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The allocation of resources for animal health

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Summary

Economics is too important to be left to the experts. This paper is therefore mainly for animal health policy-makers who are not economists but want a better appreciation of how economics can contribute to resource allocation decisions. First, the methodology of economic analysis is outlined with the objective of dispelling criticisms of its simplifying assumption of rationality. Then, unusual in economics but more familiar to biological and veterinary scientists, the technical aspects of transforming resources into products are discussed. Economics' unique contribution is to establish criteria enabling society to obtain maximum value from the production and distribution of goods and services (products) from scarce resources. Animal disease reduces the efficiency of this process. Value is intangible, but people reveal how much they value (i.e. feel a want or need for) products by what they actually consume, in quality and quantity. Animal products, and so implicitly animals themselves, are an example. The strength of people's preferences is reflected both in the prices they pay for market goods and services, and by their political votes where markets do not exist. Importantly, there is a difference between financial value (what the consumer pays for a good or service) and economic value (the maximum amount of money they would be prepared to pay for it). Allocating resources for animal health creates both costs and benefits, financial and economic. Moreover, costs and benefits are both private and social because of externalities, a major consideration in infectious diseases. Where production decisions with animal health implications are made exclusively for private benefit, government has a role in providing incentives for animal sectors to act in ways that result in socially efficient outcomes.

Keywords

Animal health – Animal health policy – Economic methodology – Economic welfare – Economics – Preference – Resource allocation – Values.

Introduction

The overarching principle for this discussion of resource allocation for animal health is that economics is too important to be left to the experts (1). Economists whose work occupies this volume need no introduction to the economic theory that underpins resource allocation decisions. But policy-makers with different specialisms do, whether they are veterinary scientists, politicians, public administrators, or the owners and users of animals in farming and for recreation, companionship and assistance.

In partial contradiction of Chang (1), economics is not mainly common sense, or essentially easy to understand. For example, a common-sense misconception in politics and everyday discourse is that economics is all about money, thus indistinguishable from finance and accountancy. Money, or rather values expressed in money units, are indispensable for economic analysis, but only as a means to an end. The end concerns making decisions about how *real* resources (in broad terms, land, labour, buildings and equipment, management and entrepreneurial skills) should be allocated to produce *real* products (e.g. in the case of animals: food, raw materials, transport and traction, recreational enjoyment, companionship, assistance) for people's benefit (Fig. 1).

The objective for this paper therefore is to clarify this and related issues in resource allocation for animal health for decision-makers who are not economists. Technical arguments familiar to economists are kept to a minimum, because helping other kinds of specialists to understand better how economists look at the world is sufficient. Crucially, animal health is an economic problem with veterinary implications, not a veterinary problem with

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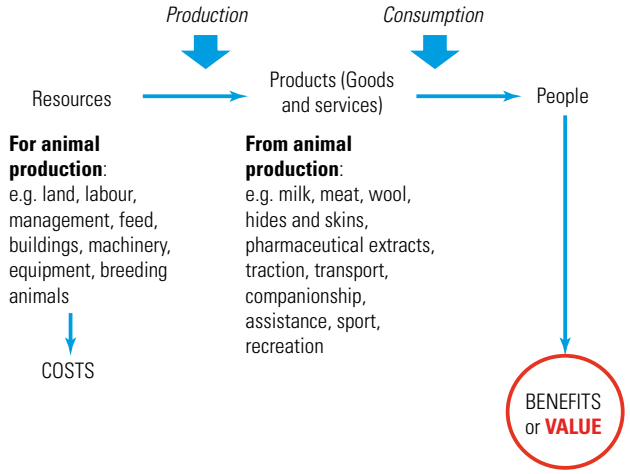


Fig. 1
The basic economic process applied to animal production

economic implications (2), because poor animal health reduces capacity to provide people with goods and services they need and want to consume. Moreover, zoonotic diseases both diminish people's ability to function efficiently in their role as an economic resource, and undermine their scope for living a fulfilling life.

In reality, animal products are so many and diverse that, for simplicity, they are defined here as a single aggregate variable, sufficient to explain the essential logic of economic principles. Confronted with an actual problem requiring modelling and empirical analysis, for example assessing the economic impacts of a specific disease outbreak, different components drawn from economic principles assume greater or lesser importance, but the purpose here is to set out the broad framework.

Importantly, economic analysis never provides information that indicates categorically that 'this is what must be done'. Economics is a discipline which contributes a unique kind of information to a policy decision process, makes the potential consequences of policy decisions transparent and explicit, and quantifies the implications for costs, benefits, and their distribution.

The methodology of economic analysis

Economics exists only because resources used in production for people's benefit are typically scarce, and so there is no alternative but to make choices about how to allocate them between different uses. One of the main purposes of economics is to establish criteria to guide such resource allocation decisions. More specifically, it is sensible to aim to obtain the greatest benefits possible from using any given quantity of scarce resources. Otherwise, potential additional benefits are foregone. That is why economics tends to emphasise optimising criteria and, in consequence, why mathematics is so important for the discipline. In particular, the application of calculus to relationships estimated from data on the economic behaviour of people or institutions enables maximum or minimum values to be calculated, such as maximum profits or minimum costs (3). It is fashionable nowadays to deride economists for their alleged preoccupation with optimisation on the grounds that, in practice, people do not behave as *homo economicus,* a person who makes rational decisions (i.e. achieved by logical reasoning, objectivity, and analysis, not subjective opinion and insight) in order to obtain their most preferred outcome given the constraints on choice. But that is to misunderstand the contribution of economic analysis based on the assumption of rationality.

Economic models and rationality

First, rationality is a simplifying assumption to help clarify relationships. Consciously or not, people inevitably create simple mental models of the world to aid their understanding of it. Any theory of behaviour, whether concerning the physical universe we inhabit or social interaction between us, involves constructing a model, meaning a conceptual picture of the most important variables to be considered, how they relate to one another systematically and, if it is to stand the test of time, reliably leads to consistent predictions of what will happen under comparable circumstances. That is not to say there can be no exceptions, but that predictions from that model are found to be correct far more often than not. Exceptions occur because not all variables will have been taken into account, only those identified as being the most important, or because the theory was deficient in the first place. The former are an element in the 'disturbance' or 'error' term of econometric analysis, the properties of which must be understood so as to enable the systematic relationship to be revealed; the latter requires the initial theory to be reconsidered, amended, and retested.

