8. Economics of Sheep Production

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Learning objectives

At the end of this topic you should be able to:

1. explain the process by which market prices are formed and the functions they fulfil in the sheep industry
2. identify factor-factor and factor-product relationships, and examine these relationships in the context of economic optimisation in the sheep enterprise
3. identify the factors influencing the supply of sheep products to markets, and understand how supply influences markets
4. identify the factors influencing demand for sheep products so as to be able to examine how demand factors influence markets
5. apply the concept of derived demand in the economic analysis of sheep production
6. demonstrate a thorough understanding of the product-product relationships in sheep enterprises and between sheep and other important enterprises in Australian agriculture
7. discuss the impacts of management decisions relating to optimal enterprise combinations and optimal combinations of activities within the sheep enterprise (ANPR450)
8. access and use recent research and extension material describing the economics of dual-purpose sheep production systems.

Key terms and concepts

Demand, economic analysis, factor-factor relationships, factor-product relationships, product-product relationships, production possibilities frontier, profit maximisation, sheep enterprise, supply, wool and meat.

Introduction to the topic

This topic is directed to the analysis of the economics of sheep production. Profitable sheep production depends on good pasture availability and efficient conversion to wool and meat. Achievement of this goal requires skilful grazing and animal management, good sheep genetics and sound product marketing. It also requires consideration of the economics of joint production within and between enterprises. The main purpose is to develop an understanding of the principles of production and price theory, and how these principles can be applied to economic problems in sheep production. The topics to be covered are the:

- input-output relationships
- relationships between inputs in producing outputs
- profit maximisation
- price theory
- relationships between supply and demand
- derived demand for factors of production
- product-product relationships.

The primary emphasis in this topic is on comparisons of profitability of activities in the sheep enterprise, and appropriate management and product marketing to maximise profit. There are also elements of risk management associated with enterprise/activity mix, management and product marketing.

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8.1 Market links to the sheep production system

In this topic, an outline is provided of the concept of a market as an allocative and distributive system in the sheep industry. Wool and sheepmeat prices are generated from the wool and sheepmeat marketing systems, respectively. These prices are then used in a wide variety of ways for decision making and thereby enter the production process. It is for this reason that you are first being introduced to the idea of a market before you are presented with a view of the production system and the decision making involved.

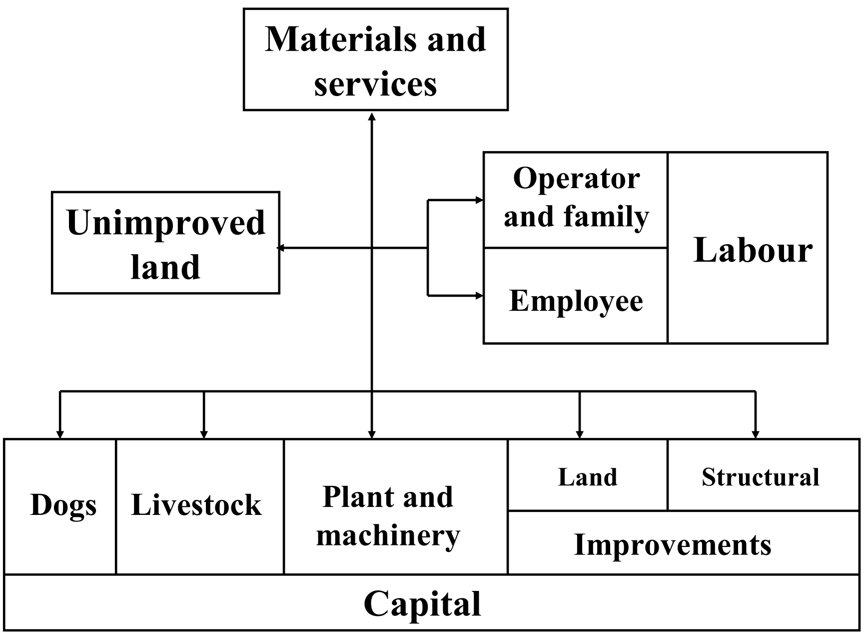
Markets exist at various levels in these production systems. Markets for inputs, markets for farm products, wholesale markets and retail markets all co-exist with various relationships between them. In a similar way, there are relationships between markets in different geographical regions and for different time periods. They provide the context for an economic analysis of the sheep enterprise.

8.2 Sheep production relationships: An overview

Production theory relates to the process of converting inputs (or factors of production) into outputs. There is a variety of inputs used in sheep production in Australia, and each has its own different attributes. During this topic, we shall consider some of these differences in attributes, reflected in the impact their use has on wool, lamb and mutton output, and the relationships between them.

A summary of input categories is presented in Figure 8.1, along with the relationships between them represented by arrows. These arrows reflect the fact that inputs are not used in isolation of each other but can be substitutes, supplements or complements. The input categories found on all sheep properties are unimproved land, capital, materials and services (alternately called variable, current or recurrent inputs), and labour.

Figure 8.1 A summary of factor relations in the sheep enterprise.



The main forms of labour are operator and family labour, with considerable variation in the use of hired labour depending on the nature of the farm organisation. Employee labour could be permanent, and therefore treated as a fixed input, or casual (often itinerant) and therefore treated as a variable input. An increasingly important category of capital, not explicitly mentioned in Figure 8.1 but subsumed under the headings of operator and family labour and employee labour, is human capital. It comprises the skills, knowledge and health embodied in the farm labour force.

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Many varieties of materials and services are used on the farm, such as feed, fuel, chemicals and various health inputs for sheep. They can be viewed as either discretionary or essential. Materials and services are typically lumped into one category despite obvious differences in their relations with other factors, especially labour and land. Services have become more important than materials in recent years.

There are also many types of capital: plant and machinery, of various types and vintages used for transport and in livestock management, pasture management and grazing management; structural improvements, such as fences, yards, buildings and watering holes; land improvements, such as fertiliser applied to pastures and conservation measures to prevent land degradation; sheep, of many different breeds, ages and types, usually measured in dry sheep equivalents (DSEs); and, last but not least, working dogs. Sheep are difficult to categorise, being a tradeable input, but are best treated as both a semi-durable capital item and output depending on the intent in their use.

Farm capital can alternatively be viewed as (a) purchased items that are not fixed to a property, such as plant and machinery, and (b) items that are fixed to a property and usually created by the farmer (dams, fencing, yards and pasture improvement). Historically, the first category has formed a relatively small proportion of capital structure and the second category a relatively large proportion. But this has changed in recent years as plant and machinery items have become more prominent in pastoral activities. In most cases, the value of the second category cannot be realised without selling the farm.

8.3 The sheep production function and factor-factor relationships

The theory of production is built on a profit-maximising objective. Production analysis has three components:

(a) how much to produce (factor-product)
(b) which inputs to use to produce the products (factor-factor)
(c) which products to produce (product-product).

The concept of economic optimisation (profit maximisation) is developed in the context of factor-product and factor-factor relationships in the following section.

