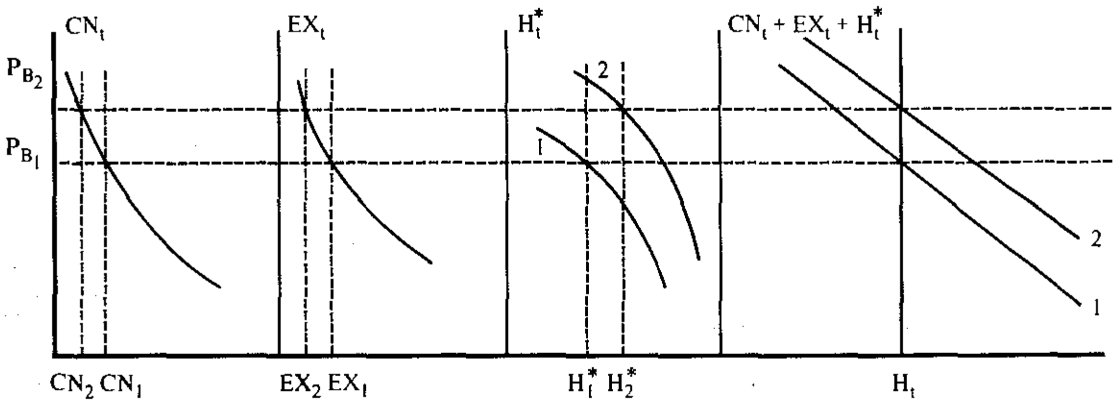
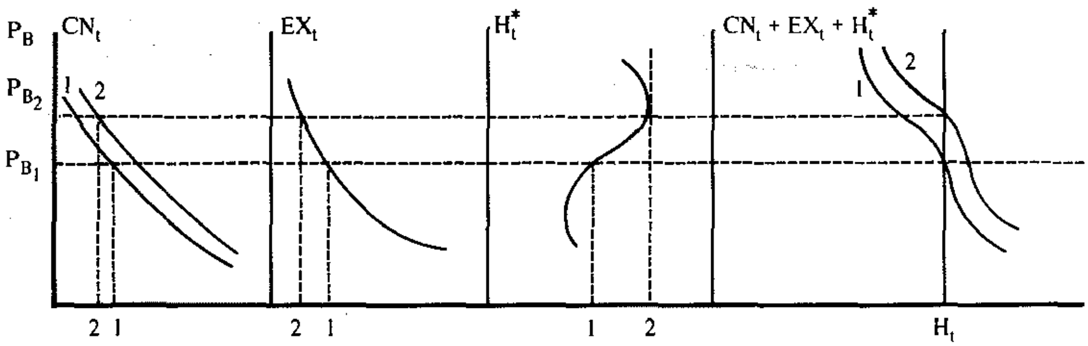


Figure 8



bid away from producers, because of the identity constraining the three demand equations to equal existing supply. Given the size of the existing herd, the three demand equations and the price of beef are sufficient for system identification because of another identity linking the size of the herd from one year to the next through births, deaths, and slaughter.

The description is oversimplified, however, because producers do not send all animals to market every day and bid to repurchase those they wish to retain. Rather, producers select some animals to slaughter and keep the rest, acting on information about current and future prices and the like. That is, producers play a more active role in determining slaughter than consumers do, precisely because price movements affect their expectations and their slaughter decisions recursively. Consumers' demand for beef is a function of the price of beef; shifts in their demand curve are not caused by variations in the price of beef. In contrast, producers' demand in the intermediate run is highly sensitive to the price of beef. Changing prices affect expectations about future prices and thereby the desired size of the herd. Herein lies the crux of price response in the cattle sector.

Consider the dynamics involved in the cattle cycle. A sequential process might begin with an exogenous increase in consumer demand which raises market prices, perhaps inducing some producers to sell additional animals. If it appears that this consumer demand shift will endure, the higher current prices will be translated into rising producer expectations, and, hence, higher capital values for many of the existing animals. These animals will be withheld from slaughter and market prices will rise further. This cumulative process will continue until the current market prices and the perceived capital values are equal.

The process would also be cumulative in a downward direction. Suppose an increase in the cost of grains caused producers to initiate the sale of animals. The resulting greater supply of beef would cause the price of beef to fall, affecting producer expectations and reducing the capital (retention) value of the animals, causing a cumulative price decline. The magnitude of these induced reactions depends not only on the shift in consumer demand or supply, but more importantly, on how this shift is translated by producers into higher or lower capital values for animals.

Producers' demand for animals for the herd is a function of the current price of beef, the expected beef/grain relative price, other input costs, climate, and other factors. Basically, it is an increasing function of the capital value of animals, represented by the variables which affect this capital value, and a decreasing function of the current market price. But it is essentially impossible to separate empirically the expectational effects caused by the current price, from the demand effects of the currect price. Because of the large positive influence of the price of beef (P_B) on the perceived capital value of animals ($VM(\theta)_t$), the anticipated sign for the coefficient associated with P_B is positive, rather than negative if only the short-run impacts are considered.

A positive coefficient on P_B in the herd demand equation implies an unstable situation, because with a completely inelastic short-run supply curve, any price change is likely to lead to cumulative price movements in the same direction. But this movement will continue only until producers' expectations become inelastic at some price level where their demand is satisfied. Producers individual demand curves can even be backward bending, though this will never be observed in aggregate, as is shown in Figure 8.

My originally proposed structural model of the cattle sector was to have contained a stochastic herd demand equation for each of the six animal categories, including the total number of calves born each year.[4] Foreign and domestic consumption equations for each category were to have been estimated in terms of beef units with these units related identically to the number of animals slaughtered to yield this beef, given the average slaughter weight of each category. Because the type of animals produced for export differs from that slaughtered for domestic consumption for some categories, several of the categories would each require two stochastic equations to determine the average slaughter weights for domestic and foreign consumption respectively. A set of identities would link the animals not slaughtered in each category with the number of animals desired in the next older category the following year, e.g., the number of yearlings demanded for the herd in year $t+1$ must equal the number of male calves not slaughtered in year t. Finally, a stochastic equation would explain the difference between the wholesale price of beef, which affects producer behavior, and the retail price of beef, which affects consumer decisions.

Because the proposed model was extremely complex, and certain necessary data were unavailable, a simpler model was chosen for estimation. This model, presented in Table 2 specifies a separate slaughter equation for each category, reflecting the desired disaggregation. These slaughter equations may almost be interpreted as mirror images of the previous herd demand equations, for the parameters affecting slaughter are assumed to have an inverse impact on producers' short-run herd demand.[5] One advantage of the specification is that more accurate data were available for slaughter than for herd size in Argentina. Thus, the model specifying slaughter equations permitted the use of the best available data for use as dependent variables while the herd data were used as independent variables. Also, the estimated model is more similar to other models of the cattle sector, facilitating comparisons.

The model contains 21 equations, including six identities. For each of the six animal categories, there is an equation to estimate the number slaughtered. The number of calves born is also estimated, but the number of animals in each of the other five categories is given by the constraints relating the herd stocks in two adjacent years with births, slaughter, and natural deaths. Two equations estimate domestic and foreign consumption (export) demand in terms of tons of beef, and a final identity equates the beef produced from slaughter with total consumption. The model satisfies the posterior rank-and-order conditions for identification; all the equations are overidentified.[6]

Table 2

Summary of the Econometric Model of Argentine Cattle Sector

$$T_t = q(x_i, ...) + \varepsilon_{1_t}$$
$$TS_t = a_1T_t - f_1(x_i, ...) + \varepsilon_{2_t}$$
$$WT_t \equiv j_i(x_i, ...) + \varepsilon_{3_t}$$
$$Y_t = TN_{t-1} - TND_{t-1} - TNS_{t-1} - TB_{t-1}$$
$$YS_t = a_2Y_t - f_2(x_i, ...) + \varepsilon_{4_t}$$
$$WY_t = j_2(x_i, ...) + \varepsilon_{5_t}$$
$$VQ_t \equiv TV_{t-1} - TVD_{t-1} - TVS_{t-1}$$
$$VQS_t = a_3VQ_t - f_3(x_i, ...) + \varepsilon_{6_t}$$
$$WVQ_t = j_3(x_i, ...) + \varepsilon_{7_t}$$
$$N_t \equiv Y_{t-1} - YD_{t-1} - YS_{t-1}$$
$$NS_t = a_4N_t - f_4(x_i, ...) + \varepsilon_{8_t}$$
$$WN_t = j_4(x_i, ...) + \varepsilon_{9_t}$$
$$V_t \equiv VQ_{t-1} - VQD_{t-1} - VQS_{t-1} + V_{t-1} - VS_{t-1} - VD_{t-1}$$
$$VS_t = a_5V_t - f_5(x_i, ...) + \varepsilon_{10_t}$$
$$WV_t = j_5(x_i, ...) + \varepsilon_{11_t}$$
$$B_t \equiv B_{t-1} - BD_{t-1} - BS_{t-1} + TB_{t-2}$$
$$BS_t = a_6B_t - f_6(x_i, ...) + \varepsilon_{12_t}$$
$$WB_t = j_6(x_i, ...) + \varepsilon_{13_t}$$
$$CN_t = g(x_i, ...) + \varepsilon_{14_t}$$
$$EX_t = h(x_i, ...) + \varepsilon_{15_t}$$
$$CN_t + EX_t \equiv TS_t \bullet WT_t + YS_t \bullet WY_t + VQS_t \bullet WVQ_t + NS_t \bullet WN_t + VS_t \bullet WV_t + BS_t \bullet WB_t$$

Table 2 (continued)[a]
Definition of Variables

T_t	=	the number of calves born in year t
TN_t	=	the number of male calves born in year t
TV_t	=	the number of female calves born in year t
TS_t	=	the number of calves slaughtered in year t
TNS_t	=	the number of male calves slaughtered in year t
TVS_t	=	the number of female calves slaughtered in year t
TND_t	=	the number of male calves dying natural deaths in year t
TVD_t	=	the number of female calves dying natural deaths in year t
TB_t	=	the number of male calves selected for retention for the bull herd in year t
WT_t	=	the average slaughter weight of calves in year t
Y_t	=	the number of yearlings in the herd in year t
YS_t	=	the number of yearlings slaughtered in year t
YD_t	=	the number of yearlings dying a natural death in year t
WY_t	=	the average slaughter weight of yearlings in year t
VQ_t	=	the number of heifers in the herd in year t
VQS_t	=	the number of heifers slaughtered in year t
VQD_t	=	the number of heifers dying a natural death in year t
WVQ_t	=	the average slaughter weight of heifers in year t
N_t	=	the number of steers in the herd in year t
NS_t	=	the number of steers slaughtered in year t
ND_t	=	the number of steers dying a natural death in year t
WN_t	=	the average slaughter weight of steers in year t
V_t	=	the number of cows in the herd in year t
VS_t	=	the number of cows slaughtered in year t
VD_t	=	the number of cows dying a natural death in year t
WV_t	=	the average slaughter weight of cows in year t
B_t	=	the number of bulls in the herd in year t
BS_t	=	the number of hulls slaughtered in year t
BD_t	=	the number of bulls dying a natural death in year t
WB_t	=	the average slaughter weight of bulls in year t
CN_t	=	the tons of beef consumed in Argentina in year t
EX_t	=	the tons of beef exported from Argentina in year t
x_i	=	the independent variables included in each stochastic equation; each of the equations, however, do not contain the same independent variables. The precise specification of each of the stochastic equations is discussed subsequently.

a. The large numbers of variables made the selection of mnemonically satisfactory variable names difficult. As a result, the names chosen reflect a mixture of Spanish and English, e.g., T is Ternemo (calf), but Y is yearling; V is vaca (cow), but B is bull.

Endnotes to III.

1. Behrman (1967), among others, has studied the behavior of marketed surplus, and Nerlove (1958) noted that grain producers might decide to abandon or graze their crops if yields were low or harvesting costs high. Despite such complications, planted crop area is usually used as the dependent variable in price response studies, even though modeling output clearly calls for a more complete simultaneous context.

2. Diaz (1965), Conome (1966), and Reca (1967) estimated single-equation models of aggregate beef slaughter which showed a negative short-run slaughter response to price. These authors concluded that the short-run supply (slaughter) curve for beef must also be negatively sloped. This holds if supply is subject to more radical shifts than demand, but it is possible that these studies measured the demand curve, not the supply curve--or some mixture of the two. Both curves should have highly negative slopes.

   Diaz tried to evade the simultaneity problem by assuming that the maximum (retail beef) prices established by government decree during several of the years included in his study substituted an artifical, very elastic consumption demand schedule for market demand. But government policy often changed when the supply forthcoming at the existing fixed price did not equate supply and demand. Besides, there was no government price intervention during much of the period studied. Moreover, neither producer demand for animals in the herd nor export demand is elastic. Prices paid for live cattle, the number of animals slaughtered, and the size of herds have varied widely; price movements do not appear to be independent of slaughter, even within periods as short as one year.

3. Otrera's 1966 model of the cattle sector was not only misspecified but was plagued by a problem common to all studies of the Argentine cattle sector: inadequacy of the data. In the next section I attempt to overcome this continuing problem.

4. Three categories of animals are not homogeneous in that they each contain animals of substantially different ages: steers, and especially cows and bulls. To model this would require three additional herd demand equations to explain producers' demand for older as opposed to younger animals in each category; e.g., cows not slaughtered one year re-enter the herd as old cows the next. The addition presents no theoretical problem, although additional constraints would be needed to ensure that slaughtered animals are attributed to the appropriate category. But accurate data on separate consumer demand, domestic or foreign, for beef from the various animal categories were not available, precluding the estimation of separate demand equations for each of the three categories. And because the primary interest was to determine how producers differentiated among animals of different sex and age, it was thought insufficient to estimate only an aggregate herd demand equation.

   To meet the constraint equating the three demand functions to the number of animals available in the herd, the dependent variable in each would be the number of animals passing through the category during the year, as opposed to the number of animals appearing in any point census.

5. If H_t^* = the herd desired by producers in year t, H_t = the existing herd in year t, and S_t^* = the slaughter "desired" by producers in year t, rather than estimating:

   1) $H_t^* = f(x_1, x_2) + \epsilon_t$, we can estimate,

   2) $S_t^* = H_t - H_t^* = H_t - f(x_1, x_2) + \epsilon_t$

   The model eventually estimated, however, is specified as:

   $$S_t = a_1 H_t + g(x_1, x_2) + \epsilon_t$$

   Then the function for H_t^* becomes:

   $$H_t^* = (1 - a_1) H_t + g(x_1, x_2) + \epsilon_t$$

   which is also a plausible herd demand function.

6. For simplicity, it was assumed that the margin between producer and retail price was constant, so only one price was determined by the system. Further, because the model was estimated using ordinary least squares and instrumental variables, the specified constraints were not imposed.

IV. The Estimation of Disaggregated Cattle Herd Stocks for Argentina, 1937-1967: An Example of the Use of Economic Models to Construct Unavailable Data Series [1]

Too often a lack of reliable data prevents our testing economic hypotheses of interest. Here we discuss how this frequently encountered problem was overcome for the case of cattle herd data in Argentina. But the methodology is more generally applicable. Theoretical models were developed to determine how available data ought to be related to the desired data. The models were used to construct and test the desired data. Then additional models and independent information were employed to adjust for errors implied by the testing.

With the constructed data, the derived econometric model was estimated and used to explain the historical behavior of the Argentine cattle sector. In addition, the data themselves provided new evidence on productivity change and investment in this sector.

Recall that, in the theoretical section, capital models treating cattle as different types of capital goods and producers as portfolio managers were developed. These models implied that slaughter could be explained as a stock-adjustment process, where herd size plays a crucial role, and indicated the desirability of disaggregating by the age and sex of the animals to provide clearer insights into producer behavior. Such a disaggregated model should be a much more useful predictor than an aggregate model, but disaggregated herd data were not available for most of the period studied; indeed even the aggregate herd data were not good.[2] It was necessary, therefore, to construct the desired series, which required a rather involved procedure. The methodology is simple and I believe appropriate to the quality of the underlying data, but the number of operations is lengthy. Only the most important are discussed.

A Brief Overview of the Process

Because of the accounting identity connecting herd size (H) from one year to the next with births (B), natural deaths (D), and slaughter (S),

$$H_t = H_{t-1} - D_{t-1} - S_{t-1} + B_{t-1}\,,$$

it is possible to construct time series data for herd stocks given one benchmark herd census and time series for births, deaths, and slaughter. Further, given disaggregated data for slaughter, mortality rates, and the herd benchmark, disaggregated herd data can be constructed as well. Argentina possesses good disaggregated slaughter data, several censuses which are thought to be accurate, informal estimates of animal mortality rates, but little information on annual calf births.[3] The most important issue was therefore to construct a series for the number of calves born annually, using the slaughter statistics.

The rationale is the following: If we know an animal's age at slaughter, we also know its date of birth. For example, all male calves born in year t are either slaughtered as calves before time $t+i$, slaughtered as yearlings between $t+i$ and $t+j$, or slaughtered as steers between $t+j$ and $t+k$, where i, j, and k are months and $t+k$ is the economic limit for fattening an animal. A very small percentage of male calves, perhaps 2 percent, is used annually as replacement in the bull herd and must be included. And natural death from disease or starvation must also be considered.

Because a large percentage of female animals enters the breeding herd and remains unslaughtered for some years, the age distribution of slaughtered cows is less determinate, making it considerably more difficult to convert female slaughter statistics back to female calf births. However, the biological birth ratio between male and female calves is known, so it is a simple matter to go from male births to female births. The resulting constructed calves-born series can be combined with a chosen benchmark census, the slaughter data, and estimated mortality rates through the system of accounting identities linking the herd categories from one year to the next, to produce the desired disaggregated herd data.

The resulting herd estimates were first checked for consistency against available information such as other censuses. Then, a much stronger test of the constructed series was made on the basis of the close relation expected between the number of calves born and the number of cows and heifers in the herd each year. Regression analysis was used and confirmed the close relation, but the residual pattern implied that the constructed series was not the "true" series. The divergence from the time series was stable and closely related to movements in the beef/grain relative price occurring at the time of slaughter. In short, producer price response altered the age distribution of slaughtered animals, thereby violating one of the assumptions used in constructing the calves-born series. But this bias was easy to estimate so the constructed series could be moved iteratively toward the "true" series.

The Slaughter Data and the Calves-Born Series

The first stage in obtaining improved herd data was to prepare appropriate slaughter data. Official slaughter data, collected and published by the National Meat Council (Junta Nacional de Carnes - JNC), are quite good.[4] Slaughter data are reported both by the producer selling the animal and by the slaughtering institution. There are only a few minor discrepancies: sales or slaughter not disaggregated by category, or animals being reported only in sales but not in slaughter or vice-versa. Simple manipulations were made to adjust the series for these problems. It was thus possible to obtain data for total slaughter plus exports-on-foot, disaggregated by category, for the entire period.[5] (for details, see Jarvis 1969).

The next step was to test the reliability of these slaughter data. Aldabe and van Rijckeghem's (1965) development of simulation model of the cattle sector raised an important question about the data. In their attempt to replicate the historical movements in the herd stocks and slaughter, they noticed an inconsistency between the official slaughter data and the official herd data: The herd estimates indicated that the stock of cows had remained roughly constant during the period studied, 1947-1963, but the number of steers and yearlings slaughtered had steadily risen. They concluded that cow slaughter was severely underestimated. (For their methodology behind this conclusion, see Jarvis 1969.)

Several factors led me to reject their conclusion and proceed to construct improved herd statistics. (For details, see Jarvis 1969).)[6] Probably most important, the official herd estimates are quite poor. Improved estimates by the Ministry of Agriculture and FAO based on a larger sample, disaggregated by province, confirmed that the herd was originally underestimated in 1965 by nearly 5 million animals. It is unlikely that the herd actually increased so rapidly just beween 1963 and 1967. Rather, by comparison with the slaughter statistics, it appears that substantial growth occurred during the entire period 1953-1964, instead of no growth as the official estimates showed.

A computer simulation of the cattle sector, assuming reasonable values for the various mortality rates and the male/female birth ratio confirmed that substantially more males would show up in cumulative slaughter as the size of the herd increased. The test was then applied to the actual data in an attempt to determine simultaneously whether these mortality rates, birth ratios, and herd build-up would be consistent with the slaughter figures. This lengthy process is explained below.

First, using the original monthly slaughter JNC data, the number of male animals born was estimated using a process somewhat like Aldabe and van Rijckeghem's. However, rather than merely summing calf, yearling, and steer slaughter in years t, $t+1$, and $t+2$, respectively, I incorporated more precise *a priori* knowledge about the calving season and the age limits of each animal category. Cattle of different age and sex fall into different slaughter categories that may be defined as:[7]

- T: A calf (*ternero*), a male or female animal zero to nine months old.
- TN: A male calf (*macho*).
- TV: A female calf (*ternera*).
- NT: A yearling steer (*novillito*), a male animal, often castrated, 10 to 18 months old.
- VQ: A yearling heifer (*vaquillona*), a female animal 10 to 18 months old, too young to bear a calf.

VN: A breeding heifer (also *vaquillona*), 19 to 28 months old and should be bearing her first calf.

V: A cow (*vaca*), 28 to 84 months old and potentially can bear a calf yearly.

N: A steer (*novillo*), 19 to 30 months old.

B: A bull (*toro*), an uncastrated male, 24 to 84 months old, used for breeding.

Most calves are born between August and November, but the distribution over this time period is not certain. Fertility is strongly affected by feed, so a natural cycle develops with most cows delivering some nine months after pasture conditions peak following the spring rains. The gestation period is nine months, leaving three months for the cow to recover after a birth before she becomes pregnant again. The Ministry of Agriculture estimates that 60 percent of the calves are born in the Argentine spring, and 40 percent in the fall, whereas CONADE and INTA both hold that 80 percent are born between June and October, just before and during spring in Argentina. Aldabe and van Rijckeghem assumed that 2 percent of the calf births occurred in each of January, February, March, April, and May; 1 percent in June and July; 12 percent in August; 30 percent in September; 25 percent in October; 15 percent in November; and 6 percent in December. This implies 69 percent between June and October, but 88 percent between August and December.

Using the slaughter age data and available information on the calving season, I computed for each male category, a weighted sum of the monthly slaughter to represent those animals born in fiscal year t slaughtered in fiscal years t, $t+1$, or $t+2$.

First, for male calves: Most calves are born during the calving season (*TP*) with the rest being spread fairly evenly over the other months. Further, calves are either sold before they are nine months old or they are no longer calves. In Figure 9, the period *TF* indicates the months during which the calves born in fiscal year t may be slaughtered while still calves; the weights represent the proportion of calves slaughtered monthly during *TF* which are assumed to have been born sometime during fiscal year t. The implication is that one-half the calves born in fiscal year t and slaughtered as calves are slaughtered in year fiscal $t+1$.[8]

From these weights the sum was:

$$CS(j)_t=\sum_{i=k}^{n}[w(i)S(j)_t^i]$$

where $CS(j)_t$ = the number of animals born in year t and slaughtered as j, $j=$ calves, yearlings, or steers; $S(j)_t^i$ = the slaughter of animals in category j in month i; and k and n depend on the age limits for the category such that

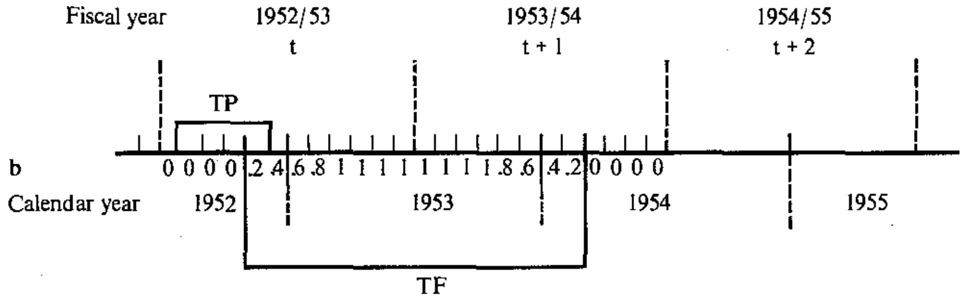
$$\sum_{i=k}^{n}w(i)=12,\ n-k\geqslant 12,\ w(i)\leqslant 1.$$

For male yearlings, it was assumed that none are slaughtered until they reach 14 months old. The ages at which animals change categories are somewhat indistinct, but yearlings range from nine to 20 months. Calves born in year t and slaughtered as yearlings must be slaughtered in the period YF in Figure 10. Thus, roughly two-thirds are slaughtered in year $t+1$, and the rest in year $t+2$.

Steers are assumed withheld from slaughter until at least age 22 months, with the majority slaughtered at age 29 months-- though some believe steers are older when slaughtered. However, the average age of slaughtered steers declined steadily through the 1940s, 1950s, and 1960s, so it seems likely that nearly all calves born in year t and slaughtered as steers will be slaughtered in year $t+2$. The period of possible slaughter is denoted *NF* in Figure 11.

The only other outlet for male calves is the bull herd, for which the data are poor. However, the number of calves going to the bull herd each year is a very small percentage of the total born, so a miscalculation would have little impact on the estimate of calves born. To estimate the calves withheld to be raised as bulls, I calculated the total number of calves chosen for the bull herd between census periods as the net change in stock, plus slaughter and estimated deaths for each period. These totals were allocated to the individual years of each intracensus period, with an inverse relation to the number of bulls being slaughtered in that year, on the assumption that both additions

Figure 9
Assumed Distribution of Slaughter for Animals
Slaughtered as Calves, born in Fiscal Year t[a]



[a]The actual years are used as illustration only.

[b]The coefficients in this row show the assumed proportion of calves slaughtered in the indicated month, born in fiscal year t. The remaining calves slaughtered are assumed born in fiscal year t-1 or t+1.

Figure 10
Assumed Distribution of Slaughter for Animals
Slaughtered as Yearlings, born in Fiscal Year t

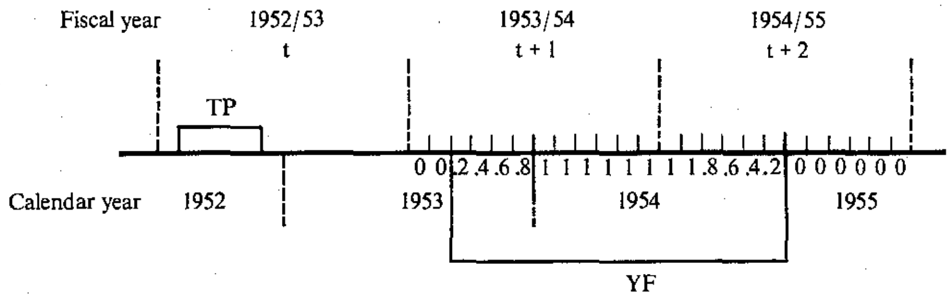


Figure 11
Assumed Distribution of Slaughter for Animals
Slaughtered as Steers, born in Fiscal Year t

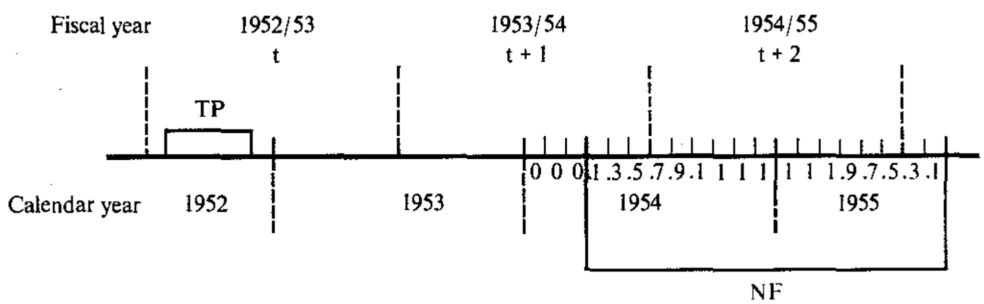
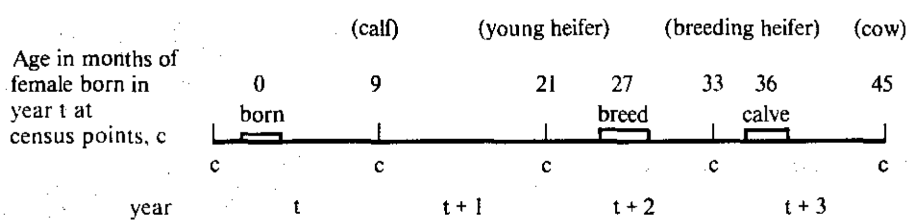


Figure 12
Approximate Monthly Age of Each Female
Animal Cohort at Time of Annual Census



and retentions would be motivated by the same economic factors. The calves withheld in year t were considered to become young bulls in year $t+2$.

Two further adjustments to the data were necessary before the male calves-born series was complete: mortality calculations and the division of calf slaughter between male and female animals. First, some calves die before being slaughtered. Hence, animal slaughter numbers should be multiplied by some factor to account for this. Deaths depend on (a) the age at which an animal is to be slaughtered, i.e., if older, chances of natural death are increased, and (b) the mortality rates for each animal category which also vary from year to year with climatic conditions and the level of animal husbandry practiced.[9] An index was constructed to adjust the mortality rates of the individual categories to variation in climate and to the level of animal husbandry. This "climatic-vaccination" index, CVI_t, is defined:

$CVI_t=0.8CC_t+0.2VAC_t$; $0<CVI_t<1$, where

$CC_t=((W_t-\overline{W})/\overline{W})\Psi$; and

$VAC_t=(HMV_t/3H_t)$.

CC_t is the percentage deviation from the mean of a de Martonne climatic index, W_t, calculated for the cattle sector.[10] Ψ is an arbitrary scalar of four chosen to give CC_t the desired magnitude of movement relative to VAC_t, the percentage of animals vaccinated against hoof-and-mouth disease, used as a proxy for the level of animal husbandry. HMV_t is the number of pharmaceutically good hoof-and-mouth vaccines sold in Argentina during year t, H_t is the number of animals in the herd. Because an animal must be vaccinated three times a year for the vaccine to be effective, HMV_t is divided by $3H_t$.[11]

The movements of CVI_t are primarily determined by CC_t, because of its larger weight. That is, seasonal variation on mortality rates was thought to be of greater impact than the long-term improvement in mortality rates with improved animal husbandry. CC_t exhibits greater variation while VAC_t shows a strong upward trend indicating that the average mortality rate during the study period fell slightly.

The climatic-vaccination index was used in calculating the multiplicative factors to adjust the animal slaughter numbers for natural deaths. Three series were constructed to represent the yearly mortality rates for three categories:

cows and calves:

$\alpha_t=0.05-0.02(CVI_t)$; $0.3<\alpha_t<0.07$

yearlings and heifers:

$\beta_t=0.03-0.15(CVI_t)$; $0.015<\beta_t<0.045$

steers:

$\gamma_t=0.02-0.01(CVI_t)$; $0.01<\gamma_t<0.03$.

Thus, α_t is roughly 5 percent per year plus or minus 2 percent depending on CVI; β_t is around 3 percent and γ_t, about 2 percent. This symmetrical effect of climate on mortality was made for simplicity even though poor climate probably has a stronger effect on mortality than good climate (because of the possibility of starvation).

Second, was the problem of dividing slaughter between male and female calves. No sex distinction is made in the calf slaughter records except in the small municipal slaughter houses, which handle about 35 percent of calf slaughter. Some previous work in Argentina assumed that male-female calf slaughter ratio is 60/40. Census figures generally show slightly more female than male calves in the herd. If we accept that 51.4 percent of the calves born are male and that male calf death losses only slightly exceed those for female calves, about 60 percent of the calves slaughtered must be male. One of the major packing plants, however, indicated that female calves were preferred because of their greater net yield per pound liveweight. Even though the same price per pound is paid for both, packing plant officials suggested that they purchased more female calves. I adjusted the former information downward in light of the latter, and decided to use a 52/48 ratio. Because only 5 percent of the calf crop is slaughtered, an error in this assumption would have a very small effect on the constructed herd series.

The data on male animals born in year t and slaughtered as calves, yearlings, and steers, $CS(j)_t$, could now be adjusted to estimate the male calves born which produce each slaughter $CB(j)_t$, using α_t, β_t, γ_t, and the male/female birth ratio, assuming the following relationships:

$$CBTN_t = CSTN_t/(1-\alpha_t) = CST_t\,/(1-\alpha_t)0.52,$$

$$CBY_t = CSY_{t+1}\,/[(1-\alpha_t)-\beta_{t+1}(1-\alpha_t)],$$

$$CBN_t = CSN_{t+1}\,/[(1-\alpha_t)-\beta_{t+1}(1-\alpha_t)-\gamma_{t+2}(1-\beta_{t+1})(1-\alpha_t)].$$

$CSTN_t$, CSY_{t+1}, and CSN_{t+2}, constructed from the monthly slaughter data, are respectively the male calves, yearlings, and steers slaughtered in years t, $t+1$, and $t+2$ which were born in year t. Their CB complements are the male calves born in year t which produced the actual slaughter; the expressions in parentheses represent the percentage which lived until slaughter. CST_t is the total number of calves slaughtered in year t which were born in year t, of which 52 percent are assumed to be male. Dividing the slaughter data for calves, yearlings, and steers through by the respective expressions in parentheses involving the mortality indices (and by .52 for calves) yields the *CB* variables, which when summed and added to the estimate of the calves going to the bull herd (CBB_t) each year, gives a series for the male calves born (*CBM*) each fiscal year: [12]

$$CBM_t = CBTN_t + CBY_t + CBN_t + CBB_t.$$

There were three additional steps before this male-calves born series could be used in an econometric model: (1) testing the consistency of the male and female slaughter data to determine whether the cow slaughter data appeared underreported, (2) extending the fiscal year series constructed for the number of male calves born during the period 1952/53-1962/63 to include the years 1937/38-1951/52 and 1963/64-1966/67, and (3) converting the series for male calves born into one for total calves born.

First, as noted previously, Aldabe and van Rijckeghem suggested that cow slaughter is underreported in Argentina. If so, the coefficients estimated econometrically for the cow slaughter equation might be biased. However, it was possible to use the male and female slaughter data for 1952-1967 to test whether the cow slaughter was underrepresented. The number of female calves born each year could be approximated using a procedure similar to that used for males. The total number of males and females born over time could then be compared. If their numbers were approximately equal, once adjusted for the male/female birth ratio and for the increase in the cow stock during the period in question, the cow slaughter statistics could be believed unbiased.