Second, a model assuming rationality serves as a benchmark against which to evaluate the consequences of actual irrational behaviour. For example, suppose a farmer aims to maximise net income from milk production, but also likes to see well-fleshed cows in his or her dairy herd. Scientific evidence shows that optimal economic efficiency is achieved when cows lose body condition over the course of lactation, so maintaining excessive body weight indicates over-feeding. The farmer's objectives are incompatible, and the additional financial cost incurred because they over-feed cows for appearance rather than economic efficiency can be estimated from input/output data on feed conversion into milk.

Third, the assumption of rationality can cast light on the origins of apparently irrational behaviour which, it turns out, is not irrational at all but an outcome of considerations not taken into account by an initial explanatory model. As a general rule, simplicity is a virtue for any model as long as its predictive ability is not compromised. Thus, assuming that a farmer knows the price they will receive for their milk in, say, a year's time may suffice for the context but, in practice, depends on several variables. These include market conditions of supply and demand, whether the price they will receive is assured under a processor contract, and government policy. Any source of significant uncertainty requires that expected price should be substituted for a hypothesised actual price at the future date. It may also require a supplementary model formulated to account for how expected price varies with changes in its explanatory variables (4). An initial model built on simple assumptions therefore serves as a benchmark against which observed behaviour can be compared, highlighting discrepancies which may require explanation.

The basic economic process

Figure 1 summarises the elements of an economic process. The concept is general but, given the context, here it is illustrated for animals. An economic process involves the transformation of resources into products (production) for people's benefit (consumption). Resources and products can be tangible (e.g. feed, milk) or intangible (e.g. management, companionship of a pet) Generically, products are classified as goods and services. Clearly, the more products people want that are obtained from any given quantity of scarce resources, the better. In other words, achieving technical efficiency in transforming resources into products is important. Although we are concerned with all classes of animal in considering resource allocation for their health, making the main focus animals in agricultural production enables many of the most important economic relationships to be explained.

Technical foundations of economic activity

Biological production relationships

Biological resource/product relationships or, in other words, input/output relationships, in both animal and crop production, can be illustrated as response curves (5). Nutrition scientists study the nature of the quantitative relationship between, say, milk produced by dairy cows and a range of predetermined levels of feed input, and a response curve can graphically depict how milk production changes in response to different levels of feed input. Such response curves serve as benchmarks for assessing the technical efficiency of feeding cattle for milk. In symbols, the relationship described can be summarised as

$Mi = f(F_i)$ Response curve, where M_i = Milk output per day, F_i = Quantity of feed, i = 1, 2, 3,… n observations

In practice, such relationships take into account the fact that ruminants' feed usually consists of more than one raw material source. At a minimum, F_i will comprise some combination of both G_i forage and C_i concentrates, a modification made below.

Such estimated relationships will normally apply to 'healthy' as distinct from 'unhealthy' animals. It is unnecessary to do more than make this binary distinction when considering the broad issue of how ill health affects the technical efficiency of resource use. In economic terms, the crucial consideration is that disease represents an input which impairs the efficiency of transforming other resources into products to benefit people by their consumption. In that sense, animal disease is a 'negative input'. Modifying the above expression, the consequence is that

$M_{iD} = f(M_i, D)$ where $M_{iD} < M_i$, and M_{iD} = Milk produced from unhealthy animals, D = Disease (negative input)

From a veterinary scientific perspective, naturally the focus is on the technical matter of how to avoid or mitigate the effects of disease, or even eradicate the causal agent itself. Depending on the specific disease, this may require measures already known from veterinary science, most prominently the application of veterinary practitioner skills, administering drugs, undertaking surgical procedures or, for emerging diseases, investing in research to understand the nature of the disease better and devise methods to counter its effects.

Economic production relationships

Economics takes a more comprehensive view of how to combat the negative effects of disease. In isolation, the response curve concept is too restrictive. It neglects to take account of the fact that disease control is not exclusively a veterinary matter, because other resources also contribute to animal health. For example, a skilled, observant farmer or stockhandler will quickly notice an animal showing signs of ill health, and take steps to address the problem. Also, animal accommodation may be designed with disease prevention in mind (for example, with good ventilation to minimise the chance of respiratory diseases, or flooring to minimise occurrence of foot problems). From an economics perspective, milk production depends on choices made

about all farm resources used, not just the transformation of feed into milk production by cows, weight gain by animals for meat, or eggs from laying hens. So, a more complete economic specification of the process of milk production is

$M_i = f(C_i, G_i, L_i, S_i, V_i, B, E, H)$

Economic production function, where M_i = Milk output, C_i = Quantity of concentrates fed, G_i = Quantity of forage fed, L_i = Labour time, S_i = Management time, V_i = Routine veterinary attention, B = Buildings, E = Equipment, H = Herd size i = 1, 2, …n

The generic economic term for all input/output relationships is a *production function*, but it is useful to distinguish explicitly between *a) response curves* and *b) economic production functions*, the latter implying reference to all relevant resources used, as in the example.

Short run and long run

In the expression above, no subscript is attached to buildings, *B*, equipment, *E*, or herd size, *H,* indicating that they are fixed inputs. Economics distinguishes explicitly between the short run and the long run, but not by chronological time. The short run is defined as a period of time in which the quantities of some inputs are fixed and others variable. Animal feed is a typical variable input. By contrast, buildings and equipment are fixed for long periods, but even they have to be replaced eventually. Herd size similarly may be constant. Being clear about the context is very important for economic interpretation. For example, if a farmer contributes manual labour to the whole farm for the long duration of their tenancy, year on year their labour is a fixed input to the total farm business; but still they make choices, often on a daily basis, about allocating shares of their total available labour time between different enterprises. So, for an individual enterprise their labour is a variable input.

The implications of the distinction for economic decisions are profound. They stem from the technical consequences of varying one or more inputs used in association with fixed inputs. The result, commonly observed in the world, is the phenomenon of *diminishing returns*, i.e. in production, as progressively more units of a variable input are added to one or more fixed inputs, the addition that each input unit makes to total product eventually declines. As more inputs are made variable, the diminishing returns effect lessens. For example, there is a biological limit to the volume of milk that a herd of given size (fixed input) can produce in a year. Indeed, excessive use of concentrate feed (variable) for maximum milk production could make the cows ill, instead causing yields to fall; in that case, diminishing returns to feed inputs is not manifested by progressively smaller positive additions to total output, but negative. But if herd size itself is increased (made variable), milk output is also increased, even without changing feeding practice.