8.3.1 The sheep production function

The sheep production function is the technical relationship that effectively limits the options of the manager of a sheep enterprise, and specifies the relationship between the inputs a farm uses and the outputs it produces. It is written as:

$$Y = f(X, Z)$$

where Y is a measure of output of sheep products, X is a set of variable inputs used in sheep production, and Z is a set of fixed and semi-durable inputs. In Figure 8.1, operator and family labour, unimproved land, plant, machinery and working dogs are generally regarded as fixed inputs. Most sheep are classed as a semi-durable input – that is, a good that is used in production for several years before being traded in the market (lambs sold for sheepmeat are an exception). Fixed and semi-durable inputs are measured in terms of an annual service flow that is the sum of three component costs: depreciation; maintenance; and opportunity cost (the revenue forgone by not using an input in its next best alternative use).

8.3.2 Total product, average product, marginal product and the three stages of production

Figure 8.2 gives a representation of a segment of a sheep production function with two variable inputs, say feed and health inputs. Isoquants represent lines of equal output, and two such isoquants are shown in Figure 8.2.

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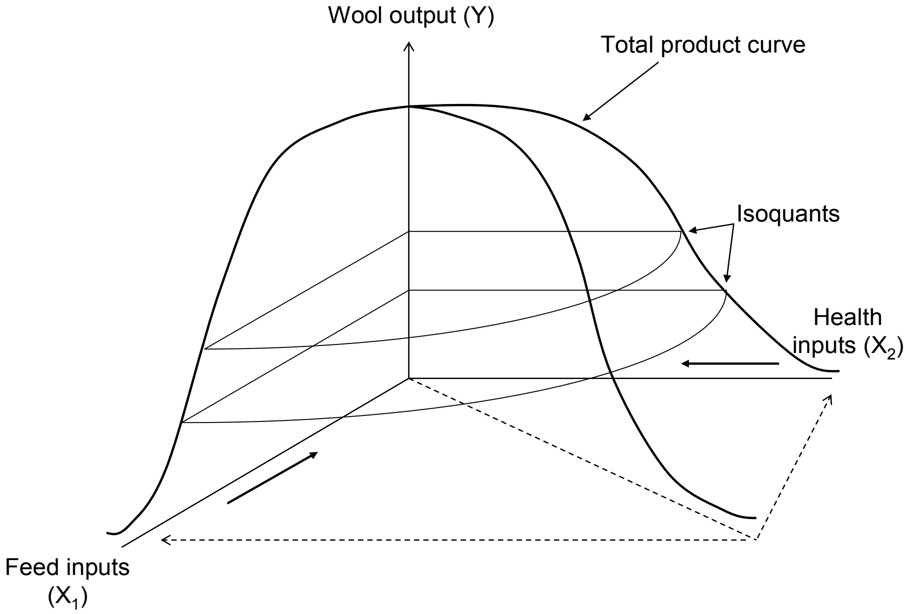
Figure 8.2 Representation of a segment of a production function with two variable inputs and one output.



At this stage, let us consider the relationship between one input and one output. The total product (TP) curve, also called the total physical product curve, relates the level of one input (say, feed) to the output of wool and any other sheep outputs, with all other inputs held constant (see Figure 8.3). Examining Figure 8.3, the average product for the feed input is the total product of sheep outputs, Y, divided by the quantity of feed used (X_1):

$$AP_{X_1} = Y/X_1.$$

The marginal product (also known as the marginal physical product) is the increase in output as a small change is made in use of the feed input, X_1:

$$MP_{X_1} = \Delta Y/\Delta X_1.$$

The marginal product is, in effect, the slope of the *TP* curve at a given point. MP_{X_1} is zero at the maximum point on the *TP* curve.

The stages of production are useful concepts in that they define input levels that are economically rational. In Figure 8.3, AP_{X_1} is at a maximum where both average product and marginal product are equal. This is the boundary between Stage 1 and Stage 2, where Stage 1 is an irrational zone in which to produce because it pays the producer to keep adding inputs as long as the average product is increasing. The boundary between Stage 2 and Stage 3 is defined by the maximum total product, when $MP_{X_1} = 0$. It obviously does not pay the producer to keep adding inputs beyond this point because output is reduced by doing so. Therefore, the rational zone of production is Stage 2.

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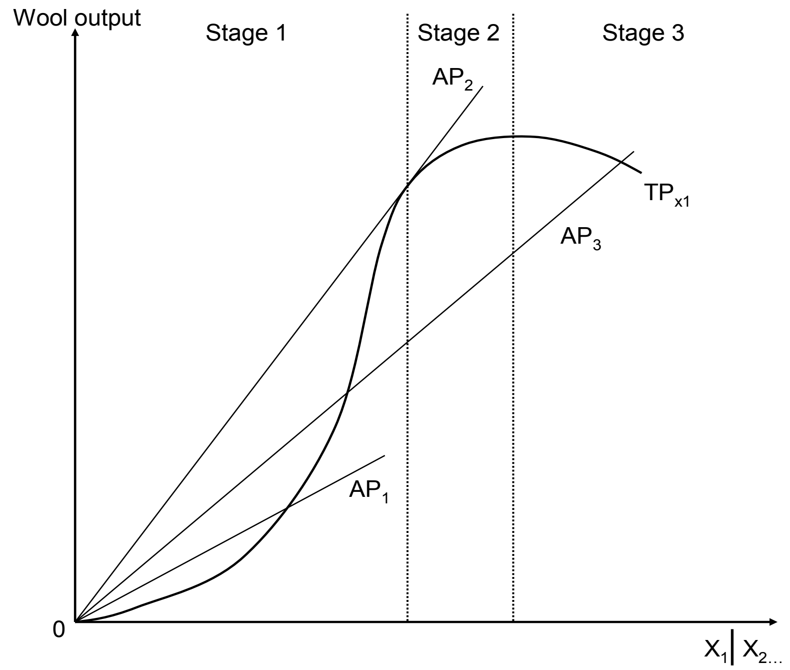
Figure 8.3 Total product curve for feed input, all other inputs remaining fixed.

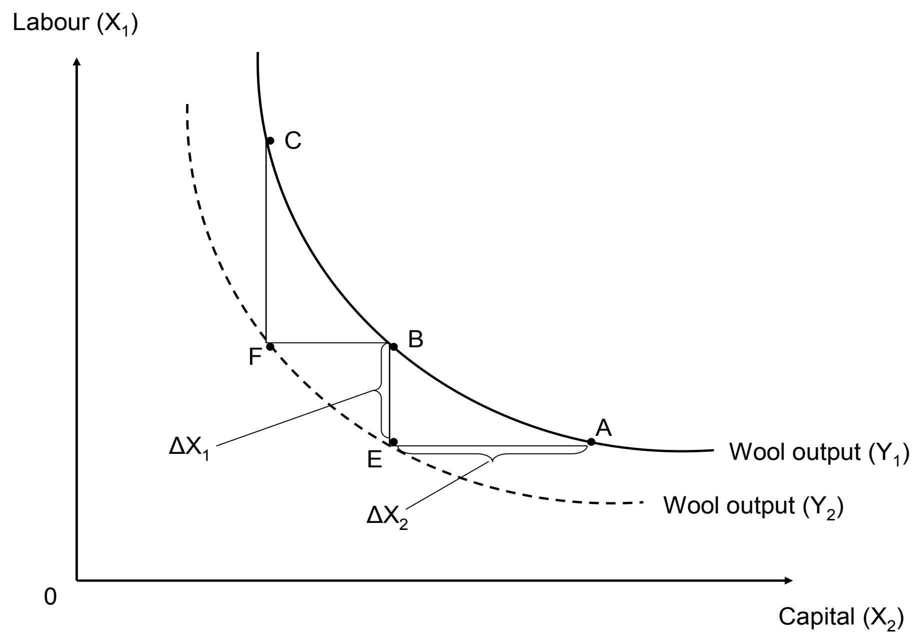


8.3.3 Isoquants and the marginal rate of substitution

Isoquants are curves that show the possible combinations of inputs for a given level of output (see Figure 8.2). They indicate the factor-factor (or input-input) relationship.