The procedure for estimating the number of female calves born was simpler; heifers were assumed to be slaughtered at 16 months, and cows on average, at age seven. [13] Thus, both heifers slaughtered in year $t+1$ and cows slaughtered in year $t+6$ were considered as born in year t. The total number of female calves (CBF_t) born in year t is found by dividing the slaughter numbers for calves (*CSTF*), heifers (*CSVQ*), and cows (*CSV*) by their respective factors, calculated similarly to those for males, and summing:

$$CBTF_t = CSTF_t\,/(1-\alpha_t) = CBT_t\,/(1-\alpha_t)0.48,$$

$$CBVQ_t = CSVQ_{t+1}\,/[(1-\alpha_t)-\beta_{t+1}(1-\alpha_t)],$$

$$CBV_t = CSV_{t+1}\,/[(1-\alpha_t)-\beta_{t+1}(1-\alpha_t)-\gamma_{t+2}(1-\beta_{t+1})(1-\alpha_t)+\cdots],\ \text{and}$$

$$CBF_t = CBTF_t + CBVQ_t + CBV_t.$$

The comparison of *CBF* to *CBM* provided an indirect test of the cow slaughter statistics, presented here in abbreviated form. Disregarding calf slaughter because the breakdown for males and females is roughly 50:50 and very small relative to total slaughter, the cumulative total of the annual sum of the *CB* variables for yearlings, steers, and bulls from 1952/53-1962/63, could be compared with the corresponding sum for cows and heifers. The respective totals are 70,642,087 and 64,885,787. From the biological male/female birth ratio of 51.4/48.6, given the number of males, we should expect 70,642,087 (48.6/51.4) = 66,827,414 females, or 1,942,000 more than the calculated total. For the slaughter data to be internally consistent, the herd would have had to increase by about five million animals between 1952/53 and 1962/63, because cows represent a rather constant fraction of the herd, almost 40 percent. While this magnitude of increase in herd size was quite

	CST^c_t	CST^c_{t+1}	CST^c_{t+2}	R^2	DW
CST	0.029	0.925	0.044	0.99	1.86
	(0.59)	(95.23)	(7.51)		
	CSY^c_{t+1}	CSY^c_{t+2}			
CSY	0.19	0.81		0.99	1.92
	(6.79)	(29.04)			
	CSN^c_{t+2}	CSN^c_{t+3}			
CSN	0.47	0.55		0.82	2.05
	(3.84)	(4.50)			

t - statistics are in parentheses.
c - refers to calendar year data.

plausible, it was kept subject to confirmation by the final herd estimates. Later improved herd estimates in fact did show that the herd increased by about five million animals during this period so the test was right on target. The official slaughter statistics were thus validated as consistent. Since the male slaughter data were not questioned, it appears that female slaughter data also contain no serious bias.

Second, the male calves-born series for 1952/53-1962/63 constructed above could be used to extend the male calves-born series for the entire period. Recall from Figure 9 that calves born in fiscal year t (1952/53) can be slaughtered as calves only in the calendar years 1952, 1953, and 1954. The series CST_t, calves born in fiscal year t and slaughtered as calves, was constructed from monthly slaughter data assuming a stable relation between births in fiscal year t and later calf slaughter. Regressing the fiscal year *CST* series on the calendar-year calf slaughter data, i.e., CST_t on CST^c_t, CST^c_{t+1}, and CST^c_{t+2}, for 1952-1963 yielded coefficient estimates to use in extending the *CBT* series. The same process was also applied to the yearling and steer slaughter data. The results of the regressions are shown above.

Because of the close fit, especially in the calf and yearling equations, the regression coefficients were used as weights to transform the calendar year slaughter data into a *CBM* series for the fiscal years 1937/38-1951/52 and for 1963/64-1965/66 period for which monthly slaughter data were not available. The three pieces--projected, constructed, and projected--may be spliced to yield complete series for the study period on *CBT*, *CBY*, and *CBN* which when combined with *CBB* yield a male calves-born series, CBM_t .

Third, the male calves-born series can be converted into one for total calves born (CB_t) for the entire study period. Consider the equation:

$$CB_t=[(0.52+0.2A_t)CBT_t+CBY_t+CBN_t +CBB_t]1.94552.$$

A_t is the average proportion of heifers slaughtered minus the proportion slaughtered in year t:$(\overline{HS}/\overline{H}-(HS_t/H_t))$. A_t was introduced to allow the proportion of calves slaughtered which are male (0.52) to flucuate with herd size. A_t varied between -0.10 and 0.16 during 1952-1963; the coefficient 0.2 converts A_t to allow the assumed percentage to vary between 0.49 and 0.54--a reasonable allowance. The factor 1.94552 is the inverse of the proportion of calves born which are male (0.514), thus transforming the series into one for males and females.

Construction of the Disaggregated Herd Estimates

The series CB_t was then used to construct estimates of herd size. Using any census year as a bench point, the number of animals in every category in every year could be calculated by introducing the calves born, advancing the previous year's herd stock, and subtracting the number slaughtered and the estimated death losses.

Table 3
Herd Size by Type of Animal, 1937 Census and Revised Estimates

	Census	Estimates
Steers	2,277,788	3,556,200
Yearlings	3,184,454	4,329,500
Cows	14,376,765	17,176,700
Heifers	4,144,284,	4,164,100
Male calves	3,587,596	5,444,784
Female calves	3,852,315	5,148,161
Bulls	1,155,070	1,258,500
Total	32,846,595	41,077,950

I used the June 30, 1937 census, believed one of the best available, but several adjustments were still needed. This census showed a total herd of 33,307,000 allocated as in Table 3. My own estimates for the *flow* of animals in the herd during 1937/38 appear in the second column. The adjustments were necessary because of seasonal variations in the various categories, definitional differences, and errors in the census.[14] For an example of an error: 3,511,610 steers were slaughtered in 1937 and 3,422,530 in 1938. As there is generally a one-to-one ratio between the size of the steer herd and steer slaughter during the year,[15] the census figures must be too low. The discrepany is likely caused by producers who for tax reasons hide their animals. Tax evasion in Argentina is a well-established custom. Producers may claim to government officials that they slaughter their "entire" steer herd, not reporting the animals still held. At any rate, there should have been at least as many steers in the herd as were slaughtered.

To correct for such discrepancies, alternative estimates were made for the number of animals in each category based on the slaughter series, the calf birth series, and later censuses.[16] For example, to determine a better estimate of the number of steers and yearlings in the herd in 1937, I worked backward from the slaughter data. Working from the one-to-one ratio just mentioned, $N_t = NS_t + ND_t$, so if NS_t and ND_t are known, N_t can be determined. In 1937/38, steer slaughter was 3,482,500. The approximate number of steer deaths, estimated from the steer mortality rate (γ_t) calculated for 1937/38[17] and the steers slaughtered in that year was 74,700. So the number of steers in the herd in 1937/38 was at least 3,556,200. Using the same process, there were 3,687,000 steers in the herd in 1938/39; from this the number of yearlings in 1937/38 could be determined using $N_t = NT_{t-1} - NTD_{t-1} - NTS_{t-1}$:

steers in the herd (1938/39)	3,687,000
+ yearlings slaughter (1937/38)	515,100
+ yearling deaths (1937/38)	127,400
yearlings in the herd (1937/38)	4,329,500

Thus, my adjusted estimates of the number of yearlings and steers in the herd in 1937/38 amount to almost 2.5 million more animals than the official census indicates. Part of this is due to the difference between point and flow estimates. Because most animals remain in a particular category for less than a year, the census point figures underestimate the number of animals passing through the category during a year's time. Working backward from slaughter or forward from births per year gives the yearly flow, which will be larger for some categories than the census figures. The remainder of the discrepancy results, I believe, from underestimation by the 1937/38 official census. Note that the adjusted figures for the steer and yearling stocks do not affect in any way the herd estimates beyond 1938/39. The herd generation process assumes that all the steer stock is slaughtered each year and that the steer herd is affected only by the number of calves born three years prior, not by the size of the past steer herd.

I also (somewhat arbitrarily) adjusted the 1937/38 bull census slightly upward, primarily because of the systematic underestimation in the other categories. Had the census figures for bulls been used instead, the numbers would have had to have been adjusted during some other period to reach the 1966/67 herd level. In any case, the yearly additions to the bull herd are very small; a different adjustment procedure from the one chosen would make a negligible difference in the results.

A more important problem was with the definition of heifer and cow herds. A heifer in the census statistics is defined differently than in the slaughter statistics. Producers asked to enumerate heifers usually include all female animals older than nine to ten months which have not yet calved. As most females do not calve until their third birthday, three-year olds may still be classified as heifers by farmers reporting to the census although by this time the slaughter statistics would have classed them as cows already for one year. Consistency between the census and slaughter definitions is essential because the size of the heifer herd is expected to be an important determinant of the number of heifers slaughtered. Also, younger heifers cannot be used for breeding and will have no direct influence on the number of calves born, while older heifers will be bred.

"Breeding" heifers, VN_t (those approximately 33-months old at the time of the census, which will probably calve in the next season) were separated from younger heifers not yet ready for breeding, VQ_t, in the census heifer statistics so that the "breeding" heifers could be pooled with the cow herd. The number of younger heifers was obtained from the previous year's calf herd (TV_{t-1}) and their slaughter and natural death figures:

$$VQ_t = TV_{t-1} - TVD_{t-1} - TVS_{t-1}.$$

This VQ_t was subtracted from the total heifer numbers reported in the census after adjustment to flow magnitudes, to obtain the "breeding" heifers; as shown in the following example:

The number of yearlings alive in 1937/38 and the average number of female calves from 1937/38 to 1939/1940 implied very similar numbers for female calves born in 1936/37. Using the latter, together with female calf deaths and slaughter, I determined the number of younger, nonbreeding heifers:

female calves (1936/37)	4,850,100
female calf deaths (1936/37)	-257,200
female calf slaughter (1936/37)	-428,800
young heifers in herd (1937/38)	4,164,100

The difference between this number and the census figure after adjustment to flow dimension,[18] was assumed to be the number of breeding heifers which would graduate in that year to the cow herd.

I emphasize that most of the difference between the official census and my estimate of the cow herd is apparent rather than real. The stock-flow issue accounts for most of it and there was some rearrangement of animal categories, especially by my shifting the breeding heifers to the cow herds.

Once the size of the herd in year t is known, the determination of herd size in future periods is straightforward, using the following model:[19] (For new definitions, see note 19 on page 42.)

$$T'_t = CB_t$$

$$TD_t = \alpha'_t T'_t = \alpha'_t CB'_t$$

$$TVD_t = 0.48 TD_t$$

$$TND_t = 0.52 TD_t$$

$$TVS_t = (0.48 - 0.2A) TS'_t$$

$$VQ_{t+1} = 0.486 T_t - TVD_t - TVS_t$$

$$VQD_{t+1} = \beta'_{t+1} VQ_{t+1}$$

$$VN_{t+2} = VQ_{t+1} - VQS'_{t+1} - VQD_{t+1}$$

$$VD_{t+1} = \alpha'_{t+1} V_{t+1}$$

$$V_{t+2} = V_{t+1} - VD_{t+1} - VS'_{t+1} + VN_{t+2}$$

$$VB_{t+2} = V_{t+1} - VD_{t+1} - VS'_{t+1} = V_{t+2} - VN_{t+2}$$

$$TNS_{t+1} = TS'_t - TVS_t$$

$$NT_{t+1} = 0.514 T'_t - TND_t - TNS_t - BTN'_t (1 - \alpha'_t)$$

$$NTD_{t+1}=\beta'_{t+1}NT_{t+1}$$

$$N_{t+2}=NT_{t+1}-NTS'_{t+1}-NTD_{t+1}$$

$$ND_{t+2}=\gamma'_{t+2}N_{t+2}$$

$$NS_{t+2}=N_{t+2}-ND_{t+2}$$

$$BT_{T+1}=BTN'_t(1-\alpha'_t)$$

$$BTD_{t+1}=\beta'_{t+1}BT_{t+1}$$

$$BTS_t=0.1BS'_{t+1}$$

$$BS_{t+1}=0.9BS'_{t+1}$$

$$BN_{t+2}=BT_{t+1}-BTD_{t+1}$$

$$BD_{t+1}=\gamma'_{t+1}B_{t+1}$$

$$B_{t+2}=B_{t+1}-BS'_{t+1}-BD_{t+1}+BN_{t+2}$$

$$H_t=T_t+VQ_t+V_t+NT_t+N_t+BT_t+B_t$$

$$VH_t=V_t+VQ_t.$$

The primed variables are given exogenously to this calculation. Of these, the number of calves born each year, the mortality rates for each category for each year, and the number of calves allocated to the bull herd were estimated as explained in this chapter. The number of animals slaughtered in each category each year was known from official slaughter statstics.

The series calculated for the total number of animals in the Argentine cattle herd, H_t, is given in Table 4 together with the official estimates H_t'.[20] $\hat{H}_t$ is an adjusted series of H_t, to be explained shortly. The estimated series H_t shows much larger herds than do the official censuses in the years 1937/38, 1947/48, 1960/61, and 1966/67, but recall that H reflects the total animals available during the fiscal year, whereas the censuses reflect the number of animals in the herd at one point in time. The total number of animals available during the year equals the number of animals in the herd at the beginning of the year plus the total calves born during the year. Unless all calves are born during one brief period and the inventory is taken immediately afterward, the point inventory must be smaller than the flow, because slaughter is continuous.[21] The composition of the herd varies considerably during the year for several reasons: Calf births are bunched, the slaughter of different categories is seasonal, and most animals change categories as they age.

Considering these several factors, H may be adjusted to obtain $\hat{H}_t$, the estimated number of animals in the herd at the end of June, the usual time of the census. It was difficult to know exactly what adjustments are needed, for the time profile of births, deaths, slaughter, and the ages at which animals switch from one category to another must be considered, but the nature of the process is clear. The adjustment for calves is given as an example.

Suppose that 35 percent of the calf births occur in the first quarter of the fiscal year (July - September); 35 percent in the second quarter; and 15 percent in the third and fourth quarters, respectively, with the census taken at the fiscal year's close. The number of calves found at the time of the census (June 30) relative to the total number born during the year is found using Table 5 whose vertical sums show for every quarter the percentage of the calves born during the previous 12 months which are still classified as calves. After nine months, the calf becomes a yearling or heifer, so an animal born in the first quarter is no longer a calf in the fourth quarter. Under these assumptions, only about 65 percent of the calves born during the year are still calves when the census is taken at the end of the fourth quarter. Subtracting slaughter and death losses, leaves only about 60 percent of the calves born during the year that are still around in June to be counted as calves by the census.

The data indicate that some producers report animals born during the last 12 months as "calves," even if they are older than nine months; they are thinking of them as yearly "crops" rather than categorizing them as they would be if sent to slaughter. Thus, the census shows more calves than the time profile adjustment would indicate, but not as many as were actually born. As an estimate of the proportion of the calves born which should appear in the census, therefore, I chose 0.80 of the yearly flow.

Table 4
Total Estimated Number of Animals in the Cattle Herd in Argentina, 1936/37-1966/67.

	H'_t		H^*_t	H_t
1936/37	33.2			
1937/38	34.3		35.6	41.1
1938/39			36.2	42.1
1939/40			35.7	41.4
1940/41			35.7	41.3
1941/42			35.2	42.0
1942/43			36.0	41.7
1943/44			35.4	40.8
1944/45			36.7	42.5
1945/46			37.8	44.0
1946/47			40.0	46.4
1947/48	41.0		41.1	47.7
1948/49			41.1	47.8
1949/50			40.9	47.6
1950/51			40.2	46.7
1951/52	45.7[a]	41.2[a]	40.6	47.2
1952/53	41.2		40.4	47.0
1953/54	43.6		42.9	49.9
1954/55	43.8		45.8	53.3
1955/56	46.9		48.0	55.8
1956/57	44.0		48.6	56.5
1957/58	41.3		47.5	55.2
1958/59	41.2		46.0	53.4
1959/60	43.5		45.9	53.4
1960/61	43.2		47.3	55.0
1961/62	43.2		48.6	56.2
1962/63	41.2		47.4	55.3
1963/64			46.5	54.0
1964/65	46.7	(51.4)[b]	47.3	55.0
1965/66		(55.3)[b]	49.8	57.9
1966/67	51.2	(56.2)[b]	51.8	60.2

H'_t = official estimates and censuses.

H^*_t = census point estimates constructed in this study.

H_t = fiscal year flow estimates constructed in this study.

---

a. The November 11, 1952 census is usually disregarded in Argentina because it is believed to be strongly biased upward. Allegedly Peron wanted to show an increase in herd size in order to enhance the image of his economic policy. Thus, the census was taken in November, when the herd approaches its peak size, rather than in June when it is low. But this November count is useful. If the 1952 census figures for the major six cattle-producing provinces are summed and seasonally adjusted back to June. The estimate is 41.2 million—a number close to my estimate, but still slightly too high.

b. These numbers in parentheses are the results of later attempts to obtain better estimates of herd size based on improved and enlarged sampling techniques. The first represents a re-estimation of the herd from the agricultural owner survey of September 30, 1965. The next two estimates use data collected on January 1, 1966, and January 1, 1967, respectively.

The difference of nearly four million animals in the estimates of September 30, 1965 and Jankuary 1, 1966, indicates how much the date of the census may affect the results. But the two January estimates show considerably larger herds than they had been based on the corresponding Junes, the usual month for the census. It is this difference that my H* series attempts to account for.

The time profile of these new estimates, shown below, indicates that these three official re-estimates, when seasonally adjusted, are reasonably comparable with my constructed estimates.

1964/65		1965/66		1966/67		1967/68	
July-June		July-June		July-June		July-June	
	1965		1966		1967		
	51.4	55.3		56.2	51.2		— H'_t
	47.3		49.8		51.8		— H^*_t
55.0		57.9		60.2			— H_t

Table 5
Percentage Distribution of Calves Born in Quarter i, Still Classed as Calves in Quarter j; i, j =I, II, III, IV.

I	II	III	IV
35	35	35	–
–	35	35	35
15	–	15	15
15	15	–	15
65	85	85	65

The other adjustments used were $\hat{T}_t = 0.80T_t$, $\hat{NT}_t = 0.75NT_t$, $\hat{VQ}_t = 0.80VQ_t + 0.45VN_t$, $\hat{V}_t = 0.90VB_t + 0.45VN_t$, $\hat{N}_t = N_t$. The reasons for the chosen adjustment factors are given in Jarvis (1969).

The adjustments are intuitively satisfactory, as can be seen by comparing the official census H' to my series H, the flow of animals through the herd, and my series H^* the number of animals found in a census taken at the end of the fiscal year. That is, the first observation in the series $\hat{H}_t$ is not to be compared with the official census of June 30, 1937, but with the estimate for June 30, 1938. The herd was very stable during this period, so the difference is small in any case.

The adjustments do not remove the entire discrepancy in 1937/38 between my estimate $\hat{H}_t$ and the official census, H'. Most of the remaining difference is due to underestimation of the steer herd in the official census, and my slight overestimation of the calf crop in 1937/38. Note that my adjusted estimated is close to the count of the 1947/48 census which was considered to be very good. (The various ˆ series for each of the individual animal categories are also very close to the 1947/48 census estimates.)

Between 1953 and 1963, my estimates differ significantly from the official estimates, particularly after 1956. Given the manner in which the official estimates were made, this is not surprising. Between 1953 and 1959, herd size was estimated by comparing small annual samples with the 1952 census results. But the 1952 census is believed to be strongly biased upward (see footnote a, Table 4). Also, the quality of the samples taken each year is believed to have gradually deteriorated. After the Perón administration was overthrown in 1955, the difference between H_t' and $\hat{H}_t$ grows markedly. This may have been partially due to the desire of the post-Perón governments to demonstrate the injurious effects of Perón's economic policies on the agricultural sector and the necessity for changing these policies.[22] As the official herd estimates grew progressively worse, so did public distrust of the figures; in 1964 the estimation process was discontinued. No further estimates were made until September 30, 1965, when data from a national survey and registry of agricultural producers became available. The resulting estimate (in parentheses in Table 4) was about 5 million head greater than the 1962/63 figure, with much of the increase due to taking the census in September rather than in June.

With the assistance of FAO experts, improved statistical techniques were used to estimate herd size using samples taken on January 1 in 1966 and 1967. These new estimates (in parentheses in Table 4) are thought to be accurate. With improved extrapolation techniques, an estimate of the herd size in June 1965 was made; the June 1967 figure was constructed using these techniques and a sample taken on June 30. Both of these June estimates are quite close to my $\hat{H}_t$ results. The difference between the January and June estimates in 1964/65 and in 1966/67 confirms the occurrence of a large seasonal variation in herd size.

The constructed herd series $\hat{H}_t$ is also consistent with the independent evidence available from the government's program against hoof-and-mouth disease. Since 1962, the government has required compulsory vaccination of all animals three times a year. If the original official herd estimates of 1963 and 1965 are compared to the number of vaccinations produced those years,[23] enough vaccine was produced to vaccinate 119 percent and 111 percent of the herd in 1963 and 1965, respectively. These percentages seem unrealistic, for even in a compulsory program some producers no doubt evade the law. In contrast, my herd estimates imply that enough vaccine was produced in these years for about 95 percent and 92 percent, respectively.

SELSA, the government agency in charge of the campaign against hoof-and-mouth disease, estimated that there were about 48 million animals in the herd in 1966 and 1967 and that about 92 percent were vaccinated. Thus, its herd estimates are larger than the "old" official estimates, but smaller than the new ones. SELSA's estimates imply that 8 percent of the vaccine was wasted, while the new official estimates and my estimates imply that only about 87 percent of a larger herd was vaccinated.

However, SELSA did not do the actual vaccinating. Producers purchase the vaccine and submit forms indicating the purchase and the number of animals vaccinated. Once the vaccinating process has begun, producers tend to treat all of their animals, but may underreport the number for tax reasons. These likely occurrences resolve the conflict between vaccine produced and SELSA's small herd estimate. In any event, the amount of vaccine produced is wholly consistent with the new herd estimates and my $\hat{H}_t$.

A Further Test of the Consistency of the Constructed Data: The Estimation by Regression Analysis of the Number of Calves Born

Although the overall increase in $\hat{H}_t$ over the study period closely approximates the increase reflected in the best official data, further checks of consistency were needed. The first general check is relatively easy. Indeed, I have already shown that my estimates imply a male to female birth ratio acceptably close to the biological one. Were this not the case, significant cumulative changes in the estimated herd size (or in the size of any component parts of the herd) could be affected by varying certain parameters, e.g., the magnitude of the various mortality rates. But there is still room for error in the transition from the point estimates being checked to the flow estimates (which will be used in estimating the econometric model).

A somewhat more involved method to check the herd estimates for accuracy involves regression analysis of the relation between the number of calves born and the number of cows in the breeding herd. For, even if the general growth in the herd over time were consistent with census benchmarks, yearly estimated fluctuations in the herd or in its component parts may not reflect the true fluctuations. There is some question concerning the age distribution of the slaughtered animals and particularly its stability. That is, animals may be slaughtered at different ages than were assumed, especially if disturbances cause producers to alter the distribution from time to time. Although the total animals born during the period would still be approximately correct, the yearly fluctuation of the herd and its parts would be incorrect.

A strong test of the internal consistency of the constructed herd data is to show that the number of cows in the herd serves well to explain the number of calves born, that is, when the former is used as a regressor on the latter. The size of the cow herd is itself determined by previous calf crops, given slaughter (which is known), and it, together with other predetermined variables thought to affect the calving rate, should explain calves born in year t. If not, the test should indicate where adjustments in the calves-born series are needed. Details of the procedure may be found in Jarvis (1969). Here it is outlined and the final results presented.

The relationship between calves and cows is simply: $T_t = V_t \cdot CR_t$, where CR_t= the calving rate. The calving rate in turn is a function of cow health and care used in breeding. In Argentina, one measure of cow health is the weather just before and during the breeding season. That is, if the weather is favorable, feed is ample, then the cows are more likely to be well fed, healthier, and fertile. Another determinant of health is medical care. Hoof-and-mouth disease is endemic in Argentina and although death losses from this disease are relatively small, its impact on health, weight gain, and fertility was once significant. The vaccination campaign against hoof-and-mouth disease alleviated this problem, thus improving the calving rate over time.[24] The percentage of the herd vaccinated against hoof-and-mouth disease was taken as a proxy for general improvements in the care given the breeding herd.

Although the multiplicative relation suggests estimating an equation linear in the logs, the inclusion of additional variables to stand in for CR, made a linear specification preferable.

The initial specification was by ordinary least squares (OLS): Calves born in t was expressed as a linear function of lagged values of the cow herd, the weather index during the breeding season, and the percentage of the herd vaccinated against hoof-and-mouth disease: $CB_t = \alpha_1 V_{t-1} + \alpha_2 WB_{t-1} + \alpha_3 VAC_{t-1} + \epsilon_t$. While the cow herd variable captured most of the explanatory power, the coefficient estimate associated with the weather variable carried the "wrong" sign and the Durbin- Watson statistic indicated the presence of positive autocorrelation. To correct for first-order autocorrelation, the second model was estimated using the Cochrane-Orcutt iterative procedure. But because residual patterns were the primary indicator of specification changes needed, subsequent models were estimated by OLS.[25]

Next, the cow herd was divided into mature cows at the beginning of t (VB_t) and replacement heifers (VN_t). Because heifers are only two years old when entering the breeding herd, most will not bear in t; therefore, the variable VN_t was expected to carry a smaller coefficient than that associated with mature cows. Contrary to expectations, its coefficient was "too large" and residuals continued to exhibit a cyclical pattern particularly after 1950. This pattern appeared to be closedly related to movements in the size of the herd which, of course, had been affected by the economic environment.

The beef/feed relative price could have been "the" omitted variable, as it could induce producers to make efforts to increase the calving rate. However, if this were the case, the positive residuals (when the calculated calves-born series exceeded the predicted values from the equation) should have occurred immediately after a large increase in the beef/grain relative price. The higher relative price would have increased the calving rate, causing the number of calves born to also increase; the regression equation would underestimate this increase if the variable were omitted. Instead, the largest positive residuals appeared slightly before the largest relative price increases.

The serially correlated residual pattern was, therefore, most probably an artifact of the method of constructing the calves-born series. The method assumed a stable age distribution of the animals slaughtered in each category each year. If these distributions varied systematically, so would the resulting construct, i.e., if producer response to changing prices affected the age at which animals were sold, the calves-born series would be distorted.

To determine the impact that producer price response ought to have on the constructed series, a numerical simulation was carried out. The results suggested that a price increase would decrease the calculated number of calves born, biasing the constructed series below the true series. A price decrease would induce the opposite bias. This suggested that a properly specified regression ought to include the "future" beef/grain relative price. Given that climatic variation also affects slaughter, with poor weather forcing slaughter and good weather inducing producers to withhold animals to an older age, "future" weather was also included in the regression equation. For both future prices and future weather, the effect from any given disturbance might be spread over several years; still, it seemed wise not to constrain the effect by a specific lag distribution. Instead, future price and weather were included under various lag structures, selecting that forward lag which maximized $\bar{R}^2$ in each case.

While the coefficient on future price was significant, the plotted residuals indicated that some severe disturbance during 1958/59-1962/63 was still unaccounted for. These were the years when Argentina devalued its currency sharply several times, severely wrenching agricultural relative prices, and stimulating large changes in the rate of inflation. To test for structural change, these years were excluded, and two other changes were introduced. First, because vaccination against hoof-and-mouth disease should have secularly increased the calving rate, the percentage of animals vaccinated was introduced. Second, because there were important hoof-and-mouth epidemics in Argentina in 1943/44, 1955/56, and 1963/64, which should have affected the calving rate, a dummy variable for these years was included.

A rising proportion of the herd was vaccinated against hoof-and-mouth disease as shown below in Figure 13. The huge jump after 1962/63 reflects the initiation of the compulsory vaccination program. Still, vaccine had been available for at least two decades so it is possible that the most serious direct losses probably had been alleviated by 1962/63. Accordingly, the hoof-and-mouth vaccination variable was changed to its square root to increase the relative effect of vaccinations before 1962/63 and the equation was estimated for the entire period 1937/38 through 1967/68.

For comparison the shorter period, ending at 1958/59 was run. Then the same equation was re-estimated using the hoof-and-mouth proportion rather than its square root because the compulsory vaccinations began after 1958/59. Statistical results were consistently better for the shorter period. Evidently the post-1958/59 period of severe inflation and severe shifts in relative prices altered producer response significantly.[26] Figure 14 shows the pattern of the residuals from one equation estimated for the entire period: calves born, as a linear function of the breeding herd in t, the proportion of the herd that was vaccinated, the percentage change in the weather index in t-1 (during breeding) and its absolute change in t+2, the percentage change in the beef/ feed price in t+2, and a dummy variable for the three years with the worst hoof-and-mouth disease outbreaks.

To determine the impact of the rate of inflation on producers' decisions, the annual percentage change in the cost of living was included in several additional specifications using alternative forward leads. The inflation variable set at t+2 was significant only at the 10 percent level when the entire period was run, but was never significant for the shorter period even though inflation averaged nearly 15 percent a year between 1945 and 1958.[27] Thus, inflation's effect operated primarily through relative price changes, at least until the more volatile period, 1958/59-1963/64, and even then there is some evidence that rising prices per se did not play a major role. As will be discussed subsequently, correcting for errors in the calves-born series--and in the herd series constructed from it--as indicated by the other regressions (without the inflation variable), resulted in the estimation of an acceptable calves-born equation for the entire period.

There were two reasons for wanting a good regression estimate for the estimated number of calves born. First, if changes in the breeding herd explain most of the variations in the estimated number of calves born, we obtain a strong indirect test of the methods used to construct the number of calves born from the original slaughter data and also on the method of calculating the number of animals in the herd, by category, each year. Second, knowing the causes of distortion in the calves-born series, it may be corrected and then used in a subsequent regression to obtain values which are expected to track more closely the actual number of calves born. In this way, the herd data will also be improved, thus yielding a better data base for subsequent estimation of the livestock sector model.

For example, suppose that the equations estimated to explain the number of calves born are written in the general form:

$$CB_t = \alpha_1 V_{t-1} + \alpha_2 WB_{t-1} + \alpha_3 VAC_{t-1} - f(P_{t+i}, W_{t+i}) + \epsilon_t,$$

where P_{t+i} and W_{t+i} represent respectively the beef/feed relative price and weather conditions in year $t+i$. Because the function f contains significant variables whose effects indicate a distortion in CB_t, these effects should be removed to obtain the actual, undistorted (though unobserved) series of calves born, $\tilde{CB}_t$. The originally constructed series, CB, and the actual series, $\tilde{CB}$ are related as follows:

$$CB_t = \tilde{CB}_t - f(P_{t+i}, W_{t+i}) + \epsilon_t,$$

and a good estimate of $\tilde{CB}$ is simply

$$\tilde{CB}_t = CB_t + f(\hat{P}_{t+i}, \hat{W}_{t+i}) + \epsilon_t,$$

where the function f is obtained by using the

Figure 13
Proportion of Argentine Cattle Herd Vaccinated
Against Hoof and Mouth Disease, 1937-67

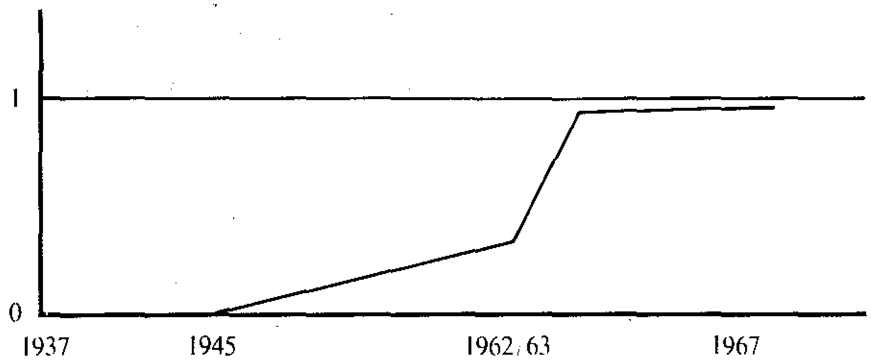
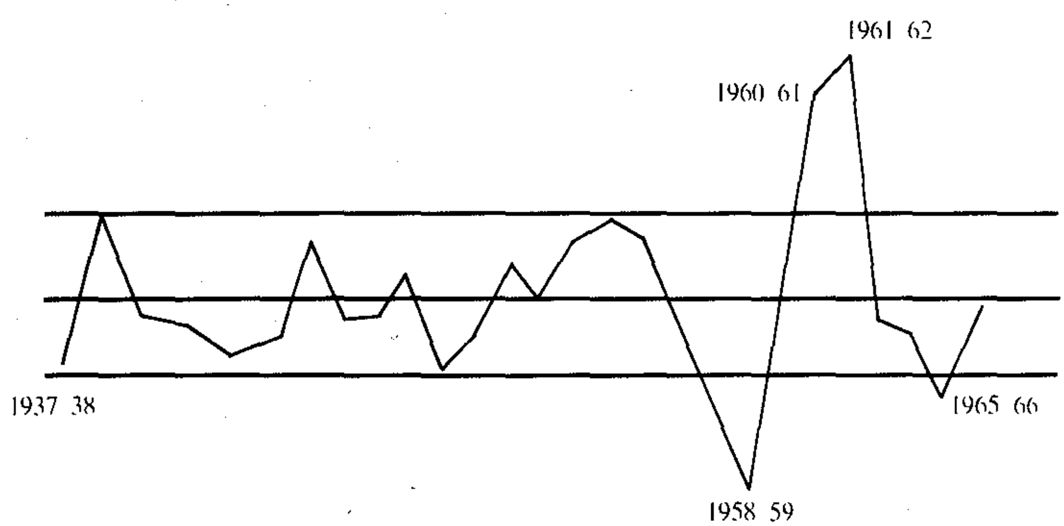


Figure 14
Patterns of Residuals from Calves-Born
Equation Estimation Before Accounting
for Post-1958 Inflation, 1937/38-1965/66



coefficients on P_{t+i} and C_{t+i} from the OLS estimate of CB.[28] $\tilde{CB}$ may then be used to construct new improved herd estimates. The correction process, though, should be done iteratively, because the herd estimates obtained using CB_t were also used to re-estimate $\tilde{CB}_t$.

After such an extensive specification search, however, I had to choose which f(.) to add to CB to obtain the improved series. Weighing the statistical results led me to choose the equation in which calves born was fitted to the size of the breeding herd (BH_t), the lagged percentage of the herd vaccinated (VAC_{t-1}), the absolute change in the weather during the past breeding season (ΔWB_{t-1}) and in the entire year, two years in the future (ΔW_{t+2}), the percentage change in the future beef/ feed price ($\%\Delta P_{t+2}$), and a dummy variable for hoof-and-mouth disease outbreaks (D_t). The equation, estimated by OLS for 1937/38 - 1957/58, was:

$$CB_t = \underset{(90.21)}{0.55BH_t} + \underset{(2.37)}{9731.09VAC_{t-1}} + \underset{(1.56)}{59.47\Delta WB_{t-1}}$$

$$- \underset{(2.77)}{152.68\Delta W_{t+2}} - \underset{(2.15)}{8682.59\%\Delta P_{t+2}} + \underset{(2.16)}{0.54D_t}$$

where $\bar{R}^2 = .92$, DW = 1.50, and t-statistics are in parentheses.

$\tilde{CB}$ was estimated for 1937/38-1957/58 by weighting the price and weather values in t by the coefficient estimates and adding them to CB in t. To ensure that this process only redistributed calves among the years (that is, it did increase or decrease the total number of calves born overall), I multiplied $\tilde{CB}$ by $\Sigma CB / \Sigma \tilde{CB}$.[29]

The predicted values of $\tilde{CB}$ for the remainder of the study period, 1958/59 through 1963/64, were obtained using the values of the exogenous (VAC_{t-1}), ΔWB_{t-1}, ΔW_{t+2}, and D_t), predetermined (BH_t), and endogenous ($\%\Delta P_{t+2}$) variables in the appropriate year, weighted by the coefficient estimates. However, two changes were introduced in the independent variables. First, the vaccination index rose so rapidly after the compulsory program began, that the extrapolation process caused distortion. To avoid this, the trend rate of growth in VAC since 1945 was used for 1962/63-1965/66. The increased rate of vaccination should have had some effect, but not as much as the index shows in this range. Second, because the impact of the hoof-and-mouth epidemics appeared to be less in 1955/56 and 1963/64, I changed the value of the dummy variable to 0.5 in these years.