Production choices

The critical questions in production are *a)* what to produce, *b)* how to produce it, and *c)* what quantity to produce?

In farming, what to produce largely concerns a choice between different types of farming, for example mixed farming (animals with arable crops) or monoculture (all cereals, large-scale beef feedlots). Natural resource (e.g. land quality) and environmental endowments (locations prone to heavy rainfall or drought, or the presence of agents conducive to disease outbreaks) commonly set constraints. Dog or horse breeders, for instance, must address identical questions – whether to produce dogs as pets, as assistance animals, or perhaps both; horses for the racing industry or for recreational riding? And so on.

Much of the technology of agricultural production – in other words, how to produce – is to facilitate control in the light of uncertain outcomes caused by unpredictability of the natural environment. The application of veterinary science in farming by routine health checks, farm health planning, vaccination and the aforementioned attention to animal buildings and equipment provision is a prominent example.

Deciding what to produce, and how to produce it, involves far more than questions about technical options, i.e. choosing between production functions. The ultimate driver for the decisions made is how much people want an end product; in other words, the choice is determined by the quantity of product that needs to be produced to satisfy demand, which, in turn, determines resource allocation.

Values, preferences and resource allocation

Opportunity cost

Figure 1 is a reminder that the purpose of production is consumption, the satisfaction of people's wants. What goods and services people want, and in what quantities and qualities, depends on their preferences which, in turn, reflect the sense of benefit they expect to obtain as a result of consumption. In brief, what people value, and how they signal their preferences to producers, is the essential missing supplement to the technical conditions of production for guiding resource use decisions.

Practitioners of veterinary and related biological sciences are concerned with the tangible world. They observe animal behaviour for abnormalities associated with disease, record symptoms, identify causes, define and apply treatments, and undertake research for better understanding or to improve diagnostic methods and treatment procedures. All are technical activities. Economics is different, because the single most important concept that underpins all of economics is 'value', something intangible and therefore unobservable.

At a given time, making a choice necessarily precludes options. For example, government financial investment in research and development to improve animal health and welfare denies use of those funds for, say, human health, transport infrastructure, education, and other potential allocations of that money and, by implication, scarce real resources. The benefits foregone from the best option not selected is the *opportunity cost* of the decision, but it is common practice for the term to be used more loosely, applying it to any source and level of benefits foregone. However, the concept of 'benefits' needs careful explanation.

Values shape preferences

In an everyday sense, value is equated with monetary worth, the price people pay for, say, a litre of milk, or a horse-riding lesson. But not everything has a money price, such as people's pleasure that animals are well cared for. What people value as individuals determines their tastes and preferences, reflecting their wants and physical needs and also social norms. But, crucially, people reveal what they value, and how much, by behaviour which can be observed, including how people choose to allocate their limited resources. Collectively, all of the aforementioned factors contribute to people's preferences, which are signalled in two ways: by their political vote and by their money 'vote'. As individuals, we indicate how much we are willing to pay according to our financial circumstances and personal preferences; in aggregate, the sum of those expressed individual preferences determines the distribution of all society's resources, including for animal health.

Determinants of the demand for animals

In any society, the demand for animals derives from people's various needs and wants, and therefore how much they value the products animals provide – food, transport, traction, companionship, recreation, assistance.

Again, for simplicity, assume that 'animal products' as a whole are a source of people's well-being that can be captured in a single variable. In symbols, the aggregate demand for all animal products is then summarised as,

$D_A = f(P_A, P_S, I, T, N)$

Demand function, where D_A = people's aggregate demand for animal products (quantity), P_A = price per unit of animal products, P_S = price per unit of substitutes for animal products, I = real income per head of human population, T = tastes and preferences, N = total human population

Thus, D_A implies the existence of a corresponding number of live animals – farm livestock of all descriptions for food production, people's pets, assistance animals for the disabled, recreation animals such as horses for riding and racing, buffaloes for traction and transport, and wild animals just because people value their existence and role in natural ecosystems. For any given configuration of prices, income, tastes and preferences, people will freely express their particular level of aggregate demand for animal products.

Price per unit, P_A

The price per unit of animal products, P_A, can be thought of as an index number, constructed as the weighted sum of representative prices for each separate component of all animal products. Commonly, economists proceed on the grossly simplifying assumption of there being only one price, or product, or resource, fully cognisant of the fact that the real world is much more complicated than that. Their purpose is to exploit the powerful simplicity of economic principles, which help analysts disentangle sometimes highly complex relationships by building up from the most basic, step by step.

Some prices (e.g. for animal food products) will be derived from market data. Others are more problematical. For example, the fees people pay veterinarians to treat their pet animals can be interpreted as a proxy for the prices owners are willing to pay for companionship. But the premium people say they are willing to pay for better animal welfare, such as by paying higher prices for eggs produced by free range instead of battery hens, can be unreliable because so many factors are involved (6). So-called choice experiments may be necessary to elicit values expressed as notional monetary amounts.

For the great majority of products, price and quantity consumed are inversely related when other variables are held constant, a phenomenon easily recognised from our personal consumption behaviour. When eliciting a monetary value for a product proves impossible, for instance animal welfare in general, there is no alternative but to concede that fact. However, absence of a monetary price does not mean absence of value, only that currently there is no reliable way of matching the two. Still, such 'true value' must be accommodated in decision-making, and monetary estimates of value must be qualified by judgements about the importance of other factors.

Price per unit, P_S

The price of substitutes, P_S, is similarly representative for many competing potential sources of people's money expenditure. Invariably, choices are made between consumption of animal products and alternatives. The focus here is on how changes in *relative* prices affect changes in consumption patterns, given a fixed budget. For example, confronted by an increase in veterinary fees a pet owner may conclude that the financial cost of keeping her companions healthy has become excessive, and so decides to keep fewer animals, or relinquishes ownership altogether. The money saved can instead be spent on some other source of pleasure, say more recreational days out, or holidays. It all depends on how the satisfaction (value) gained from one use of their money compares with that from another.