Consider, for example, the isoquant map for wool production in Figure 8.4, using the two inputs of labour (X_1) and capital (X_2). 'Capital' here refers to any one of a number of fixed capital items, such as fences, yards, machinery, and working capital items, such as drenches, other health inputs, services and fuel. As an example, consider the construction of new sheepyards that reduces the time taken by the farm manager in handling sheep for tasks such as shearing and drenching.

Figure 8.4 Representation of a typical isoquant in factor-factor space for wool output level



***Y*1.**

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The movements from A to B and from B to C show that successively smaller amounts of capital are given up (or saved) (ΔX_2) for given increments in labour (ΔX_1). The main measure used to describe the ease with which one factor can be substituted for another is the marginal rate of substitution (*MRS*), also called the marginal rate of technical substitution. The marginal rate of substitution of input X_1 for input X_2 (MRS_{12}) is the number of units of X_2 given up for a unit increase in the use of X_1, output remaining constant. More succinctly, $MRS_{12} = \Delta X_2/\Delta X_1$. If the isoquant is sloping down from left to right, as in Figure 8.4, this value will be negative ($\Delta X_2 < 0$, $\Delta X_1 > 0$), implying that these inputs are substitutes. MRS_{21} (the marginal rate of substitution of input X_2 for input X_1) is the reciprocal of MRS_{12}, defined as $\Delta X_1/\ \Delta X_2 = 1/MRS_{12}$.

Substitution of labour (X_1) for capital (X_2) involves the movement around the isoquant from A to B in Figure 8.4. Here, $MRS_{12} = \Delta X_2/\ \Delta X_1$ = AE/EB. As more units of X_1 and fewer units of X_2 are used, it is apparent that there is a change in the relative magnitudes of ΔX_1 and ΔX_2. If ΔX_1 is held constant, ΔX_2 becomes smaller. That is, successively smaller quantities of capital (X_2) are replaced. Alternatively, if ΔX_2 is held constant, successively more units of labour (X_1) must be added. Hence, *MRS* is 'diminishing', or the ease of substituting labour for capital is being reduced.

The movement along the isoquant from A to B for a wool producer usually involves two effects:

- reduced production of wool (Y) due to the employment of less capital (X_2) (less by AE)
- increased production of wool (Y) due to the employment of more labour (X_1) (more by EB).

The first effect involves a shift to a lower isoquant, from Y_1 to Y_2 (a lower level of wool output). That is, less wool is produced as units of capital (X_2) are withdrawn. The second effect involves a movement back to the higher isoquant (Y_2 to Y_1). That is, more wool is produced with the addition of more X_1. Thus, the change in the level of production of wool is the net result of two effects; and, with the constraint to remain on the same isoquant, the effects exactly offset each other. That is, there is no change in wool output ($\Delta Y = 0$).

Specialising to the two-factor case, the move from A to B can be expressed as:

$$\Delta Y = MP_1\ \Delta X_1 + MP_2\ \Delta X_2 = 0.$$

Thus, with a bit of simple algebraic manipulation,

$$MP_1\ \Delta X_1 = -MP_2\ \Delta X_2$$

Or

$$-(MP_1/MP_2) = \Delta X_2/\ \Delta X_1 = MRS_{12}.$$

This will be recognised as MRS_{12} that is defined above. This redefinition of *MRS* in terms of marginal products is most convenient and useful. Note particularly the important minus sign attached to the ratio. That is,

$$MRS_{12} = -(MP_1/MP_2) \text{ and } MRS_{21} = 1/MRS_{12} = -(MP_2/MP_1).$$

Now, check the connection between the behaviour of *MRS* and diminishing returns (the decline in successive increments of output with constant increments of inputs). The movement from A to B in Figure 8.4 involves increased use of X_1 and reduced use of X_2. On the basis of diminishing returns, this means that MP_1 will be reduced and MP_2 will be increased. Thus, the measure of the ease of substituting X_1 for X_2, namely MRS_{12}, will become a smaller negative value. (Take care with this point because what is known as a 'diminishing MRS_{12}' actually involves the numerical value becoming larger, i.e. from a negative value towards zero.)

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8.3.4 Elasticity of input substitution

Another important measure used to describe the ease with which one input can be substituted for another is the elasticity of input substitution, which is derived from *MRS*. You will hear and read a good deal about elasticity coefficients in the unit. Remember that, in general terms, an elasticity coefficient is the ratio of two percentage changes. Assume, as above, that we are substituting X_1 for X_2 and keeping output (Y) unchanged, i.e. moving along the isoquant. The elasticity of substitution (ES_{12}) of X_1 for X_2, is defined as the relative change in X_2 divided by the relative change in X_1. This definition can be represented approximately as:

$$ES_{12} = \frac{\Delta X_2 / X_2}{\Delta X_1 / X_1}$$

Note that the *MRS* ($\Delta X_2/ \Delta X_1$) is a component of this definition and that the sign for competitive inputs is negative. ES_{12} can be interpreted as the percentage change in X_1 needed to maintain Y at a particular level if we change X_2 by 1 per cent. An alternative definition is where the elasticity of substitution is defined for factor *i* with respect to factor *j* by:

$$E_s = \frac{\Delta X_i}{\Delta X_j} \frac{\Delta P_j}{\Delta P_i}.$$

This definition reflects the cross-price elasticity of demand for one input in respect of the price of another input. There is more on the concept of a cross-price elasticity below in relation to product demand.

The elasticity of substitution is commonly used instead of the marginal rate of substitution in livestock response analysis because it has the desirable property of being free from the effects of input magnitudes. An elasticity less than unity in magnitude means substitution is relatively difficult. In this case, a relatively large amount of X_1 is needed to compensate for the withdrawal of a relatively small amount of X_2 in order for Y to remain constant. An elasticity of zero indicates no possibility of input substitution. Elasticities greater than unity in magnitude indicate relatively easy substitution, becoming easier as the elasticity value becomes higher. It means that there is a great potential for the manager to substitute one input for another in production. Long-run elasticities are typically higher than medium-run elasticities, which in turn are higher than short-run elasticities. This is because sheep producers have greater opportunity to alter fixed input levels over time whereas these fixed inputs, by definition, cannot be altered in the short term.

8.3.5 Economies of scale

A change in the scale of production is defined as a proportionate increase in all inputs (or factors) including what, in the short term, are the fixed inputs.

Figure 8.5 illustrates constant, decreasing and increasing returns to scale with each total product curve representing a new set of values for all other inputs. Factor-factor space may also be used to represent economies of scale. As you move away from the origin, constant returns to scale prevail if the isoquants are equally spaced (constant increments in output). When the isoquants become closer together, it indicates increasing returns to scale; and when they become further apart, decreasing returns to scale prevail. Remember that all factors must be variable in the same proportion to represent economies of scale while economies of size may be represented with different factor proportions at different levels of output.