The resulting $\tilde{CB}$ observations were spliced onto the adjusted $\tilde{CB}$ series for 1937/38-1957/58 to obtain an adusted $\tilde{CB}$ series for the entire period. This adjusted series was used to calculate new estimates of the herd using the model developed previously. Thus, new estimates were also obtained for the breeding herd ($\tilde{BH}$) and its components, mature cows ($\tilde{VB}$) and replacement heifers ($\tilde{VN}$).

These new herd series were used as independent variables to estimate equations in which the original CB and the adjusted $\hat{CB}_t$ were used alternatively as the dependent variable. An iterative process was continued until the difference between the estimated coefficients of an equation using the original series and the adjusted series was no longer significant--this occurred in the first iteration.

Equations using the original CB series and the adjusted $\tilde{BH}$ (and $\tilde{VB}$, $\tilde{VN}$) series performed much better statistically when estimated over the entire period than had the original versions. Thus, much of the problem in the earlier regressions for the 1958/59-1963/64 period must have been due to distorted herd data. This hypothesis is supported by the absence of any difference between the earlier and later periods in the behavior of the equations estimating slaughter and average slaughter weight for each animal category, which use the improved data. These equations are discussed in sections V and VI.

As a final test, the $\tilde{CB}$ series is used with the fully adjusted $\tilde{BH}$ variable. The coefficients on future price ($\%\Delta P_{t+2}$) and weather (ΔW_{t+2}) became insignificant, indicating that the distortion has been accounted for. All other coefficients, except weather during breeding (ΔWB_{t-1}), were highly significant:

$$\tilde{CB}_t = \underset{(84.52)}{0.529\tilde{BH}_t} + \underset{(5.17)}{112482.38VACX_{t-1}} +$$

$4783.49\Delta WB_{t-1} + 40.84\Delta W_{t+2} +$
(1.31) (0.77)

$1090.58\%\Delta P_{t+2} - 12288.56DX_t$
(0.27) (3.76)

where $VACX_{t-1}$ is the VAC variable until 1961/62 and the 1949-1966 trend thereafter; DX_t=1 for 1943/44, 0.5 in 1955/56 and 1963/64, = 0 otherwise; $\bar{R}^2$=.953; DW = 2.34; t-statistics are in parentheses. The strong relation between the constructed calves-born series and the herd data gives strong support to this method of generating cattle herd stock statistics for Argentina.[30 31]

Summary

The periods of herd growth and of decline indicated by the final estimates, $\hat{H}$, are intuitively satisfactory, though different from the official figures. Both my estimates and the official data show nearly identical increases from 1937/38 to 1947/48, significantly different movements during the next decade, and similar increments thereafter. Looking back at Table 4: The herd was constant during the early war years, 1938/39-1943/44, and then rose rapidly (5.7 million) to the end of the postwar boom in 1947/48. The next few years were stationary; British beef purchases fell considerably after 1947, but the Korean War spurred demand by other countries. The Argentine droughts in 1950/51 and 1952/53 prompted herd reductions in these years.

Meanwhile domestic consumption rose almost monotonically, from 5 million animals in 1942/44 to 8 million animals in 1950/51, and exports fell from 2.3 million to 1 million. By 1952, Perón recognized that policy revision was needed. Discrimination against agriculture to provide funds for industrialization was slowly but surely forcing capital out of agriculture; labor was leaving the rural areas for this and other reasons; and the fall in the real price of beef had increased domestic consumption beyond acceptable levels.

The announcement of new agricultural policies in 1952 and the ouster of Perón in 1955, coupled with a large increase in the beef/grain relative price in 1951 and 1952 gave rise to a new period of growth for the cattle sector. Between 1952/53 and 1956/57 the herd rose by 7.6 million head to a new high of 48.6 million animals, on a census point basis. The greatest difference between the rate of growth in the official statistics and my estimates occurs during these years. The official estimates show that the herd rose by 5.7 million from 1953 to 1956, and then fell by 5.6 million from 1956 to 1958. In contrast, my estimates rise by 7.6 million from 1952/53 to 1955/56, and fall by only 2.1 million animals from then until 1958/59.

In both series the herd remains relatively constant after this date, fluctuating from year to year during the tumultuous years 1958/59-1963/64; then it begins to grow again, adding about 5.3 million animals by 1966/67.

It is clear from either series that the Perón administration favored the cattle sector relative to grains. This is ironic for Perón frequently spoke of reducing the power and wealth of the landed elite, while his policies discriminated more heavily against the grain farmers who were much smaller in size and wealth. Perhaps he was not strong enough politically to directly attack the cattle barons. At any rate, during his administration, the aggregate cattle herd increased by 28.8 percent or by 10.4 million animals.

The calves-born equation results indicate that the withholding of cows and heifers from slaguhter, to increase the breeding herd, rapidly increases the number of calves born. Thus, the short-run negative response of slaughter to price ultimately results in greater future slaughter. The equation also demonstrates (via its proxies) that the calving rate is reasonably stable from one year to the next, suggesting in turn the possibility of predicting rather accurately the changes in the calf crop when the breeding herd is increased or decreased.

Weather was a more important determinant of the calving rate at the beginning of the period studied, but was never as important as expected. Even during the earlier period, weather variation caused no more than a 3 percent change in the calving rate.

My estimates put the calving rate per cow, defined as the number of calves born during year t divided by the number of mature cows in the herd at the beginning of year t, at approximately 72 percent during the mid-1960s. See Appendix V. These estimates are close to those provided by other sources. For example, INTA estimated the calving rate in the Pampas breeding area in 1958/59, 1961/62, and 1964/65 as 70, 74, and 76.2 percent, respectively. My estimates of 69.6, 71.7, and 72.4 percent for these years are close and show the same monotonic increase.[32] My estimates also suggest that the calving rate rose from 64 percent in the late 1930s to 70.4 percent in the mid 1950s. Most of the increase took place between 1947/48 and 1955/56, the latter part of the Perón administration. Except for 1937/38-1943/44 when the calves-born figures appear first too high and then too low, the increase is nearly monotonic. This increase is highly correlated with the percentage of the herd vaccinated against hoof-and-mouth disease, at least until the beginning of the compulsory program in 1962. But since then the rate of increase has slowed markedly suggesting that other factors, such as increased supervision of the breeding process, better pasture management, other types of vaccinations, have not yet played a major role.

Endnotes to IV.

1. A version of this section was presented at the winter meetings of the Econometric Society, New Orleans, December 1971, and was published in Spanish as "Un ejemplo del uso de modelos económicos para la construcíon de datos no disponibles: la estimacíon de la existencia de vacuno disagregado en Argentina 1937-1967." *Económica*, (1) Enero-Abril, 1973.

2. For one attempt to overcome faulty herd statistics, see Yver, 1965. Although his method produced estimates indicating the secular trends in the aggregate herd size, they were not sufficiently accurate to yield reliable estimates of the parameters of an econometric model.

3. There are no good statistics for the number of calves born each year. Producers do not regularly report births to any statistical agency and only occasionally have national agricultural censuses or sample estimations focused on births, deaths, or movement of animals within the agricultural sector during the year. The censuses and herd estimates are generally concerned only with the number of animals existing at the moment of the investigation. Therefore, except for periodic sample estimates or the conventional wisdom, there is no information about the trends in the calving rate or the mortality rate, let alone the effect of climate or disease on births, deaths, and herd movements. To help combat hoof-and-mouth disease, producers are required to purchase a low-cost permit before moving animals from one *partido* (county) to another. Unfortunately, these data are not assembled in a form usable for studying general animal movements over time.

4. The JNC is financed by a tax on all slaughtered animals, thus ensuring its financial independence and solvency. Accordingly, slaughter statistics are carefully collected and reported. In contrast, the Ministry of Agriculture, responsible for the official herd censuses, suffered from the general starvation of funds to the agricultural sector with the result that two herd censuses and particularly the interim herd estimates are quite bad during much of the study period.

5. The JNC data are on a calendar year basis for the entire period and on a monthly basis, for most animals slaughtered, for 1952-1966. Because the natural cattle year corresponds to the fiscal year, and because the official herd censuses and estimates are usually taken on June 30, I constructed fiscal year slaughter data for the entire period first by averaging the calendar year data across years for 1952-1966 and then using regression analysis to obtain weights to transform the annual calendar year data for 1937-1951 and 1963-66. This resulted in some smoothing of the data, particularly for the earlier period, but its effect seemed minor. Further, this manipulation did not affect in any way the data used to construct the calves-born series. The methodology and results are reported in Jarvis (1969).

6. Besides taking the official herd statistics too literally, Aldabe and van Rijckeghem used a 50:50 ratio of male to female birth rates in their calculations rather than the biological average ratio of 51.4:48.6. Also, they assumed a 5 percent mortality rate for cows and a 3 percent average mortality rate for all other animals, but then calculated the difference in male and female deaths as 2 percent of the cow herd. Because there are more than twice as many cows and heifers as steers and yearlings in the herd, this severely underestimated the difference between the mortality figures for male and female animals; $(0.05(2X)-0.03(X))$ is not equal to $(0.02(2X))$.

7. The definitions are based mainly on those of CONADE, the National Development Council, and INTA, the National Institute of Agricultural Technology, though there are some definitional difficulties. For instance, whether a male animal is to be classified as a calf or a yearling, a yearling

or a steer, is sometimes affected by weight and appearance as well as age. The Ministry of Agriculture considers females to be heifers (*vaquillonas*) until age two years, and then cows; CONADE and INTA consider the change to occur at three years instead.

8. As the calving season occurs at the end of the calendar year, it is very unlikely that the calves slaughtered within a given calendar year were born in that same calendar year, yet Aldabe and van Rijckeghem worked under this assumption. Henceforth, reference is to fiscal year unless otherwise noted.

9. Estimates of the category mortality rates vary. In 1956, CONADE estimated 3.0 percent for cows; 2.0 percent for heifers; 2.0 percent for bulls; 0.4 percent for steers; and 4.0 percent for calves, while Aldabe and van Rijckeghem used the following: cows, 4.0 percent; heifers, 2.5 percent; steers, 2.0 percent; yearlings, 3.0 percent; calves, 9.0 percent. These latter rates are those from other sources received in personal communication, but the calf mortality rate appears too high. One difficulty is to know whether calves born alive but dying within a few days are counted among the deaths or merely not counted as live births.

10. CC_t is a nonlinear climatic index that attempts to capture the interdependence of monthly rainfall and temperature based on observations at 37 rural observatories. The construction of W_t and CC_t is explained in Appendix III.

11. Because the number of animals in the herd each year was not known, I used the official estimates at this stage. Then, later I recalculated CVI using my constructed estimates of the herd. This type of iterative process was used whenever the original data differed substantially from the final estimates.

12. The series computed for the annual climatic variation, the climatic-vaccination index, the yearly mortality rates for each class, and the resulting factors used to divide the slaughter data to yield the various calves- born series, are shown in Appendix III.

13. Although the method used for females is less accurate than that for males, over a long period, the error should be small. Because the female calves born in 1962/63 would not be slaughtered as cows until 1968/69, I extrapolated assuming constant cow slaughter for 1967/68 and 1968/69. The conclusion regarding the accuracy of the cow slaughter statistics was not affected by the extrapolation since the same conclusion was reached using totals only through 1960/61.

14. Reca (1967) first mentioned the necessity to make such adjustments. The only permanent effect of the original census on my subsequent herd estimates is on the cow and bull categories, where the annual additions and substractions to the herd via births and deaths are made to a non-zero base.

15. Yearlings which pass into the steer category are usually fattened for approximately one year before slaughter. Slaughter throughout the year is reasonably continuous. Hence, the number of steers in the herd at any one time bears a close relation to the total number slaughtered during the year.

16. There are many ways to check the internal consistency of any assumptions and the associated results because of the system of identities connecting the static and dynamic behavior of the cattle sector. In all cases, I attempt to use what I consider the most reliable data to adjust and test what seems implausible. For example, the 1967 census is more consistent with the 1967 slaughter data than are the earlier censuses. This fact implies that the earlier censuses underestimated herd size.

17. $NS=N(1-\gamma_t)$. $ND=(NS/1-\gamma_t)\cdot\gamma_t$.

18. Examination of the unadjusted census figures for 1937/38, 1947/48, and 1966/67, and the constructed series for calves born for the same years, indicated that the calving rate was the highest in 1937/38, dropping to its lowest in 1947/48, then rising again to its next highest in 1966/67. But the calving rate is more likely to have increased monotonically over the period. Because the implied calving rate seemed too high in 1937/38, the cow stock was increased enough to reduce the calving rate to the 1947/48 level. This increase in the beginning cow herd will increase the total herd in every year thereafter by nearly as much (mortality is proportional to the herd size). This will not affect significantly the year-to-year fluctuations in the herd, but it will reduce the implied calving rate.

19. Note that the variable CB_t becomes T_t. Other variables, not previously defined are:

    VN_t= number of breeding heifers in the herd in year t

    VB_t= number of cows retained from the cow herd in year $t-1$

    BTN_t= number of calves allocated to the bull herd in year t

    BT_t= number of yearling bulls in year t

    BTD_t= number of yearling bulls dying in year t

$BTS_t =$ number of yearling bulls slaughtered in year t

$BN_t =$ number of three-year-old bulls joining the bull herd in year t

$VH_t =$ total number of heifers and cows in the herd in year t.

20. Results of the calculations for the various disaggregated series are available from the author.

21. Most official censuses were taken at the end of June when the herd reaches its yearly low just before the calving season. At this time the cull cows and many steers, unwanted heifers, and so forth have been sold and the new calves have not yet arrived. Because most of the calves are born during the first part of the fiscal year, the herd reaches a maximum in November or December and then decreases steadily until the calving season begins again the following August.

22. For example, the official 1959/1960 herd estimate, taken after a very large devaluation and a professed change in agricultural policies, shows an increase of 2.3 million animals from the previous year, although the devaluation occurred too late to affect the calf crop in 1959. My own estimate indicates that the herd continued to fall until the next year. See the calves-born series, where $T_{1959/1960}$ is smaller than $T_{1958/59}$. So is the cow stock. The issue is not whether more animals existed, for my estimates do show more than 43.5 million animals in 1959/1960. However, the official estimates underestimated the herd for several years prior and the question is how, using the same methods and without an improved census as a base, they could show a substantial increase in the herd when it appears in fact to have been falling. See Jarvis (1969) for an anecdote explaining the 1960/61 discrepancy.

23. The statistics used are those for vaccine which has passed the government quality control tests; they do not include the rejected vaccine--enough for another 7 or 8 million animals (Salces 1967).

24. Other diseases, such as *brucellosis* (contagious abortion), also affect the calving rate, but there are no vaccine statistics available.

25. Several of the variables used as "independent" explanatory variables in this and following regressions, especially the herd and price variables, have errors that are surely correlated with those associated with the "dependent" variable. Nonetheless, OLS was used for simplicity.

26. Major devaluations occurred between 1958/59 and 1962/63, and an increased rate of inflation followed immediately. Toward the end of 1958, herds were being liquidated because of poor profit expectations. The huge devaluation prompted a sharp reversal, and the herd rose by about 2 million animals during the next two years. By 1962/63, however, the price gains of the 1958/59 devaluation had been more than eroded and liquidation of the herd was again in process. Argentina devalued the peso again in 1963, but because of a large export tax imposed on beef, this had very little effect on the beef/ grain relative price. Only in 1964 and again in 1965 did the relative price increase.

    Slaughter actually increased in 1963 after the devaluation, suggesting that producers expected another inflationary period and a falling beef/grain relative price, as had followed the 1958/59 devaluation, and decided to take advantage of the high prices while they could. However, when the relative price rose after 1963, the liquidation stopped and the herd rose rapidly again. The average beef/grain relative price during the years 1964/67 was 5.1, compared to the previous 25-year average of 3.5.

27. Inflation during 1959 was 115 percent.

28. The use of herd data which have been adjusted using price movements, to subsequently determine the price responsiveness of producers involves potential circularity. This is a problem. However, I believe the approach followed produces more accurate results than any known alternatives, given the necessity to adjust the data. Errors in the data which are related to prices will exist unless the method of constructing the herd estimates can ensure that animals are assigned the proper birthdate. This seems nearly impossible given data available. However, although there will be errors in the constructed data, the errors should be as small as possible. In particular, because there is known to be a bias related to prices, it is better to correct the data for this bias than to leave the data uncorrected. Ultimately, the relationship found between calves and the breeding herd is felt to provide a rigorous test of the data. This equation is also an important part of an econometric model of the cattle sector.

29. $\tilde{CB}$ was not constrained so that the number of animals born within short periods was always the same. This may have introduced some bias, for the results indicate more animals being born just before World War II, and fewer during the war, than I believe reasonable. As the herd was smallest during these years, the linear adjustment to $\tilde{CB}$ made by adding f may have shifted too many animals from one year to another. However, the price variable P used in f, does not show strong serial correlation. There is only one period when the price moved in the same direction for four consecutive years: during the first four years when the reported distortion appeared to exist.

30. Yver (1971) attempted to recalculate the herd stocks produced here. Using data from Kohout (1969) on the relation between age and weight for animals in Argentina, Yver suggested that the slaughtered animals are slightly older than I have assumed. He uses a fixed age distribution throughout and does not consider either historical or cyclical changes in the age distribution of slaughtered animals. This procedure results in data which provide uniformly poorer results, judged by the usual statistical tests of significance, for both the calves-born equation and the other equations in the cattle sector model which utilize the constructed data.

    Yver is correct that the weights of the slaughtered animals could be used to determine their respective ages, but while this is practical for secular changes in the slaughter ages of different animal categories, it is not practical for cyclical changes in the slaughter ages. The data available provide only the average slaughter-weight of animals, and it is extremely difficult to determine how cyclical changes in this average are related to changes in the specific age distribution of slaughter. It was precisely the lack of individual data on slaughter-weight which led to the monthly assignment of slaughtered animals in the construction of the series of calves born. I do believe, however, that some adjustment should have been made for secular changes in the age-weight relation, this has not been constant throughout the period studied.

31. For simplicity, only the improved estimates of the herd data are shown in Table 4. Thus, $\tilde{H}$ is shown has H. The unimproved herd data are available from the author.

32. Both INTA's and my increased calving rates conflict with some in Argentina who hold that there was little or no such increase (Fienup, Brannon, and Fender, 1969).

V. The Specification and Estimation of the Slaughter and Average-Slaughter-Weight Equations

A theory of cattle producer behavior was developed in Section II and used to design a structural model of the cattle sector in Section III. Then, in Section IV the data required to estimate the model were constructed. Now, the slaughter and average-slaughter-weight equations are specified and estimated.

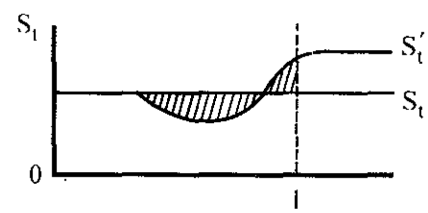
The most important independent variables entering the various slaughter equations are prices, climate, and stock level in the particular category, but several other variables that could affect producer expectations will also be considered: changes in nonfeed relative prices, e.g., changes in the real wages of agricultural workers; the rate of change in inflation--reflecting changes in the rate of discount of producers; an index of wholesale rural to wholesale nonrural goods--representing the intersectoral terms of trade; and devaluation-- representing expectational effects not immediately reflected in relative prices. Each of these variables should have similar effects in the various category slaughter equations, at least in the short run.[1] For example, an increase in the beef/grain relative price, or improved weather, should, *ceteris paribus*, cause an immediate decrease in slaughter in every category, although the slaughter elasticities will differ across categories.[2]

Note that producers apparently slaughter a relatively constant proportion in each category each year. As a result, the coefficient on the total herd variable in each category estimates the average rate of slaughter in that category, while the coefficients associated with the other independent variables estimate the degree to which this rate of slaughter varies from year to year.

General Notes on the Slaughter Equations by Animal Category

Steers. Given the technical and price relations holding in Argentina, no steer is far from his time of slaughter. As a result, although the immediate price response should be negative, changes in price expectations should not have a large impact on steer slaughter in the short run. The theoretical production model indicated that an increase in the beef/grain relative price will increase the optimal slaughter age. It will do this for living animals as well as for the yet unborn. Hence, animals nearly ready for slaughter will have this date postponed. This postponement of slaughter must reduce the number of animals slaughtered for a time; the slaughter flow of steers will gain and pass its former level only after the number of animals being fattened as steers has been increased. Figure 15 illustrates the point:

Figure 15



S_t is the daily slaughter of steers over time. After a price increase, the flow is altered: S'_t falls. Even if by the end of the year, the daily slaughter rate S'_t has risen above S_t, total yearly slaughter should be smaller, i.e.,

$$\int_o^1 S'_t dt < \int_o^1 S_t dt.$$

Thus, the coefficient on price in the steer slaughter equation will be negative unless expectations are inelastic, yearlings withheld from slaughter can be slaughtered as young steers within the year, or an increase in steer slaughter is prompted by other factors.

A similar, though even smaller, effect is expected from weather change variables. While improved weather will make more feed available, lowering the opportunity cost of maintaining a steer and prompting retention, it does not change the long-run desired number of steers. A lower slaughter rate now increases the average age distribution of steers in the herd and should result in a higher slaughter rate later when the herd returns to the normal age distribution.

Yearlings. A price increase will reduce yearling slaughter in the short run, but the long-run effect of a sustained higher price will depend on whether it increases the flow of calves more than it changes the composition of slaughter. If the price increase comes from a shift in the demand for quantity, not quality of beef, the composition of slaughter will not be greatly affected and yearling slaughter is likely to increase. But the higher beef/grain relative price also increases the "least cost per pound" age, reducing the premium on beef from older animals which could prompt withholding more yearlings until they become steers. Better weather should also reduce yearling slaughter. Because calf slaughter is relatively minor, there are fewer calves to withhold to yearling age than there are yearlings to hold to steer age. Hence, as more food becomes available, yearling slaughter will fall.

Calves. Calf slaughter will be reduced in the short run both by an increase in relative price and by improved weather, particularly if the changes are too late to affect the number of calves born.

Cows. Cow slaughter should be sharply reduced in the short run by a relative price increase, provided that the increase is expected to last long enough to affect the value of the calf crop. Because the discretionary supply of heifers is always small and heifers must mature before being bred, an increase in the desired breeding herd must always be partially met by reducing cow slaughter in the short run. When heifer replacements mature, older cows will be slaughtered along with cows of "normal" slaughter age, temporarily increasing the rate of cow slaughter. Similarly, improved weather will prompt the retention of cows as extra feed becomes available, but the effect will neither be large nor long lasting.

Heifers. Heifer slaughter will be reduced in the short run by a relative price increase, as more are withheld for the breeding herd. The rate of heifer slaughter will be reduced until the breeding herd is of the desired size. Because the supply of discretionary heifers is small, this adjustment will require several years.[3] Improved weather has only a relatively temporary influence on the sustainable breeding herd, so it should not cause the retention of more heifers for breeders, although there may be some effect in temporarily increasing the heifer slaughter age.

Bulls. In the short run, bull slaughter should be reduced by a relative price increase proportionately more than for cows, because bull supply is more inelastic in the short run and because demand for bulls for breeding use will increase.[4] If the relative beef/grain price rises, the demand for bulls will increase. Bulls will be withheld from slaughter both to complement the increased cow breeding herd and to increase the calving rate.

Technological change, such as artificial insemination or a more supervised use of fewer bulls, may reduce the number of bulls required per cow, so the slaughter rate of bulls will rise until the desired smaller bull herd size is attained.

Specification of the Slaughter-Weight Equations by Animal Category

Although average slaughter weights vary only moderately from year to year, the explanation of this variation, both through the cattle cycle and over longer periods will provide a more accurate indication of the quantity of meat produced by slaughtering animals in the various categories. The most important independent variables in these equations are again prices and climate, but their expected effects are not always clear. A certain change that affects the weights of individual animals may have a different effect on the average weight of slaughtered animals because the change may alter the type of animals slaughtered. Recall that the theory indicated that individual animals will be fed to heavier weights when the beef/feed relative price rises, and probably when the discount rate falls or the weather improves. However, if the weights of animals within the herd are not homogeneous and if a certain change induces producers to slaughter animals of a particular type, the average slaughter weights could vary inversely with individual animal weights.

Heifers. This inverse relation between average slaughter weights and individual animal weights is especially likely with dual purpose animals, such as heifers which may be either fattened and slaughtered or retained for breeding. When the beef/feed relative price rises, it becomes more profitable to feed heifers longer before slaughter, but more heifers are also desired for the breeding herd. The net effect on the average slaughter weight depends on which heifers are withheld for breeding purposes. Experimental farm, extension workers, and beef experts advise keeping the healthiest, largest, and fattest. So the change in the average heifer slaughter weight depends on the current weight distribution of heifers, the number of additional heifers withheld for breeding purposes because of the price change, and the proportional change in individual slaughter weights resulting from the price change.[5]

For example, suppose the distribution of heifer weights were normal so that before the price increase one-half were being slaughtered each year. If, because of the price changes, only the lightest one-fourth was sold, the average slaughter weight would drop--unless the price change induces producers to feed animals for slaughter to heavier weights,[6] offsetting the other effect.

Cows. A price increase, and a corresponding increase in the size of the desired breeding herd, will have a similar, but smaller effect on the cow average slaughter weight. A price increase will induce producers to retain some additional cows, likely the healthiest of those available. The cow weight distribution is likely to be more homogeneous than that of heifers, and individual cows are not likely to gain as much by the fattening process. In essence, a cow is held only until she can no longer produce efficiently, then she is sold for slaughter. While the slaughter value is substantial, it is not particularly responsive to changes in age or feed. Cows are relatively inefficient converters of feed into beef, so a higher beef/grain relative price may slightly prolong the cow feeding period, but cow slaughter weights are more likely to be strongly affected by weather and other influences.

Calves. An increase in the beef/grain relative price will increase the capital values of calves relative to those animals in other categories unless enough calves can be withheld from slaughter to satisfy the increased herd demand. If veal demand is more price inelastic than beef demand, an increase in the beef/grain price will not greatly reduce calf slaughter and live calves will increase in value, and the calf average slaughter weight will also rise. If they have to choose, producers would tend to retain the larger of two calves of the same age for further fattening because it has more potential for weight gain. But whenever they fatten calves to older ages, they maintain them through their most efficient feed conversion period, thus reducing the premium for (older) veal. Then, the closer the calf gets to the "least cost per pound" age, the cheaper the beef becomes. Of course, meat quality changes are involved as well, but a beef/price increase should reduce the slaughter of the youngest calves first, thus increasing the average slaughter weight of calves. The effect of weather variation on calf slaughter weights should be insignificant. Suckling calves are relatively unaffected by the pasture availability, for cows can continue providing milk for some time after pastures have deteriorated. Pasture condition is important though to calves as they begin to graze, and all calves can be adversely affected by heat or shortage of water.

Yearlings. Yearlings are either slaughtered or retained for fattening to steer age. An increase in the beef/grain relative price will induce their being fed to heavier weights, but yearlings eventually become steers, so the effect of a price increase on slaughter weights of the yearling category is mixed. That is, it depends both on the individual weight effects and on the distribution of slaughtered yearlings. The proportion of yearlings slaughtered also depends importantly on consumer tastes-- that is, by the price differential between meat from yearlings vs. that from steers. Changes in consumer tastes within and among Argentine export markets can also significantly affect the age distribution of yearling slaughter.

Steers. As in other categories, changes in the average slaughter weight of steers depend both on changes in the age distribution of the slaughtered animals and on changes in individual animal weights. A beef/grain relative price increase makes further fattening of steers profitable, but also induces producers to withhold yearlings, perhaps until they become young steers. Because feed costs vary among regions, the optimum slaughter age varies regionally. In particular, yearlings being fattened in relatively high- cost feed areas, although retained awhile longer in response to a price increase are not likely to be fattened to steer age.[7] There is a great deal of potential, therefore, for significant variation in the age distribution of slaughtered steers. Moreover, a short-run feed constraint can suddenly raise the opportunity cost of feed, inducing producers to sell their heavy steers immediately to make room for other animals.

Bulls. There are no reliable data on the age distribution of the bull herd, but apparently it is very heterogeneous: Some uncastrated males fattened for slaughter are technically bulls but function as steers; some castrated oxen are classified as bulls. Only the stud animals from this larger "bull" population are the breeding animals. Therefore, the effect of parameter changes on the average slaughter weight of "bulls" is not possible to disentangle; meaningful interpretation of estimation results is difficult.

Estimation of the Slaughter and Slaughter-Weight Equations

Slaughter Equations

First, two general formulations of each slaughter equation were estimated. Further, estimation procedures involved a search for the best lag distribution for the price and weather variables. Finally, additional equations were estimated including variables representing influences other than weather and prices.

The slaughter equations were originally specified in the following generic form:

$$S_t = H_t - H_t^* + \epsilon_t$$

where

S_t=slaughter in year t

H_t=the existing stock (annual flow)

H_t^*=the desired stock of animals

ϵ_t=the disturbance term

H_t^* was specified as a function of certain variables, which in the most general case, are lagged values of the beef/grain relative price P and weather W:

$$H_t^* = f(\alpha_0 + \alpha_1 P_t + \alpha_2 P_{t-1}, \cdots + \beta_0 + \beta_1 W_t + \beta_2 W_{t-1}, \cdots),$$

so

$$S_t = H_t - \gamma - \Sigma \alpha_i P_{t-i} - \Sigma \beta_i W_{t-i} + \epsilon_t$$

where $\gamma = \alpha_0 + \beta_0$. A coefficient near unity was expected for H_t and the coefficients on the price and weather variables were anticipated to be negative.

The results of this first formulation are presented in Table 6. Slaughter in each category in year t was regressed on that category's stock level in t, the percentage change in the beef/grain relative price, $(\Delta P/P)_t$, the percentage change in the weather index, $(\Delta W/W)_t$, lagged past prices and weather, and a constant term. The percentage changes in price and weather rather than their levels in t were used on the assumption that producers base their expectations not only on past experience but also on the current rate of change of these variables. A separate weather variable was calculated for each category by weighting the proportion of live animals maintained in each geographic area represented.

The equations have high explanatory power and the coefficients on the change-in-price and the change-in-weather are negative in all but the steer equation; most are highly significant. Only a few of the coefficients of the lagged weather variables or the more distant price variables attain statistical significance at any reasonable level. Moreover, these coefficients frequently turn positive in $t-3$ before converging to zero, contrary to expectations. The Durbin-Watson statistic continues to signal the presence of positive autocorrelation, even after the variables were transformed using ρ.

Table 6.
Slaughter Equations, Initial Specifications, Aggregated and by Animal Category[a]

	H_t	Const.	$(\Delta P/P)_t$	P_{t-1}	P_{t-2}	P_{t-3}	$(\Delta W/W)_t$	W_{t-1}	W_{t-2}	W_{t-3}	$\bar{R}^2$	DW	SER	ρ
Eq. 1 S_t:	0.278	-9959	-25496	-21570	-389	6799	-7319	-163	-1	54	0.896	1.45	5148	0.743
	(4.83)	(0.24)	(3.33)	(5.21)	(0.13)	(2.41)	(1.00)	(1.42)	(0.01)	(0.97)				
Eq. 2 NS_t:	0.306	29551	-979	-5139	512	2225	3000	67	43	21	0.887	1.410	833	0.966
	(2.53)	(2.01)	(0.40)	(3.55)	(0.50)	(2.22)	(1.35)	(1.87)	(1.91)	(1.21)				
Eq. 3 YS_t:	0.151	9275	-6665	-1727	-748	-172	-3319	-18	-4	2	0.860	1.25	943	0.686
	(2.76)	(1.69)	(5.01)	(2.30)	(1.34)	(0.33)	(2.55)	(0.86)	(0.30)	(0.22)				
Eq. 4 TS_t:	0.037	7031	-5076	-3370	168	1291	-2076	-37	6	18	0.584	1.38	1389	0.764
	(0.73)	(0.63)	(2.39)	(3.00)	(0.20)	(1.70)	(0.97)	(1.19)	(0.31)	(1.18)				
Eq. 5 VS_t:	0.201	-8916	-7688	-6796	-45	2221	-1505	-44	-15	1	0.812	1.16	1716	0.787
	(3.64)	(0.60)	(3.05)	(4.93)	(0.04)	(2.43)	(0.61)	(1.21)	(0.64)	(0.03)				
Eq. 6 VQS_t:	0.388	13193	-10392	-5489	-1024	806	-8138	-103	-2510	10	0.883	1.56	1593	0.636
	(4.27)	(1.41)	(4.63)	(4.42)	(1.09)	(0.92)	(3.61)	(2.92)	(1.21)	(0.56)				
Eq. 7 BS_t:	-0.214	7602	-823	-447	-33	116	-337	0	2	2	0.928	1.49	154	0.968
	(1.25)	(2.53)	(3.70)	(3.63)	(0.38)	(1.50)	(1.69)	(0.09)	(0.90)	(1.36)				

a. The dependent variable in Equation 1 is S_t, the total number of animals slaughtered in year t. The dependent variables in Equations 2-7 refer to slaughter in individual categories: steers, NS_t; yearlings, YS_t; calves, TS_t; cows, VS_t; heifers, VQS_t; and bulls BS_t. The independent variables are with respect to the particular category. $(\Delta P/P)_t$ is the percentage change in the price of beef relative to an index of grain prices; P_t is the actual price of beef relative to an index of grain prices. $(\Delta W/W)_t$ is the percentage change in the weather index in year t; W_t is the weather index in year t. Weather variations in each location were weighted by the proportion of the relevant category maintained in the region of each weather observatory.

The equations with 17 degrees of freedom were estimaated by OLS after transforming the variables for first order autocorrelation, using the rho (reported in the last column) determined from the Cockrane-Orcutt interative procedure, checked by the Hildreth-Lu scanning technique on rho, to ensure that the convergence was at a global minimum of the sum of the squared residuals. The Durbin Watson statistic (DW) is that obtained after the transformation. The price and weather lags were constrained by a second-order polynomial distribution tied to zero in the year preceding the last lag. R^2 is the multiple correlation coefficient corrected for degrees of freedom; SER = the standard error of the regression; t-statistics are in parentheses.

And the coefficients on the herd stock variables were far from unity. Increasing the stock by one animal does not mean increasing slaughter by one according to these estimates; in fact the bull stock coefficient is even negative. What is striking though is the similarity of several of the coefficient estimates to the average rate of slaughter in each category (omitting bulls):

	Coefficient:	Slaughter Rate:
aggregate	.28	.25
steers	.31	.98
yearlings	.15	.20
calves	.04	.07
cows	.20	.11
heifers	.39	.24

This suggests that the slaughter decision is less flexible than originally assumed, and implies a model where producers plan to slaughter a certain proportion of their herd during the year and make only relatively small changes in their planned slaughter proportion as conditions change. It appears that producers plan to meet a customary demand for animals of each type. Because of the qualitative difference between finished animals and those which are still to be fattened, adjustments in these plans are relatively costly. As a result, the coefficients on price and climate appear to represent the linear addition to, or subtraction from, the normal or planned slaughter in each category. This is a subtle difference, but it suggests a modification in the model.