Again, typically this is not a binary choice; it is a decision about how much personal loss is felt from an incremental or *marginal* reduction in pet health expenditure (because healthy pets create happy owners) relative to the *marginal* gain in satisfaction felt by spending the money saved in some alternative way. In other words, there is a *trade off* between keeping animals healthy and other uses for money that similarly add to human well-being. The choice any individual person makes depends on their personal preferences, and how a dollar transferred from one use to its alternative adds to the value they feel relative to the inevitable loss. Clearly, per dollar transferred from one use to an alternative, as long as the additional sense of value gained exceeds the loss, it pays to keep redistributing expenditure until the marginal gain precisely offsets the loss. Such *marginal analysis* is central to many areas of economic decision-making.

Real income per head, I

People's income affects their consumption choices. In general, the higher a person's real income (i.e. consumption of goods and services calculated at constant prices), the more choices they have. A striking phenomenon is the tendency for people worldwide to consume more food produced from animals as they get richer, and world consumption is growing (7). Also, with higher incomes there is more scope for discretionary spending on animal-based recreation and, especially, pet ownership. A change in focus of veterinarians' work in high-income countries away from farm animals to companion animals is evidence for the phenomenon, and of how veterinarians respond to normal economic incentives.

Tastes and preferences, T

Even though, in aggregate, people everywhere overwhelmingly are consistent in economic behaviour, human society is not homogeneous. Each of us is subject to the influence of social norms determined by our collective history and culture, shared beliefs and, even in secular societies, religion. Thus, the British are often considered to possess an exaggerated concern for the well-being of animals, including horses. For most of them, eating horsemeat is a taboo, and incomprehensible to other Europeans who do. Jews and Muslims do not consume pig products. For the latter, meat consumed must be halal, while Hindus revere and do not slaughter cows. Economics has nothing to say about such differences; its role is confined to illuminating the implications of people's preferences for the allocation of scarce resources, not whether they are right or wrong, the province of ethics.

Population, N

Any discussion of aggregate demand, on a national or international scale, must take into account the size, composition, and rate of change in the human population. Population growth for high-income countries, such as those in Europe, is very low or even negative, and relatively high but slowing in low-income countries. The age distribution of the population (demographic structure) is also a determinant of the structure of demand for animal products.

The demand curve

The single most important relationship derived from a demand function is the demand curve, the relationship between the quantity of product consumed and its own price, other variables constant, written

$$D_A = f(P_A, \mid P_S, I, T, N)$$

A key distinction is between movement along a demand curve (increase or decrease in demand) and a shift in a demand curve (Fig. 2).

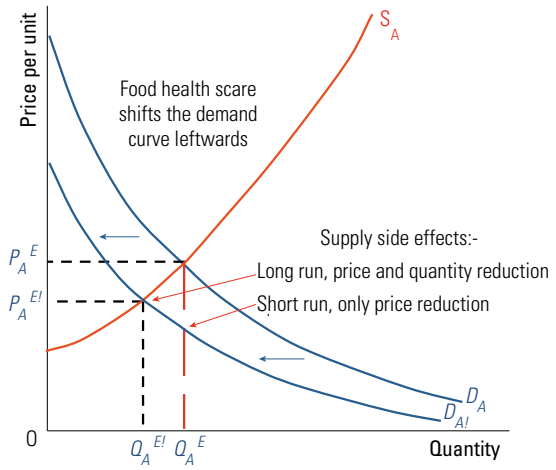


Fig. 2
The market for animal products

The variables held constant, indicated by being to the right of the vertical, are *demand shifters*. If the price of animal product substitutes, P_S, falls the demand curve D_A shifts left, and vice versa. As already noted, growth in income per head has a positive effect on consumption of animal products, and so shifts the aggregate demand curve to the right. Tastes and preferences, *T*, for individual products are influenced positively by advertising and information, and negatively by food scares. For example, public concern for the detrimental effects of excessive consumption of dairy products and red meat on human health shifts the demand curves for those individual products to the left, as will wider acceptance of the perceived merits of a vegetarian diet. Zoonotic disease outbreaks, such as bovine spongiform encephalopathy (BSE) in beef cattle and salmonella in eggs, shift the respective demand curves leftwards; for BSE, the demand curve for beef can be virtually eliminated, at least in the short run, as risk-averse consumers stop eating beef at any price.

The supply curve

Just as a demand curve expresses how the quantity of animal products consumed changes according to their price, other variables held constant, so a supply curve relates quantity of products supplied to their own price, $S_A = f(P_A)$, other variables held constant. But whereas quantity consumed and price are inversely related (demand curve slopes downwards), quantity supplied and price are positively associated (supply curve slopes upwards). Moreover, the specific characteristics of an aggregate supply curve for a product made using domestic resources depend on its underlying production function, demonstrated here for a single variable input, concentrate feed.

For simplicity, take the economic production function $Mi = f(Ci \mid Gi, Li, Si, Vi, B, E, H)$, i.e. milk output as a function of variable concentrate feed inputs, forage and other variables fixed. At each point along the milk/concentrates production function, the gradient shows the variable (marginal) amounts of milk produced, *dM,* from the last unit increment of concentrates fed, *dC*. The law of diminishing marginal returns means that *dM/dC* diminishes as input *C* is increased in equal unit amounts. Thus its inverse, $1/(dM/dC) = dC/dM$, must get larger.

But we are not interested in this inverse technical relationship for itself. Rather, we are interested in how it helps us to find how the quantity of milk produced changes in response to milk price, P_M. Intuitively, the financial return from producing additional milk must be sufficient at least to cover its cost of production. The financial cost of producing an additional unit of milk output, i.e. its marginal cost, *MC*, is found as $Pc \times (dC/dM)$, where *Pc* is the price per unit of concentrates. This is the general expression for the marginal cost curve, which is the short-run supply curve. Because it derives from a production function which exhibits diminishing returns, the marginal cost curve must slope upwards at an increasing rate.

It is a supply curve because it traces out the locus of points where price per unit of milk (e.g. price per litre) equals the marginal cost of producing the last increment, $P_M = MC$. As milk price increases, it follows that it pays to produce additional increments of milk even at correspondingly higher marginal costs, and vice versa. The point where $P_M = MC$ is of unique interest because it defines the total quantity of milk produced at which the net financial margin (i.e. value of total milk output minus the total variable costs of concentrates used) is maximised. The result derives from basic mathematics, the fact that the sum of marginal amounts over a given range is the total for that range. So, given a supply curve, the implications for real resource use, and therefore total costs, can be derived from knowledge of how quantity supplied adjusts to changes in product price. An alternative name for the net financial margin is gross margin, and subtracting the fixed costs of other resources used gives maximum profit.