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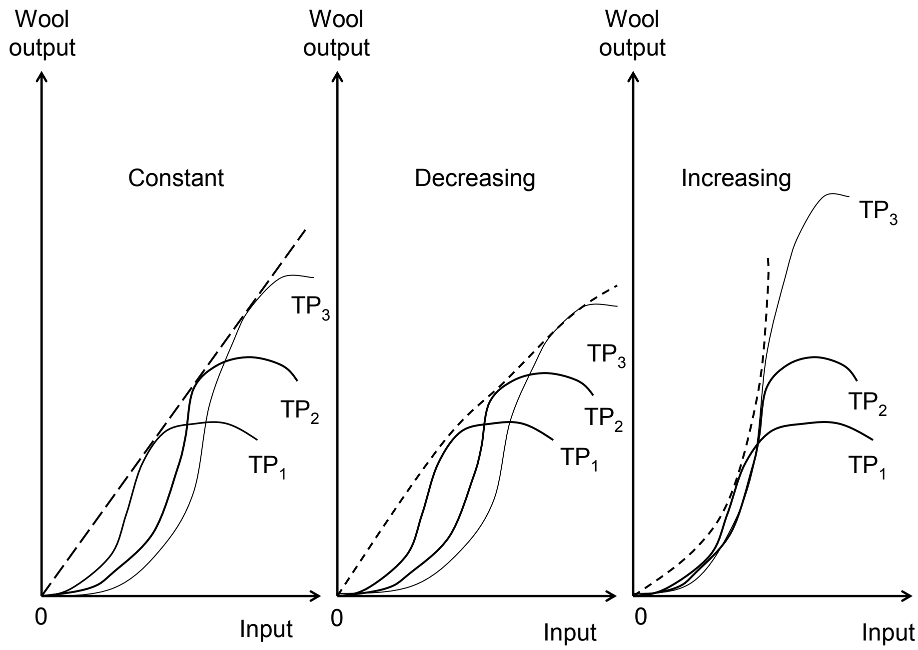
Figure 8.5 Representation of returns to scale in factor-product space.



8.3.6 Elasticity of production, economies of scale and homogeneous production functions

Changes in scale involve proportionate increases in all inputs. As such, scale lines drawn on an isoquant map are straight lines emanating from the origin. There is a family of scale lines corresponding to all possible ratios of X_1 to X_2. The ratio between X_1 and X_2 is constant along any scale line.

Returns to scale are measured by the total elasticity of response, E (also called elasticity of production, output elasticity or scale elasticity). This concept measures the responsiveness of output to changes in inputs along a scale line. It is possible to distinguish between partial and total elasticity concepts. First, we can define the partial elasticity of response associated with the i-th factor of production X_i as E_i, which is the proportionate change in output for a small proportionate change in input:

$$E_i = (\Delta Y/Y)/(\Delta X_i/X_i) = (\Delta Y/\Delta X_i)/(Y/X_i),$$

which equals MP_i/AP_i where AP_i is the average product, Y/X_i (see above). The (arc) partial elasticity definition is commonly expressed approximately as the percentage change in output associated with a one per cent change in input.

Total elasticity relates the responsiveness of output to a proportionate change in all inputs. It is measured by summing the responsiveness to each individual input. For the two-factor case:

$$E = E_1 + E_2, = MP_1/AP_1 + MP_2/AP_2.$$

The 'critical' value of the total elasticity is unity. Where $E > 1$, increasing returns to scale prevail. If $E < 1$, decreasing returns to scale prevail; and, if $E = 1$, constant returns to scale prevail. For some functions, E is constant for all levels of X_i. These are called homogeneous functions. In most functions, E is related to the level of X_i, and they are distinguished as non-homogeneous functions.

There is also a special case referred to as the linear homogeneous production function. This is the case where $E = 1$ for all levels of X_i. A function that meets this requirement is the Cobb-Douglas

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function, $Y = aK^b L^c$, where $b + c = 1$. Such functions have been used frequently, partly because of their ease of manipulation, despite the severe constraints imposed on the nature of the production process so modelled. Mounter (2007) observed that an assumption of constant returns to scale is reasonable for sheep production in Australia. This observation was based on estimates that have been made of the production function for sheep enterprises (see for example, Sheep CRC Project 1.2.6).

8.4 Profit maximisation (ANPR450 students only)

8.4.1 Profit maximisation in the one-factor, one-product case

To begin, you should distinguish between technical efficiency – that is, maximum physical production – and economic efficiency, that is, maximum profit. This distinction is described in more detail in Topic 9. At this stage, we assume that the manager faces no risk in making decisions. This assumption is dropped in Topic 11 but for now some economic measures are introduced to the riskless theory of production elaborated in earlier sections. The paradigm of profit maximisation is followed and the analytical tool used is marginal analysis. The approach is one in which the concern is to identify decisions on the basis 'if the sheep producer wishes to maximise profits, how would enterprise and variable input levels be determined?'

Profit (designated π) is defined as total revenue minus total cost, *TR* – *TC*. The simplifying (and reasonable) assumption is made that, for a perfectly competitive farm firm, the price of output (p_y) is constant irrespective of the level of output. That is, individual sheep farmers are price-takers in their product markets. Prices of inputs, p_i, i = 1, 2. ..., *N*, are also constant for all levels of use, meaning that farmers are price-takers in their input markets. Thus,

$$TR = p_y Y, \text{ and}$$

$$TC = \sum_{i=1}^{N} p_i X_i ,$$

so that:

$$\pi = p_y Y - \sum_{i=1}^{n} p_i X_i ,$$

where Σ denotes summation.

In the factor-product case, only one input is variable (other inputs are assumed to incur fixed costs, *FC*), so the problem is to determine:

(a) whether profitable production can take place, and
(b) the best level of the variable input or factor.

For input X_1, as $p_y MP_1 = MVP$ (marginal value product) and $p_1 = MFC$ (marginal factor cost), the profit equation is maximised when:

$$MVP - MFC = 0, \text{ or}$$
$$MVP = MFC.$$ [1]

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[1] For those with a mathematical background, the simplified profit equation for input X_1,

$$\pi = p_y Y - p_1 X_1 - FC,$$

is maximised when the first derivative $\partial\pi / \partial X_1 = 0$. Now,

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The solution of this equation determines the 'optimal' (that is, profit-maximising) input level. Alternative arrangements of these profit-maximising conditions are possible, such as $MP_1 = p_1/p_y$, which is the equation of marginal product with the 'price ratio' (price of input divided by price of output), termed the isoprofit function, which is a line joining points of equal profit.