Several variations of a lagged adjustment model were considered, but none seemed satisfactory. Thus, a different interpretation was given to the estimated slaughter equation, based on a model involving no stock adjustment. Slaughter was viewed as composed of two components: a normal component related to the size of the herd, S_t^H, and a transitory component, S_t^T, reflecting the adjustments to the normal component brought about by variations in prices, climatic conditions, and the like. The estimated equation for $S_t = S_t^H + S_t^T$ becomes $S_t^H = \alpha H_t$ and $S_t^T = h(P_{t-i}, W_{t-i}, \cdots)$. This formulation implies that the coefficients of S_t^T might be affected by the size of H_t. Multicollinearity prevented meaningful estimation of a multiplicative relation between the S_t^H and S_t^T components, but the fact that H_t was relatively constant during the study period means that a linear specification of the transitory component is a good approximation, i.e.:

$$S_t^T = h(P_t, W_t, H_t)$$
$$= h^T(P_t, W_t) \cdot H_t^S$$
$$= h'(P_t, W_t) \cdot \theta, \text{ where } \theta \text{ is a constant.}$$

S_t^T could also be interpreted as the "part" of the "potential" cattle herd most easily switched into other activities such as crops. This amount could be relatively constant, even if H_t were not. This interpretation (S^T constant) seems preferable to H_t constant because if H_t were constant, it would not belong in the estimating equation, i.e.:

$$S_t = \alpha H_t + h'(P_t, W_t) \cdot H^S$$
$$= \alpha\theta + h'(P_t, W_t) \cdot \theta$$
$$= \theta(\alpha + h'(P_t, W_t)).$$

In sum, it is difficult to determine the theoretically correct interpretation of the coefficients to be estimated. It appears, though, that those in prices, climate, and other transient factors may be modeled simply as a linear addition-subtraction to the herd as these factors fluctuate.

Recall that the shape of the estimated lag distribution on prices differed from what was expected, i.e., in becoming positive. Producers were assumed to respond to an expected price when making their slaughter decisions; this expectation was modeled as a function of past prices and the current rate of change in price. But the relevant expected price is the one expected to prevail when the animal, or its product, will be sold. This expectation differs by category. For steers it is the price which will hold in the immediate future; for a breeding heifer, it is the average price prevailing over the period in which her calves will be born. Thus, the form of the lagged distribution may need to be specified differently for each category. Still, the distribution should never turn positive as did the first estimates.

There are three possible explanations for these counter indicated results. First, a severe reduction in slaughter in year $t+1$ caused by a price change in year t could force the constrained quadratic to overshoot the zero axis. However, the lag turned positive even when unconstrained. Second, the shape could reflect an over-reaction by producers. The dynamics of the supply response process in which animals are withdrawn from slaughter when the price increases could induce first overaction, then compensatory action. If this is the case, then producers are not forming price expectations by taking account of past prediction errors. That is, they are not learning from experience. If they considered their past prediction errors, they should be able to avoid overshooting their mark.

Third, and the most plausible: Changes in prices may cause basic changes in the quality of the stock variable. A price increase inducing producers to withold animals from slaughter changes the age distribution of the herd. The same effect, only sometimes more so, occurs within the categories. A change in the age distribution of the herd can easily affect the proportion of the herd slaughtered in future years. For example, in year $t+i$, the stock variable for steers, N_t^S, may include a number of animals to be slaughtered as young steers rather than old yearlings. Because in the model

$$S = S_t^H + S_t^T$$
$$= \alpha H_t + h(P_{t+i}, W_{t+i}),$$

α is constant, the effect of changing the proportion of the stock slaughtered each year over the cycle, as opposed to long-trend movements, is forced onto the price variables. This result suggests that disaggregation by animal categories was not sufficient to obtain homogeneous stocks. To reflect the cyclical variation in the age distribution of the herd stock, α should be a function of past prices:

$$\alpha_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \alpha_3 P_{t-3} + n_t,$$

which would transform the slaughter equation to:

$$S_t = \alpha_t H_t + h(P_{t-i}, W_{t-i}, \cdots)$$
$$= \alpha_0 H_t + \alpha_1 P_{t-1} H_t + \alpha_2 P_{t-2} H_t + \cdots$$
$$+ \beta_1 P_t + \beta_2 P_{t-1} + \cdots + \epsilon_t.$$

This specification did change the lag structure as expected in the aggregate and category slaughter equations. The "normal" proportion, α, became an increasing function of past prices, while the coefficients on past prices representing S_t^T either increased (becoming less negative) until reaching zero, or decreased and then increased to zero.[8]

But the equations generally evidenced high serial correlation, even after an attempted correction by the Hilduth-Lu technique, and rarely was more than one of the α_i coefficients significant even at the 10 percent level.[9] An exception is the aggregate equation for slaughter, presented in Table 7. All coefficients have the expected signs and most are significant at the 5 percent level.

Because of the general failure of the first formulation where S^T was distinguished from S^H and α was allowed to vary, I returned to the model where prices and climate affected only S^T, not S^H. The exercise, however, served to remind us that the coefficients on prices involve something more than the change in the magnitude of a desired stock of homogeneous animals.

In the second general formulation of the slaughter equations, the polynomial distributed lags were not forced through zero, a multiplicative stock-time trend variable was included in each equation along with the stock level, and $(\Delta W/W)_t$ was replaced by weather in year t. The proportion of the stock slaughtered in certain categories has varied over time, so the stock-trend variable, $t \cdot H_t$, is an attempt to capture this. For example, the secular increase in the calving rate provided an increasing number of heifers relative to the replacement needs of the breeding herd, so that a growing proportion of the heifer stock has been slaughtered over time. Because the rise in the calving rate has been constant, this effect can be formulated as:

$$S_t^H = \alpha_t H_t$$
$$= (\alpha_0 + \alpha_1 t) \cdot H_t$$
$$= \alpha_0 H_t + \alpha_1 (t \cdot H_t); \; t = \text{time trend}.$$

Similar arguments can be made for other categories. For yearlings α might represent the variation in proportion slaughtered as tastes change. The trend effect may also serve to represent technological change that affects slaughter.

Table 7
Estimation Results for the Aggregate Slaughter Equation Where
$\alpha H_t = (\alpha_0 + \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \alpha_3 P_{t-3})\, H_t$

S:	H	P1H[a]	P2H[a]	P3H[a]	P_t	P_{t-1}	P_{t-2}	W_t	W_{t-1}	W_{t-2}	$\overline{R}^2$	DW	SER
	0.263	0.0225	0.0236	0.0208	-13870	-17050	-12430	-109	-308	-271	0.936	1.60	4029
	(5.35)	(1.14)	(1.18)	(1.78)	(2.31)	(1.76)	(1.12)	(1.92)	(3.71)	(3.43)			

(t-statistics are in parentheses.)

a. $P1H = P_{t-1} \bullet H_t$; $P2H = P_{t-2} \bullet H_t$; $P3H = P_{t-3} \bullet H_t$.

Table 8
Slaughter Equations, Third Specification, Aggregated and by Animal Category[a]

	H_t	tH_t	Const.	$(\Delta P/P)_t$	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	W_t	W_{t-1}	W_{t-2}	W_{t-3}	$\bar{R}^2$	DW	SER	ρ
Eq. 1 S_t:	0.122	0.003	59704	-34391	-31090	-2422	5276	-7991	-83	-62	2	100	0.940	1.99	3893	0.814
	(1.05)	(1.77)	(1.45)	(6.01)	(7.34)	(1.11)	(2.59)	(2.14)	(1.45)	(0.87)	(0.02)	(1.67)				
Eq. 2 NS_t:	0.204	0.013	20868	-1750	-5552	796	2789	425	-14	12	20	12	0.908	1.57	1691	0.605
	(0.88)	(2.54)	(2.21)	(0.81)	(3.33)	(0.80)	(2.96)	(0.26)	(0.44)	(0.41)	(0.74)	(0.41)				
Eq. 3 YS_t:	0.350	0.003	14934	-6792	-3966	-389	-83	-2783	-8	21	30	18	0.866	1.71	829	0.673
	(0.38)	(1.53)	(2.70)	(5.71)	(4.28)	(0.82)	(0.19)	(3.42)	(0.62)	(1.49)	(2.11)	(1.45)				
Eq. 4 TS_t:	0.065	0.003	18051	-7205	-5985	-278	849	2605	23	-2	12	21	0.754	1.80	1078	0.866
	(1.23)	(1.88)	(2.52)	(5.36)	(5.63)	(0.45)	(1.55)	(2.64)	(1.33)	(0.14)	(.072)	(1.46)				
Eq. 5 VS_t:	0.010	0.003	5552	-9920	-9336	-596	1784	-2195	-19	-27	-18	9	0.857	1.71	1498	0.895
	(1.05)	(1.80)	(0.37)	(5.10)	(6.45)	(0.65)	(2.19)	(1.57)	(0.81)	(0.97)	(0.60)	(0.37)				
Eq. 6 VQS_t:	0.159	0.005	17733	-9574	-7451	-640	1269	-1703	-61	-39	-4	43	0.901	1.30	1471	0.859
	(0.921)	(1.66)	(1.79)	(4.55)	(4.95)	(0.78)	(1.64)	(1.18)	(2.44)	(1.53)	(0.17)	(1.93)				
Eq. 7 BS_t:	0.336	0.007	4529	-599	-445	42	191	0	-3	1	3	4	0.942	1.85	132	0.459
	(1.97)	(5.41)	(2.22)	(2.72)	(3.27)	(0.58)	(2.67)	(0.00)	(1.34)	(0.25)	(1.18)	(1.95)				

a. See Table 6 for explanation of symbols. The only addition is the multiplicative variable tH_t, and its respective category counterparts, where the herd stock is multiplied by a time trend.

The equations for this formulation (Table 8) explain the variation in slaughter well, but the significance level of many of the coefficients is low. The lag structures were similar in most cases to the tied lag specification.

A number of variations of each equation was next estimated to compare results. For these equations (Table 9) more than one specification are presented when different versions appeared to have equal merit.

Most of the coefficients in the equations predicting total slaughter are now significant at the 10 percent level. When both H_t and tH_t were included, $\bar{R}^2$ and the Durbin-Watson statistic rose and the estimated rho dropped. The coefficient on tH_t is positive as expected, perhaps caused by declining mortality rates, or a move toward marketing younger animals. The only price coefficient which is not significant in this equation is on P_{t-2} as the lag passes from negative to positive values. A price increase in year t appears to have a negative effect on the transition component of slaughter in years t and $t+1$, leave it unchanged in year $t+2$, and increase it in years $t+3$ and $t+4$. This is not the same as saying that slaughter itself is reduced or increased by the amount of the respective coefficients in these years, for a reduction one year increases the herd the next. It is the net effect from the "permanent" and "transitory" components which is the true price effect.

Note that the price and weather elasticities of slaughter must be calculated with care, i.e., if the equation for aggregate slaughter were:

$$S_t=\alpha H_t+\beta_0 P_t+\beta_1 P_{t-1}+\beta_2 P_{t-2},$$

the elasticity of slaughter with respect to current prices is:

$$\frac{E_S}{E_{P_t}}=\frac{\beta_0/\bar{S}}{1/P}$$

but with respect to last year's price it is:

$$\frac{E_S}{E_{P_{t-1}}}=\frac{\beta_1-\alpha\beta_0/\bar{S}}{1/\bar{P}}.$$

That is, animals "withheld" in year t in response to a price increase in that year will increase the herd and hence slaughter in year $t+1$. As a result, the net effect on slaughter in year $t+1$ must include the direct effect on the transitory component in that year and also the effect on the permanent slaughter from the animals "withheld" last year. The same effects hold for each of the individual categories, although animals "withheld" from slaughter one year may not increase the stock of the same category the next year, but rather a different category. For example, the elasticity of cow slaughter in year $t+2$ depends both on the coefficients α_V, β_0^V, and β_1^V in cow slaughter equation and also on β_0^{VQ} in the heifer slaughter equation.

In Equations S_1 and S_2, weather first reduces and then increases transitory slaughter, S_t^T, though the impact of weather variation is less than that from price variation (when the relative magnitudes coefficients, standardized by the standard deviations of their respective variables were compared).

In the steer category, Equation N_1 includes both a stock and stock-trend variable, but only the latter is significant. Neither of the coefficients on the percentage change in price or weather is significant, and both have positive signs. Further, the distributed lag on prices is negative only for P_{t-1} and that on weather is never negative. This would suggest that steer producers respond to a price increase by dumping their animals on the market rather than withholding them for futher fattening. The positive coefficient on tH_t in Equation N_1 indicates that a rising proportion of the steer herd has been slaughtered over time. This is consistent with evidence that the slaughter weights of steers have declined over time, implying that they are being slaughtered younger and, hence are less likely to remain in the herd as steers more than one year.[10]

Equation N_2 includes the variable $EXPB_{t-1}$ as a proxy for variation in the beef grading scale.[11]

EXPB is the percentage of total beef produced which is exported to the United Kingdom as chilled beef in year $t-1$. The traditional export market for Argentine beef was the United Kingdom, so most of the grading scales were originally set with this market in mind.[12] Both beef exports as a per-

Table 9
Slaughter Equations, Additional Specifications,
Aggregated and by Animal Category[a]

	H_t	tH_t	Const.	$(\Delta P/P)_t$	P_t	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	$(\Delta W/W)_t$	W_t	W_{t-1}	W_{t-2}	W_{t-3}	W_{t-4}	$EXPB_{t-2}$	$\overline{R^2}$	DW	SER	ρ
Eq. S_1:	0.147	0.0021			-16060	-6483	-87	3125	3154	-4625		-170	79	190	164		0.929	1.94	4237	0.489
	(1.95)	(1.95)			(6.89)	(4.19)	(0.05)	(1.88)	(2.77)	(0.79)		(1.42)	(0.92)	(3.73)	(3.56)					
Eq. S_2:	0.131	0.0025		-27820		-18970	-3854	4348	5633	-9914		-178	79	194	168		0.924	1.69	4400	0.500
	(1.64)	(1.76)		(4.78)		(5.83)	(1.90)	(2.07)	(3.49)	(1.78)		(1.40)	(0.88)	(2.66)	(3.46)					
Eq. N_1:	0.222	0.0144		1708		-3260	1231	3271	2861	865		31.3	58	47			0.897	1.65	1781	0.414
	(1.17)	(3.40)		(0.79)		(2.75)	(1.70)	(4.18)	(4.69)	(0.37)		(0.82)	(2.71)	(2.52)						
Eq. N_2:	0.697			6423		-261	3209	4409	3340	-4569		-85.9	32	61		-31521	0.894	2.53	1801	0.115
	(10.20)			(2.70)		(0.25)	(4.05)	(5.47)	(5.60)	(1.90)		(2.58)	(2.70)	(3.13)		(3.57)				
Eq. Y_1:	0.143		10307	-7382		-1804	-1306	-839	-403	-2673							0.836	1.70	917	0.592
	(2.83)		(2.51)	(5.71)		(2.65)	(2.70)	(1.78)	(1.18)	(3.16)										
Eq. Y_2:	0.151			-6665		-1727	-747	-172		-3319	9274	-18	-4	2			0.847	1.52	043	0.686
	(2.76)			(5.01)		(2.30)	(1.34)	(0.33)		(2.55)	(1.69)	(0.86)	(0.30)	(0.22)						
Eq. T_1:	0.017		17034	-5323	-1377	-1836	-1377			-3815		-467					0.545	1.70	1442	0.754
	(0.34)		(2.11)	(3.33)	(2.79)	(2.79)	(2.79)			(1.72)		(1.50)								
Eq. T_2:	0.021		17005	-6134		-3432	-132	1012			-40	-29	-16				0.610	1.30	1335	0.713
	(0.59)		(2.32)	(3.81)		(3.19)	(0.18)	(1.52)			(2.03)	(1.52)	(0.94)							
Eq. V_1:	0.170	0.0015			-5786	-2377	-94	1063	1094		-37	-378	-32	-19			0.804	1.66	1755	0.830
	(2.63)	(1.08)			(5.94)	(3.18)	(0.12)	(1.35)	(2.07)		(1.66)	(1.46)	(1.06)	(0.87)						
Eq. V_2:	0.211	-0.1430		-8558		-5564	-1235	1136	1547	-4019		-16	-41	-7	7		0.783	1.49	1848	0.670
	(4.61)	(0.86)		(3.69)		(3.71)	(1.32)	(1.15)	(2.04)	(3.69)		(2.17)	(1.79)	(0.32)	(0.44)					
Eq. VQ_1:	0.490			-8951		-4337	-1157	626	1011	-8260		-127	-21	35	42		0.920	1.82	1322	0.400
	(11.8)			(5.42)		(5.25)	(2.06)	(1.04)	(2.22)	(5.14)		(5.04)	(2.21)	(3.18)	(4.23)					
Eq. VQ_2:	0.329	0.0037		-9665		-5062	-1464	579	1067	-7236		-102	2	48	49		0.921	1.67	1311	0.484
	(2.30)	(1.26)		(5.72)		(5.25)	(2.38)	(0.945)	(2.31)	(4.14)		(-3.34)	(0.14)	(2.85)	(3.96)					
Eq. B_1:	0.0056		-65	-349	-124	23	93	85.1		-4		0	3	3	2		0.946	1.63	132	0.691
	(8.96)		(0.525)	(4.67)	(2.30)	(0.37)	(1.49)	(2.01)		(2.21)		(0.40)	(2.70)	(3.21)	(3.33)					

a. See Table 6 for explanation of the symbols. Additionally, VB = the number of mature cows in the breeding herd, VN = the number of two year old heifers in the breeding herd, $EXPB_{t-1}$ = the percentage of total beef produced which was exported in the United Kingdom as chilled beef in t-1.

cent of total slaughter and exports to the United Kingdom as a percent of total exports declined over the study period studied. The coefficient on $EXPB_{t-1}$ is significant and negative and its inclusion increased $\bar{R}^2$. An interpretation is that an increase in the export of animals to the United Kingdom reduces transitory slaughter, because heavier, older steers are needed for the UK market.

In the yearling slaughter, equations Y_1 and Y_2, the coefficients on $(\Delta P/P)_t$ are large, negative, and statistically significant; the coefficients on P_{t-1} through P_{t-4} are negative and decline monotonically in absolute value. This pattern suggests that the reduction in slaughter which occurs after a price increase is felt for some years, considerably longer than in the other categories, and indicates that a large proportion of the yearlings is retained to be fattened and slaughtered as steers. Weather has an important effect only in year t, judged by the large significant coefficient on $(\Delta W/W)_t$.

The $\bar{R}^2$s are lower in the calf equations, but both weather and prices have the expected negative coefficients, though the lags are short. The best specification appears to be Equation T_1, where except for the stock level, the coefficients are significant at the 5 or 10 percent level. Weather apparently has a stronger impact on slaughter in $t-1$ than in t. That is, it may take some time for bad weather to affect pastures and hence slaughter.

The coefficients of the cow slaughter equations have the expected signs and magnitudes and nearly all are significant. In the V_1 multiplicative trend-herd variable has a small but positive coefficient indicating that an increasing proportion of the cow herd was sold, which reflects either a shortening of a cow's average life span or a reduction in mortality. Both have probably occurred.[13] The negative coefficients on lagged price for t through $t-2$, indicate that producers require considerable time to build up their herd after a price increase as it requires several years for a young animal to mature. Roughly 75 percent of the heifer herd is retained for replacement purposes each year, and only 11 percent of the cow herd is slaughtered, so there is little opportunity to make large rapid percentage increases in the breeding herd. The positive coefficients on prices $t-3$ and $t-4$ could represent the greater than normal proportion of the herd slaughtered as the animals which were withheld in response to the price increase in t, age. All coefficients on weather are negative with the largest in absolute magnitude occurring in $t-1$ and $t-2$.

The equations for heifer slaughter do surprisingly well, for this is the most volatile category.[14] $\bar{R}^2$ is greater than 0.9 and nearly every coefficient is statistically significant. The coefficients on $(\Delta P/P)_t$, $(\Delta W/W)_t$, P_{t-1} and C_{t-1} are all large and negative, indicating high elasticities of heifer slaughter with respect to an increase in the beef/grain relative price or to an improvement in weather.

Bull slaughter is markedly different from that in other categories. Although both the size of the bull herd and the number of bulls slaughtered annually rose considerably during the entire study period, BS/B (the proportion slaughtered) increased particularly around 1955/56.[15] The proportional rate of slaughter averaged 8 percent between 1937/38 - 1955/56 and then ranged from 11 to 17 percent between 1956/57 - 1966/67.[16] The increased proportion is due principally to the fact that an increasing number of uncastrated males are being grown as steers for slaughter, but are classified as bulls. Also, producers have attempted to increase productivity by culling impotent and aged bulls.[17]

Next, an equation in each category in Table 9 was reestimated using additional explanatory variables to test for the impact of changes in various exogenous factors on the slaughter rate: the lagged money wage of a rural worker, divided by the Buenos Aires cost-of-living index: $WAGE_{t-1}$; the percentage change in the exchange rate in t and $t-1$, FX_t and FX_{t-1}; the percentage change in the cost-of- living index in $t-1, CL_{t-1}$; and the ratio of the wholesale price indices of rural to nonrural goods in $t-1$, RNR_{t-1}. Results appear in Table 10. $WAGE_{t-1}$, was used to test whether rising labor costs had forced producers out of grain into cattle production during 1945-1952.[18] Because cattle production is substantially less labor intensive, it is frequently alleged that legislated rural wage increases contributed to the shift. Contrary to expectations, five of the seven coefficients are positive.[19] Actually, it turns out that rural wages were not as important a

Table 10
Slaughter Equations, Aggregated and by Animal Category with the Inclusion of Additional Variables.[a]

	H_t	tH_t	$(\Delta P/P)_t$	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	$(\Delta W/W)_t$	W_{t-1}	W_{t-2}	W_{t-3}	W_{t-4}	$EXPB_{t-1}$	$WAGE_{t-1}$	FX_t	FX_{t-1}	CL_{t-1}	RNR_{t-1}	$\overline{R^2}$	DW	SER	ρ
S_t:	0.227		-28135	-22170	1330	8721		-12857	-334	-96	29	71		9486	3861	6602	5309	24435	0.947	1.27	3673	0.635
	(7.48)		(4.68)	(5.49)	(0.40)	(3.20)		(2.46)	(3.84)	(2.45)	(1.01)	(2.17)		(0.71)	(0.92)		(1.07)	(2.16)				
NS_t:	0.567		6072	-2323	2192	4084	3353	-8260	-148	52	101		-43077	8358		-6739	530	7799	0.897	2.44	1782	0.10
	(4.60)		(2.08)	(1.32)	(2.32)	(4.46)	(4.63)	(2.19)	(2.92)	(2.59)	(3.02)		(3.35)	(1.16)		(2.22)	(0.16)	(1.84)				
YS_t:	-0.301	-0.0042	-5885	676	946	721		-2046	-9	-28	-25			-5090		4944	1025	6178	0.915	2.15	667	0.200
	(4.41)	(2.73)	(4.22)	(1.07)	(2.20)	(1.79)		(1.85)	(0.41)	(2.17)	(2.11)			(2.81)		(4.60)	(1.15)	(3.40)				
TS_t:		-0.0340	-4596	-1711	2779	3349		-2054	-39	-9	4			-1611	1175	5569	1761	10836	0.830	1.80	895	0.513
		(1.54)	(2.92)	(1.67)	(3.59)	(4.91)		(1.38)	(1.57)	(0.97)	(0.40)			(0.49)	(1.11)	(3.78)	(1.31)	(4.27)				
VS_t:	0.186		-9923	-5523	-1134	1249	1627	-1052	-26	-47	-50	-34		3655	2122	2757	515	273	0.760	1.51	1944	0.695
	(3.67)		(3.14)	(2.47)	(0.73)	(0.93)	(1.77)	(0.42)	(0.67)	(2.04)	(1.91)	(1.66)		(0.54)	(0.98)	(0.91)	(0.19)	(0.05)				
VQS_t:	0.278	0.0040	-11781	-7715	-1881	691		-8257	-101	-12	48	49		7639		462	3226	1352	0.932	1.78	1202	0.331
	(1.90)	(1.14)	(5.51)	(5.22)	(1.64)	(0.76)		(2.85)	(0.07)	(0.07)	(2.62)	(3.73)		(1.72)		(0.26)	(2.06)	(0.33)				
BS_t:	0.005		-710	-570	-224	-14	61	-580	-11	-1	4	4		1279	0392	-679	-391	1322	0.945	2.42	131	0.578
	(1418)		(3.92)	(6.08)	(3.77)	(0.30)	(2.09)	(2.95)	(5.83)	(1.00)	(3.97)	(4.97)		(5.04)	(1.86)	(3.73)	(2.76)	(4.27)				

a. See Table 6 for explanation of the symbols. Additionally, $WAGE_{t-1}$ = the real wage of a rural laborer in t-1; FX_t = the rate of change of the foreign exchange rate in t; FX_{t-1} = the rate of change of the foreign exchange rate in t-1; RNR_{t-1} = the index of the relative wholesale prices of rural and nonrural goods in year t-1; CL_{t-1} = the rate of change of the cost-of-living index in t-1.

factor as were government intervention in tenancy contracts and government discrimination against agriculture in general in inducing the shift. Both intervention and discrimination reduced the demand for agricultural labor, causing a positive correlation between the wage series and the shift out of grains.[20]

The inclusion of the foreign exchange variables was to test producer slaughter response to changes in the inflation rate with a negative effect on slaughter expected if producers think that foreign demand will gradually increase from a devaluation. The coefficient on FX_t was never significant, but the strong positive effect of FX_{t-1} in several of the equations suggests that devaluations have some independent effect on slaughter.[21]

An increase in the rate of inflation could improve producers' expectations about future beef prices or it could be a proxy for producers' discount rate--that is, as the effective rate of interest declines producers would hold animals beyond their ordinary optimal slaughter age for use as a wealth hedge.[22] The wage-price spiral in Argentina followed a definite pattern. As domestic prices rose, exporters and consumers were caught between falling external demand and falling real incomes, respectively. Devaluation improved the exporters' situation, but raised prices of important wage goods which induced workers to press for wage increases. Manufacturers, facing rising import costs for intermediate goods and rising wages, increased their prices, continuing the cycle. An increased cost- of-living may decrease consumer demand for beef and the relative beef price. If producers recognize this cycle, an increase in the rate of inflation might induce them to sell animals immediately. The coefficient on CL_{t-1} was significant at the 10 percent level only for heifers and bulls, so it appears that inflation was not a terribly disruptive influence independent of its effect on the relative beef/grain price.

The terms-of-trade variable, RNR_{t-1} was entered to reflect changes in the relative opportunity costs between agricultural and nonagricultural investments. Besides the intrasectoral price response, i.e., between field grain and cattle production, there is also an intersectoral shift between rural goods and industrial goods as relative prices change. While *RNR* oversimplifies what actually takes place, an increase in *RNR* is expected to increase resources going to beef production and cause herds to be built up, so the coefficients on *RNR* should be negative. Instead, the coefficient on *RNR* was usually positive indicating that an increase in the intersectoral terms of the trade favoring agriculture caused greater slaughter.

This would seem to be a perverse result, except that the terms of trade variable is positively correlated with movements in the level of herd stocks and with the level of slaughter. For example, the simple correlation coefficients between *RNR* and *N* and *NS* are respectively 0.51 and 0.41. An increase in the agricultural terms of trade is associated with a rise in the cattle herd and with the number of animals slaughtered. However, the rise in the terms of trade also increases the rate of slaughter, suggesting either that new investment increases the efficiency of production and thereby the rate of slaughter, or that the rise in the terms of trade is associated with a different composition of slaughter.[23]

Thus, few of these additional explanatory variables performed as expected. But there is still another problem with the equations as specified in Table 9. Note that the coefficients on the stock levels α_i in Table 9, where i is the particular category, are generally *not* equal to the average rate of slaughter in that category; for example $\alpha_{VQ} \neq \overline{VQS}/\overline{VQ}$. The reason is that the variables which affect the transitory component of slaughter are lagged price and climate. Negative coefficients imply that this transitory component will always be negative. Then in the equations where the constant is suppressed, α_{VQ} must be less than $\overline{VQS}/\overline{VQ}$, and α_i yields the "maximum" or "minimum" percentage slaughtered each year, changes in price and climate determine how far actual slaughter is below or above this percentage.[24] While this result is somewhat plausible, α_i modeled as the average slaughter rate seems more reasonable.

To do so, differences from the mean price and climate were used instead of their levels as independent variables affecting "transitory" slaughter. This is the same as adding a constant term constrained to equal the sum of the coefficients of the variables

Table 11
Slaughter Equations, Aggregated and by Animal Category, Using Differences from the Means of the Price and Climate Variables[a]

	H_t	tH_t	$(\Delta P/P)_t$	P_t	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	$(\Delta W/W)_t$	W_t	W_{t-1}	W_{t-2}	W_{t-3}	W_{t-4}	$EXPB_{t-1}$	$\overline{R^2}$	DW	SER	ρ
S_t:	0.159	0.0018	-28322		-18510	-4227	3621	5030	-29322		183	23	123	115		0.915	1.74	4659	0.529
	(12.98)	(3.10)	(4.35)		(5.38)	(1.79)	(1.54)	(2.88)	(4.35)		(1.99)	(0.36)	(2.12)	(2.82)					
NS_t:	0.929	0.0021	9927	-2548	11	3233	3742	2665	668		-8	49	96	53	-22157	0.838	2.31	2236	0.213
	(10.51)	(0.45)	(3.18)	(2.26)	(1.24)	(2.95)	(3.46)	(3.65)	(0.21)		(0.17)	(1.47)	(2.21)	(2.33)	(1.74)				
YS_t:	0.210		-6845		-1620	-1030	-563	-220	-3345		-16	-7	-1			0.820	1.56	964	0.683
	(19.50)		(5.08)		(2.19)	(2.00)	(1.12)	(0.60)	(2.49)		(0.69)	(0.49)	(0.12)						
TS_t:	0.056		-2230	-2541	-857	128	414	-26			-23	-14				0.588	1.67	1393	0.718
	(7.45)		(1.39)	(2.91)	(1.39)	(0.17)	(0.68)	(1.54)			(1.35)	(0.96)							
VS_t:	0.094	0.0096	-8928		-5632	-743	1526	1773		-18	-27	-27	-18			0.765	1.44	1921	0.627
	(6.08)	(1.32)	(4.15)		(3.54)	(0.77)	(1.58)	(2.47)		(1.04)	(1.04)	(1.04)	(1.04)						
VQS_t:	0.123	0.0065	-10838		-5723	-1928	292	934	-10838		-95	0	48	48		0.914	1.54	1363	0.525
	(2.69)	(2.94)	(5.71)		(5.74)	(2.84)	(0.43)	(1.83)	(3.53)		(2.73)	(0.02)	(2.33)	(3.36)					
BS_t:		0.0060	53	-353	-132	13	84	79	-201		-4	2	4	4		0.945	1.92	133	0.694
		(22.07)	(0.32)	(4.85)	(2.30)	(0.195)	(1.26)	(1.77)	(1.12)		(1.24)	(0.80)	(2.45)	(3.05)					

a. See Tables 6 and 9 for an explanation of the symbols.

times their respective means.[25] The resulting α_i coefficients were very close to the average rate of slaughter and their respective t-statistics increased substantially. The signs, magnitudes, and significance levels of the coefficients on the price and climate variables were similar to their counterparts in Table 9 as were the $\bar{R}^2$s (Table 11). Now the α_i coefficients represent the average rate of slaughter in the category and the price and climate variables determine the annual fluctuation about this average.

The Average-Slaughter-Weight Equations

Because the average-slaughter-weight equations are more straightforward and easier to interpret than the slaughter equations, and because they will be discussed in more detail in the next section, results are presented in Table 12 with only brief comments. The dependent variables for the individual category equations are their respective average live weights at the time of sale to slaughter, while the dependent variable for the aggregate equation is their average dressed weight. Changes in this variable reflect changes in the dressing percentages of the slaughtered animals, changes in individual weights, and the slaughter composition. Besides the price and weather variables used in the slaughter equations, a time trend, t, and the percentage of the herd vaccinated against hoof-and-mouth disease in $t-1$, VAC_{t-1}, are included. Note that the price and weather variables are entered at their levels rather than as differences from their means.

The aggregate equations. $\bar{R}^2$ is lower than for most of the individual category slaughter-weight equations, indicating the difficulty of capturing the effects of changes in the composition of slaughter in a single aggregate equation. Most coefficients carry the expected signs and are significant. The coefficients on the rate of change in price and on the lagged prices are all positive and significant through year $t-2$ indicating that a price increase results in heavier slaughtered animals. The response to weather is also positive. The larger coefficient on $(\Delta W/W)_t$ than on W_t suggests that the strongest effect of weather occurs with a lag because weather affects pasture quality only gradually.

Steers. The weak price effect may indicate either that steers are not held back very long in response to an increase in the relative price, or that the age distribution of steer slaughter is altered sufficiently to make the average weight relatively stable. Better weather tends to increase the average slaughter weight as does British export demand. Animals exported to Great Britain were traditionally heavier. The result suggests that the greater was the proportion of output exported to Great Britain when the animals were born in $t-2$, the heavier the weights to which they are fed.[26]

Yearlings. The insignificance of the weather coefficients may reflect weather's net effect of changing the age distribution of yearling slaughter (negative) and of causing individual yearlings to be fattened to heavier weights (positive). Prices have a significant positive effect on yearling slaughter weights.[27]

Calves. The insignificance of weather on calf slaughter weight is no doubt due to the fact that calves suckle rather than graze.

Cows. Most coefficients have the expected signs and are statistically significant at least at the 10 percent level. The negative coefficient on t reflects the substantial secular decline in the average weight of cows (that is, in the size of mature animals). The positive coefficient on VAC_{t-1} suggests that the hoof-and- mouth vaccination program and/or associated improvements in herd management have increased the slaughter weight of cows, presumably by improving their health.

Heifers. The current rate of change of price has a significant positive coefficient of large absolute magnitude, but lagged prices are not significant. This suggests that individual animals may be withheld temporarily, but that the feeding program for heifers is not strongly affected by the beef/grain price ratio. The significant negative coefficient on the time trend is of smaller absolute magnitude than the corresponding coefficient in the cow equation.

Bulls. The coefficients again indicate that the size of mature cattle in Argentina declined over the study period, despite an improvement in the health and weight of

Table 12
Average Slaughter-Weight Equations Aggregated and by Animal Category[a]

	Const.	t	SS_{t-1}	$(\Delta P/P)_t$	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	$(\Delta W/W)_t$	W_t	W_{t-1}	W_{t-2}	W_{t-3}	W_{t-4}	$EXPB_{t-2}$	$\overline{R}^2$	DW	SER	ρ
Eq. 1 W_t:	150	0.25	-10.57	20.91	9.30	4.80	1.75	0.147	1.86	0.112	0.115	0.097	0.059			0.703	1.72	3.36	0.057
	(7.33)	(0.53)	(0.98)	(4.00)	(4.55)	(3.35)	(1.22)	(0.14)	(0.39)	(1.93)	(2.75)	(1.99)	(1.57)						
Eq. 2 W_t:	150			16.8	7.66	3.86	1.31	0.024		0.130	0.133	0.112	0.068			0.720	1.51	3.29	0.255
	(13.79)			(4.44)	(3.93)	(2.82)	(0.91)	(0.02)		(2.63)	(4.37)	(3.51)	(2.74)						
Eq. 3 WN_t:	420	-2.63	31.9	9.71	2.65	2.04	1.40	0.720	20.11		0.407	0.147	0.008	-0.057	87.2	0.925	1.77	5.71	0.711
	(7.46)	(1.62)	(1.17)	(1.17)	(0.57)	(0.64)	(0.47)	(0.33)	(2.43)		(2.45)	(1.43)	(0.10)	(1.06)	(1.98)				
Eq. 4 WY_t:	311	1.31	-18.7	5.34	2.76	-2.70	-3.63									0.856	2.24	2.31	0.126
	(61.26)	(5.55)	(3.04)	(1.69)	(2.05)	(2.64)	(3.58)												
Eq. 5 WT_t:	236	-0.98	15.9	3.09	5.39	-3.45	-5.25			-0.029	-0.057	0.047				0.535	1.76	3.09	0.511
	(13.46)	(1.70)	(1.23)	(0.741)	(2.14)	(2.06)	(3.31)			(0.604)	(1.19)	(1.15)							
Eq. 6 WV_t:	449	-4.00	40.9	14.5	14.4				9.23		0.282					0.907	1.95	6.28	0.292
	(18.49)	(4.33)	(1.81)	(1.83)	(1.45)				(1.78)		(1.83)								
Eq.7 WVQ_t:	282	-0.80	12.26	12.26	3.03	1.73	0.717			0.192	0.116	0.052				0.840	2.13	3.60	0.157
	(19.62)	(5.01)	(2.86)	(2.86)	(1.37)	(1.00)	(0.41)			(3.51)	(2.38)	(1.18)							
Eq. 8 WB_t:	730	-10.70	167	-35.54	-25.2						0.072	0.158				0.906	2.02	11.8	0.532
	(16.03)	(5.22)	(3.46)	(2.50)	(2.399)						(0.41)	(0.01)							

a. See Tables 6 and 9 for an explanation of all symbols except t = a time trend with unit increase each year, and SS_{t-1} = percentage of the herd vaccinated against hoof-and-mouth disease in t-1.