Price determination

Beyond reference to people's willingness to pay, to this point nothing has been said about how product prices, such as P_A, are determined. To do so, demand and supply sides must be brought together. In any market, meaning an institutional arrangement that matches people's consumption wants with the potential suppliers, it is the interaction of demand and supply that determines how much is produced and consumed, and at what price. Specifically, this requires knowledge of the demand curve for a product and its corresponding supply curve.

Figure 2 is a market diagram for animal products in aggregate. The intersection of aggregate demand curve D_A and aggregate supply curve S_A identifies the market equilibrium price and quantity produced and consumed for animal products, respectively P_A^E and Q_A^E, i.e. that unique combination of price and quantity from which there is no incentive to depart. At any price per unit of animal products above P_A^E there would be an incentive to produce more than consumers are willing to consume at those prices; below P_A^E, consumers want more animal products than producers would be willing to supply at those prices. Free from external interference, notably government use of policy instruments aimed at achieving specific objectives, the price adjusts spontaneously until consumption equals production. Policy instruments include food price subsidies to ensure that poor consumers are adequately fed, and minimum price guarantees for agricultural products to support farmers' incomes. Such deliberate market distortions invariably have unintended consequences, beyond the scope of discussion in this paper.

A food health scare causing the demand curve to shift leftwards reduces the equilibrium price to $P_A^{E!}$ which, in turn, signals to suppliers that they should produce less for the market, $Q_A^{E!}$. In practice, how long the scare lasts determines the magnitude of the price fall because time affects producers' scope for adjusting supplies and resource use. In the very short run it is impossible, the supply curve in effect becoming vertical (broken line), and the impact of the food scare is experienced entirely as a price reduction. In the economic long run, a sustained lower product price gives producers an incentive to move back down the production function, and therefore supply curve, as they reallocate some resources to other uses. For animal production, biological factors are highly influential in determining speed of response. For example, egg production has a high short-term supply response because a single culled laying hen reduces production by up to 300 eggs in a year, as has pig production with over two farrowings each of around ten weaners reared per year. In contrast, cattle rearing from calf to finished animal for beef, or entering a dairy herd, takes years.

More about supply

Just as the relationship between quantities consumed and own price (i.e. a demand curve) is an incomplete explanation of aggregate demand, so is the relationship between quantities supplied and own price (i.e. a supply curve) incomplete for aggregate supply. A complete specification for a supply function is

$S_A = f(P_A, P_S, R, K, X)$

Supply function, where S_A = aggregate supply of animal products (quantity), P_A = price per unit of animal products, P_S = price per unit of substitutes for animal products, R = domestic resources, K = technology, X = net imports

The variables not already considered are as follows.

Price per unit, P_S

Following the practice adopted here to simplify, P_S represents the value captured by prices paid for all products made from non-animal sources that compete for the same kinds of resources used for animal products. In general, the higher the prices received for non-animal products relative to animal products, the more resources will be reallocated to those alternatives. This is a significant consideration in relation to the efficiency of national resource allocation for maximum societal benefits.

Domestic resources, R

Intuitively, the greater the quantity of domestic resources available, the greater is the potential for both animal and non-animal production.

Technology, K

Production potential depends on two factors, the quantities of domestic resources available, R, and technology, K, the latter having a major role in determining the technical efficiency with which R are used. Technology is central to the idea of choice between production functions. From a technical standpoint, it is irrational for a producer to select a production function yielding less output for any given quantity of scarce resources than is obtainable from a better option. Ideally, any producer will aim to select a production function at the *efficiency frontier*, i.e. where the production function has the characteristic that the average productivity (output per unit input) for any level of resource use is greater than for any other currently available production function. But whichever is selected, disease reduces average resource productivity below its potential maximum for every level of resource use. One solution is to add veterinary resources to the affected production function so as to offset the negative disease effects. Assuming technical feasibility, the economic question is whether it is worth it in terms of the opportunity cost of resources so allocated, and whether there is some alternative solution, such as a change in production methods yielding lower costs and higher net benefits (8).

Net imports, X

Part of the solution to disease-induced domestic production losses is to replace them with imports. Strictly defined, these are net imports because a country may well export and import animal products simultaneously, the latter more than compensating for the former to the advantage of domestic consumers. Net exports reduce quantities available for domestic consumption. In both cases the aggregate supply curve is the domestic supply curve adjusted for international trade. Whatever configuration results, there are financial and economic implications for society.

Financial and economic values

In Figure 3a, the financial value of animal products bought and sold at equilibrium is $P_A^E \times Q_A^E$. Trade ensures that there cannot be more than one price for a given product in one transparent market. Anyone attempting to gain financially by buying cheap to sell dear, the process of arbitrage, brings about convergence on a single price that ends the process. But, crucially, financial value and economic value are not synonymous. Economic value concerns *welfare economics* and its concepts of consumer surplus and producer surplus. A third welfare economics concept, taxpayer transfers, is introduced later.