The geometric derivation of the optimum input level involves the equation of two slopes. The first is the slope of the total product curve, indicated by the marginal product of the input, while the second is the slope of the isoprofit function, p_1/p_y, which is the ratio of the input price to the output price. To derive the isoprofit function, ignore fixed costs (which do not enter marginal analysis) and redefine the profit (or objective) function in terms of just one variable input as:

$$\pi = p_y Y - p_1 X_1$$

Next, select some constant profit level, π^*. Then,

$$\pi^* = p_y Y - p_1 X_1$$

which can be arranged explicitly for Y as:

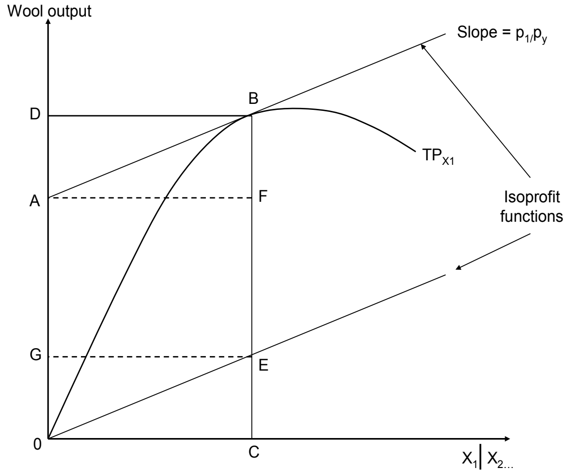
$$Y = \pi^*/p_y + (p_1/p_y)\, X_1$$

which relates levels of X_1 and Y and yields the constant profit π^*. It is a linear function, with slope p_1/p_y and intercept π^*/p_y, and is a member of a family of parallel straight lines for varying π^*.

Figure 8.6 illustrates the geometric derivation of the optimal point, B. The isoprofit line drawn from the origin indicates break-even combinations of X_1 and Y. At all points along the line there is sufficient value of output ($p_y Y$) to cover the cost of the input ($p_1 X_1$). So long as some point on the *TP* curve lies above this break-even line, production will yield a surplus over the cost of the variable input, thereby indicating that production will be undertaken in the short run somewhere in Stage 2 of Figure 8.2. The line AB is drawn parallel to the first isoprofit line and tangential to *TP* (at point B). This indicates the optimal point where the slope of the *TP* curve is equated with the slope of the isoprofit line. The level of profit is determined as $\pi = p_y(0D) - p_1(0C) = p_y(0D) - p_y(AD)$ (because rectangles ADBF and 0GEC are identical) = $p_y(0A)$.

Another means of graphical solution is to plot the profit or gross margin function directly as a function of an input and to read off the profit-maximising level of the input. Worked examples will be given in Moodle.

Figure 8.6 Profit maximisation in the one factor, one product case.



$\partial\pi / \partial X_1 = p_y\, (\partial Y / \partial X_1) - p_1 = p_y MP_1 - p_1.$

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8.4.2 Profit maximisation with two factors and one product

The two-factor case introduces the concept of an isocost line, which is a line that joins up all points of constant budget outlay. For a particular cost level C*, the isocost line is represented by the following function:

$$C^* = p_1X_1 + p_2X_2$$

or, explicitly for X_1, as:

$$X_1 = C^*/p_1 – p_2/p_1X_2.$$

In factor-factor (or input-input) space, this is a straight line with an intercept on the X_1 axis of C^*/p_1, which is the amount of X_1 purchasable with C^*. The slope of the line, $-p_2/p_1$, reflects the amount of X_1 that may be acquired if units of X_2 are given up. Two such isocost lines are sketched in Figure 8.7. The isocost line closest to the origin has the lowest cost; thus, the minimum cost of producing the output on isoquant Y^* occurs where that isoquant touches the isocost line closest to the origin. This implies a tangency solution as shown in Figure 8.7 at point A. This is obviously lower cost production than, say, point B which lies on the higher isocost line $C'C'$.

Optimisation in factor-factor space reduces to:

$$MRS_{21} = -MP_2/MP_1 = -p_2/p_1$$

as a necessary condition for efficiency in producing any level of output. The second problem is to find which isoquant, or level of output, is best. This is seen most readily by defining an objective function for the two variable factor case:

$$\pi = p_yY – p_1X_1 – p_2X_2 - FC.$$

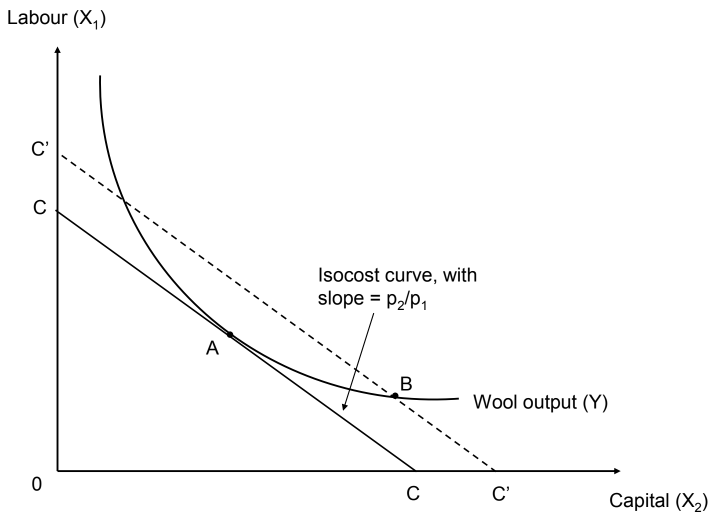
The profit-maximising conditions for this function are:

$$p_yMP_1/p_1 = p_yMP_2/p_2 = 1.$$

Because p_1 does not change as the amount used by the farm changes (the price-taker assumption), $p_1 = MFC_1$ for all levels of input use. The above equation can now be restated as:

$$MVP_1/MFC_1 = MVP_2/MFC_2 = 1.$$

Figure 8.7 Least-cost input combination.



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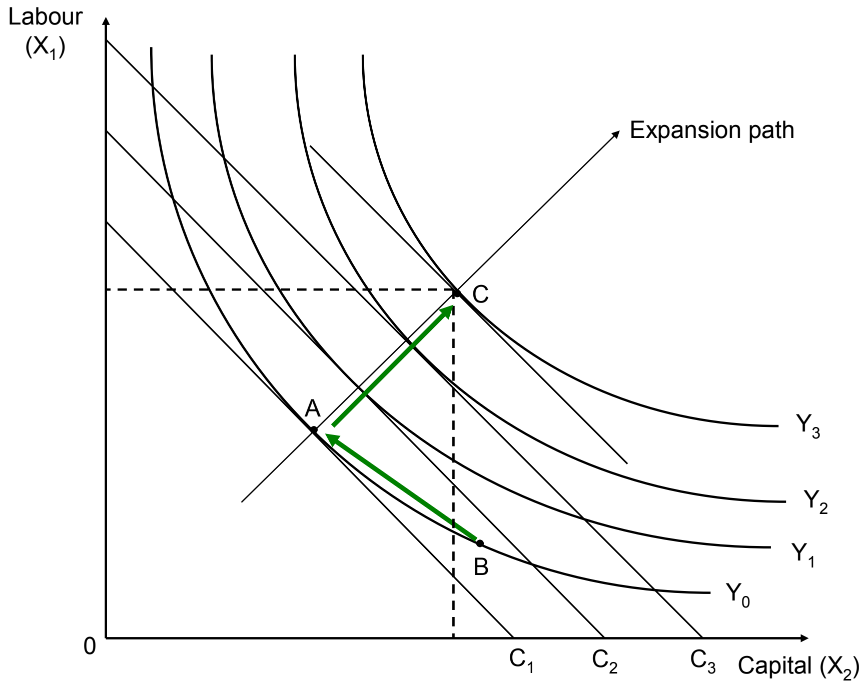
That is, the ratio of *MVP* to *MFC* must be unity (as for the single-factor single-product optimisation). Clearly, this subsumes that necessary condition, noted above, of $MRS_{21} = -p_2/p_1$. Think about why this is so. We can now define efficient combinations of the variable factors for different levels of output. In factor-factor space, the line joining these points is termed the expansion path. Profit maximisation can thus be thought of as climbing up the expansion path until the marginal product of input X_1 falls to such an extent that the marginal return associated with each input ($MVP_i = p_y MP_i$) exactly covers the associated marginal cost (p_i or MFC_i). Put in a more familiar way, to maximise profit the producer should set marginal revenue (*MR*) equal to marginal cost (*MC*).