The average slaughter weights for the respective categories during the period were $\overline{W}$ = 213; $\overline{WN}$ = 454; $\overline{WY}$ = 323; $\overline{WT}$ = 205; $\overline{WV}$ = 434; $\overline{WVQ}$ = 311; $\overline{WB}$ = 536. The dependent variables in individual categories are the live weights (kg) at time of sale to slaughter; for the aggregate equation it is the average dressed weight of a slaughtered carcass.

animals from the hoof-and-mouth disease program. Weather appears to have very little effect, but this may be due to the heterogeneity of the bull stock. The most plausible explanation for a sharp drop in weight in response to a price increase is again the heterogeneity of the bull stock. A price increase may prompt the slaughter of younger and lighter "bulls," thereby lowering the average slaughter weight.

Endnotes to V.

1. The distinction sought between "short run" and "long run" is the same usually made in static theory, even though the cattle sector never actually reaches a state of long-run equilibrium. Short-run effects are reflected by the coefficients of the estimated model. "Short run" means in this context, sometimes one year, sometimes a few more.

2. Effects of the weather may be measured by either the level of an index or the change in its level. A certain amount of feed is needed to maintain a certain number of animals. If a weather-induced variation in feed supply occurs, producers will have to adjust herd size. Which of the two variables best captures the "unplanned" feed gain or loss and the accompanying repercussions of the desired herd level depends largely on the formation of producer expectations regarding weather. If producers view weather as a random variable with constant mean, their expectaions will be based on long-run observations, regardless of recent experience, making level the better variable. If, however, producers extrapolate from recent experience, the change in level would be superior. Also, past weather experience may be important if pastures deteriorate or improve rather slowly even though producers may adjust their herds to weather-induced feed supply variations rather quickly. Weighing these several considerations led me to use a change-in-weather level in the current year as well as a distributed lag on its level.

   The beef/grain relative price is primarily a proxy for the opportunity cost of land where the alternative is to grow commercial grain crops for cash sale. As such, it is more a long-run measure of desired herd size. The weather index, in contrast, is a short-run measure allowing us to represent feed availability. Note that only one cattle price is used in these equations. To the extent that the relative prices of the categories differ from time to time, this is inferior to using the own-price for each category. But theoretically, these relative prices should not vary substantially, and empirically they do not.

3. Recall that calving rate had an important influence on the rate of heifer slaughter. A higher calving rate means a higher stock of heifers relative to the breeding herd. If the proportion of cows replaced each year is unchanged, a smaller percentage of heifers is needed as replacements, so heifer slaughter will rise.

4. As will be shown later, empirical work will suggest that the bull herd is not homogeneous. Rather, a substantial percentage of the "bull" herd is used for draft power or raised for beef. The result is that the bull slaughter equation does not conform closely to one representing breeding animals, whose capital value would be highly sensitive to price changes.

5. Note that the decision about which heifers to retain for breeding and which to fatten for slaughter is usually made several months before actual slaughter. Therefore, although heavy weight may be an important original criterion for selecting breeding animals, producers are not likely to withhold their heaviest fatted heifers from slaughter.

6. This is a short-run phenomenon. Although the prices of beef and feed and the interest rate are used as parameters to determine the optimal slaughter age, they are exogeneous only in a partial equilibrium sense. Whatever the general equilibrium level of the "parameters," if no change in the production function or in the composition of slaughter occurs, the percentage of heifers being slaughtered in equilibrium must be the same as before the parameter change. Hence, for any persisting increase in the beef/grain price ratio, the average heifer slaughter weight would be greater. The difficulty arises not so much in determining the equilibrium effect of a "parameter" change, but the more immediate effect.

7. Recall the argument for the popularity of veal in Europe.

8. While weather effects are similar to price effects on slaughter, they are weaker, and there is no reason to use them in the reformulation of α.

9. When the model was estimated in log-linear form, most of the standard errors were larger relative to their coefficients than were their counterparts in the linear model.

10. The mature size of cattle has also been declining, which could be a factor.

11. The grading scale, which determines the relative price per pound for animals within the same category, can have an independent effect on the average weight and hence on the ages at which these animals will be sold. The grading system is government controlled and was set for the purpose

of maintaining the production of a particular type of animal with respect to weight and fat. Changes in the classification premiums have been frequent and are difficult to quantify. There were five basic classifications and several scales within each, and the relative prices which animals of each "scale" commanded varied substantially.

12. During World War II, when only frozen and canned beef could be exported, the Argentine authorities were concerned that the reduction of the market for higher quality chilled beef would induce producers to let their herd deterioriate. Through the grading system they forced producers to raise animals suitable for export as chilled beef, even though there was no such immediate market.

13. Animal husbandry improved somewhat during the study period studied, so producers became somewhat more careful about culling "infertile" cows from the herd.

    To discover whether any obvious difference existed between the slaughter rates of mature and younger cows, the number of last year's heifers which are this year's herd replacements, VN, and the number of cows which have been in the breeding herd more than one year, VB, were included in another cow equation, not shown. The coefficient on VN was insignificant, but their respective coefficient magnitudes were of plausible order.

14. The coefficient of variation of VQS is 0.36.

15. When estimating the number of calves being retained for the bull herd, I alloted a relatively small number in 1953 through 1956 (180,000 annually on average) and substantially more (250,000) from 1956 to 1959. Reversing the magnitudes might have been more accurate.

16. Yver (1971) suggested that the increase was due to farmers' mechanizing and disposing of their draft animals, including oxen. But the bull herd grew more rapidly than the herd in general during these years disaffirming Yver's hypothesis. Also, there was no clear tendency for the proportion to decline even after very few oxen were used for draft: The proportion of bulls slaughtered in 1966/67 was 15.6 percent.

17. The rapid rise in the level of the bull herd can be explained fairly simply. When Perón's policies turned more favorabl' to agriculture in 1952, import restrictions were still in place, including those on agricultural capital inputs, and the domestic input-supply industry was not well developed. As producers' expectations improved with the hope of a better policy environment, they increased investment in the only type of capital available-- cattle--and, in particular, bulls to improve the stock.

18. Goods purchased by a rural worker differ from those of an urban worker, particularly in the weights given to transportation, electricity, rent, and food.

19. The ratio of rural to urban wages was used to indicate the opportunity cost facing permanent rural laborers with similar, i.e., positive results.

20. As a result, a different variable was formulated to better reflect these events. The rationale of this variable, and the results of its inclusion, are discussed in the next section.

21. Devaluation could cause a change in the composition of demand, if foreign demand is qualitatively different from domestic demand. Because devaluation in Argentina has often been accompanied by an export tax design to lessen its impact on the beef market and hence on prices, the devaluation should be considered net oj 't anges in export taxes. For reasons of data unavailability, I was unable to do this, and this could have affected the results especially in recent years. Nores (1972) considered changes in export taxes and subsidies when calculating changes in the effective exchange rate.

22. In Nores' (1972) slaughter equations, a negative and statistically significant credit variable reflecting total bank loans for cattle production, indicated that producers reduce slaughter to build up herds when credit is eased.

23. Reca (1970) estimated a total supply response function in which the volume of agricultural production responded positively to changes in the agricultural terms of trade as measured by the ratio of agricultural to nonagricultural implicit GDP prices.

24. Where the coefficients on lagged price are generally positive as in the steer equations, $\alpha_N < NS/N$.

25. In the previous specification (Table 9), the unconstrained constant stole much of the effect of the herd level variable.

26. The length of the lag may reflect the time required to alter the genetic composition of the herd as well as changes in feeding programs. A major problem for Argentine producers has been to change the meat conformation and fat content of their animals to meet shifts in demand, particularly foreign demand. These changes must be accomplished chiefly through shifting breeds or selecting animals of the same breed with different characteristics. Winsberg (1968) discusses the changes in the breed composition of the Argentine herd and the secularly changing characteristics exhibited by individual members of different breeds, and indicates that changes of both types have been quite significant, particularly since World War II. The heaviest of the major breeds, shorthorns, which were traditionally produced primarily for the English market, decreased from 75 to 34 percent of the herd between 1937 and 1960. Further, the mature modern shorthorn weighs about 1,200 pounds, whereas the first Shorthorns imported into Argentina sometimes exceeded 3,000 pounds.

27. The negative sign of the coefficient on VAC_{t-1} is contrary to expectation and is difficult to explain.

VI. Estimation of the Slaughter and Average-Slaughter-Weight Equations by Instrumental Variables

The slaughter and average-slaughter-weight equations were reestimated by instrumental variables (IV). Because the beef/grain relative price was positively serially correlated, its lagged values were considered endogenous as were the various current category herd stock variables. Past herd levels, weather, and several variables affecting domestic and foreign consumption demand constituted the instruments.

The residual pattern encountered in the equations marked with a subscript 1 in Table 9 exhibited autocorrelation even more extreme than experienced with the OLS version. This led to a search for a new variant of the rural wage variable to represent the labor and tenancy market disruptions during the Perón era. This new variable was highly significant in several of the equations and its inclusion removed most of the serial correlation previously evident. The final instrumental variable results presented in Table 13 are quite good; their asymptotically valid statistics implied a high degree of significance for most of the coefficients under the usual assmumptions.

The (IV) results for the first equations in each category are quite similar to those by OLS presented in Table 9, except in two cases the residual patterns evidenced more pronounced serial correlation than did their counterparts. Recall though that the OLS estimates had been corrected using autoregressive transformations, so it is not surprising that the untransformed IV results exhibit some of this problem.[1] What is surprising is the improvement that occurred with the inclusion of the new wage variable. The effect was so dramatic that it merits further discussion.

Recall that the real rural wage index WAGE had not been a satisfactory measure on the effect of (perceived) changing factor costs on the choice of production activities. Reexamination of WAGE revealed why the variable had performed so poorly and suggested a reformulation. Apparently the demand for agricultural labor was more important in determining the wage level than were those government policies which attempted to institutionally increase the wage rate. Actually the administered wage fell rapidly in real terms because it was not readjusted to keeping up with inflation. Producers' concern about labor costs induced a significant shift out of grains into cattle, but the shift was due more to the expected or potential cost of tenant rental contracts legislated by the government. It was the increase in this cost that caused producers to shift away from sharecropping, simultaneously reducing the demand for hired labor by the tenants themselves. Indeed, this shift brings on a sharp drop in the real wage of the agricultural worker. It was not that these falling wages reflected an increased supply of labor, but rather a decreased demand for it.

The WAGE variable reflected the low prices for grains during World War II[2] and the associated low demand for agricultural laborers as well. WAGE fell even more abruptly (from 107 to 67) between 1946 and 1952. This 40 percent decline was caused by the combined effects of administered wages in the agricultural sector, inflation, and lagging agricultural demand. Finally, after 1952, when a heavy rural outmigration was taking place, and especially after 1958 when machinery inputs began to appear again, revitalizing grain production, the agricultural wage began to rise in real terms. But, even then, it remained below its pre-1944 level. After the mid-1950s, WAGE rose somewhat, fluctuating greatly during the time of rapid inflation and stablizing in the mid-1960s.

Perón's policies were most discriminatory against agricultural producers during 1945-52--the years of the most severe decline in WAGE--and the years when the rural worker was supposedly being aided most. First, the low grain prices lowered the demand for agricultural labor by inducing a shift from grains to the less labor-intensive cattle production. Moreover, imports of agricultural machinery, severely restricted during the depression years of the 1930s and during the war, continued to be restricted by protective tariffs designed to favor domestic industry. Capital in the form of agricultural machinery was more complementary to the

Table 13
Aggregate and Individual Category Slaughter
Equations by Instrumental Variables[a]

	H_t	tH_t	$(\Delta P/P)_t$	P_t	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	P_{t-5}	$(\Delta W/W)_t$	W_t	W_{t-1}	W_{t-2}	W_{t-3}	W_{t-4}	W_{t-5}	ΔRL_t	ΔRL_{t+2}	$EXPB_{t-2}$	$\overline{R}^2$	DW	SER
Eq. S_1:	0.170	0.0011	-25469		-17075	-3089	4419	5449		-11916		-343	-7.19	162	164					0.899	1.53	4935
	(14.92)	(2.05)	(4.07)		(6.12)	(1.71)	(2.22)	(3.55)		(1.55)		(3.19)	(0.10)	(2.49)	(3.58)							
Eq. S_2:	0.165	0.0016	-30735		-19520	-4771	3399	4989		-15337		-340	-8.63	158	161		296			0.924	2.44	3844
	(18.35)	(3.05)	(5.94)		(8.42)	(3.15)	(2.14)	(4.14)		(2.51)		(4.06)	(0.15)	(3.13)	(4.50)		(3.08)					
Eq. NS_1:	0.964		5984	-1860	1527	3406	3778	2643		2724	-86.4	2.92	47.1	46.1					-23509	0.827	1.61	2289
	(74.8)		(2.05)	(1.78)	(1.87)	(3.32)	(3.64)	(3.74)		(0.91)	(2.30)	(0.18)	(1.83)	(2.07)					(2.42)			
Eq. NS_2:	0.965		4695	-1655	1478	3210	3541	2471			-62.7	-6.19	28.4	40.9	31.5		4.21		-25831	0.827	1.74	2271
	(68.3)		(1.80)	(1.57)	(1.81)	(3.24)	(3.57)	(3.67)			(2.11)	(0.38)	(1.60)	(2.15)	(3.32)		(0.08)		(2.55)			
Eq. YS_1:	0.249	-0.0020	-6719	-2023	-1694	-1380	-1055	-716	-364	-2023		-3.87	16.1							0.633	0.86	1289
	(11.9)	(1.91)	(4.42)		(2.38)	(2.99)	(2.34)	(1.64)	(1.22)	(1.02)		(0.13)	(0.78)									
Eq. YS_2:	0.221		-8243		-2424	-1886	-1375	-890	-432	-2995		-1.15	-837				95.7			0.763	1.18	1037
	(45.6)		(6.16)		(4.07)	(4.79)	(3.69)	(2.51)	(1.80)	(1.86)		(0.05)	(0.57)				(3.96)					
Eq. TS_1:	0.0590		-2191	-2540	-438	686	831				-32.6	-7.09	6.85	9.21						0.080	0.62	2134
	(16.9)		(0.81)	(2.12)	(2.12)	(0.63)	(0.67)				(1.08)	(0.42)	(0.35)	(0.58)								
Eq. TS_2:	0.0672		-4537	-2509	-1307	-471					-49.6	-36.1	-19.6				167			0.620	1.73	1364
	(24.8)		(2.02)	(2.17)	(1.76)	(0.47)					(2.42)	(2.61)	(1.41)				(5.70)					
Eq. VS_1:	0.109	0.0001	-9006		-4495	-980	940	1267			-37.4	-32.3	-24.4	-13.6						0.702	1.21	2129
	(12.9)	(0.25)	(3.63)		(3.72)	(1.23)	(1.10)	(1.94)			(1.15)	(1.34)	(0.92)	(0.68)								
Eq. VS_2:	0.0099	0.0008	-3453	-5854	-2049	-97.8					-35.8	-36.9	-25.0				146			0.863	1.69	1505
	(17.2)	(2.45)	(1.40)	(4.45)	(2.49)	(0.09)					(1.53)	(1.94)	(1.38)				(4.01)					
Eq. VQS_1:	0.168	0.0042	-10999		-5566	-1901	248	882		-8325		-135	-10.8	53.3	56.9					0.872	1.16	1645
	(4.63)	(2.35)	(5.34)		(5.96)	(3.16)	(0.38)	(1.74)		(3.21)		(3.77)	(0.45)	(2.51)	(3.79)							
Eq. VQS_2:	0.105	0.072	-11026		-4696	-2023	-217	722	794	-6299		-76.5	11.7	63.5	78.8	57.7	-24.0			0.864	1.68	1692
	(2.09)	(2.91)	(4.90)		(4.82)	(3.12)	(0.35)	(1.21)	(1.97)	(2.19)		(1.92)	(0.39)	(2.48)	(3.72)	(4.31)	(0.57)					
Eq. BS_1:		0.0062	338	-299	-6.53	170	230	173		-40.7		-4.37	4.15	7.73	6.34					0.934	1.99	145
		(58.59)	(2.01)	(4.57)	(0.15)	(3.26)	(4.24)	(4.60)		(0.20)		(1.67)	(3.29)	(6.30)	(6.27)							
Eq. BS_2:		0.0062	367	-292	1.79	178	236	177				-4.21	4.33	7.78	6.43			-1.41		0.945	1.94	137
		(50.0)	(2.26)	(4.56)	(0.04)	(3.29)	(4.33)	(4.74)				(2.10)	(4.11)	(6.51)	(6.50)			(0.43)				

a. See Tables 6 and 9 for explanation of symbols. Additionally ΔRL = the net annual change in the rural labor force; t-statistics are in parentheses.

demand for rural labor than was capital in the form of livestock, so a decline in the stock of machinery also decreased the demand for labor services.

Second, even those policies ostensibly designed to improve conditions for rural workers seem to have operated in the opposite direction. To assist workers, Perón introduced rural labor unions, established rural minimum wages, froze tenancy agreements, prohibited landowners from ejecting tenants, and even threatened widespread expropriation and redistribution of farm land. Such policies induced a shift from grain to cattle, thereby creating an excess supply of labor. This in turn caused significant migration from rural to urban areas where, fortunately, jobs were available. Indeed, producers directly encouraged outmigration by purchasing tenants' contracts. Thus, the grain-to-cattle switch was not a response to increased real agricultural wages but rather to an increase in the expected cost of keeping a tenant. Producers reacted to the threat of expropriation just as they might have to higher wage costs. And in a sense the actual effect was similar, for the existence of a tenant on the property increased the probablity of expropriation and increased costs in avoiding it.[3]

Third, although the rural minimum wage was fixed in nominal terms during much of this period, rapid inflation quickly eroded the real wage and apparently no significant effort was made by the Perón government to prevent this.[4]

The best available measure of the net effects of these various policies was the net annual change in the rural labor force. The Argentine National Development Council (CONADE, 1963) estimated the size of the rural labor force through 1962, based on sample information in both urban and rural areas. The resulting series is only approximate and does not consider variations among regions or particular production activities, but it is a relatively good general index of labor movements occurring in the Pampas during the period studied.[5] The data indicate that the rural labor force increased from 1937/38 to 1942/43, declined slowly to 1952/53, declined rapidly to 1959/1960, and then declined somewhat more slowly to the late 1960s.

The increase in the rural labor force stops almost abruptly with the beginning of Perón's administration, but its greatest decline followed Perón's ouster in 1952/53 to 1959/1960, even while the beef/grain relative price was rising. This seems counter to the conventional belief that the greatest outmigration was during the early years of Perón's rule. Grain prices were first depressed by the war and then by government controls, with corresponding impact on the demand for agricultural labor. Perón then froze the existing tenancy contracts in 1948. Given the rate of inflation, which rapidly reduced the real value of the rent payments toward zero, this action amounted to temporary expropriation and redistribution of the land to tenants. Owners effectively lost control over their land held by tenants, received little real payment, and could use only bribes or threats to induce tenants to yield their position.

Then in 1952, Perón announced a major policy reversal. Faced with a deteriorating balance of payments caused by the inability of the stagnant agricultural sector to meet the rising intermediate good needs of the growing industrial sector, he promised higher agricultural prices, suggested legislation permitting new tenancy agreements, and at least momentarily ended the threat of expropriation. The effect is clear. Tenants' expectations changed; some who previously had refused to leave, hoping for eventual outright ownership, decided to sell their contracts and try alternative opportunities in the growing industrial sector.[6] The producers, who had been burned once, took no chances and switched to cattle, despite the rising relative price of grains. It was not for several years after the ouster of Perón that producers began to return to grains.

The variable RL_t, the change in the rural labor force (with mean zero) was included in the slaughter equations improving the results considerably. Compare the second equation in each category with the first in Table 13. The coefficient on ΔRL_t is positive and significant at the 1 percent level for calves, yearlings, cows, and aggregate slaughter, indicating that a reduction in the rural labor force is associated with a reduction in the transitory component of slaughter for several categories. The interpretation of this positive relationship is somewhat complex:

Table 14

Signs of the Coefficients on P_t and $(\Delta P/P)_t$ in the Instrumental Variable Slaughter Equations.

	Specification 1	Specification 2		Specification 3
	P_t	$(\Delta P/P)_t$	P_t	$(\Delta P/P)_t$
H_t	$-$	$-$	$-^{*}$	$-$
N_t	$-^{a}$	$+$	$-^{a}$	$-^{a*}$
Y_t	$-$	$-$	$-^{a}$	$-^{*}$
V_t	$-$	$-$	$-^{*}$	$-$
VQ_t	$-$	$-$	$-^{*}$	$-$
T_t	$-$	$-$	$-$	$-^{a}$
B_t	$-$	$+^{a}$	$-^{*}$	$-$

a. Coefficient not asympotototically significant at the 5 percent level using a one tailed test.
* indicates which of the three equations in each category had the highest $\bar{R}^2$.

Conditions that promote a switch from grains to cattle entail a rural to urban labor migration (i.e., a reduction in the rural labor force) and a temporary reduction in slaughter as the herd buildup begins. The significance of the coefficients of the other variables increased markedly and nearly all of the serial correlation of the residuals was removed. The strongest effect of the labor disruption was on the reduction in slaughter of calves, yearlings, and cows--the animals most in demand for fattening, for the land involved in the grain-to-cattle switch was of high quality. Producers making the switch usually planted their land to alfalfa or other artificial pasture and purchased animals to graze it. Some producers moved into breeding as well, but on the more productive land, the more profitable enterprise was fattening.

In the steers equation, there is no effect evident from ΔRL, but there is no reason to expect one. Although the steer stock increased, for a given size the same percentage was slaughtered as in the absence of the grain-to-cattle switch. The higher the opportunity cost of the feed, the lower is the optimal slaughter age of a fattened animal. The land being taken out of grain production was highly productive, so animals fattened there could not be kept economically to an extreme age.[7] Hence, there is no reason that the optimal age of the slaughtered steer should have changed or the rate of steer slaughter varied.

The nonsignificant effect of ΔRL in the heifer equation might be explained in part by the increased calving rate during this period making it less necessary to withhold heifers from slaughter, though this explanation is not entirely satisfactory. The nonsignificant of ΔRL in the bull equation might be explained by the heterogeneity of the bull stock. But on the conjecture that the bull herd series was constructed so as to leave the estimated bull herd too low in 1952/53-1955/56, I entered ΔRL_{t+2} to reduce the anticipated serial correlation in the residuals when estimated with the corrected data. The effect was not significant,[8] but the regressions for the bull slaughter-weight equations imply that bulls were being withheld during this period for use in the breeding herd.

Recall that in the specification of the price coefficients, it was assumed that producers respond to an expected price when making their slaughter decisions and that this expected price could be modeled as a function of current and past prices and the current rate of change of price. The relevant price is that expected to prevail at the time the animal, or its product, will be sold. For steers this expected price is much more short term than, say, for heifers, so the specification and the form of the lagged distribution should probably differ across categories. Three alternative specifications of the category-relevant expected price were used: (1) current and past prices, (2) the current price, past prices, and the current rate of change, and (3) past prices and the current rate of change. The equations in the three specifications were identical except for the price variables.[9] The general results are presented schematically in Table 14. Specification two gave uniformly better results than specification one; for every category except bulls, the rate in change of price was significant in this second specification. Specification three gave better results than two for steers, yearlings, and calves in terms of $\bar{R}^2$.

After this selection process for the best specification for expected price, several additional equations were estimated for each category to determine the best specification for the weather lag distributions. The preferred results are presented in Table 15 as the second equation for each category, together with other versions.[10]

The final econometric results are very satisfactory. Each equation explains a high degree of the variation in slaughter of the respective category, and the coefficients of the independent variables are highly significant and consistent both in sign and magnitude with the previously developed theory. The expected negative coefficients were obtained on all price variables except in the steer and bull equations where only the price in year t is negative. Thus, in most categories, the annual rate of slaughter is reduced temporarily by an increase in price.

There is some empirical support that the effect of the current rate of change of price is strongest for those animals destined for slaughter in the near future, i.e., the extrapolation of the current rate of change holds for short periods only, with longer price expectations being based on an average of past prices. The relative impact of the current rate of change of price is, in descending order, strongest for heifers, yearlings, calves, cows, bulls, and steers, with the last two categories going positive. The normal proportion of the heifer and yearling steer stocks slaughtered is small, and apparently producers are easily able to retain even greater numbers with a given price signal. With an improvement in price, yearlings are retained for further fattening or for breeding.

The positive price coefficients in the steer and bull equations (the rate of change of prices and the lagged prices after year t-1) might be explained in either of two ways. First, a price change may cause significant qualitative changes in the composition of the various category stocks. For example, a price increase inducing producers to withhold yearlings from slaughter in greater numbers may cause a temporary change in the age distribution of the steer herd. This can affect the percentage of the steer category slaughtered in future years as the adjustment works itself out. In the model used, the coefficient on the stock variable is not allowed to vary cyclically so the effect of changing the proportion of the stock slaughtered over the cycle is forced onto the lagged price variables. Second, an enduring increase in the beef/grain relative price ought to increase the number of steers slaughtered relative to the number of yearlings, lowering and raising the proportion slaughtered in the two categories, respectively. The positive coefficients on the lagged price variables in the steer slaughter equation might be reflecting this effect. Further support for this interpretation is found in the long, statistically significant negative distributed lag on the price coefficients, of opposite sign, in the yearling equations.

The positive sign on the rate of change of price in the steer equation also has at least two possible explanations. First, the price effect causes yearlings to be withheld, but if some of them are held only for a moderate time period and become steers within the year, it makes it look as if existing steers were slaughtered rather than withheld. The question is whether such withheld yearlings slaughtered as steers are sufficient to explain the observed positive coefficients.[11]

Second, Yver (1971) argues that if producers face a short-run feed constraint, they will be unable to increase the herd in the short run as much as they would like. Their desire to retain animals of all ages will cause a rise in the opportunity cost of feed, which in turn will prompt the slaughter of some. The animals most likely to be affected will be those near their time of slaughter, such as steers, for the capital values of animals with longer productive lives will be less sensitive to a short-run change in the cost of feed.

While Yver's explanation is ingenious and plausible, and this same situation may apply to bulls, this feed constraint could not hold very long because additional land could

Table 15
Aggregate and Individual Category Average-Slaughter-Weight Equations
by Instrumental Variables[a]

	Const.	t	VAC_{t-1}	$(\Delta P/P)_t$	P_t	P_{t-1}	P_{t-2}	P_{t-3}	$(\Delta W/W)_t$	W_t	W_{t-1}	W_{t-2}	W_{t-3}	RL_t	RL_{t+2}	$EXPB_{t-2}$	$\bar{R}^2$	DW	SER
Eq. W_1:	207	0.648	-17.7	22.9		8.96	7.95			0.138	0.122	0.177					0.627	1.88	3.70
	(34.65)	(1.18)	(1.43)	(3.56)		(2.94)	(1.78)			(2.15)	(1.93)	(2.45)							
Eq. W_2:	233	-1.73	26.8	8.28	7.54	1.93	5.63		9.63		0.143	0.064		-0.403			0.839	2.03	2.49
	(30.71)	(2.44)	(1.87)	(1.24)	(1.95)	(0.47)	(1.88)		(2.21)		(2.07)	(1.20)		(3.90)					
Eq. WN_1:	478	-3.53	66.8	0.867		-6.58			27.8		0.497	0.114	-0.052			99.3	0.859	1.26	7.79
	(21.13)	(2.41)	(2.42)	(0.08)		(1.07)			(2.11)		(2.40)	(1.00)	(0.62)			(2.60)			
Eq. WN_2:	444			8.94		-4.66				0.363	0.265	0.172	0.084	0.654		84.4	0.884	1.77	7.07
	(90.37)			(1.19)		(0.97)				(3.88)	(5.20)	(3.05)	(1.84)	(3.34)		(3.77)			
Eq. WY_1:	302	1.60	-23.0	9.52		3.03	-1.95	-2.96		0.037	0.038	0.025					0.831	2.30	2.50
	(81.56)	(4.59)	(2.96)	(2.70)		(1.77)	(1.58)	(2.55)		(0.92)	(1.14)	(0.86)							
Eq. WY_2:	315	0.403			3.91	-1.31	-3.70	-3.27		0.021	-0.014	-0.213		-0.143			0.827	1.95	2.54
	(143.83)	(3.12)			(3.05)	(1.78)	(4.04)	(4.40)		(0.58)	(0.49)	(0.78)		(2.38)					
Eq. WT_1:	211	-0.568	12.1	3.66		4.88	-7.34			0.011	-0.032						0.075	1.45	4.33
	(38.11)	(1.04)	(0.90)	(0.58)		(1.40)	(1.76)			(0.16)	(0.43)								
Eq. WT_2:	206		-1.29		5.38	-0.989	-4.01	-3.68		0.032	-0.031	-0.41		0.111			0.172	1.49	4.10
	(132.36)		(0.32)		(2.51)	(0.83)	(2.69)	(3.03)		(0.52)	(0.65)	(0.94)		(1.32)					
Eq. WV_1:	488	-3.80	38.8	16.7		7.57			16.7		0.287						0.888	2.14	6.81
	(54.68)	(4.32)	(1.82)	(1.93)		(1.46)			(1.93)		(1.76)								
Eq. WV_2:	471	-2.04		22.2		10.6			20.3		0.382			0.204			0.873	1.92	7.26
	(92.14)	(6.69)		(2.73)		(2.14)			(1.77)		(2.36)			(1.15)					
Eq. WVQ_1:	324	-0.772		12.1		3.62			19.9		0.358	0.020					0.836	2.11	3.62
	(123.69)	(5.50)		(3.12)		(1.57)			(3.50)		(4.36)	(0.37)							
Eq. WVQ_2:	326	-0.985		13.7		4.80			21.3		0.366	0.018		-0.111			0.832	2.05	3.66
	(110.51)	(5.18)		(3.32)		(1.90)			(3.64)		(4.39)	(0.33)		(1.25)					
Eq. WB_1:	669	-13.4	224	-44.0		-32.7					-0.17	-0.35					0.881	1.50	12.9
	(41.91)	(8.36)	(5.76)	(2.89)		(3.36)					(0.83)	(1.82)							
Eq. WB_2:	712	-14.7	248	-45.7		-33.3					-0.222	-0.381		-0.245			0.874	1.60	13.3
	(21.48)	(4.58)	(3.74)	(2.85)		(3.31)					(0.93)	(1.83)		(0.46)					
Eq. WB_3:	737	-17.6	309	-28.0	-20.8	-10.2	-3.25	0.165		-0.255	-0.425	-0.340			-0.937		0.910	2.38	11.3
	(33.43)	(7.93)	(6.33)	(1.76)	(3.23)	(2.43)	(0.56)	(0.03)		(1.35)	(2.68)	(2.47)			(2.70)				

a. See Tables 6, 9, and 13 for explanation of the symbols; t-statistics are in parentheses.

be made available for pasture and forage if larger herds were desired. Therefore the higher rate of slaughter reflected in the lagged price coefficients could not be due to a feed constraint.

In Nores' (1972) quarterly model of the Argentine cattle sector, the coefficient on the current quarter's price in the steer equation is negative and highly significant, as is the coefficient on P_t in the two steer equations. Thus, whether yearlings cross categories, or whether an increase in the opportunity cost of feed occurs with some lag inducing producers to sell more steers in the intermediate run, the immediate slaughter response of steers appears to be negative.

The price coefficients in the bull equation are similar to those in the steer equation, but somewhat more difficult to explain. Perhaps a large number of bulls are raised specifically for slaughter. Thus, the bull category is more heterogeneous than the other categories. The price coefficients in the bull equation reflect the net effect from the withholding bulls for the breeding herd and the increased slaughter of the uncastrated males being fattened. An increased slaughter of uncastrated males with a price increase would support Yver's feed constraint argument. And the average slaughter weight of bulls does decline significantly in response to a price increase, suggesting the slaughter of more younger and lighter animals.

The aggregate slaughter equation (Table 13) performed very satisfactorily, but being aggregate cannot yield detailed insights into producer behavior and slaughter composition which the individual category equations provide. Nor is its predictive ability quite as great.

To test the hypothesis that the behavior of producers is asymmetrical in periods of rising vs. falling prices because the supply constraint is binding as prices rise, slaughter equations for each category were estimated separately for the rising price and falling price. Whenever an observation was lower than the previous observation, but higher than the average of the previous three years, it was included in both sets; the same procedure was followed with the opposite occurrences.

The coefficient on the corresponding stock variables was slightly higher for every category where prices were falling, but never more than 1 percentage point, and the stock level coefficients in each set of regressions were always very close to the magnitude of the stock level coefficients in the ordinary instrumental variables equations. The coefficients on P_t (always negative) were of larger absolute magnitude for the years of rising prices in every case except for cows, but the difference was never large.

The Average-Slaughter-Weight Equations

The IV estimates for the average-slaughter-weight equations are presented in Table 15. Recall the meaning of the two additional variables: EXPB, the percentage of beef exported to Great Britain, with a positive effect on slaughter weight expected and *VAC*, the percentage of the herd vaccinated against hoof-and-mouth disease, also positive. Because average slaughter weights are not very volatile, the constant term is highly significant. The aggregate slaughter weight (which declined about 5 percent over the study period) shows stronger response to the beef/grain relative price and weather than do any of the individual categories. Although most of these effects were significant for the categories, the aggregate captures changes in the composition of slaughter as price and weather varies.

The size and weight of mature animals declined overtime, apparently as a function of a change in breeding practices.[12] The decline in average slaughter weights of cows and bulls is evidence for a decline in the actual animal size since the slaughter weight of these mature animals is not strongly affected by consumer tastes. The average slaughter weight of steers and heifers also declined, with that of the former being strongly affected by consumer tastes, relative prices, and other factors. The slaughter weight of calves remained roughly constant; that of yearlings increased, due to better herd management, improved pastures, and expanded veterinary services.

Steers. The pattern of the coefficients on the price variables coincides with the slaughter equation evidence: Steers are not held back long in response to a price increase; a change in the age distribution of slaughtered steers (as withheld yearlings enter) reduces the average steer slaughter weight. Better weather, however, has a strong positive effect on slaughter weights through year t-3.