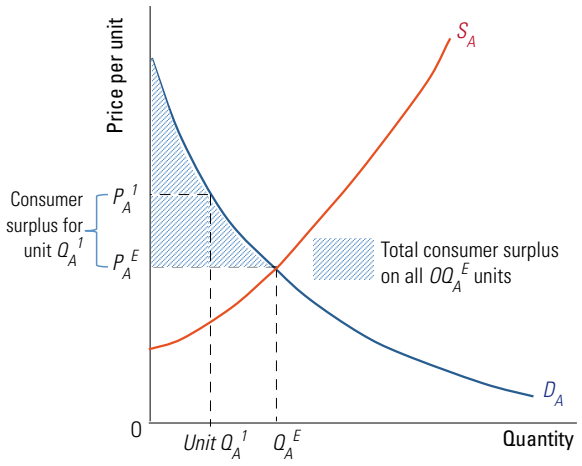


Fig. 3a
Consumer surplus and the market for animal products

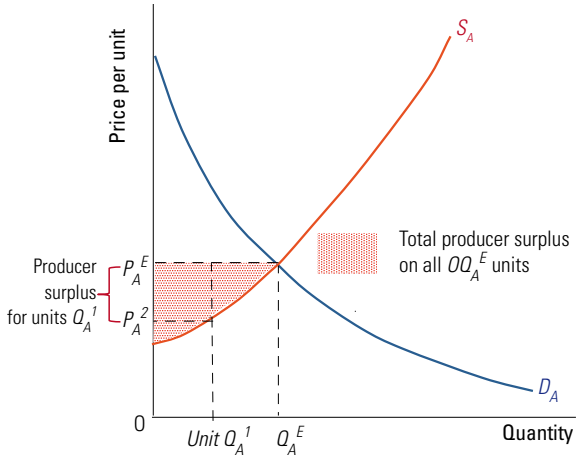


Fig. 3b
Producer surplus and the market for animal products

Consumer surplus

Assume that Q_A^1 is an arbitrary unit of animal products currently sold at market price P_A^E, as is every other individual unit of product up to OQ_A^E total units. Each point along demand curve D_A above price line P_A^E has an important interpretation. It tells us that although someone actually paid P_A^E for unit Q_A^1, they would have been prepared to pay price P_A^1; in other words, in money terms they value unit Q_A^1 at $(P_A^1\text{-}P_A^E)$ more than they paid for it, called the *consumer surplus*. Adding up the corresponding values for all other units of Q_A to the left of Q_A^E gives the total consumer surplus, a measure in monetary units of economic welfare.

Producer surplus

In Figure 3b, starting from the same initial position, each point along supply curve S_A below price line P_A^E also has an interpretation. It tells us that although a consumer actually paid P_A^E for the unit Q_A^1, its producer would have been prepared to supply it at the lower price P_A^2; in this case, the animal product supplier receives $(P_A^E - P_A^2)$ more money for unit Q_A^1 than the marginal cost of producing it, a monetary bonus called the *producer surplus*. Adding up the corresponding values for all other units of Q_A to the left of Q_A^E gives the total producer surplus, another measure of economic welfare.

Animal health and society

The principles outlined above are the bedrock of microeconomics, which concerns the study of the implications of choices made by decision-makers as individuals (e.g. farmers, pet owners, veterinarians) and as groups (e.g. all dairy farmers, racehorse owners), as well as the effect on these of government policy intervention (e.g. campaigns to eradicate infectious diseases, public finance for veterinary research). Importantly, economics' main concern is the well-being of society as a whole, which necessarily involves consideration of the distributional consequences of different patterns of resource allocation for the well-being of people in groups and as individuals. Historically, the economics of animal health evolved mainly from the need to address problems in farm animals and the implications of those problems for farmers. As veterinary epidemiology grew in prominence, livestock population health rather than individual animal health became the priority, and so economic perceptions changed too. Most recently, veterinary public health and One Health revive older perspectives for current needs (9). From a preponderance of financial analysis at individual farm or farm-sector level (10, 11), more often accountancy than economics strictly defined, the wider societal economic dimensions are now recognised (12, 13). Thus, the following discussion begins with issues at societal level, an inversion of past approaches.

Who gains from animal disease control, who loses, and by how much?

Figures 4a and 4b represent the market for products of an animal population in which disease is endemic. Supply curve S^U is therefore for the products obtained from 'unhealthy' animals. Following previous arguments, S^U derives from a short-run production function for 'unhealthy' animals. Suppose that the technical means to reduce the negative production effects of disease exist, and are successfully implemented. Following previous explanation, the production function shifts upwards so that a new 'healthy' supply curve S^H supersedes curve S^U with the following results.

The initial coordinates for the market equilibrium price, $P_A^{E(U)}$, and quantity, $Q_A^{E(U)}$, change to lower price $P_A^{E(H)}$

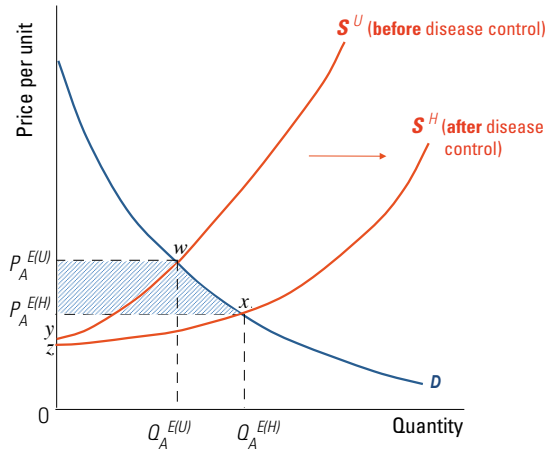


Fig. 4a
Consumer surplus and disease control

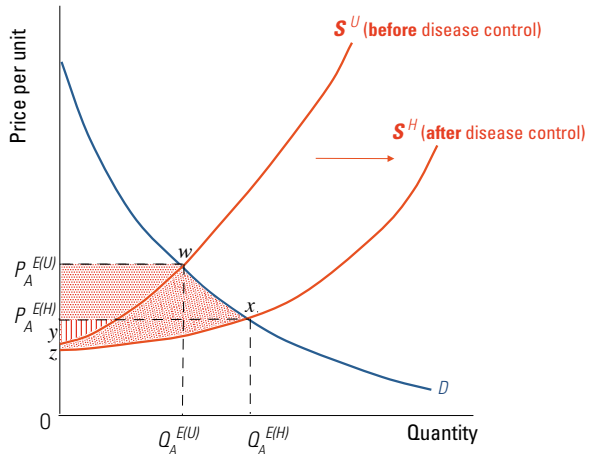


Fig. 4b
Producer surplus and disease control

and higher quantity consumed $Q_A^{E(H)}$. Consumer surplus increases by area $P_A^{E(U)}wx\ P_A^{E(H)}$, unambiguously a welfare gain because more product consumption at a lower price *always* benefits consumers (Fig. 4a). But for producers the outcome is less clear-cut (Fig. 4b). Producer surplus was $P_A^{E(U)}wy$, now lost and replaced by $P_A^{E(H)}xz$. Whether producers are better off, worse off, or in about the same situation both before and after disease control depends on the relative sizes of the two areas (excluding their common component). This can be ascertained only by knowing the specific characteristics of the demand and supply curves, including the extent of supply curve shift. Importantly, economic principles identify what relationships need to be investigated but, as here, only by estimating them is it possible to reach a definitive conclusion. Sector gross margin (total gross output minus total variable costs) changes from areas $(P_A^{E(U)}w\ Q_A^{E(U)}) - (Oyw\ Q_A^{E(U)})$ to areas $(P_A^{E(H)}x\ Q_A^{E(H)}) - (Ozx\ Q_A^{E(H)})$. The effect for society as a whole is the sum of changes in consumer and producer surpluses, which amounts to a net gain of area *wxzy*. So, society as a whole benefits from animal disease control, but although consumers invariably feel the benefits, this is not always the case for producers.