Consider some point B on the isoquant Y_0 in Figure 8.8, analogous to point B in Figure 8.7. The cost of production at point B lies somewhere between isocost lines C_1 and C_2. The optimisation procedure involves two steps. First, wool output can be maintained at less cost (C_1) by moving around the isoquant from B to A. Second, profit can be increased by moving up the expansion path until a maximum is reached at, say, point C on isoquant Y_3.

Our discussion has emphasised two-input factor-factor relationships and one- and two-factor factor-product relationships in sheep production. Naturally, all these relationships can be generalised to many factors and many products.

Figure 8.8 Profit maximisation in factor-factor space.



8.5 Product-product relationships in sheep production

8.5.1 What makes a farm a mixed-enterprise and a sheep enterprise dual-purpose?

The first part of the question in the title to this section is easy to answer: a mixed enterprise farm is one in which there is more than one enterprise as part of the normal operations of the farm. For our purposes, mixed-enterprise farms of particular interest are properties running sheep and beef, those with cropping and sheep enterprises, and those with sheep, beef and cropping enterprises commonly found in the wheat-sheep zone.

To begin with, a procedural distinction is made between a farm enterprise and a farm activity. A farm enterprise entails the production of a particular output, or group of related farm outputs for sale or domestic use, whereas a farm activity is a specific method of production within a farm enterprise. For example, Merino wool production and prime lamb production are two activities within the sheep enterprise.

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Maximising profit in wool and meat production within sheep enterprises is a major focus of this topic. It is also important to consider the risks facing the sheep producer and the need to manage them, especially those associated with commodity price swings. Options for different activities within the sheep enterprise include varying activity mixes ranging from:

1. self-replacing Merinos; through to
2. first-cross terminal meat sire breeds crossed with Merinos; and
3. specialist prime lamb production using terminal meat sire breeds over crossbred ewes.

Moving from (a) through to (c) results in progressively greater production and income from meat compared with wool. Options also include varying production between the sheep and other enterprises on the farm.

Some enterprises comprise more than one activity, or different ways of producing outputs in the same enterprise. In the sheep enterprise, there are obviously many different ways in which wool and meat are produced. Activities along the spectrum include specialist Merino wool production and specialist prime lamb production, at either extreme,and a variety of dual-purpose sheep enterprises in between.

There is considerable flexibility in the composition of dual-purpose sheep enterprises as all Australian sheep produce both wool and meat. However, at each end of the spectrum are the extremes of wool enterprises with Merinos often on more marginal land or environments not capable of turning off lambs or hoggets for meat, to prime lamb systems with specialist terminal meat sires mated with highly productive crossbred ewes on more fertile land.

The definition of dual-purpose sheep enterprises used here is those in which at least 25 per cent of income is derived each from wool and meat. This means enterprises that are largely Merino based, including self-replacing Merinos or purchase of replacement Merino ewes, and terminal sires mated with varying proportions of Merino ewes.

The main categories of dual-purpose sheep enterprises are:

- Merino ewes turning off store or prime lambs
- Merino ewes turning off yearlings (14-18 months)
- terminal sires with Merino ewes turning off store or prime lambs.

In the above examples, the Merino ewes can be either from self-replacing systems or bought in. With terminal sires, varying proportions of the Merino ewe flock may be used depending on breeding replacement requirements. Intensive lamb production from specialist meat sires and crossbred or composite ewes is not regarded as a dual-purpose enterprise.
The above options present two main scenarios based on (a) development of dual-purpose Merinos with good meat qualities (growth rate and muscling) to accompany premium wool production, and (b) dual-purpose systems based on specialist terminal meat breeds with Merino ewes focussed mainly on wool quality and quantity. Each option has its merits with dual-purpose Merinos striving for genetic improvement in both wool and meat traits while the dual-purpose system relies on good meat genetics from the sire and good wool genetics from the dam. Obviously, use of self-replacing Merinos will result in a greater proportion of wool relative to meat than with use of terminal sires. The relative influences of the various enterprise structures on profitability are outlined in the following sections.

8.5.2 Extent of dual-purpose enterprises

The composition of the flock is a key determinant of the outputs produced in the sheep enterprise. These outputs include wool, sheepmeat and live sheep for export. The heavy dominance of ewes can be attributed in part to the increased importance of lamb for meat, particularly cross-bred lambs, and to producers reducing their flock to core breeding stock in response to recent adverse seasons.

Almost 40 per cent of lambs are first and second cross using specialist sire breeds for meat production. In addition to a small proportion of Merino lambs, this has contributed to annual lamb carcase output of just over 400 kt. Along with an almost equal quantity of mutton from adult sheep,

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and with some 4.5 million live sheep exports, ABARE (2006) observed that just under 50 per cent of the gross value of production from the sheep industry is from sheepmeat, a trend that is predicted to continue.

The shape of the Australian sheep industry has changed from the early 1990s when meat accounted for less than 10 per cent of the gross value of production. By the turn of the century this proportion had progressively climbed to almost 50 per cent (ABARE 2006). With the ABARE market outlook for meat stable and despite recent recovery in the price of wool, it appears the sheep industry will continue to be largely dual-product driven.

The composition of the sheep flock determines the relative quantities and value of wool and meat production. Currently, around 90 per cent of the Australian flock are Merinos and 73 per cent of the 57 million adult Merino ewes are mated to Merino rams. Of all lambs born in 2004-05, 63 per cent were pure Merino with 37 per cent first or second crosses with specialist meat breeds.

8.5.3 Sheep enterprise comparisons

Recent trends

With the emphasis to meat production, the national flock is now younger and contains a higher proportion of ewes than previously (Barrett et al. 2003). For many farmers, revenue from lamb sales is contributing a greater proportion to farm receipts, and prime lamb production is now considered by a growing number of sheep producers to be their primary activity. Wool producers are becoming more interested in running dual-purpose Merino flocks, for wool and meat production, as a hedge between price fluctuations of either product. Only 30 per cent of wool producers sold lambs for slaughter in 1992; by 2002, this proportion had risen to 47 per cent (Barrett et al. 2003). Specialist prime lamb producers have become more focussed on producing heavier carcase weights to meet specifications of processors, and capture price premiums. Of course, relative prices can quickly change as recent increases in wool prices show.

The increased interest in lamb production by woolgrowers has led to management changes, such as:

- joining Merinos ewes to terminal sires
- lambing earlier (i.e. autumn or early winter) to produce heavier lambs
- breeding larger framed ewes or injection of SAMM (South African Mutton Merino) or Dohne genetics
- more focus on increasing lambs weaned per ewe.

Producers appear to be focused on price/kg meat rather meat/ha and many may be running fewer ewes/ha so they can carry lambs through to heavier weights.

Comparison of profitability of activities in the sheep enterprise

Warn et al. (2005) compared the profitability of 14 activities in the sheep enterprise in four environments, ranging from self-replacing Merino wether flocks (wool enterprise) to specialist meat breeds crossed with non-Merino ewes (meat enterprise). Profitability was measured as gross margin per ha. Refer back to Topic 7 for a description of gross margin and how it is calculated.