Because of the substantial positive serial correlation of this equation, particularly between 1947/48 and 1958/59,[13] RL_t was included (Equation W_2). Because of its high collinearity with t and SS, however, RL captured their explanatory power, so they were excluded from the W_2 equation. That is, as the rural labor force has declined over time, so has the steer slaughter weight while the percent vaccinated increased.

Yearlings. The addition of RL to the slaughter-weight equation for yearlings had a similar effect. The significant pattern of the price variables indicates that a price increase momentarily increases the average yearling slaughter weight, but later decreases it as the better yearlings are held over to be slaughtered as young steers.

Calves. Very little of the variation in calf slaughter weights is explained by the estimated equation, but calf weights have little variation to explain. However, there is a significant positive response to price in year t.

Cows. The cow slaughter-weight equation is dominated by the constant and the negative trend. Cows' slaughter weight should vary only to the extent that current prices or pasture conditions make their fattening profitable for an extra period; the coefficients on lagged prices beyond the first were not significant. Equation WV_1 is preferable to WV_2 because VAC_{t-1} is theoretically preferred to RL for cows, and both could not be included because of their high collinearity. Improved health should positively affect the slaughter weights of cows; VAC_{t-1} is a good proxy for this effect.

Heifers. Heifer slaughter weights show little sensitivity to either VAC_{t-1} or RL_t. The decline in heifer slaughter weight over time is captured by the trend. Price and weather in years t and t-1 are significant and positive. If much of the weight gain achieved by heifers after their reproductive organs are fully developed is of little slaughter value, producers would be induced by a price increase to cull their slaughter heifers somewhat earlier to free their pasture for other, more efficient converters.

Two large residuals for heifer slaughter weights occur in 1951/52 and 1953/54, negative and positive, respectively. There was a severe drought from 1949 to 1951 in the cattle breeding area with 1951 the worst year which forced the sale of heifers raised on poor pasture through two consecutive drought years, so their weights were much lower than usual. In 1953/54, the climate improved dramatically; the only heifers sold were fattened to heavy weights.

Although the same outliers did not appear in the cow slaughter-weight equation, the residuals in the cow slaughter equation did show a higher actual than predicted slaughter in 1949/1950-1950/51 during the drought, lower in 1952/53-1954/55 during the recovery. This effect is not apparent in the heifer slaughter equation. Indeed, in 1950/51 the actual slaughter of heifers lies below predicted slaughter. The cow negative and heifer positive residuals may mean that producers sacrifice their older breeding animals rather than their incoming heifers when drought occurs.[14]

Bulls. As usual the bull equation coefficient patterns differ from those for other categories. When the price increases or the weather improves, the slaughter weight drops sharply. In 1959/1960 and 1960/61, when the beef/ grain relative price rose dramatically, the average weight of bulls slaughtered was more than 100 pounds lighter (10 percent) than in the preceding or succeeding several years.

As in most of the other equations, the introduction of RL_t substantially improved the Durbin-Watson statistic, but the variable was not statistically significant. On the theory that the same influence was present but began at a slightly different point in time, I tried RL with a two-year lead. RL_{t+2} had a significant negative coefficient, indicating that bulls were slaughtered at heavier weights during the grain-to-cattle switch; VAC_{t-1} continued to have a highly significant positive coefficient. Because RL_{t+2} leads the switching effect evident in the other categories, new cattle enterprises cannot have produced heavier bulls. Rather, it must be that the existing breeders withheld younger bulls from slaughter to increase the bull/cow ratio, thereby shifting the slaughter composition to heavier bulls.

Aggregate slaughter weight. The aggregate slaughter equation shows the combined effects of the changes in slaughter composition and the changes in individual slaughter weights with respect to changes in price, weather, and other factors. The inclusion of RL_t in the second equation sharply increased $\bar{R}^2$ and the significance of all the other variables, and reversed the signs of t and of VAC_{t-1} so that they were now as expected *a priori.* There has been a secular decline in the overall average slaughter weight, but this trend has been partially offset by the increased weight due to reducing hoof-and-mouth disease. The negative coefficient on RL_t indicates that a higher aggregate slaughter weight was associated with the switch from grains to cattle. The primary use of the new pastures from farmer crop land was for fattening animals that otherwise would have been slaughtered younger.

The price and climate effects are also interesting. The current and lagged coefficients on both price and weather are always positive, indicating that the *net* response is to produce a heavier average animal. When both the rate of change of prices and the price level in year t are included, both have positive, marginally significant coefficients. Thus, there appears to be a response to the rate of change in prices, as well as to the level.

Endnotes to VI.

1. For most animal categories actual slaughter lay above predicted slaughter from 1946/47 to 1952/53 and substantially below predicted slaughter from then until 1958/59. The consistency of this result across categories implies that it was not caused by a change in consumer demand, that is, it was not merely a switch in slaughtering between categories. Apparently it is more related to the fact that in 1952/53 Perón announced a change in policies, promising less discrimination toward the rural sector.

2. Grains could not be exported during the war because of the shortage of shipping space. Grain prices were supported by the government, but were allowed to decline to very low levels.

3. Diaz (1970) found the urban wage rate a significant negative factor in the area planted to corn each year, implying that corn producers reduced their planted acreage when the opportunity cost of labor increased. Labor's primary role in corn production was in its manual harvest. This seasonal, transient labor often entered the rural sector only during the harvest months, so its opportunity cost is properly measured by the urban wage. This does not mean that the urban wage would necessarily be a good measure of opportunity costs for permanent agricultural workers and tenant farmers.

4. Had the government intervened to maintain the minimun wage at higher levels, the shift away from the use of labor might have been even faster. On the other hand, while the agricultural policies implemented by Perón were designed to reduce incomes accruing to the agricultural sector, the policies were supposed to be aimed at the rich, not the poor. To assure this, effective countermeasures were taken to protect rural wages. Whether these measures worked is hard to say. It appears that the rural worker actually bore a large share of the burden of the discriminatory agricultural policy. Thus, Perón's policies are better classified as anti-agriculture, pro-industry, rather than anti-rich, pro-poor. The appendix contains a brief summary of the changes in rural welfare during Perón's administration.

5. I extrapolated this series through 1966 at a slightly declining rate, as suggested by colleagues in Argentina.

6. The capital/labor ratio in the Pampas rose considerably during this period, but mostly because labor left, not because the stock of industrial capital was increased (see Diaz, 1970). However, if the increase in animal capital (cattle) is included in the capital stock, the capital/labor ratio rises even faster.

   Between the censuses of 1947 and 1960, the number of tenant-worked agricultural units declined from 120,000 to 50,000; their total area farmed fell from 21 million hectares to only 9 million. This corresponded with a decline in the economically active population in the Pampean region of 37 percent.

7. Older steers are produced primarily in the western grazing regions where land is relatively less productive.

8. ΔRL_{t+2} will play an important role in explaining the variation in bull slaughter weights.

9. The other variables included were the herd stocks, weather, change in rural labor force, and, in the case of steers, the percentage of slaughter exported to Great Britain. In formulations one and two, a polynomial distributed lag on prices of

four periods beginning with year t and tied to zero in year t-4 was used. In formulation three, the lag distribution on prices began in year t-1 and was forced to zero in year t-5.

10. The preferred bull slaughter equation includes only a multiplicative herd stock trend and no simple herd stock variable. Both the aggregate slaughter equation and the heifer slaughter equation use the third price specification, i.e., without the current price. The calf slaughter equation includes the current price variable with a shortened lag on past prices.

11. But Yver (1971) cites data on the average slaughter weights of the different categories, including their cyclical variation, to suggest that withheld yearlings could not reach steer weight within one year. His data, however, give only the means, not the whole distribution of slaughter weights and hence do not prove the point.

12. This change increased the efficiency of the animals as feed converters making them more compact. If animals approach their mature weight more rapidly (and if the composition of slaughter changes), the net effect of declining animal size on aggregate average slaughter weight and on average unit meat production would be offset.

13. This positive bulge from 1946/47 through 1958/59 implies a higher calving rate during this period. It appears that this increase was associated with the switch between grains and cattle. Because the land involved was of generally higher quality than that traditionally devoted to cattle, the calving rate could have been increased. It should also have increased because the producers who began to breed cattle in this area needed higher calving rates to make breeding profitable and hence devoted more effort to ensure this. Thus, when producers began to switch back to grain production in the late 1950s, this positive effect ended.

Or perhaps the average mortality rates also declined during this period so that a higher proportion of the calves born lived to slaughter. Observers comment that rural land in Argentina is often held purely as a hedge against inflation by individuals who are not deeply worried about its real productivity. Nevertheless, during the 1950s when the rate of inflation was high and land markets were relatively free, there was an improvement in several productivity indices in the cattle sector. Probably much of the land switched from grains into cattle had higher potential productivity in grains, and to this extent there was a real loss. But there is no evidence that the average level of cattle management deteriorated.

14. The heifer and cow slaughter-weight equations predict better after 1954/55 than before. The problem does not lie with the slaughter-weight records, for it does not occur in the other categories. Perhaps the seasonal slaughter of cows and heifers changed more than that of the other categories which could have adversely affected the way the earlier calendar year data was transformed into fiscal year data using monthly weights for 1952-1966. When calculating the fiscal-year average slaughter weights, I used fixed weights for transforming the calendar-year data into the desired form. I had monthly data only for the years 1952 and 1966 and used the weights from these years for the prior years as well. Therefore, a change in the seasonal distribution of slaughter between these periods, particularly for heifers where the problem is most severe, could have caused this result.

VII. The Estimation of the Domestic Consumption and Export Equations

Demand in this model encompasses both domestic and export demand. Several specifications of the domestic consumption equation where total domestic consumption of beef in tons per year, C_t, was seen as a function of relative prices, income, and population; none was entirely satisfactory. The emphasis in this study was on producer behavior and supply response. Demand-side results are presented and discussed only briefly, for completeness. The estimated price and income elasticities for domestic consumption were quite similar to those obtained later by Bieri and de Janvry (1971).

Neither was the export demand equation satisfactory due to deficient data and lack of advanced statistical techniques, now available. Rather than reestimate it, however, my early results are presented with only brief comment. I also make several qualitative remarks and refer readers, users, and policy makers to Nores' more thorough foreign demand study (1972).

Domestic Demand for Beef

Several sequential equations are presented in Table 16. In the first, beef consumption, BC is regressed on population, PP_t; the deflated retail price of beef (relative to the Buenos Aires cost-of-living index), RP_t; and per capita gross national product, YC_t; where the logarithms of the observation values were used. The statistically significant estimate of the relative price elasticity of beef is about -0.55. But the coefficient on population, 1.6, seems too large and the coefficient on income is negative and insignificant. The Durbin-Watson statistic lies at the lower end of the indeterminacy range for serial correlation. Consumption functions for beef of this type have been estimated by Guadagni and Petrecolla (1966).

In the second equation, to test the effect of beef consumption of past income and prices, lagged values of each were included, but neither was significant.

In the third equation, four variables from Guadagni and Petrecolla study replaced YC_t and RP_t: the per capita earnings of salaried and nonsalaried workers YW_t and YR_t; the retail price of beef relative to other foods and to nonfood goods in the cost-of-living index, RF_t and RG_t. Because these series were available only through 1961, the regressions covered 1937-1961. Calendar-year data were used for the consumption and export equations.

The use of these relative price variables avoided the difficulty that beef itself is a major component in the cost-of-living index, and it provided an opportunity to partially separate the cross-price elasticities of demand for beef between food and nonfood goods. However, the high collinearity between them made it difficult to separate their effects; neither was significant. Neither income coefficient was significant, but the sign on YW was positive. An important income distributional effect may be indicated by this result.

In the fourth equation, the same two income variables were run together with RP_t with the same income pattern holding. Thus, though none of the coefficients was significant, an inelastic income effect is suggested. Recall that beef is very much a wage good in Argentina. Per capita beef consumption has been very high. The average annual per capita consumption of beef in Argentina during 1961/64 was 175 pounds, whereas New Zealand and the United States consumed only 98 pounds each. And the average in Argentina was above 200 pounds per person for extended periods during much of the 1940s and 1950s. Given such extraordinary consumption, it seems likely that the income elasticity of demand for beef would be low.

This finding, if valid, has an important bearing on policy, for Argentines frequently pose the dilemma of wanting both to consume and to export beef. Some contend that the working classes will increase their beef consumption substantially if they had higher real incomes, yet the low elasticity indicates that they may not. An increase in the relative price of beef is politically unpopular, but the evidence here indicates a price elasticity high enough to reduce domestic consumption, thus creating a larger exportable surplus. Then, this increased surplus might in turn contribute to higher per capita incomes by easing the foreign exchange bottleneck. [1]

The consumption equation was also estimated in linear form (equations 5 and 6). The results were sensitive to the choice of the income variables. In the fifth equation, the coefficients were of the same sign as the previous regressions, all were significant (more than 10 percent), each coefficient was of a reasonable magnitude, and the Durbin-Watson statistic rose to 1.44, the inconclusive range. When YC'_t was used instead, it carried a positive coefficient significant at the 1 percent level, but the Durbin-Watson statistic dropped, indicating the probable presence of positive autocorrelation. [2]

Several times the Argentine government attempted to reduce domestic consumption to increase beef exports by declaring "meatless" days during which no beef could be consumed in restaurants or purchased from butchers. A dummy variable was included for the years this policy was in force, from 1952 to 1955 and again from 1964 to 1966; its coefficient was negative, but not significant. However, nearly all of the equations had a large negative residual in 1964, suggesting that the impact of meat rationing was greater in this year. Although avoidance of the rationing devices should have been easier during the 1960s period because of the greater availability of refrigerators, a substantial black market is reputed to have arisen in 1964. [3]

In still other versions of the domestic consumption equation, the relative prices of other meats were included but were insignificant, suggesting that the consumption of beef is insensitive to the relative prices of other meats and fish. (Argentines generally regard other meats and fish as inferior to beef.) These results are generally consistent with those of Bieri and de Janvry, and Nores.

The poultry industry grew significantly, especially in the five years after 1966. The per capita consumption of poultry rose to 33.4 pounds in 1972, nearly one-fourth the amount on beef consumed. This growth was caused by improvements in the quality of the poultry available, as well as the decline in the price of poultry relative to beef. The per capita consumption of mutton declined steadily since 1939 from about 22 to 12 pounds per year, despite a significant decline in its price relative to beef. The per capita consumption of pork is low and has oscillated between 15 and 20 pounds through the 1950s and 1960s. Studies have encountered a large cross-price elasticity between beef and pork.

Still, historical evidence indicates that consumers once did react sharply to a large rise in the relative price of beef to pork and thereby suggests that the cross-price elasticities estimates using data from periods when relative price changes were small, may underestimate the effect which would occur from more significant changes in relative prices.

During World War II corn could not be exported for lack of available shipping tonnage. Its price fell dramatically and, in addition to being used as fuel, it encouraged the development of the hog industry. Between 1939 and 1944 the production of pork increased 250 percent, pork exports rose 88 percent to 182,000 metric tons, and domestic consumption more than doubled to 258,000 metric tons. During 1942/45, per capita pork consumption in Argentina averaged 32 pounds per year, double the amount during either the preceding or succeeding four-year periods. During the same period, per capita beef consumption dropped, averaging 22 pounds less than during the preceding four years. These facts can best be explained by the existence of an important cross-price effect beef-to-pork, not captured by my equations or by other studies. [4]

Other trials produced some slight evidence that changes in the rate of inflation affect beef consumption. The large negative residuals in all of the beef-consumption equation regressions for 1945 and 1946 may be due to the effect of changing expectations toward the rate of inflation. The cost-of-living index was roughly constant from 1936 to 1944, then rose 23 percent in 1945 and 18 percent in 1946. Beef consumption rose rapidly after 1944, but not as fast as predicted by the estimated equations, given the changes occurring in relative prices.

Thus, consumers may have been *relatively* reluctant to pay the higher nominal prices until they became accustomed to the expectation of further inflation. Similar, though smaller negative residuals appear in 1955 and 1956 when, after constant prices had prevailed for three years, inflation broke out again. An exception to this hypothesis, however, occurs in 1959: The increase in the cost-of-living index was 111 percent, substantially above any previous inflation, and the retail price of beef rose 250 percent in absolute terms, but the estimated equations yield a positive residual.

Because inflation may affect consumption, and because the coefficient on population in the log-linear model seemed too large, two more variables were tried: the changes in the Buenos Aires cost-of-living index and the proportion of the population living in rural areas. Significant rural-to-urban migration occurred between 1947 and 1957 and continued thereafter. Because the rural populace is sometimes attributed with a greater average propensity to consume beef than is apparent in the consumption estimates of the Ministry of Agriculture, the migration may have caused an increase in per capita beef consumption that needs to be accounted for.

Neither of these variables, separately or together, with or without the population and cost of living variables, provided additional evidence beyond what is presented in Table 16. The only robust result from the domestic consumption estimation effort seems to be that the coefficient on the relative price of beef to other goods implies a relative price elasticity of about -0.5. Beef consumption is probably not very income elastic in Argentina. Moreover, although the distribution of income may affect beef consumption, the effect appears to be weak. Rural-urban migration and changes in the rate of inflation may also affect consumption, but no satisfactory measure of their impact has been determined.

The Beef Export Equation

Several of the more important determinants hypothesized to affect the study period were either difficult to quantify, and, even if quantifiable, the requisite data were not available. The estimated equation is, therefore, unsatisfactory. I present it in Table 17 and rather than reestimating it using the better data now available, I present a qualitative discussion of the factors thought to affect beef exports. Because the structure of external demand has changed significantly during the last 30 years, the results obtained by Nores (1971) for a more recent period seem more useful for specific policy decisions than my equation.

First, one important but frequently confused issue needs clarification. Several past studies of the Argentine cattle sector have assumed that beef exports are a residual, determined essentially by subtracting domestic consumption requirements from production. This approach results in the estimation of what might be termed export supply functions rather than export demand functions. Because beef production has not increased as rapidly as domestic consumption during certain periods of the last three decades, particularly during the late 1940s and the 1950s, many Argentines accept the corresponding decline in exports as evidence of the residual theory. However, this theory does not appear to be justified either theoretically or empirically. While the government has often taken steps to absorb or reduce the shocks from external sources which might affect domestic consumption, the data suggest strong competition between exports and domestic consumption for the available meat supplies. For example, the time profile of total slaughter, domestic consumption, and exports show the same secular pattern. Domestic consumption is not constant, nor does it grow at a constant rate, and exports have not absorbed the total variation in total slaughter. Furthermore, there is apparently a significant relation between movements in the effective foreign exchange rate for beef and the level of internal beef prices in Argentina. When the peso is devalued, the peso value of beef exports rises in percentage terms by the amount of the devaluation, less the change in export taxes, and, in equilibrium, internal prices must rise to the same level. To cushion the impact of devaluation on domestic prices, the government has frequently imposed export retentions and price controls. These interventions should be understood as shifts in the external demand curve. Argentine producers

Table 16
Domestic Beef Consumption Equations 1937-1966[a]

	Const.	RP_t	RP_{t-1}	RF_t	RG_t	YC_t	YC_{t-1}	YW_t	YR_t	PP_t	$\bar{R}^2$	DW	SER
BC_1	-8.63	-0.547				-0.096				1.57	0.945	1.16	0.050
	(3.99)	(11.73)				(0.37)				(9.82)			
BC_2	-9.88	-0.571	0.016			-0.023	-0.226			1.66	0.938	1.11	0.053
	(3.18)	(5.54)	(0.16)			(0.06)	(0.56)			(7.39)			
BC_3	-9.41			-0.152	-0.367			-0.142	0.139	1.49	0.942	0.984	0.052
	(3.60)			(0.33)	(0.87)			(0.87)	(0.70)	(6.11)			
BC_4	-8.29	-0.565						-0.117	0.126	1.55	0.945	0.964	0.045
	(3.81)	(6.50)						(0.83)	(0.67)	(8.49)			
BC_5				-34711				-32842	13022	0.083	0.913	1.43	88.2
				(5.99)				(1.99)	(2.85)	(78.00)			
BC_6		-1201				13288				0.081	0.922	0.94	82.8
		(10.43)				(5.63)				(93.51)			

where BC_i is beef consumption in tons per year; YC_t = per capita GNP in year t; YW_t = per capita earnings of salaried workers in year t; YR_t = per capita earnings of nonsalaried workers in year t; RF_t = retail price of beef relative to other foods included in the cost-of-living index in year t; RG_t = retail price of beef relative to other nonfood goods included in the cost-of-living index in year t; RP_t = retail price beef relative to the cost-of-living index in year t; PP_t = population of Argentina in year t; t-statistics are in parentheses.

a. The first four equations are in double-log form; the last two are linear. Equations 3 and 4 are estimated for 1937-61.

Table 17
Argentine Beef Export Equations, 1937/38-1966/67

	Const.	t	DEM	DMEAT	DWAR	FP_t	FP_{t-1}	FP_{t-2}	$\bar{R}^2$	DW	SER
EX:	554.74	2.96	-276.31	117.74	141.00	-1.38	-1.31	1.60	0.604	1.74	95.88
	(5.32)	(0.52)	(3.06)	(1.07)	(2.19)	(0.46)	(0.46)	(0.84)			

Where

EX = beef exports from Argentina; t = a time trend with unit increase from 1937/38 = 1 through 1966/67; DEM = a dummy variable for the years of the Argentine embargo of beef exports to Great Britain, 1951/52-1954/55; DMEAT = a dummy variable for the years during which "meatless" days were imposed, 1952/53-1954/55 and 1964/65-1965/66; DWAR = a dummy variable for the years of World War II, 1940/41-1944/45; FP_t = the foreign price of Argentine beef. The mean level of exports during the period 1937/38-1966-67 is 511.6; t-statistics are in parenthesis.

prefer to sell abroad if the peso price received is higher there than in domestic markets, and changes in effective foreign demand, whether caused by domestic policy intervention or by external events, must be incorporated into the model.

In my equation, exports were seen a function of the foreign price of beef, i.e., the dollar cost of Argentine beef abroad, the price of Argentine beef relative to beef from other countries and to other goods, the income of the countries constituting Argentina's market abroad, and several dummies representing serious disruptions in foreign markets or restrictions imposed on exporters by the Argentine government.

The foreign price of beef was defined as the live price of beef in Liniers Market in Buenos Aires, P_t, times the quantity one plus the export tax rate[5] divided by the exchange rate in force.[6] That is, $FP_t = P_t(1+t)/FX_t$. Multiple exchange rates existed for much of the period studied, and devaluations were frequent. Published series were not consistent for the 1950s; I chose a series constructed by Díaz (1971)[7] --the average exchange rate applied to exports. Thus constructed, the foreign price of beef will diverge from the true price faced by foreign consumers whenever the particular exchange rate of beef differs from the average exchange rate, or when subsidies to the packinghouses were granted by the Argentine government and/or foreign import tariffs were in force. Changes in transportation costs or quota restrictions were not accounted for, but were thought to be of less importance.

I did not include a price variable for an international substitute for Argentine beef. Nores included the dollar price of Danish export steers and obtained a positive and significant coefficient.

Because of the changing pattern of major importers of Argentine beef over the study period, an income variable was not defined. At the beginning of the period, 80 percent of Argentine chilled beef exports went to the British market. In the late 1960s, it dropped to about 25 percent, with the EEC and other countries dividing the remaining 75 percent. Because changes in tariff and quota policies in different countries (including the use of government contracts) apparently influenced the effective size of the market more than the rate of growth in these countries, a time variable was used as a proxy for income growth[8] and two sets of dummy variables represented the major structural changes in foreign markets during this period.

Argentine beef exports were strongly affected by government contracts during most of the study period. Between 1940 and 1946, more than 97 percent of the refrigerated beef and 70 percent of the canned beef exports went to the United Kingdom, primarily as the result of contracts between the British and Argentine governments. In contrast, during the early 1950s, when Argentina contested the prices received for beef, an embargo was imposed on exports to the United Kingdom. The percentages of refrigerated and canned beef exports fell to 51 and 20 percent, respectively, in 1952. Thus, government contracts were the major determinants of the amount sold to various customers at certain times and influenced the magnitude of total beef exports.

Dummy variables were included for three periods: during World War II, when beef was sold in large quantities to the allied nations; during the embargo of shipments to the United Kingdom; and during the years when "meatless" days were enforced. The first two dummy variables represent direct changes in effective foreign demand, but the last is included because exporters occasionally could not obtain sufficient beef to fulfill their export contracts. This usually occurred when both retail and hoof prices of beef were fixed at levels too low to induce producers to supply enough beef to satisfy both domestic demand and export contracts. Rather than allow retail prices to rise, the government chose to ration beef on the domestic market, hoping thereby to free supplies for export.[9]

The estimated equation, given in Table 17 shows that the dummy variables account for most of the explained variation in exports. The coefficient on the dummy for the war years is significant and positive, the coefficient for the years of the embargo is negative and significant, and the coefficient for the periods of meatless days is positive, but not statistically different from zero. None of the other coefficients achieved statistical significance.[10]

The dynamic effect of exchange devaluation on beef exports cannot be analyzed because the coefficients on the foreign price of beef were not significant. Nevertheless, certain observations can be made. The devaluation was particularly large (relative to the rate of change of the exchange rate in the preceding years) in 1939, 1950/51, 1956, 1959, and 1962. In every case except 1950/51, the export share of the animals slaughtered increased in the year of the devaluation. This increase ranged from 1.1 percent in 1959 to 3.9 in 1956. This evidence suggests that the foreign demand response to lower prices is quick: Beef was bid away from the domestic sector.[11] Also, there was an absolute rise in exports in each of the years cited except 1959, implying that the foreign sector is able to increase exports in the short run following a devaluation.[12]

However, in every year immediately succeeding a devaluation, both the export share and total beef exports dropped (except for 1965) to levels significantly below those before the devaluation. Later, however, the export share and total exports rose again (in 1941/43, 1958, and 1962/63). The drop in 1952/54 reflects the embargo on England.

The result of devaluation is thus reasonably clear. Exports increased *absolutely* after the devaluation, declined in the next year as producers, in response to the rising prices, bid for animals to increase their herds, later rising again to higher levels, where they remained until inflation eroded their value. There is a sizeable perverse response to a devaluation to be faced in year t+1, which governments must be prepared to weather, but the balance of payments can be improved by devaluation in both the very short run and the intermediate run.

Endnotes to VII.

1. A 5 percent decrease in domestic beef consumption from 1969 levels would have increased beef exports nearly 15 percent and total exports by about 8 percent, assuming a constant real price received.

2. Another version was also tried using the wage share and the size of the rural population; both coefficients were negative, but neither was significant and the Durbin-Watson statistic was below unity.

3. In 1964, rigorous controls were clamped on slaughterhouses and butchers. According to official statistics, consumption in the federal capital dropped by 10 kilograms per capita compared to 1963, even though a ceiling was instituted on retail prices at the time the meatless-days declaration was made. In the next several years, when fewer controls were used and maximum prices abandoned, consumption rose again to the pre-1964 level. Nores (1971) estimated that the implementation of beefless days during parts of years 1964 through 1966 reduced consumption by about 7 percent. He notes that slaughter also declined during this period and suggests that producers sought to avoid the impact of domestic rationing, expected to be of short duration, by withholding animals until demand was freed.

4. Unfortunately, retail prices for mutton and pork were not available. I had to use the price of live animals in Liniers Market. These data show a 75 percent increase in the cattle/hog relative price from 1939 to 1944, as the live price of cattle rose 66 percent and the live price of hogs fell 8 percent. However, because price controls were in effect during much of the period, the retail price of beef rose only 30 percent. Meatpackers were subsidized to offset the difference. The rise in the retail beef/pork relative price appears to have been about 35 percent. The decline in the per capita beef consumption suggests a significant price cross-elasticity of demand.

5. The export tax was introduced both for revenue and as an instrument to cushion the domestic market against the impact of devaluation.

6. Nores (1972) includes the net effective exchange rate and the farm price of beef as separate variables in his export equation, rather than combining them in a single multiplicative relationship, in order to be able to separate more easily the effects of changes in the exchange rate and the domestic price.

7. Diaz (1971), Statistical Appendix, Table 62.

8. Nores determined that the variation in weighted average of the rates of income growth of the countries to which Argentina has exported beef during the last decade may be closely approximated hy a linear trend.

9. Occasionally this policy was reversed. Then, the government would prohibit exports in order to guarantee sufficient beef supplies for domestic consumption.

10. Nores (1969) estimated an export equation for nearly the same period using a similar specification, but different data, and reported a significant negative coefficient for the dollar value of Argentine beef and a positive significant coefficient for importing countries' weighted income. But the equation included no adjustment for the effective exchange rate. Nores' recent estimate (1972) of a quarterly export equation was rather successful. The Argentine farm price has a negative and significant coefficient, the effective exchange rate a positive and significant coefficient, and foreign beef supplies (Danish export steers) a positive and significant coefficient. The trend term, representing the growth of foreign income, is positive, but insignificant, and lagged exports are positive and highly significant.

11. The drop in 1950 was only 0.4 percent. The slight difference here was caused by the drought of 1949/1951 in the breeding area. The slaughter share of steers and yearlings, the choice export animals, declined while that of cows and heifers, which are usually consumed in the domestic market, rose.

12. The reduction in slaughter from 1958/59 was nearly 27 percent, so large that even the increased export share did not increase actual exports.

VIII. Summary and Conclusions

The stagnation of Argentine agriculture during the period 1945-1965 revived a historical interest in the functioning of the Argentine cattle sector, long a prototype of large scale ranching in Latin America and the source of a significant proportion of world beef exports (nearly 20 percent during the 1960s). The "structuralist" economists in the 1960s emphasized the pattern of land ownership and the associated tenure system as major casual factors in agricultural stagnation. In Argentina semi-absentee landlords traditionally dedicated large tracts to extensive agriculture, particularly cattle ranching. They employed short-term tenants to cultivate grain crops intermittently with improved pastures and forage crops, thereby providing a grain-cattle rotation. This rotation system permitted the large scale production of cereals and oilseeds as well as beef, and usually maintained the high fertility of the Pampas soils, but many claim it worked against efficient resource allocation and discouraged the adoption of potentially profitable new inputs and techniques.

Some argue that the large landlords were "satisficers" rather than profit maximizers, favoring traditional methods which required little direct supervision. Or they maximized other than pure profit goals by remaining in Buenos Aires or other urban centers, supervising their ranching operations from a distance. Many were alledgedly not even aware of new technology as it became available. Land was held as a status symbol or as a hedge against inflation rather than as a productive asset whose return is to be maximized. Such producers were thought to be unresponsive to price changes or not willing to invest in more intensive production methods. [1]

The tenancy system was also thought to have impeded price response and the adoption of technical change, particularly in the area of cereal cultivation. Responsibility for cereal cultivation was generally delegated to tenants. Yet the tenants were often contracted to produce specific crops, contracts which could be altered only by agreement with the landlord. These negotiations frequently proved clumsy, especially if the landlord was not physically present at the time decisions had to be made. The system made it difficult to introduce improvements in production methods, such as the use of yield-increasing inputs, for any such changes required renegotiation of input and output shares.

In addition, insurance against crop failure (for natural causes) was unavailable in Argentina and tenants had limited access to credit, so they were unwilling to accept the risks associated with nontraditional, more intensive production methods. And tenants had little education which limited their access to production related information. All of these factors have potential to seriously distort resource allocation. [2]

Ferrer (1963) suggested that the faults of the land ownership and tenure system largely explain "the continued low yields per hectare of the main products of the Pampean region (and) the failure of the price incentive policies followed after 1950 for the purpose of increasing agricultural output in the Pampean region." This view is defensible only if it can be demonstrated that producers and/or tenants have not responded to economic incentives in an apparently rational manner, e.g., if they have not responded to price changes or have not adopted new production techiques which are privately profitable. [3]

Several efforts were made during the 1960s to empirically test the price responsiveness of Argentine agricultural producers. These studies sought to address the questions regarding producer behavior and to provide policy makers with a framework for predicting the effect on production (and exports) of changes in agricultural prices. Contrary to findings of most studies of other countries, little price response has been discovered in Argentina. [4] Almost no response was found for corn, a major crop which had experienced considereable output variation; the response evident during 1945-1965 for wheat, linseed, and oats is of much smaller magnitude and lower statistical significance than that encountered for these crops in most other countries with similar agricultural resources.

This apparent lack of price response gave some support to be "structuralist" interpretation of stagnation and suggested that price policy, per se, may have a very limited usefulness in Argentine agriculture. Nonetheless, Ferrer's view, which suggested the need for land reform to introduce more modern and vigorous producers into the agricultural sector, was challenged by Reca (1967). Although his empirical work found little price response during the postwar period, Reca argued this behavior was caused by the discriminatory and capricious government price policy during the 1940s and 1950s which so frustrated and confused producers that they ceased to respond to the usual market indicators of profitability. In short, Reca accepted the lack of price response, but suggested that it was caused by government intervention in markets rather than by a lack of producer sensitivity. Reca presented evidence that producers were highly price responsive between 1924 and 1944, thereby confirming that government policy rather than producer motivation should be blamed for the more recent lack of response.[5] But Reca's model was simple; his adjustments to the cattle herd data were probably not adequate to the econometric model undertaken, and he omitted important variables such as the price of grain in the slaughter equation. Reca also argued that low farm prices which discouraged new investments and more intensive farming, played an important role in the postwar agricultural output stagnation.

Because cattle production can be increased only by increasing the size of the breeding herd and/or withholding animals for further fattening, producers must bid animals away from consumers to increase the capital stock which is the source of higher future beef production. And the slow rate of biological reproduction causes the negative supply response to persist for some time. Had the official herd data been better it might have been clearer to observers that a price increase does lead to an increase in production which, properly considered, involves both slaughter and a change in inventory.

As a result of the continuing confusion within Argentina regarding the cause and implications of the short-run reduction in slaughter, I sought to show that this behavior was rational, that a properly specified model would show a significant price response, and that one could even show a theoretically correct differentiation of producers' behavior toward animals of different age and sex.[6] To accomplish these ends, microeconomic models were developed to provide a theoretical framework on which an econometric model of the Argentine cattle sector could be based. In this theory, producers hold cattle as long as their capital value exceeds their slaughter value. In essence, producers become portfolio managers seeking the optimal combination of different categories of animals to complement their noncattle assets, given existing conditions and future expectations. The theoretical models show that parameter changes have a differential impact on the capital values of animals of different age and sex, indicating that the equations explaining slaughter and average slaughter-weight in an econometric model should be disaggregated by animal categories if a meaningful explanation of producers' responses is to be obtained. Accordingly, an econometric model was developed and estimated for the Argentine cattle sector for 1937-1967. Judging by conventional statistical tests, it performed well in explaining the operation and past behavior of the Argentine cattle sector. And the empirical results supported the theoretical model theory.