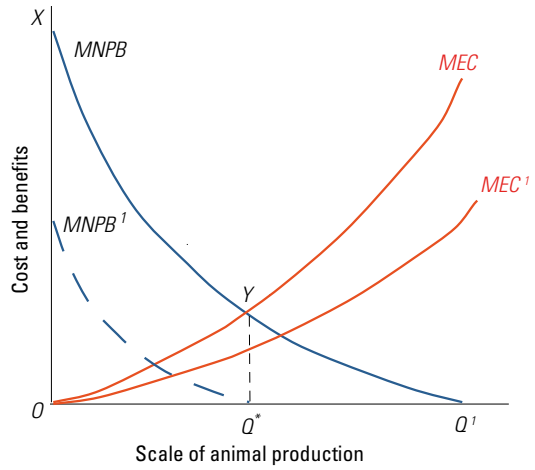
Missing from this account of economic welfare effects from animal disease control are resources committed to developing the technical means of control and its implementation, namely the research capacity embodied in laboratory facilities and scientists, including veterinarians, providing the essential know-how that results in the supply curve shift. To the extent that such capacity is resourced from government sources, the consequent public expenditure made from tax revenues must be set against the monetary value of area *wxzy*, and the net outcome computed. Taxation is a way of transferring economic welfare between different groups in society, such as from the active working population to the unemployed, or to animal health provision.

Private and social costs and benefits

As previously noted, market prices do not tell us everything about people's values. Sometimes conventional markets do not exist at all, such as for 'animal welfare', and sometimes they do not enable us to distinguish between *private valuations* and *social valuations*. Differences between private and social costs and benefits are *externalities,* and allowing for externalities in economic analysis can be a major concern. An externality is a cost, or a benefit, arising from an economic activity that falls on a third party and is not taken into account by those who undertake the activity.

Infectious diseases make externalities very important in the economics of animal health. For example, external costs are imposed on others by farmers who fail to prevent an infection from spreading beyond their own herd or flock. But why should any individual farmer be so negligent? Aside from ignorance or malevolence, the reason is that a farmer might rationally calculate that it is simply too expensive to implement measures conducive to stopping disease spread. In short, (s)he calculates that the *private costs* will exceed the *private benefits*. So, (s)he under-invests in biosecurity because it is not worth doing otherwise. But if as a result other farms become infected, the consequent *social costs* exceed the farmer's private costs. The difference is the externality or, in this instance, specifically the *external cost* or *negative externality*.

From Howe and Whittaker (14), Figure 5 summarises the implications of external costs for resource allocation at sector level for a livestock population. *Marginal net private benefit* (*MNPB*) is defined as the addition to total net private benefit brought about by using more resources



MEC: marginal external cost
MNPB: marginal net private benefit

Fig. 5
Externalities and disease control

to produce more products. Incrementally, more resources for additional production translate into marginal costs, and the associated increments of product into marginal revenues; the difference between marginal private revenues and marginal private costs is therefore the *MNPB*. Recalling that the sum of marginal units is the total, it follows that total net private benefit is maximised when *MNPB* is zero. Left to pursue their private interests, livestock farmers will aim to produce at output OQ_1 because they take no heed of external costs imposed on third parties if their herd or flock is a reservoir for an infectious disease.

Marginal external cost (*MEC*) is a variable whose magnitude depends on factors such as: livestock population density; the proximity to each other of susceptible animals on different farm holdings; geographical factors such as topography, wind direction and ambient temperature; frequency of animal contacts from auction market trading, and so on. Given the context, *MEC* more likely reflects the *expected* external costs of disease, its magnitude reflecting the risks associated with the aforementioned variables. Epidemiological evidence complements economic principles when the objective is empirical analysis. Consistent with the typical behaviour of marginal costs, *MEC* slopes upwards at an increasing rate.

The intersection of *MNPB* and *MEC* at *Y* defines Q^* as the optimal volume of livestock production that coincides with an optimal level of externality given by area OYQ^*. Area *OXY* is therefore the social optimum for total net benefit which, from Figure 5, is seen to be lower than the private optimum, area OXQ^1. Above all, this outcome suggests that there is a need to reduce the scale of livestock production (reduce animal numbers) for greater social benefit.

Seen from an environmental economics perspective, animal disease is a type of pollution. In principle, it is socially just that the polluter (say, a negligent farmer who fails to take steps to avoid infection or, at least, notify relevant authorities that others may be at risk) pays the cost to others of his neglect. The externality is then *internalised*, meaning that the social costs of disease are translated into a private cost. If negligent farmers were obliged to pay all the costs they would adjust their production behaviour to overall social benefit. Some form of penalty, say a tax or levy equal to YQ^* per head, should induce marginal net benefits to shift in the direction of the social optimum, shown as curve $MNPB^1$. Also, better disease prevention could reduce external costs so that *MEC* becomes MEC^1, enabling greater social benefit from higher production.

A justification for a disease control policy that encourages cost-sharing between government and farmers is that farmers are not always able to avoid infection, such as when animals contract wind-borne diseases (e.g. foot and mouth disease, highly pathogenic avian influenza, bluetongue). On the other hand, farmers can take steps to limit further spread by, for example, quarantining infected animals, observing movement restrictions, taking immediate steps to make veterinary interventions aimed at minimising disease spread, and so on. A farmer who reacts quickly to an outbreak of an infectious animal disease and quarantines affected animals, or employs veterinarians and medicines to help control disease spread and cure already infected animals, creates *external benefits* – the total beneficial effect for all farmers exceeds that for the individual – even though the socially responsible individual's private costs are increased. Arguably, such farmers should be rewarded by society, or at least other livestock farmers, for being socially responsible.