Using average wool and meat prices for 1999-2003, a dual-purpose activity (specialist meat breeds crossed with Merino ewes) was most profitable with self-replacing Merino flocks least profitable. Dual-purpose and specialist meat enterprises were most profitable as more meat per ha was produced than with self-replacing Merinos. These results are discussed in detail in the Appendix.

While gross margin analysis provides a basic understanding of the relative profitability of different activities within the sheep enterprise, it does not provide a full picture of the physical and economic relationships between these activities. These relationships are now described. A guide as to the way profit can be maximised among the different activities while reflecting these relationships is provided in Topic 7.

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8.5.4 Economic analysis of product-product relationships

The nature of the product-product relationship

The production possibilities frontier is the basic concept used to describe the physical relationships between outputs in sheep production. It represents all feasible combinations of output produced by fully employing all available inputs on the farm. As in the case of factor-factor relationships (see above) where the marginal rate of substitution describes the slope of the isoquant, the marginal rate of product transformation is used to describe the slope of the production possibilities frontier.

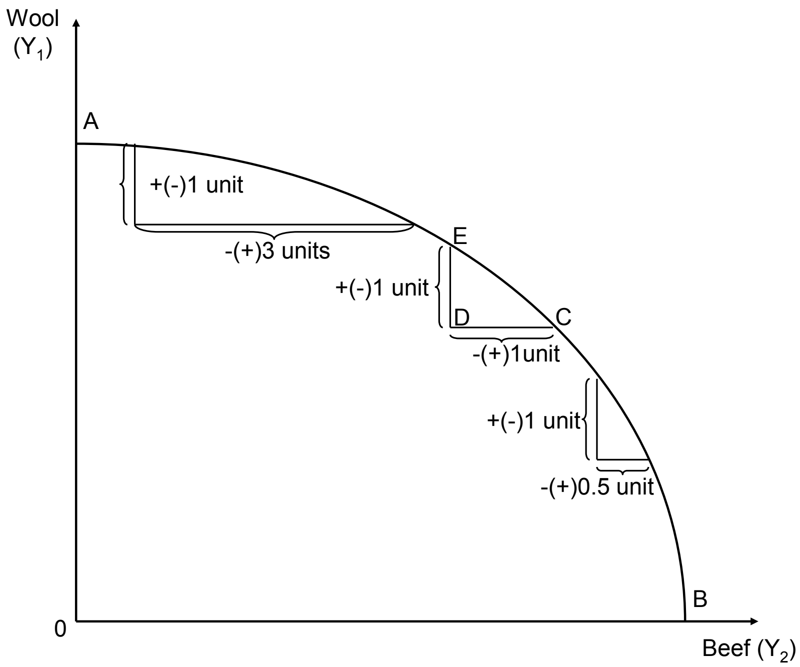
It is assumed for the moment that wool and lamb are competitive products in production. The slope of the frontier is a measure of the ease with which one product may be substituted for another and the synergies that can be reaped by producing both products. Consider the case of a producer with both Merino wool and lamb activities in the sheep enterprise. To distinguish this from the factor-factor case, and the marginal rate of substitution, use will be made of the marginal rate of (product) transformation of lamb (product 2) into wool (product 1), MRT_{12}. It is defined as the amount of lamb that will have to be surrendered to increase marginally the production of wool. That is,

$$MRT_{12} = \Delta Y_2/\Delta Y_1 = 1/MRT_{21}$$

MRT can be considered in a manner analogous to the factor-factor case. Referring to Figure 8.15, the movement from C to E involves substituting the production of Y_1 for the production of Y_2 so that MRT_{12} = CD/DE. (Note in figure 8.15 that whether the change is a plus or a minus depends on whether the producer is moving from B to A or A to B.) The movement from C to E involves two changes (assuming for simplicity that there is only one input X_1):

a) reduced employment of input X_1 in producing lamb (that is, moving from point C to point D).
b) increased employment of input X_1 in producing wool (that is, moving from point D to point E).

Figure 8.15 Production possibilities curve with competitive relationships at an increasing rate. Source: Fleming, (unpub. data)



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Further, the change in employment of X_1 resulting from a change in the production of Y_i is given by $\Delta X_1 = \Delta Y_i/MP_{1i}$. You will remember that this is the marginal product for factor X_1 used in producing product Y_i. Thus, the net change in use of X_1 is the sum of these effects:

$$\Delta X_1 = \Delta Y_1/MP_{11} + \Delta Y_2/MP_{12}.$$

But the movement from C to E involves the same resource use, i.e. $\Delta X_1 = 0$, and so:

$$-\Delta Y_1/MP_{11} = \Delta Y_2/MP_{12}$$

Or

$$-MP_{12}/MP_{11} = \Delta Y_2/\ \Delta Y_1 = MRT_{12}.$$

This definition, in terms of marginal products, makes it clear that since *MP*s are always positive in rational production, *MRT* will be negative in the rational zone of production described above. It is positive in any (irrational) 'complementary' zone of production (see below) and zero in any (irrational) 'supplementary' zone of production (also see below).

Depending on the nature of the competitive product-product relations, the frontier could be:

- a straight line, indicating neither scope economies nor scope diseconomies;
- concave to the origin, indicating scope economies; or even
- convex to the origin, indicating scope diseconomies.

Scope economies, or synergies in production, exist when two or more products can be produced within a production system at a lower cost than producing each of the products in separate production systems. Scope diseconomies occur when the joint production would cost more. The presence of scope economies is considered the most likely situation in sheep production, and recent evidence from Sheep CRC analyses of groups of benchmarked farmers indicates that they are especially strong in dual-purpose sheep production.

In Figure 8.15, it is clear as we move from B towards A, substituting the production of Y_1 for the production of Y_2, that the sacrifice becomes greater. That is, the products are 'competitive at an increasing rate'. Thus, the products compete for resources but as more of one product is produced, the other becomes more competitive because increasing sacrifices are needed for further product substitution. As more wool (Y_1) is produced, MRT_{12} becomes more negative as diminishing marginal returns prevail. In terms of marginal products, $-MP_{12}/MP_{11}$ will become larger, i.e. more negative, because less Y_2 is produced. Therefore, MP_{12} will increase; and, alternatively, MP_{11} will fall with more Y_1 produced.

As indicated above, a number of different types of product-product relationships can be defined. Figure 8.15 shows the most common type of competitive relationship. In Figure 8.16, another type of competitive relationship, a linear 'curve' is shown which indicates that *MRT* is constant, implying a constant rate of transformation (that is, neither scope economies nor scope diseconomies). In this situation, the same relationship prevails between the two outputs across the whole range of production. The products still compete for resources; but as more of one product is produced, the other remains equally competitive because the level of sacrifice needed does not change with further product substitution. That is, as more Y_1 is produced, for example, MRT_{12} does not change. In terms of marginal products, the ratio, $-MP_{12}/MP_{11}$, is fixed between A and B.