The estimated equations yield solid evidence that cattle producers have responded in an economic manner to changes in the beef/grain relative price and to its rate of change. The instantaneous response of slaughter to a price increase is negative for every animal category. However, even though the lagged price coefficients (and their sum) are negative in most of the individual category slaughter equations, the model as a whole indicates that the long-run elasticity of slaughter is positive. This fact has frequently been misunderstood. Previous studies based on single equation estimations could only show the negative short-run response of slaughter. Because these models could not show that a growing herd, through larger calf crops, would lead to increased slaughter over time, they tended to be misinterpreted as implying a negative long-run elasticity as well. The estimated price coefficients in my model (and most others) give only the effect of price on the "transitory" component of slaughter, not the "permanent" component. A reduction of slaughter one year increases the size of the herd the next-- and therefore the permanent component of slaughter. It is the net effect of changes in both the permanent and transitory components which yields the true effect of price.[7] Indeed, the greatest impact on future production comes from the increase in the calf crop, as females are withheld to increase the size of the breeding herd. Thus, the equation estimating the number of calves born is crucial to the estimation of the long-run price elasticity.[8]

I believe my results should abolish all doubts about whether Argentine cattle producers respond to price. The results were obtained using herd data that were greatly improved over those previously available. The statistically significant results identify the slaughter response in the various animal categories. They show that producers systematically reallocate their portfolios in the expected manner when the recursive effect of their decisions is strongly evident, i.e., with continuously operating markets for disposable productive assets. And because much of the indicated response is an interactivity shift within the agricultural sector between grains and livestock the price response shown by cattle producers implies a response by field crop producers as well.[9]

Finally, producers also react to nonprice disturbances, such as when government intervention in the tenancy market caused a reevaluation of the relative risk of the various activities, thereby shifting demand for the respective productive factors. Given this type of shift, producers remain just as sensitive to market prices; i.e., prices continued as the most important short-run determinant of production variation throughout the study period.

Further, the macro-policy effects of the producer price response have particularly important implications in Argentina, given the structure of the economy, yet they have not received sufficient attention in the past. While the cyclical rise and fall of prices, production, and slaughter in the cattle sector have been seen as a type of the "cobweb" behavior familiar in agricultural activities, and a description of the causes of this cycle (including the timing of its turning points) has been identified as an important task, little emphasis has been given to the fact that the cattle cycle (regardless of its cause) itself contributes to the general economic cycles experienced in Argentina during the postwar period.

The econometric model developed and estimated here "explains" the dynamic behavior of the cattle sector in the sense that it describes the effect of exogenous events such as devaluation, price fixing, export embargos, general economic growth, and climatic change on the level of prices, herd growth and slaughter. However, while the turning points of the cattle sector must be explained by reference to the economy as a whole, and particularly to government decisions regarding devaluation and the like, neither government policy nor private activity is independent of the cattle sector. The cattle sector is important in Argentina because of the large role it plays in exports. Substantially more work is needed to describe the other side of this interaction. Here I can only sketch out what I believe to be the major issues.

The cattle cycle is partially caused by the substantial recursive effects which current decisions have on the market price of cattle, and because producers' expectations are price elastic over some range, price movements tend to be cumulatively destabilizing. As a result, price policies designed to increase the supply of beef in the long run can be expected to decrease the current supply in the process. The stronger is producer response the more slaughter will be reduced in the short run, and the higher prices will climb.

Policy makers have frequently resorted to devaluation in Argentina when the balance of payments has been in crisis. A devaluation raises the domestic price of tradable goods relative to other goods with the intent of reducing the consumption of exportables, such as beef, while simultaneously stimulating internal production and increasing external demand for these goods. The evidence suggests that devaluation in Argentina usually has slightly increased beef exports in very short run. The decrease in domestic consumption and the increase in foreign demand during the first year is usually sufficiently great to outweigh the decrease in slaughter which results as producers attempt to increase herds.

However, as producers respond to higher cattle prices, these prices rise even further, partially offsetting the effect of the previous devaluation in years two and three, suggesting that the government must be prepared to weather a period of almost three years before devaluation can significantly assist the balance of payments. Indeed, this balance is likely to become worse before it gets better, and whether it improves eventually depends largely on the degree of inflation which occurs during the interim.

Devaluation does not increase nonbeef agricultural exports as much as might be expected for two reasons. First, agricultural producers are unable to increase crop production except by planting new acreage or applying more inputs, particularly fertilizers and pesticides to increase yields. Because the land frontier in the Pampas has been closed for over three decades, and because fertilizers have never been used in significant amounts on the major export crops, increased crop production is likely to occur in the short run only if acreage is switched from beef to crop production. Yet there is no incentive for this to occur. To the contrary, devaluation will initially raise grain and cattle prices in equal proportions, but while grain prices are likely to fall in real terms as inflation continues, beef prices may well increase as producer response reduces slaughter. In short, producer response in the cattle sector will usually induce a switch out of grains into cattle, thereby reducing the aggregate short-run devaluation response of grain production. The same short-run response which is said not to exist is in fact a partial cause of the lack of agricultural export increase.[10]

Second, even though Argentine manufacturing exports grew at a rate exceeding 10 percent per year during the 1950s and 1960s, they accounted for only about 5 percent of total exports in 1965 and 10 percent in 1970. Thus, even a very favorable response to devaluation in this sector would have little proportionate impact on the balance of payments. However, Ericksson (1970) found that changes in the effective exchange rate explain less than half the quite substantial variation in the *growth* of manufactured exports between 1950-1965, i.e., devaluations have not had a major impact on industrial exports. Indeed, the variation in export growth is inversely correlated with domestic growth in GNP, suggesting that manufacturers have attempted to enter foreign markets only when the domestic market enters recession.

The cyclical problem in Argentina is complicated by the close link between devaluation and inflation, and by the fact the internal demand for tradable goods is relatively price inelastic. It has been established that cost push elements are more important than monetary expansion as the causal factors in postwar Argentine inflation. The rate of inflation is associated with changes in relative prices (and associated changes in the sectoral distribution of income), so devaluation, which leads to large relative price increases for agricultural products creates immediate pressures for higher wages in the urban-industrial sector. These pressures, plus the higher cost of imports, are likely to soon result in general industrial price increases. At the same time, devaluation is not likely to affect imports. Diaz (1970) notes that the import-substituting industrial sector is vitally dependent on imported fuels, raw materials, intermediate products, and capital goods, and that these imports are quite price inelastic. Thus, the import bill is largely determined by the level of industrial output rather than by the relative price of imported goods. The average propensity to consume imported goods between 1947-1965 was only 0.11, but the marginal propensity was 0.29. Thus, increases in real income and expenditure quickly lead to increased demand for imports, leading to exchange rate pressures and eventually to balance of payments crises. Because neither exports nor imports respond in the short run to devaluation, the governnemnt has to impose quantitative controls on imports and severe monetary restrictions to balance the merchandise trade account. These together bring an economic recession.

Considerable attention has been paid to the fact that devaluation and the accompanying stabilization policies in Argentina resulted in real output contractions during the postwar period. Because devaluation is conventionally expected to increase aggregate demand, this adverse phemonemon was hard to explain. Two basic reasons have been given for this behavior: One emphasizes the redistributive effects of devaluation (which coupled with differential marginal spending propensities and a wage lag lead to a decrease in aggregate demand); the other points to the restrictive impact of monetary policy which, even when expansionary in nominal terms, has usually been restrictive in real terms.[11] Certainly both of these factors have played a major role, but focus on them diverts attention from the fact that when devaluation does *not* correct the balance of payments equilibrium, the only "solution" is economic contraction. There may be debate about whether contraction automatically follows devaluation or whether it is induced by other policy actions, but there is no doubt that it follows. Its necessity is only because of the long-run inability of the agricultural sector to expand output and of the industrial sector to develop substantial export markets. Social and economic conflict (and misunderstanding) has precluded the design and implementation of fundamental policies which might alleviate or solve these problems.

In addition, however, I think too little emphasis is placed upon the importance of the cattle sector and its economic peculiarities which make the short-run problem even more technically difficult to solve. The negative short-run price response complicates the situation by exacerbating domestic price increases at the most inflationary moments, and by reducing the export response to devaluation, thereby requiring deflation to solve the short-run balance of payments crisis.

Periodic devaluation thus cannot achieve its desired goals in Argentina. It is unable to increase exports, and the ensuing price inflation rapidly eats away the competitive price advantage originally achieved. By the time cattle stocks have been built up in response to the devaluation- induced relative price increase for agricultural products, the economy is in recession and inflation has increased nonagricultural prices, reversing the agricultural terms of trade. Fueled by falling domestic and foreign demand for beef, an increased slaughter flow then comes onto the market. The resulting increase in supply and decline in the relative price of beef will reduce inflationary pressures and increase exports. Once herds are liquidated, however, exports will slow. As an export surplus develops (largely because the economy has been in recession), controls are loosened to permit output to increase, but growth will soon result in a shortage of foreign exchange, and pressures for price relief via a new devaluation will grow from the agricultural sector.

Although this "Argentina's economy in a nutshell" argument is somewhat oversimplified, I believe it describes well the overall pattern of stop-go economic cycles and inflation, as well the corresponding cycles in the cattle industry itself.

Another issue deserving comment is the price inelasticity of the demand for beef in Argentina, approximately -0.5. Its magnitude is sufficient that a 10 percent increase in price, given the associated reduction in domestic absorption and the relatively small proportion of beef production that is exported (27 percent in 1970) should result in a corresponding 12 percent increase in exports. It thus appears that the elasticity of domestic demand is sufficient to make price policy an attractive instrument to reduce domestic absorption and thereby achieve higher exports in the longer run. This is confirmed by the fact that although there was an increase in slaughter of only about 10 percent between 1951-55 to 1962-66, domestic consumption was sharply reduced after the 1958 devaluation and the increase in relative prices, and beef exports expanded 42 percent. In the short run, however, because demand is relatively price inelastic, the decrease in domestic consumption is offset by the decrease in total slaughter resulting from the price increase, so that exports expand very little if at all. The problem lies not so much with the inelasticity of consumer demand, but with producer price response.

An unwillingness to accept sharply higher beef prices following devaluation has led the Argentine government at different times to impose export taxes on beef, thereby cushioning the price increase caused by devaluation, and to introduce meat rationing to reduce absorption.[12] Despite the fact that beef prices have risen relative to grains and to nonagricultural output over the 1950s and 1960s (somewhat erratically), higher beef prices have been resisted because they cause an increase in the cost of living for urban workers and thereby inflationary pressures, and because they signal higher agricultural incomes and a (presumably) worsened distribution of income. Argentine governments should consider the nature of the tradeoff

more carefully, however. Only higher agricultural prices and lower agricultural input prices, combined with support measures to encourage technological change and provide credit and assistance, will increase agricultural production. And only higher prices will effectively reduce domestic absorption in substantial amounts.[13] Past (abortive) efforts to hold prices at lower levels, holding consumption with quantitative devices only highlight the fundamental inability to devise a system of taxes on agricultural land and on incomes, which could achieve improved distributions of income consistent with increased exports and national income.

Endnotes to VIII.

1. One variant of the above argument suggests that landlords were traditional minded, semi-feudal producers who preferred their urban enjoyments to those of the countryside and who accordingly sought only an income which would maintain their living standards. A variant of this argument suggests that the rapid inflation experienced in Argentine (and the insufficient availability of alternative assets which might serve as a store of value) drove many to invest in land, which is supposedly a less risky asset than plant and equipment during inflationary periods. This portfolio demand allegedly caused land prices to increase more rapidly than should have occurred given the changes in output prices and in the availability and prices of complementary inputs, thereby driving rates of return on land investment to low levels. Correspondingly, and more importantly from the social viewpoint, many investors were supposedly unable to or uninterested in maximizing their profits, seeking only to protect their capital; these producers adopted traditional production methods requiring little supervision, such as extensive livestock production.

2. The traditional rotation system under which tenants were permitted to cultivate crops for only a few consecutive years on a given sector of land also provided for little reimbursement by the landlord for improvements made by the tenant to the land or to physical facilities. Tenants were allowed to request from the owner at the time of their departure a maximum of only 20 percent of the cost of permanent improvements made. Indeed, the tenant was usually required to remove, at his own expense, any buildings constructed so that the full area could be returned to pasture. The tenancy legislation introduced during the 1940s, and continued until the late 1960s, intensified rather than alleviated the problem because it induced landlords to move toward even shorter term (one year) contracts to avoid the tenancy legislation and thus provided even less security and provision for reimbursement. This system inhibited both the use of fertilizers, whose economic value may be spread over several years, and the practice of improved soil conservation techniques which are of little interest to tenants under the circumstances.

3. Black (1957) helped to set the stage for the ensuing debate by suggesting that Argentine agricultural prices and output seemed to move in opposite directions during the 1940s and early 1950s just as frequently as they moved together.

4. Diaz (1965) and (1970), Colome (1966), Reca (1967), and Williams (1966), all estimated acreage or output response equations for different products, and all found little price response. Diaz, for example, concluded that other factors such as soil erosion, weather, the availability of inputs, social overhead facilities, and credit affected producers more than prices and had, on balance, shifted the supply schedule to the left over time.

5. In the case of cattle slaughter, Reca found that the price of beef was a less statistically significant variable during 1924-1944 than in 1944-1965, and that the short-run price elasticity of slaughter declined from -0.43 to -0.19 between the two periods.

6. Diaz (1965) provided the first clear outline of the theory developed here, pointing out that a relative rise in beef price induces producers to invest further in beef production which can be accomplished only by reducing current slaughter.

7. Yver (1971) developed a method to determine the time profile of the net impact of exogenous disturbances on the dependent variables in a model similar to mine.

8. Models which estimate only the number of animals slaughtered, without considering changes in the average weight of the slaughtered animal, will also underestimate the long-run supply response because a price increase will cause animals within each category to be fed to somewhat heavier weights, and more animals will be withheld to older ages, e.g., slaughtered as steers rather than yearlings. This latter effect is frequently forgotten by those who note the relative constancy of individual category slaughter weights, but it is a significant factor in total supply. The cumulative elasticity of dressed weight with respect to the beef/grain price is nearly 0.10.

9. The asymmetry between these results and past studies of field crops may be due to measurement difficulties. I have found, for example, that when corn production data are disaggregated at the *partido* (county) level, some individual *partidos* show significant price response even though their aggre-

gate does not. The degree of response for the individual *partidos* seems to be related to the level of the yields achieved and to the type of competing agricultural activities in the area. One of the factors confounding the aggregate results is the difficulty of separating those corn plantings which are desired for grain harvest from those to be used for grazing cattle. In some *partidos* an increase in the price of cattle is associated with an expansion of the area planted to corn, but with a reduction in the percentage of the planted area harvested (as corn is planted for forage); in other *partidos* the beef price increase is associated with a reduction in the area planted to corn.

10. Diaz (1970) notes that the variation of the agricultural export quantum depends in the short run much more on climatic events than on prices.

11. As an extreme example, in 1959 the exchange rate for merchandise trade increased 164 percent, the Buenos Aires cost of living index rose 114 percent, and the money supply rose approximately 45 percent. The corresponding decline in the real supply of money, and of real balances, induced the rate of GDP growth to fall from approximately 6 percent in 1958 to -5 percnet in 1959; industrial production declined even more.

12. I found nonmarket rationing to have had little effect during the period studied, with the possible exception of 1964, but Nores' (1972) more detailed work suggests that during the late 1960s rationing may have reduced consumption as much as 6 percent.

13. Attempts to increase the price elasticity of beef have a long but relatively unsuccessful history. Chicken and fish consumption has increased somewhat in recent years as their quality has improved and their relative prices fallen, but they are not yet rival to beef.

Appendix I

The Burden of Discriminatory Agricultural Policies

"One focal point of the political conflict in Argentina continues to be redistribution of income from wealthy landowners to urban labor. During the decade of 1945-1955, income was transferred from owners of cattle and agricultural land to urban workers and to government, *essentially by taxing output* through price ceilings on foodstuffs and through increased prices of agricultural inputs."[1] This statement is true, but contrary to the conventional wisdom, the evidence in this study indicates that the burden of the discriminatory policies toward agriculture did not fall heavily on the large landowners of the rural sector, i.e., the cattle producers.

To summarize this evidence again, first, the agricultural product monopsony established by Perón was more severely discriminatory against grain prices than against cattle prices.

Second, although Perón's interference with tenancy contracts hurt cattle producers who contracted tenant farmers, the relatively more specialized was a cattle producer, the less affected by this policy.

Third, while the wage of the rural *peon* rose relative to grain prices, rural wages *fell* relative to cattle prices. The Economic Commission for Latin America (ECLA) gives the following data for the movements in the rural wage relative to the respective product prices.[2]

	Wheat	Corn	Cattle
1935-39	100	100	100
1940-44	139	152	82
1945-49	91	126	89
1950-54	124	118	79
1955-59	122	115	76
1960-63	70	95	50

Because grain production is also relatively more labor intensive than is cattle production, grain-producing activities are more adversely affected by any "relative" wage increase. Thus, small grain producers were hurt much more by the change in labor costs than were cattle producers.

Fourth, a much larger increase occurred in the wage/grain price ratio for seasonal (harvest) labor than for permanent agricultural labor. This also hurt crop producers relative to cattle producers.

Fifth, the wage of a rural *peon* fell drastically relative to industrial workers. The ECLA study reported the following index for peon industrial worker relative salaries:

1935-39	100
1940-44	78
1945-49	39
1950-54	36
1955-59	36
1960-63	35

More importantly, the real wage of rural *peones* also declined significantly during Perón's administration. The real rural wage rate during the years 1946-1952 was 40 percent lower than in 1944. Therefore, although Perón supposedly tried to improve rural laborer's welfare, the evidence indicates that the opposite occurred. The increase in fringe benefits offered by new rural legislation during this period was not nearly large enough to overcome the decrease in real wages, let alone the unemployment which also occurred.

Sixth, although the agricultural tenants first gained by the freezing of the land contracts (by costlessly obtaining temporary possession of the land), many tenants were forced to leave the land and seek a new livelihood in the city when the era of recontracting returned. Tenants were also badly hurt by the very low grain prices prevailing during the years when they had control of the land. Possibly they were worse off during this period than before, even though they paid much lower rents.

Perón's agricultural policies did not single out wealthy landowners, particularly cattle producers, for economic punishment. Nearly everyone in the agricultural sector was directly harmed, and many of them were harmed relatively more than the cattle producers.

Endnotes to Appendix I.

1. Reca (1967). Italics in original.
2. *ECLA*, 1959, Vol. 3, p. 19.

Appendix II

A Simulation of Productivity Change in the Feed/Beef Conversion Process

This appendix considers several sources of productivity change in the cattle sector and the manner in which this productivity change can be measured using a simple simulation model. The model is simple in conception and useful mainly for quick and easy calculations. More detailed models can be constructed where greater accuracy is desired. The model permits study of the sensitivity of herd production to variation in calving, slaughter, and mortality rates, to changes in the efficiency of the feed/beef conversion process, and to seasonal patterns of feed supply. Such data could provide the basis for cost-benefit analysis of livestock development programs designed to increase feed availability and improve livestock productivity.

If we separate the cattle production process into two interrelated but distinct activities, we can imagine that productivity change occurs either in the pasture activity or in the feed/beef conversion activity. For example, if new grasses or legumes can be developed which carry more animals per acre at no greater cost than did the old pastures, total factor productivity has obviously increased. However, while pasture improvement may be one of the more important potential sources of productivity gain in the beef sector, it is certainly not the only source. The other major source of productivity is in the feed/beef conversion process, where for a fixed amount of feed more beef for final consumption is obtained from the herd. Productivity change of this sort may be obtained by developing animals which individually grow faster and more efficiently, by reducing death losses, or by increasing the calving rate. Mortality rates and the calving rate can, of course, be affected by new breeds as well as better medical care, better service techniques, and better nutrition.

Because crop production is a rival activity to cattle production as it is carried on in Argentina, cattle production may be decreased by productivity change in crops, at least to some degree. For example, if the yields of artificial pastures and forage crops do not increase in like proportion, an increase in corn yields will make it profitable to use some land for corn rather than beef production. Of course, if the increased productivity in corn production were to reduce the price of corn sufficiently, corn could be used as a feed concentrate and feedlot operations could be developed. If so, the production of cattle could increase as a result of productivity change in corn production. If, however, the demand for corn were very elastic, the increased production of corn in Argentina would not significantly lower the price of corn. As the opportunity cost of cattle production would have risen, the cost of beef would rise and cattle production would fall. The price of beef might rise so high that it would eventually be profitable to use corn as a cattle feed, but this is a different matter. The important issue is that productivity increases in crop production have different implications for cattle production depending on the direct effect of the technical change on the cattle/crop price ratio. Further, the best situtation for Argentina is one in which there is a perfectly elastic demand for corn, for although technical change in corn production in Argentina has a strong negative effect on cattle production, total real income would be increased substantially.

To study the quantitative effect of productivity change in the feed/beef conversion process, a simple simulation model may be used. The simulation begins by assuming as given a fixed number of cows in the herd and from this, given the prevailing mortality rates for each category of the herd, the calving rate, the service life of a cow, and the percentage of existing calves and yearlings slaughtered each year,[1] the steady state size and composition of the herd, and yearly slaughter can be calculated. By multiplying each slaughtered animal by the number of pounds of beef which it provides, the total pounds of slaughtered beef by category and by gross total are obtained.

Further, by multiplying each animal in the herd by its yearly food allowance, the sum of total feed units required for the basic herd can be determined. If this amount of feed is assumed to be the fixed supply available, the new steady state herd level and slaughter consistent with this feed supply can be found whenever a parameter value is altered. That is, we can let mortality rates, calving rates, the productive life of a cow and tastes vary to examine how such variations affect the production and the composition of the beef which can be obtained from a given feed supply. For simplicity, I assume that the seasonal pattern of pasture availability and of herd requirements coincide.

It would be a simple matter to assume that different prices are secured for beef from different animal categories. Any vector of relative prices can be used to multiply the vector of slaughter corresponding to the respective solutions to obtain the value of slaughter. By doing so, we could obtain a more accurate indication of the changes in the value of total slaughter, or total herd size. It is conceivable, for example, that a change in the composition of slaughter could cause the total value of slaughter to vary inversely with the total volume of beef produced. Prices are not included in these calculations to make the solution simpler.

The model used for the simulation is reproduced below and selected numerical results follow. We begin by assuming a cow breeding herd of a fixed size, composed of the surviving cows of different age cohorts, V_i.

1) $V=\sum_{i=1}^{\phi} V_i(1-\delta_v^i)$

Cow slaughter is equal to the number of cows age ϕ.

2) $VS=V_\phi(1-\delta_v^\phi)$

The number of calves born is determined by the size of the breeding herd and the calving rate, ψ.

3) $T=V\psi$.

The steady state composition of the herd and of slaughter then depends on the individual category mortality rates and category slaughter rates.

4) $TD=T\delta_T$

5) $TS=(T-TD)\gamma$

6) $Y=(T-TS-TD)\,w$

7) $YD=Y\delta_y$

8) $YS=(Y-YD)\beta$

9) $VQ=Y(1-w)/w$

10) $VQD=VQ\delta_{VQ}$

11) $VQS=(VQ-VQD)-V$

12) $N=Y-YD-YS$

13) $ND=N\delta_N$

14) $NS=N-ND$

15) $S=TS+YS+VQS+VS+NS$

16) $F=T[(1+\delta_T)/2]f_T+\cdots+N[(1+\delta_N)/2]f_N$

17) $\theta=x/F$

δ = category mortality rates, e.g.,

δ_T = mortality rate for calves

ϕ = service life, or slaughter age of cows

γ = calf slaughter rate

β = yearling slaughter rate

ψ = calving rate

θ = multiplcative herd adjustment factor

w = male/female birth ratio

F = total herd food requirements; f_i = category food requirements

x = available feed supply

The notation is that used throughout this study, with the following exceptions, which are newly defined.

VSP = proportion of total slaughter represented by cows

TSP = proportion of total slaughter represented by calves

VQSP = proportion of total slaughter represented by heifers

YSP = proportion of total slaughter represented by yearlings

NSP = proportion of total slaughter represented by steers

ST = total metric tons of beef produced by slaughter

VST = total metric tons of beef produced by slaughter cows

TST = total metric tons of beef produced by slaughter of calves

VQST = total metric tons of beef produced by slaughter of yearlings

NST = total metric tons of beef produced slaughter of steers

VP = proportion of total herd represented by cows

TP = proportion of total herd represented by calves

VQP = proportion of total herd represented by heifers

YP = proportion of total herd represented by yearlings

NP = proportion of total herd represented by steers

HPP = the potential beef production, in metric tons of dressed weight equivalents, which is represented by the animals in the herd at the beginning of the year.

Certain assumptions of the model may be explained briefly. First, the number of cows slaughtered each year is equal to those cows who have survived to age ϕ, where ϕ is taken to be the optimal age of slaughter for a breeding cow.[2]

Second, VN, the number of new cows (ex-heifers) entering the breeding herd each year, is set to equal the replacement needs of the breeding herd, VN = VS + βV, where β is the mortality rate for cows and V is the total number of cows of all ages in the herd. All heifers not needed as breeding replacements are slaughtered.

Third, there is a maturing process for heifers entering the cow herd such that the calving rate for "first-year" cows is only one-half the calving rate for older cows. This is consistent with actual fact, although it probably overstates new cow calving rates. Because cow mortality is strongly affected by calf bearing, the mortality rate used for first-year cows is also somewhat lower than that used for mature cows.

Fourth, the slaughter of calves is divided equally between males and females, and all surviving steers are slaughtered each year.

Fifth, for simplicity, bulls are not included in the model. they make up a very small proportion of the herd and of beef slaughter.

Finally, certain assumptions needed for the dressed carcass weight, the feed requirements, and the beginning mortality rates of each category, are given in the following table.[3] During the simulation the mortality rates were halved, the calving rate (ψ) rose from 60 to 80 percent, the calf slaughter rate (γ) rose from 10 to 40 percent, the yearling slaughter rate (β) rose from 10 to 40, and then to 70 percent, and the service life (ϕ) rose from 5 to 7 years.

	Mortality Rate	Dressed Weight	Feed Requirements
Cows	0.04	210	8
Heifers	0.02	170	7
Yearlings	0.02	200	8
Steers	0.01	270	10
Calves	0.04	125	5

The steady state herd size and slaughter amounts can be accommodated to any specified feed supply by multiplying such state variables by the adjustment factor, θ. The category slaughter amounts may then be multiplied by their respective dressed weights, and summed, to obtain the composition and supply of total beef. Relative prices may be included in the model in a similar fashion.

The effects of certain parameter variations may be studied by examining the selected numerical results (see Appendix Table 1). In each case both the parameter values and the herd- slaughter values are given.

Case 1 versus Case 4: Reducing the mortality rates by one-half, given the other initial conditions, results in an increase in S, the total annual slaughter, of 7.2 percent and an increase in ST, the total annual tons of beef produced by slaughter, of 6.8 percent. This is a significant increase, considering that it results from a reduction of the average mortality rate by less than two percentage points. Nevertheless, it demonstrates that when mortality rates are low, attempts to reduce mortality further will have relatively small returns. Note that S and ST rise by similar amounts and that the composition of slaughter changes little, except that there are more heifers available for slaughter. Further, note that both H and BUH drop. This occurs because feed requirements are calculated assuming that any animal which dies uses only half as much food as those which live through the year. As fewer animals die, more food per "beginning" animal in the herd is required. The composition of the herd is altered only slightly.

Case 1 versus Case 3: Increasing the calving rate from 0.6 to 0.8 has a more striking effect. S rises 16.6 percent, ST rises 15 percent, H increases 1 percent (but BUH drops slightly), and the composition of both slaughter and the herd changes markedly. As fewer cows are now required to produce the same number of calves, there is room for the herd to expand. However, the steady state number of cows remains lower than in Case 1, and hence VS remains lower. The numerical slaughter of every other category rises, but only the proportion of heifer slaughter rises dramatically. The composition of the herd is unchanged except for there being fewer cows, but this must be so because nothing other than the calving rate has been affected. There is an unambiguous increase in productivity in this case, in value as well as tons of dressed beef, because the only category whose proportion of slaughter decreases is cows, whose beef is also the least valuable per pound.

Case 1 versus Case 6: Lengthening the service life of a cow from five to seven years has little effect. S increases by 1 percent but ST declines slightly. VS falls from 40 to 26.6, and VQS rises from 0.5 to 14.0. Because cows calve to an older age, fewer heifers are needed each year to maintain a breeding herd of given size. Further, because the proportion of the cow herd which is "maturing" is smaller, the "average" calving rate rises even though the calving rate of mature cows does not change. V falls, but the steady state of number of animals in every other category rises. Because most of the change in total animals slaughtered is due to the tradeoff between cows and heifers, and heifers weigh less, ST falls slightly. The value of slaughter probably increases as the beef from heifers is worth considerably more per pound than the beef from cows, but no increase in physical productivity as measured by tons of meat occurs. The latter result is somewhat paradoxical, for there are more younger relative to older animals in the herd in the new situation and the former are supposedly more

Appendix Table 1
Simulation Results to Study Output Effects from Productivity and Taste Changes

Case 1.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	99.999	40.005	11.252	0.511	4.911	43.319	485.622	111.707	118.442	50.634	50.634	44.203	
		VSP	TSP	VQSP	YSP	NSP		VP	TP	VQP	YP	NP	
		0.400	0.112	0.005	0.049	0.433		0.456	0.243	0.104	0.104	0.091	
	ST	VST	TST	VQST	YST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	22.573	0.372	0.062	0.003	0.043	0.518	5.000	0.600	0.100	0.100	0.050	0.030	0.020
Case 2.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	109.757	43.651	12.227	0.557	37.514	15.756	477.731	241.915	129.239	55.249	55.249	16.077	
		VSP	TSP	VQSP	YSP	NSP		VP	TP	VQP	YP	NP	
		0.397	0.111	0.005	0.341	0.143		0.486	0.259	0.111	0.111	0.032	
	ST	VST	TST	VQST	YST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	22.553	0.406	0.068	0.004	0.332	0.188	5.000	0.600	0.100	0.700	0.050	0.030	0.020
Case 3.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	116.580	34.242	12.841	14.451	5.605	49.439	490.972	189.772	135.176	57.787	57.787	50.448	
		VSP	TSP	VQSP	YSP	NSP		VP	TP	VQP	YP	NP	
		0.293	0.110	0.123	0.048	0.242		0.386	0.275	0.117	0.117	0.102	
	St	VST	TST	VQST	YST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	25.722	0.279	0.062	0.095	0.043	0.518	5.000	0.800	0.100	0.100	0.050	0.030	0.020
Case 4.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	107.195	41.158	11.333	4.922	5.023	44.758	479.832	216.385	116.237	50.999	50.999	45.210	
		VSP	TSP	VQSP	VSP	NSP		VP	TP	VQP	YP	NP	
		0.383	0.105	0.045	0.046	0.417		0.450	0.242	0.106	0.106	0.094	
	ST	VST	TST	VQST	VST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	23.986	0.360	0.059	0.034	0.041	0.503	5.000	0.600	0.100	0.100	0.025	0.015	0.010
Case 5.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	123.324	35.172	12.913	18.515	5.723	50.999	485.095	184.916	132.444	58.109	58.109	51.514	
		VSP	TSP	VQSP	VSP	NSP		VP	TP	VQP	YP	NP	
		0.285	0.104	0.150	0.046	0.413		0.381	0.273	0.119	0.119	0.106	
	ST	VST	TST	VQST	VST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	27.062	0.272	0.059	0.116	0.042	0.508	5.000	0.800	0.100	0.100	0.025	0.015	0.010

Case 6.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	101.007	26.644	11.421	13.984	4.985	43.971	486.192	218.308	120.224	51.395	51.395	44.868	
		VSP	TSP	VQSP	VSP	NSP		VP	TP	VQP	YP	NP	
		0.263	0.113	0.138	0.049	0.435		0.449	0.247	0.105	0.105	0.092	
	ST	VST	TST	VQST	VST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	22.269	0.251	0.064	0.106	0.044	0.533	7.000	0.600	0.100	0.100	0.050	0.030	0.020
Case 7.	S	VS	TS	VQS	YS	NS	H	V	T	VQ	Y	N	
	124.708	24.034	13.079	30.141	5.797	51.656	485.649	181.604	134.150	58.358	58.858	52.177	
		VSP	TSP	VQSP	VSP	NSP		VP	TP	VQP	YP	NP	
		0.192	0.104	0.241	0.046	0.424		0.373	0.276	0.121	0.121	0.107	
	ST	VST	TST	VQST	VST	NST	ϕ	ψ	γ	β	δ_V, δ_T	δ_Y	δ_N
	26.912	0.187	0.060	0.190	0.043	0.518	7.000	0.800	0.100	0.100	0.025	0.015	0.010

efficient converters of feed to beef. The result must be dependent on the particular assumptions used here of feed requirements and weights, a small change in which might result in an increase in PS as well. Nevertheless, it is clear that extending the producing life of a cow cannot be expected to have a major effect on productivity and explains why producers do not expend much money on such an attempt.[4]

Case 1 versus Case 5: Reducing mortality rates and increasing the calving rate simultaneously increases S by 23.2 percent and ST by 21 percent. Note that this increase is less than the sum of the increases brought about by these improvements when they were made independently.[5] Although this is in one sense disappointing, the net increase in productivity is quite large and indicates the potential improvements in productivity which are available in a country like Argentina (the calving rate in Argentina was about 0.70 in the late 1960's, but in the United States it was between 0.85 and 0.90). The other results are similar to those results already described for other cases.

Case 1 versus Case 7: Reducing mortality rates, increasing the calving rate, and lengthening the service life of a cow results in an increase in S by 24 percent and in ST by 20 percent.

Case 1 versus Case 2: If we now inspect the effect of a change in tastes on slaughter and herd composition, we can see how misleading this change can be. Suppose that most consumers suddenly change their tastes, prefer younger beef and refuse to pay a premium for steer beef as opposed to yearling beef. In this case the percentage of yearlings slaughtered will certainly rise. Assume, for example, that 70 percent of the yearlings now are slaughtered. As fewer steers are left in the herd, the other categories may expand. In Case 2, more animals are slaughtered but they are also younger animals. Further, keeping the additional cows required to produce the extra calves uses up more food in this example and makes the total feed/beef conversion process slightly less efficient, in a physical sense.[6] S rises by 9.8 percent, but ST declines slightly; H rises substantially, but BUH falls.

If the total slaughter of animals is casually observed, one might conclude that productivity in the beef sector was rising, but this would be a mistake. Even the relative constancy of ST is not a trustworthy indicator because part of the increase in S comes from cows, the least valuable beef per pound. There is no increase in beef produced even though more animals are slaughtered. Similar comments can be made when the proportion of calves slaughtered rises. The point is that unless the composition of slaughter has remained constant, the number of animals slaughtered may not reflect true increases in productivity; inferences drawn from numbers alone should be made with caution.

One additional point can be made. In general equilibrium, the profit rate earned in the beef sector does not depend on any particular assumption about the slaughter rate of any category nor, for that matter, on any of the other parameters we have dealt with. Hence, no particular slaughter composition can be assumed to be inherently better than another.[7]

Endnotes to Appendix II.

1. The percentage of calves and yearlings slaughtered is a proxy for tastes indicating the relative consumer demand for younger as opposed to older animals. Tastes can affect the magnitude and the composition of slaughter without there being any implied productivity change.

2. The primary reason cows are sold to slaughter at age ϕ is that the probability of their conceiving and delivering a valuable calf in year $\phi + 1$ is so low that the expected value of this calf is less than the expected cost of feeding the cow during this period. Therefore, ϕ can change with changes in p, c, and r, the price of beef, cost of feed, and the interest rate, respectively, without thereby implying any change in productivity. Productivity change in this phase comes only if the physical productivity of cows can be increased or their breeding life extended. In the latter case the fixed cost of the maturing process of a cow can be spread over a longer producing life, thus reducing the total feed requirements needed for a breeding herd which produces a certain number of calves each year.

3. Although the parameter values selected are reasonable, as are the assumed dressed slaughter weights and the feed requirements per animal, caution should be used in interpreting the results, clearly the results are not exact.