Howe and Whittaker (14) also consider economic incentives for farmers to take resource use decisions conducive to their moving in the direction of the social optimum, as well as towards the optimal level of precaution. Zoonoses can be another major consideration. When they are, this further dimension to externality effects, and the wider economic implications of human health impacts, must also be taken into account (15). This, above all, is the direct link between animals and people that makes the evolving One Health perspective so important. But, as with other such considerations, markets that necessarily deal only in terms of *private* valuations cannot provide a complete picture of *all* relevant *social* valuations that should guide what happens in the best interests of everyone. Thus, government intervention has a role to play in compensating for so-called *market failures* in resource allocation.

Conclusions

Resource allocation for animal health is a matter for all of society, because choosing to use scarce resources for one

purpose has an opportunity cost. The economics of animal health is an applied field of microeconomics, part of the general discipline of economics, with its concern for the well-being of people as a whole. Net benefits from allocating resources to animal health must be compared with those potentially obtainable by using the resources to meet other needs and wants instead. Within animal health, the same economic criteria apply to decision-making between policy options.

This section has aimed to outline economic principles that take the economics of animal health beyond its long-standing preoccupation with farm-level issues and applications of cost–benefit technique. Undoubtedly, these will continue to have an important role, but other perspectives are of growing importance. Nevertheless, the above discussion is traditional in the sense that examples drawn from farm livestock production are still the most useful for illustrating key ideas and relationships. Moreover, they are highly relevant for developing agrarian economies, whereas people's willingness to pay for the well-being of their pets and recreational animals in high-income countries arguably is of less pressing economic concern. In any event, the outline here provides a foundation for further investigation of economic principles for non-specialists concerned with animal health policy.

Les ressources allouées à la santé animale

K.S. Howe

Résumé

L'économie est trop importante pour être laissée entre les seules mains des experts. C'est pourquoi cet article s'adresse principalement aux responsables des politiques de santé animale qui ne sont pas économistes mais qui souhaitent néanmoins évaluer l'apport de l'économie aux décisions relatives à l'affectation des ressources. L'auteur commence par rappeler la méthodologie de l'analyse économique afin de réfuter les critiques sur le caractère supposément simplificateur du postulat de rationalité. Il examine ensuite les aspects techniques liés à la transformation de ressources en produits, concept familier pour les biologistes et les chercheurs en médecine vétérinaire mais moins courant chez les économistes. La véritable contribution de l'économie consiste à déterminer les critères qui permettent à une société de valoriser le plus possible la production et la distribution de biens et de services (produits) à partir de ressources limitées. Les maladies animales compromettent l'efficacité de ce processus. La valeur est intangible par nature mais les individus expriment la valeur qu'ils attachent à un produit (c'est-à-dire le désir ou le besoin qu'ils ont de ce produit) à travers leur consommation, au plan qualitatif et quantitatif. Les produits d'origine animale et partant, implicitement, les animaux eux-mêmes illustrent parfaitement ce phénomène. L'influence des préférences des individus se manifeste par le prix qu'ils sont disposés à payer pour les biens et les services pour lesquels il existe un marché, et par le vote politique pour tout ce qui est extérieur au marché. La distinction entre la valeur financière (prix payé par le consommateur pour un bien ou un service) et la valeur économique (le montant le plus élevé qu'il serait disposé à payer pour ce même bien ou service) est un aspect important. Les ressources allouées à la santé animale génèrent à la fois des coûts et des bénéfices, financiers et économiques. De plus, du fait des externalités, ces coûts et bénéfices sont de nature tant privée que sociale, facteur essentiel à prendre en compte pour les maladies infectieuses. Dans les situations où les décisions en

matière de production animale obéissent aux seuls impératifs du profit privé, sans tenir compte des répercussions sur la santé animale, les gouvernements ont un rôle incitatif à jouer pour que le secteur de l'élevage infléchisse son action en vue de résultats efficients pour la société.

Mots-clés
Affectation des ressources – Économie – Méthodologie économique – Politique de santé animale – Préférence – Prospérité économique – Santé animale – Valeur.

La distribución de los recursos en sanidad animal

K.S. Howe

Resumen
La economía es demasiado importante para abandonarla a los expertos. Por ello este artículo va dirigido sobre todo a los planificadores de políticas zoosanitarias que no son economistas pero desean tener una idea más clara de cómo puede ayudar la economía a tomar decisiones sobre la asignación de los recursos. Ante todo el autor presenta sucintamente la metodología del análisis económico, a fin de refutar las críticas que achacan una excesiva simplificación al postulado de la racionalidad. Después aborda algo inusual en economía, pero más familiar para biólogos y veterinarios: los aspectos técnicos de la transformación de los recursos en productos. La singular aportación de la economía estriba en definir criterios que permiten a la sociedad extraer el máximo «valor» de la producción y distribución de bienes y servicios (productos) a partir de recursos escasos. Las enfermedades animales restan eficiencia a este proceso. El «valor» es algo intangible, pero las personas revelan cuánto valoran un producto (es decir, hasta qué punto sienten que lo desean o lo necesitan) por lo que en la práctica consumen, tanto cualitativa como cuantitativamente. Los productos animales, y por ende, implícitamente, los propios animales, son ejemplo de ello. La fuerza de las preferencias de la gente se manifiesta en el precio que paga por bienes y servicios, cuando hay un mercado para ellos, o por su voto político, cuando no lo hay. Es importante señalar que hay una diferencia entre el valor monetario (lo que pagan los consumidores por un bien o servicio) y el valor económico (la cantidad máxima de dinero que estarían dispuestos a pagar por él). La forma en que se distribuyen los recursos en sanidad animal genera costos y beneficios, tanto monetarios como económicos. Además, esos costos y beneficios son tanto privados como sociales debido a la existencia de externalidades, factor este de gran importancia en el caso de las enfermedades infecciosas. Allí donde las decisiones de producción que tienen consecuencias zoosanitarias se rijan únicamente por el criterio del beneficio privado, las administraciones públicas deben cumplir la función de ofrecer incentivos a los sectores ligados a la producción animal para que su proceder se traduzca en resultados socialmente eficientes.

Palabras clave
Bienestar económico – Distribución de los recursos – Economía – Metodología económica – Política zoosanitaria – Preferencia – Sanidad animal – Valores.

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