4. There is one special exception. Purebred breeding cows which have a particularly high value because of the quality of their calves may be fitted with false teeth to allow them to live and prosper. Clearly only the extra value of their offspring makes this expense profitable.

5. The increase in the calving rate decreases the proportional number of cows required in the steady state herd. Because these animals have the highest mortality rate, a generalized decrease in mortality rates saves proportionately fewer resources when there are fewer cows.

6. Although calves are more efficient converters of feed into beef than are older animals, this simulated cow-calf combination may well produce less marketable beef with a certain amount of feed than were older animals being fattened. If the feed used by cows has a very low opportunity cost and is not suitable for the fattening of other animals, the qualitative result is changed.

7. A type of feed/beef conversion productivity change, not considered explicitly in this simulation, is a faster growing animal which requires less total feed. As animals require a large amount of feed just to maintain their life processes, apart from weight gain, speeding up the gaining process can reduce the total feed required for a given desired slaughter weight. The required amount of daily movement of the animal, the environmental temperature, and the temperament of the animal are factors which affect the feed/beef conversion process, and are therefore potential sources of productivity increase.

Appendix III

Construction of the Climatic (Weather) Indexes

It was expected that cattle production would be sensitive to changes in climatic conditions, and a variable was constructed to measure this influence.[1] Several previous studies of the cattle sector have used simple rainfall indices as a proxy for climatic variations.[2] However, Oury (1965) has shown that considerably better results can be obtained if temperature and rainfall are combined in a weather index. He suggests the use of the de Martonne index, W, which combines average monthly rainfall in the following manner:

$$W=\sum^{t} R_i/[(\sum^{t} T_i/t)+K]$$

where R_i = rainfall per month in millimeters, T_i = average monthly temperature in centigrade, t = the number of months in the period, and K = a constant.[3] This index is easy to construct and fully utilizes the available data. Subsequent testing confirmed that the de Martonne index had considerably more explanatory value than did a pure rainfall index.

Climatic conditions may, of course, affect cattle production in two separate ways. Climate conditions affect the growth of the plants which must be consumed by the animals when cattle production is carried out by grazing, and climate may also affect the rate at which animals convert feed of a given nutrient value into marketable beef. In general, "good" climate affects each process in the same direction, but there is no reason that the optimal climate for the one should be the same as the optimal for the other. This suggests the use of two indexes, one to measure the effect of climate on the availability of feed nutrients and the other to measure the effect of climate on the feed/beef conversion process itself. However, multicollinearity then becomes a serious problem. More importantly, the data on natural and artificial pastures and forage crops in Argentina are very poor, making it impossible to measure directly the amount of feed available. A single climatic index was therefore used to measure both effects of weather variation on beef production.[4]

Data were first selected from 37 weather stations. Nearly all of these are located in the Pampean region, although several stations were chosen to represent smaller regions which also produce cattle for commercial slaughter. The observatories used are listed below, by province and city.[5]

Buenos Aires

Ayacucho
Carlos Casares
Coronel Pringles
Chascomús
Gral. Madariaga
Gral. Villegas
Guaminí
Las Flores
Lobería
Mercedes
Olavarría
Salto
Tres Arroyos
Trenque Lauquén
Veinticinco de Mayo

Chaco

Charata

Córdoba

Belle Ville
El Tío
Laboulaye
Río Cuarto
Rio Tercero
Vicuña Mackenna
Villa Huidobro
Virgen del Rosario

Corrientes

Mercedes

Entre Ríos

Guilbert
Gualaguay
Seguí
Villaguay

La Pampa

Ateucó
Eduardo Castex

San Luis

Mercedes

Santa Fe

Casilda
Galvez
Landeta
Rafaela
Venado Tuerto

Santiago del Estero

Garza

Using data supplied by the Servicio Meteorológico Nacional for cumulative monthly precipitation and monthly average temperatures, these climatic indices were constructed for each weather station. One index corresponded to the fiscal year, and two shorter period indexes were constructed for the cattle-breeding season (December to May) and for the calving season (August to January). The shorter period indexes were for inclusion in the equation estimating the number of calves born. Cow fertility is thought to be significantly affected by the cow's health and condition during the breeding period, which in turn are affected by climate and feed intake. Similarly, conditions during the calving season could affect the mortality rate of newborn calves, though this effect is probably much weaker.[6]

Aggregate indexes for each of the periods mentioned were then constructed, where the weights assigned to each weather station depended on the number of animals of each category in that particular region. These weights are taken from the 1960 census.[7] Although the regional distribution of cattle production has shifted somewhat during the period studied, both in terms of gross numbers and in terms of the relative numbers of a specific category within each area, the 1960 census provides a good indicator of the general distribution of the different categories of the herd.

If one region enclosed the area "covered" by three weather stations, the observations from these weather stations were combined in a weighted average,[8] the weights being determined by the geographical area spanned by each weather station within the region. To form a climatic index for each cateogry, the resulting climatic index for each region was then weighted by the percentage of the total number of animals of each category within its boundaries.

Similarly, a climatic index for the herd aggregate was constructed by assigning weights to the animals in each different category according to their size and then weighting the regions by the percentage of the total "meat units" which lay within their boundaries. The weights used were cows, 1; steers, 1; yearlings, 0.7; heifers, 0.7; and calves, 0.5.

The different climatic indexes computed are given in Appendix Table 2.[9]

Endnotes to Appendix III.

1. Recent work on the use of climatic variables in agricultural models has shown that a climatic index should combine information on various factors such as rainfall, temperature, soil conditions, the root depth of the plant involved, and the months of the year during which climatic factors are most crucial to the production process, in order to capture the biological interrelations among climate, other related factors, and the plant (Shaw 1964, Oury 1965, Stallings 1960, and Conome 1966). However, such detailed information often is not available, so less sophisticated measures must be constructed. Argentina's official meteorological stations collect data for rainfall and temperature.
2. Diaz (1965), Reca (1967), and Otrera (1966).
3. The constant in the de Martonne index may be arbitrarily set or varied parametrically to determine which level gives the best result. A reasonable approach is to let K vary, choosing that value which maximizes R^2 in the equation being estimated. I did not do this, but chose ten, a number which has been used in other studies under similar conditions.

Appendix Table 2
Computed Climate Indexes

YEAR	C	WT	WN	WHY	WP	WB	CC	CVI	ALPHA	BETA	GAMMA
1937/38	93.36	93.36	93.36	93.36	90.00	99.00	-0.2328	-0.1862	0.0537	0.0327	0.0218
1938/39	84.09	84.09	84.09	84.09	82.00	90.00	-0.6068	-0.4855	0.0597	0.0372	0.0248
1939/40	119.31	119.31	119.31	119.31	117.00	82.00	0.8142	0.6514	0.0369	0.0202	0.0134
1940/41	136.06	136.31	143.10	134.39	150.67	117.00	1.4901	1.1921	0.0261	0.0121	0.0080
1941/42	104.22	104.18	111.68	102.80	100.56	155.69	0.2053	0.1643	0.0467	0.0275	0.0183
1942/43	94.31	94.26	93.61	94.50	82.06	107.66	-0.1944	-0.1555	0.0531	0.0323	0.0215
1943/44	115.39	115.15	117.00	115.33	130.68	80.14	0.6561	0.5248	0.0395	0.0221	0.0147
1944/45	85.24	85.40	84.38	85.23	86.69	116.67	-0.5604	-0.4483	0.0589	0.0367	0.0244
1945/46	118.36	119.76	114.30	117.68	107.51	86.65	0.7759	0.6222	0.0375	0.0206	0.0137
1946/47	136.86	136.48	141.85	136.28	143.12	114.32	1.5224	1.2207	0.0255	0.0116	0.0077
1947/48	96.01	96.30	101.54	94.61	83.91	143.24	-0.1258	-0.0965	0.0519	0.0314	0.0209
1948/49	93.58	94.48	97.00	91.96	83.15	110.03	-0.2239	-0.1736	0.0534	0.0326	0.0217
1949/50	85.03	86.04	88.19	83.32	78.03	103.43	-0.5689	-0.4481	0.0589	0.0367	0.0244
1950/51	99.16	99.70	98.62	98.70	114.47	76.14	0.0012	0.0101	0.0497	0.0298	0.0198
1951/52	91.44	92.63	90.44	90.38	104.93	97.04	-0.3102	-0.2335	0.0546	0.0335	0.0223
1952/53	117.10	117.22	117.88	116.81	121.04	85.41	0.7251	0.5977	0.0380	0.0210	0.0140
1953/54	112.11	112.79	114.25	110.96	122.91	113.50	0.5237	0.4385	0.0412	0.0234	0.0156
1954/55	99.25	98.76	101.18	99.39	82.47	108.80	0.0048	0.0255	0.0494	0.0296	0.0197
1955/56	95.49	94.92	91.51	96.88	86.00	114.72	-0.1468	-0.0948	0.0518	0.0314	0.0209
1956/57	85.19	83.54	83.50	87.28	74.40	97.26	-0.5624	0.4182	0.0583	0.0362	0.0241
1957/58	90.04	89.66	84.96	91.44	94.29	78.25	-0.3667	-0.2594	0.0551	0.0338	0.0225
1958/59	99.91	97.94	92.01	103.56	93.48	101.92	0.0314	0.0644	0.0487	0.0290	0.0193
1959/60	84.58	84.91	80.89	84.95	86.97	93.97	-0.5871	-0.4257	0.0585	0.0363	0.0242
1960/61	98.88	99.86	101.26	97.37	97.70	75.32	-0.0100	0.0459	0.0490	0.0293	0.0195
1961/62	67.69	68.39	65.95	67.30	71.84	102.02	-1.2686	-0.9408	0.0688	0.0441	0.0294
1962/63	89.15	89.31	85.85	89.64	84.09	65.62	-0.4027	-0.2262	0.0545	0.0333	0.0222
1963/64	106.63	106.19	100.30	108.34	118.55	88.95	0.3026	0.4246	0.0415	0.0236	0.0157
1964/65	76.53	76.59	73.84	76.99	81.24	95.54	-0.9119	-0.5567	0.0611	0.0383	0.0255
1965/66	99.00	99.00	99.00	99.00	99.00	68.50	-0.0052	0.1770	0.0464	0.0273	0.0182
1966/67	103.00	103.00	103.00	103.00	103.00	99.00	0.1561	0.3064	0.0438	0.0254	0.0169

YEAR	X1	X2	X3
1937/38	1.0567	1.0977	1.1127
1938/39	1.0635	1.0854	1.0943
1939/40	1.0383	1.0511	1.0707
1940/41	1.0268	1.0559	1.0791
1941/42	1.0490	1.0840	1.1002
1942/43	1.0560	1.0799	1.1070
1943/44	1.0411	1.0808	1.0959
1944/45	1.0625	1.0850	1.0936
1945/46	1.0390	1.0513	1.0738
1946/47	1.0262	1.0595	1.0831
1947/48	1.0547	1.0903	1.1176
1948/49	1.0564	1.0967	1.1190
1949/50	1.0626	1.0953	1.1203
1950/51	1.0524	1.0888	1.1043
1951/52	1.0578	1.0805	1.0977
1952/53	1.0395	1.0644	1.0859
1953/54	1.0430	1.0748	1.0978
1954/55	1.0520	1.0861	1.1131
1955/56	1.0527	1.0944	1.1197
1956/57	1.0619	1.0992	1.1209
1957/58	1.0584	1.0900	1.1171
1958/59	1.0512	1.0908	1.1126
1959/60	1.0621	1.0942	1.1127
1960/61	1.0516	1.1001	1.1251
1961/62	1.0739	1.1110	1.1287
1962/63	1.0576	1.0832	1.1116
1963/64	1.0433	1.0849	1.1050
1964/65	1.0651	1.0950	1.1139
1965/66	1.0487	1.0760	1.0971
1966/67	0.0000	0.0000	0.0000

W	=	Climatic index for the aggregate cattle herd, June-July
WT	=	Climate Index for Cows and Calves, June-July
WN	=	Climatic index for steers, June-July
WHY	=	Climatic index for heifers and yearlings, June-July
WP	=	Climatic index during the calving season
WB	=	Climatic index during the calf breeding season
CC	=	Climatic variation impact index
CVI	=	Climatic-vaccination variation index
ALPHA	=	Index of previous mortality for calves slaughtered
BETA	=	Index of previous mortality for yearlings slaughtered
GAMMA	=	Index of previous mortality for steers slaughtered
X1	=	Multiplicative factor for calves slaughtered
X2	=	Multiplicative factor for yearlings slaughtered
X3	=	Multiplicative factor for steers slaughtered

The original unweighted De Martonne climatic indices for each observatory are available from the author.

4. A high value of W is expected to be positively correlated with production, although an excess of rain or freezing temperatures can obviously be detrimental. The temperate climate in the Argentine Pampas makes the risk of frost damage very small, but excess water can be a factor in certain areas. One could assume that a certain amount is optimal, using the difference from this amount as an indication of the weather's influence. If too much rainfall has a qualitatively different effect than too little, two indexes could be constructed, one for excess and the other for insufficient water, letting each assume a value of zero when the observation lay within the other's range. Such complications were not necessary for this study.

5. There are occasional gaps in some of the series from the individual locations for rainfall, temperature, or both. When these gaps occurred, data from the nearest or otherwise most similar observatory were substituted. The observatory from which data were substituted was not always one of the set of 37 used in this study; there are many weather stations in Argentina. The 37 weather stations included were chosen because they covered the geographic area studied fairly equidistantly. It was not difficult to find other weather stations close by which experience similar weather according to official isohyet charts, which had collected data when one of the selected 37 had been shut down.

6. In an unpublished study on Argentine corn production, I used two climatic indexes, constructed from the same basic data. The first index measures climatic conditions just prior to and during the planting season and attempts to measure the effect of climate on the acreage planted, which may be affected either because planting requires that certain soil moisture conditions be met beforehand or because the crop in question is a secondary crop and will be planted if and only if conditions are too poor to permit the planting of the more profitable crop. The second index measures climate conditions from the time of planting to the time of harvest and attempts to determine climatic influence on yields per acre. Both indexes are generally statistically significant.

7. A study of the cattle sector by CONADE, the Argentine government planning and development agency, grouped the 1960 census data by 18 separate regions, attempting to gerrymander regional boundaries according to the homogeneity of the agricultural enterprises within. They also compiled data for the size and composition of the herds within each region. I added three areas not included in the CONADE study for which the same data are available.

8. The de Martonne indexes constructed for the individual observatories have different means and variances because climatic conditions vary systematically from one location to another. To aggregate them, I decided to center each index on 100 rather than on its mean as measured by the de Martonne index raw figure. I did this believing that the yearly variance from a standardized mean would provide a better measure of climatic change than using the raw figures from each de Martonne index itself, although clearly this gives more weight to locations with a large variation in climate. This is desirable if the strength of the effect of climatic variation increases as the percentage change increases.

9. Although climate is usually believed to be a good example of a purely random variable, it is interesting to note that climate, as measured by these indices, was distinctly worse during the period 1956-1965 than for the period 1940-1965. The mean for the whole period is 99.87 and for the later ten-year period is only 89.76--a marked difference statistically significant at the 5 percent level, assuming the index is normally distributed. Although rainfall during the latter period was close to the long-run average, temperatures were much higher.

   The de Martonne index generally gave more significant results in my estimating equations than did a simple rainfall index, suggesting that the former is a better indicator of climatic effects on agricultural production. This result also suggests that unfavorable weather was an important cause of lower output growth during 1956-1965, and that part of the increase observed in agricultural output after 1964 may be due to a return to more normal climatic conditions. And this result suggests that research should be done to determine how producers form their climatic expectations, and whether these expectations affect the allocation of resources.

Appendix IV

"Production" Versus Slaughter as an Indicator of Output

The total production of meat by the cattle sector during any period of time is equal to the summation of both slaughter and the net change in the herd. Most previous models have dealt with production in terms of gross animals produced, that is, the number of animals born less the number of animals that die of natural causes. A better indicator of production should consider both the addition of animals or meat units from net births, plus the change in weight of the existing herd during the year. The net number of animals born from year to year varies relatively little (as the size of the breeding herd and the calving rate change) and will be negative only under extraordinary circumstances. However, production defined as net meat units produced can vary substantially, especially in a country like Argentina where climatic variations have such serious impact on animals weights via changing pasture and forage availability.

However, "production" probably should not be used as an explanatory variable in the model. Consider the determination of the herd within the context of portfolio selection. Producers choose from various alternative assets portfolios which best satisfy their preference functions. A farmer with a larger number of alternative assets such as land, cattle, machinery, buildings, cash, and stocks and bonds, must decide how to allocate capital among them. This farmer behaves in precisely the same fashion when selecting the animals for the herd. A producer does not choose to hold so many dollars worth of cattle irrespective of type. The decision about the total value of animals to hold is the result of choosing the optimal number of animals of each size, sex, and age, given their respective risks and returns on a basis complementary to one another and to other productive assets. Specifying the herd demand (or slaughter) by separate classifications of animals is an attempt to sort out the behavior of producers toward different types of assets under different conditions. Clearly, a cow is not a steer, nor does it fulfill the same functions within the herd.

We then need to consider how sensitive the capital values of different types of animals are to changes in expectations and how these changes will affect the numbers of each sent to slaughter. The "price per pound" of an animal in the slaughter market or as a capital good depends on its condition, fatness, and so forth. However, the total value of the animals is not given by multiplying weight times a fixed price, but by a price which varies with weight given the category of the animal. But such a price may be much more sensitive to weight changes for some categories of animals than others. Consider several examples. Although a steer must be in top condition to bring a good price, and the difference between top and bottom prices may be substantial, there are moments when the value of a cow being used as a breeding animal is quite insensitive to its weight, such as during the early months of pregnancy. The only effect of weight on price at this moment is the effect on its capital value via the effect on the value of its future calf, which at this stage is negligible. Similarly, if a calf is being raised for slaughter at a future date, and its capital value now dominates its slaughter value, any change in its weight has an effect on its value today not through the change in what it is worth in the slaughter market today, but through the change in its present discounted future slaughter value.

As a result, producers must consider both numbers and average weight when selecting a desired herd, for both of these have an effect on the value of each animal to each producer. But as the effect on producers' decisions of weight and numbers is not strictly multiplicative, it seemed better to include each of these as an explanatory variable in the slaughter equation, rather than their product.

In fact, there was no way to obtain the weights of animals in the herd independently of those being slaughtered, and the slaughter weight of animals was not significant when included. A better proxy for average herd weight is the climatic (i.e., weather) variable, which of course was included. Again it must be pointed out that the weather coefficients reflect several possible effects.

Appendix V

Estimated Annual Calving Rates In Argentina, 1937/38—1966/67[1]

YEAR	CR
1937/38	0.730
1938/39	0.775
1939/40	0.680
1940/41	0.648
1941/42	0.657
1942/43	0.589
1943/44	0.541
1944/45	0.639
1945/46	0.630
1946/47	0.656
1947/48	0.653
1948/49	0.667
1949/50	0.655
1950/51	0.655
1951/52	0.696
1952/53	0.654
1953/54	0.726
1954/55	0.697
1955/56	0.691
1956/57	0.684
1957/58	0.672
1958/59	0.696
1959/60	0.698
1960/61	0.703
1961/62	0.717
1962/63	0.689
1963/64	0.700
1964/65	0.724
1965/66	0.723
1966/67	0.721

[a] The calving rate is defined as follows: $CR_t = T_t/VB_t$.

References

CAFADE Consejo Federal de Inversiones

CONADE Consejo Nacional Argentino de Desarolla

INTA Instituto Nacional de Tecnologia Agropecuaria

JNC Junta Nactional de Carnes

SELSA Servicio de Luchas Sanitarias

Aldabe, Hernan and Willy Van Rijckeghem [1965], *Faena y Existencia de Ganado Vauno*, Buenos Aires: CONADE.

Athearn, J. L. [1956], "Price Expectations, Plans, and Decision Making Among Ohio Commercial Cattle Feeders," *Journal of Farm Economics*, Vol. 38 (February).

Balboa, Manuel and Alberto Fracchia [1959], "Fixed Reproducible Capital in Argentina," in Raymond Goldsmith and Christopher, eds., *The Measure of Wealth*, London: Bowes & Bowes.

Ballesteros, Marto A. [1958], "Argentine Agriculture, 1908-1954: A Study in Growth and Decline," unpublished Ph.D. dissertation, University of Chicago.

Banco Central de la Republica Argentina [1966], *Origen del Producto y Composicion del Gasto Nacional, Suplemento del Boletin Estadistico No. 6*, Buenos Aires, (June).

Banco Ganadero Argentina [1965], *Temas de la Economia Argentina: Mercados y Precios del Ganado Vacuno*, Buenos Aires.

Banco Ganadero Argentina [1965-1967], "La Produccion Rural Argentina," various quarterly issues.

Barrcira, E. [1959], *Importacion y Comercializacion de Fertilizantes en la Argentina*, Buenos Aires: INTA, Instituto de Suelos y Agrotecnia.

Behrman, Jere [1967], "Price Elasticity of the Marketed Surplus of a Subsistence Crop," *Journal of Farm Economics*, Vol. 49 (February).

Bieri, Jurg and Alain de Janvry [1972], *Empirical Analysis of Demand Under Consumer Budgeting*, Giannini Foundation Monograph No. 30, University of California, Berkeley.

Black, John D. [1957], "Observations on the Agriculture of Argentina," *Journal of Farm Economics*, Vol. 39 (August).

Bolsa de Cereales [1967], *Revista Institutional, Numero Estadistico*, Buenos Aires.

Bordarampe, H. and A. Amigo [1959], *Zonas de Produccion de Carne Vacuna en la Region Pampeana*, Buenos Aires: CAFADE.

Braun, Oscar and Leonard Joy [1968], "A Model of Economic Stagnation—A Case Study of the Argentine Economy," *The Economic Journal*, (December).

Bray, James O. [1963], "Farm Tenancy and Productivity in Agriculture: The Case of the United States," *Stanford Food Research Institute Studies*, Vol. 4, No. 1 (February).

Bray, James O [1966], "Beef Productivity Increases in the Southeastern United States Since 1920," *Stanford Food Research Institute Studies*, Vol. 6, No. 1 (February).

Breimyer, Harold F. [1955], "Observations on the Cattle Cycle," *Agricultural Economics Research,* Vol. 7 (January).

Breimyer, Harold F. [1962a], *Seminario sobre la Economia Ganadera y Comercializacion de la Carne,* Buenos Aires: CAFADE, Publicacion Tecnica No. 14.

Breimyer, Harold F. [1962b], "The Three Economies of Agriculture," *Journal of Farm Economics,* Vol. 44 (August).

CAFADE [1966], *Panorama Estadistica de la Produccion y Comercio de la Carne Vacuna,* Buenos Aires.

Comite Interamericano de Desarollo Agricola [1966], *Tenencia de la Tierra y Desarollo Socio-Economico del Sector Agricola, Argentina,* Washington, D.C.: Panamerican Union.

CONADE [1963], *Tenencia de la Tierra, Aspectos de la Estructura Agraria y su Incidencia en el Desarollo Agropecuario Argentino,* Buenos Aires: CONADE and Consejo Federal de Inversiones

CONADE [no date], *Diagnostico Preliminar del Sector Agropecuario,* Buenos Aires.

Conome, Rinaldo A. [1966], "Funciones de Oferta Agropecuaria de la Region Pampeana en el Periodo 1940-1960," mimeo, Universidad Nacional de Cordoba (July).

Courant, Richard [1951], *Differential and Integral Calculus,* London: Blackie.

Dagnino-Pastore, J. M., J. H. Meier, J. C. de Pablo, and F. Ballesteros [1965], "Metodologia y Resultados del Estudio de una Industria: Tractores," mimeo, Instituto Torcuato Di Tella (December)

Diaz-Alejandro, Carlos F. [1965], *Exchange Rate Devaluation in a Semi-Industrialized Country: The Experience of Argentina, 1955-1961,* Cambridge, Mass.: The M.I.T. Press.

Diaz-Alejandro, Carlos F. [1970], *Essays on the Economic History of the Argentine Republic,* New Haven, Connecticut: Yale University Press.

Economic Commission for Latin America [1959], *El Desarollo Economico de la Argentina,* 3 Vols, New York: United Nations.

Ericksson, John R. [1970], "El Comportamiento de la Exportación de Manufacturas en la Argentina, 1951-1965," *Desarrolo Económico,* Vol. 9, No. 36 (Enero/Marzo).

Felix, David [1965a], "Did Import Substituting Industrialization in Argentina Save Foreign Exchange in 1953-1960? A Report," mimeo (preliminary draft), Instituto Torcuato Di Tella (September).

Felix, Davis [1965b], "Import Substitution and Industrial Exports in Argentina," mimeo, Instituto Torcuato di Tella (September)

Fener, Aldo [1967], *The Argentine Economy, Berkeley: University of California Press.*

Ferrer, Aldo [1963], *La Económia Argentina,* Buenos Aires: Fondo de Cultura Económia.

Ferrer, Aldo and E. L. Wheelwright [1966], "Industrialization in Argentina and Australia: A Comparative Study," mimeo (preliminary draft), Instituto Torcuato Di Tella (June).

Feuer, A. and A. Fracchia [1961], *La Produccion, los Ingresos, y Capitalizacion del Sector Agropecuario en el Periodo 1950-1960,* Buenos Aires: CAFADE.

Fienup, Darrell F., Russell H. Brannon, and Frank Fender [1969], *The Agricultural Development of Argentina,* New York: Praeger Publishers.

Fracchia, Alberto and Oscar Altimir [1966], "Income Distribution in Argentina," *Economic Bulletin for Latin America,* Vol. 11, No. 1 (April).

Freire, Remy [1966], "Price Incentives in Argentine Agriculture," mimeo, Development Advisory Service, Harvard University (June).

Frente, Alicia A. de la and Fernando V. Corral [1967], "Investigacion por Muestro de los Existencias de Ganado Vacuno en las Principales Provincias Ganaderas de la Republica Argentina," mimeo, Secretaria de Estado de Agricultura y Ganaders (August).

Gallo-Mendoza, G. and N. Silvia Tadeo [1964], *La Mano de Obra en el Sector Agropecuario,* Buenos Aires: CONADE (October).

Goodsell, W. D., J. R. Gray, and J. Hildebrand [1962], *The Beef Grass-Grain Economy in the Pampas,* Buenos Aires: CAFADE.

Griliches, Zvi [1957], "Hybrid Corn: An Exploration in the Economics of Technical Change," *Econometrica,* Vol. 25 (October).

Griliches, Zvi [1958a], "The Demand for Fertilizer: An Economic Interpretation of Technical Change," *Journal of Farm Economics,* Vol. 40 (August).

Griliches, Zvi [1958b], "Research Costs and Social Returns: Hybrid Corn and Related Innovations," *Journal of Political Economy,* Vol. 44 (October).

Griliches, Zvi [1959], "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," *Journal of Farm Economics,* Vol. 41 (May).

Griliches, Zvi [1960], "The Demand for a Durable Input: Farm Tractors in the U.S. 1927-1957," in A. Harberger, ed., *The Demand for Durable Goods,* Chicago: University of Chicago Press.

Griliches, Zvi [1963a], "The Role of Capital in Investment Functions," in C. K. Christ, ed., *Measurement in Economics,* Palo Alto: Stanford University Press.

Griliches, Zvi [1963b], "The Sources of Measured Productivity Growth: U.S. Agriculture, 1940-1960," *Journal of Political Economy,* Vol. 71 (August).

Guadagni, Alieto A. and Alberto Petrecolla [1966], "La Funcion de Demanda de Carne Vacuna en Argentina en el Periodo 1935-1961," mimeo (revised), Instituto Torcuato Di Tella.

Italconsult Argentina, S. A. [1965], *Encuenta Entre Productores Agropecuarios,* Buenos Aires.

Hanson, Simon G [1938], *Argentine Meat and the British Market,* Palo Alto: Stanford University Press.

INTA [1959], "Una Etapa en las Realizaciones del INTA," *Boletin Informativo No. 1,* 1959.

INTA [no date], *Estacion Experimental Agropecuario Pergamino: 1912-1962,* Buenos Aires.

Inter-American Committee for Agricultural Development [1964], *Inventory of Information Basic to the Planning of Agricultural Development in Latin America: Argentina,* Washington, D.C.

Inter-American Committee for Agricultural Development [1965], *Land Tenure Conditions and Socioeconomic Development of the Agricultural Sector: Argentina,* Washington, D.C.

Jarvis, Lovell S., *Supply Response in the Cattle Industry: The Argentine Case, 1937/38-1966/67*, Ph.D. dissertation, Massachusetts Institute of Technology, 1969.

Johnson, Bruce F. and Herman Southworth, eds. [1966], *Agriculture and Economic Development*, Ithaca: Cornell University Press.

JNC [1964], *Recuperacion Ganadera*, Buenos Aires, (April 4).

JNC [1957 and 1966], *Resena*, Buenos Aires.

JNC [1967], *Estadisticas Basicas 1967*, Buenos Aires.

Krishna, R. [1963], "Farm Supply Response in India- Pakistan: A Case Study of the Punjab Region," *Economic Journal*, Vol. 73 (September).

Maki, Wilbur [1962], "Decomposition of the Beef and Pork Cycles," *Journal of Farm Economics*, Vol. 44 (August).

Mallon, Richard D. [1966], "Exchange Policy: Argentina," mimeo, Development Advisory Service, Report No. 33, Harvard University (June).

Maynard, Geoffrey and Willy Van Rijckeghem [1966], "Stabilization Policy in an Inflationary Economy: Argentina," mimeo, Development Advisory Service, Report No. 34, Harvard University (June).

Meiburg, Charles O. [1965], "Factor Costs of United States Agriculture: 1940-1962," *Stanford Food Research Institute Studies*, Vol. 5, No. 1 (February).

Meiburg, Charles O. and Karl Brandt [1962], "Agricultural Productivity in the United States: 1870-1960," *Stanford Food Research Institute Studies*, Vol. 3, No. 2 (May).

Mellor, John [1966], *The Economics of Agricultural Development*, Ithaca: Cornell University Press.

Miller, Fred D [1967], "The Effects of Highway Improvements on Agricultural Production: An Argentine Case Study," unpublished Ph.D. dissertation, Michigan State University.

Nerlove, Marc [1958], *The Dynamics of Supply: Estimation of Farmers' Response to Price*, Baltimore: Johns Hopkins Press.

Nores, Gustavo A. [1969], "An Econometric Model of the Argentine Beef Cattle Economy," unpublished M.S. thesis, Purdue University.

Nores, Gustavo A. [1972], "Structure of the Argentine Beef Cattle Economy: A Short Run Model, 1960-1970," unpublished Ph.D. dissertation, Purdue University.

Otrera, Wylian R. [1966], "An Econometric Model for Analyzing Argentine Beef Export Potentials," unpublished Ph.D. dissertation, Texas A and M University.

Oury, Bernard [1965], "Allowing for Weather in Crop Production Model Building," *Journal of Farm Economics*, Vol. 47 (May).

Panorama de la Economia Argentina (1957-1969], various issues, Buenos Aires.

Pecura, E. J. [1960], *Empleo de Fertilizantes en la Republica Argentina: Estadistica del Periodo 1958-1959*, Buenos Aires: INTA, Instituto de Suelos y Agrotecnia.

Peffer, E. Louise [1960], "The Argentine Cattle Industry Under Perón" *Stanford Food Research Institute Studies*, Vol. 1, No. 2 (May).

Peffer, E. Louise [1961], "State Intervention in the Argentine Meat Packing Industry, 1946-1958," *Stanford Food Research Institute Studies*, vol. 2, No. 1 (February).

Peffer, E. Louise [1962], "Foot-and-Mouth Disease in United States Policy," *Stanford Food Research Institute Studies*, Vol. 3, No. 2 (May)

Pendle, George [1963], *Argentina*, 3rd edition, New York: Oxford University Press.

Prebisch, Raul [1960], "The Structural Crisis in Argentina and Its Prospects of Solution," in Eastin Nelson, ed., *Economic Growth: Rational Problems and Cases*, Austin: University of Texas Press.

Raj, K. N. [1967], "Investment in Livestock in Agrarian Economies: A Theoretical and Empirical Analysis," mimeo presented in seminar at M.I.T., (December 14).

Reca, Lucio G. [1967], "The Price and Production Duality Within Argentine Agriculture, 1923-1965," unpublished Ph.D. dissertation, University of Chicago.

Reca, Lucio G. [1970], "Cambio Tecnológico y Precios: Su Impacto en la Ganaderia Argentia, 1924-1969," Económica (Enero-Abril).

Rentlinger, Shlomo [1966], "Short-Run Beef Supply Response," *Journal of Farm Economics*, Vol. 48 (November).

Review of the River Plate [1958-1969], various issues, Buenos Aires.

Ruttan, Vernon W. [1956], "The Contribution of Technical Progress to Farm Output: 1950-1975," *Review of Economics and Statistics* (February).

Salces, Florentino [1967], *La Lucha contra la Fiebre Aftosa en la Republica Argentina*, Buenos Aires: SELSA (October).

Schultz, Theodore W. [1956], "Reflections on Agricultural Production, Output and Supply," *Journal of Farm Economics*, Vol. 38 (August).

Schultz, Theodore W. [1964], *Transforming Agriculture*, New Haven: Yale University Press.

Schwartz, Hugh H. [1967], "The Argentine Experience with Industrial Credit and Protection Incentives, 1943-1958," unpublished Ph.D. dissertation, Yale University.

Scobie, James R. [1964a], *Argentina: A City and a Nation*, New York: Oxford University Press.

Scobie, James R. [1964b], *Revolution on the Pampas: A Social History of Argentine Wheat*, Austin: University of Texas Press.

Secretaria de Estado de Agricultura y Gandera [1965], *Empadronamiento Agropecuario Nacional: Cifras Provisionales*, Buenos Aries (October).

Shaw, Lawrence H. [1964], "The Effect of Weather on Agricultural Output: A Look at Methodology," *Journal of Farm Economics*, Vol. 46 (February).

Snapp, Roscoe R. [1955], *Beef Cattle*, 4th edition, New York: John Wiley.

Stallings, J. L. [1960], "Weather Indexes," *Journal of Farm Economics*, Vol. 42 (February).

Taylor, Carl C. [1948], *Rural Life in Argentina*, Baton Rouge: Louisiana State University Press.

Techint [1955-1969], various issues, Buenos Aires.

Vila, Antonio J. [1958], *Precios de Paridad para Productas Agricolas en la Argentina*, Buenos Aires: Asociacion de Productores Agricolas.

Villanueva, Javier [1964], "The Inflationary Process in Argentina," mimeo, Instituto Torcuato Di Tella.

Wiley, Jay Wilson [1948], "Some Problems of Foreign Exchange Control in Argentina," unpublished Ph.D. dissertation, University of Illinois.

Williams, Hadley Cogswell [1966], "The Role of Agriculture in Argentine Development: A Problem of Farmer Response," unpublished B.A. thesis, Harvard University.

Winsberg, Morton D. [1968], "Modern Cattle Breeds in Argentina: Origins, Diffusion, and Change," Occasional Publications No. 13, Center for Latin American Studies, University of Kansas (September).

Yver, Raul E. [1965], "La Oferta de Ganado Bovino en la Argentina," *Revista de Desarollo Economico*, Vol. 5, Nos. 17-19 (December).

Yver, Raul E. [1971], "The Investment Behavior and the Supply Response of the Cattle Industry in Argentina," unpublished Ph.D. dissertation, University of Chicago.