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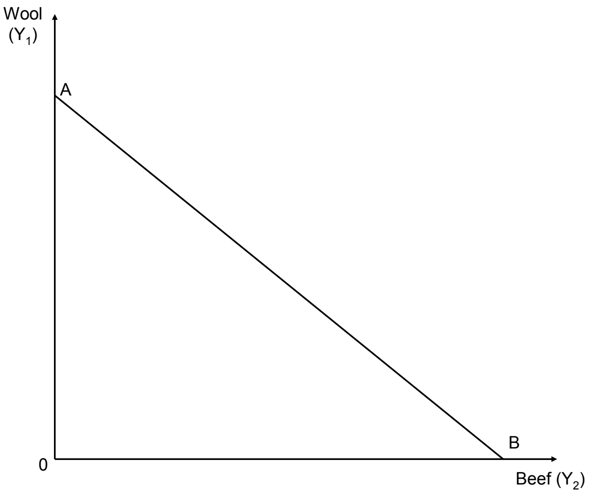
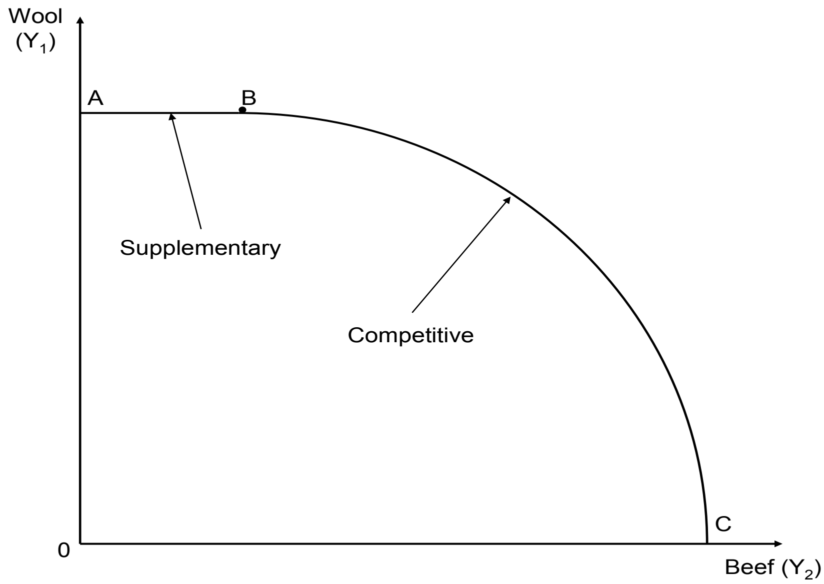
Figure 8.16 Production possibilities frontier with a constant rate of transformation.



Supplementary products arise from the possibility of increasing the production of one output without either increasing or decreasing the production of other products. This type of situation is depicted in Figure 8.17. It may arise where permanent labour is used to run a small sideline fat lamb enterprise without reducing the production in the wool and other farm enterprises, taking advantage of seasonal feed supply. The spring flush of feed may be used to fatten store lambs without reducing production from the wool flock. Another supplementary relationship may arise from simultaneous grazing of cattle and sheep, at least over part of the production possibilities frontier. Their differing grazing habits may result in an increase in net forage production and utilisation. This relationship is depicted in Figure 8.17 where movement along the part of the curve AB indicates the possibility of increasing production of Y_2 without diminishing the production of Y_1. The remainder of the curve BC indicates that the products are competitive at an increasing rate (as in Figure 8.15). In these cases, the optimal production will be in the competitive range, BC, and the range, AB, would be in the irrational zone since it would pay the farmer to expand beef production without reducing wool output up to point B.

Figure 8.17 Production possibilities curve with zones of supplementary and competitiveproduction.



With complementary products, the transfer of resources from one product to the other (this time using lamb and wool as an example) results in an increase in the output of both products. This is indicated in Figure 8.18 where the complementary range is AB in which $MRT_{12} > 0$. This implies that $-MP_{12}/MP_{11}$ is positive, so that one of the marginal products must be negative in the complementary range. Thus, it is irrational for a farmer to produce in this area. In the range AB in

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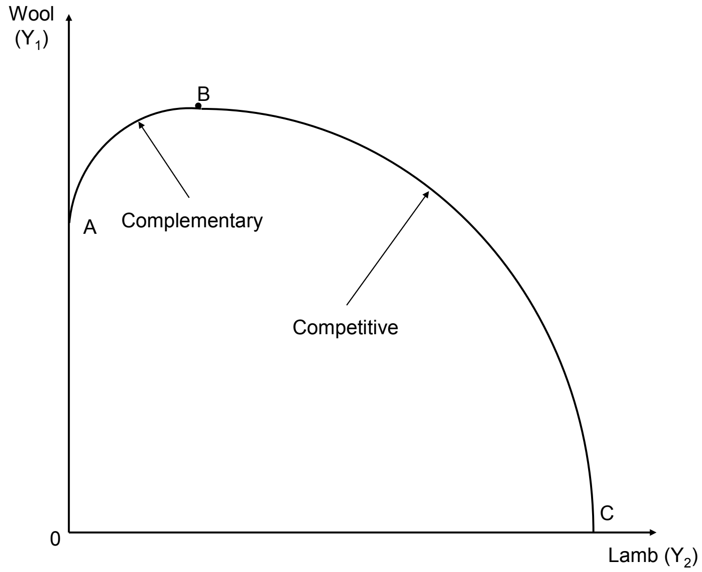
Figure 8.18, MP_{11} would be negative, indicating overuse of input X_1 in the production of output Y_1. The optimal production will be in the competitive range, BC.

Examples of genuine complementary relationships are rare, but may be found in some circumstances. One such circumstance might be where a production unit moves from running solely wethers for wool production to a combination of self-replacing Merinos plus some wethers. Another might be a self-replacing Merino flock with a small amount of lamb production based on first-cross lambs. In these situations, it is typical that the complementary relationship quickly evaporates with the expansion of the minor enterprise because competition for resources soon emerges between activities or enterprises.

The discussion has so far concentrated solely on single-factor two-product relationships. Naturally, these relationships can be generalised to many factors and many products, but the algebra becomes more complicated so we will avoid any such generalisation.

Figure 8.18 Production possibilities curve with zones of complementary and competitive



production.

Estimates of the medium-term (3-5 years) elasticity of product transformation at different industry levels are provided in Table 8.6. Note that elasticities between wool and lamb, and between different micron categories of wool, are less than one. These estimates indicate that it is quite difficult to substitute between different outputs in the medium term at the farm level. The magnitude of the elasticity of transformation between ≤ 19 micron wool and 20-23 micron wool is estimated to be about double that between 20-23 micron wool and 24-27 micron wool.

Table 8.6 Estimates of Medium-Term Elasticities of Product Transformation in Australian Sheep Production. Source: Mounter (2007).

Industry level	Elasticity of transformation between:	Estimate
Farm	≤ 19 micron wool and 20-23 micron wool	-0.5
	20-23 micron wool and 24-27 micron wool	-0.25
	Wool and lamb	-0.2
	Mutton and live sheep exports	-1.8
Wool warehouse	Greasy wool for export and greasy wool for processing	-2.0
Wool processing	Semi-processed wool of different fibre diameter categories	-0.1
Sheepmeat processing	Lamb carcass for export and lamb carcass for the domestic market	-0.5
	Mutton carcass for export and mutton carcass for the domestic market	-1.0

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8.5.5 Product-product optimisation (ANPR450 students only)

The optimising procedure presented in this section involves considering the two response processes involving a single input X_1, namely, $Y_1 = f(X_{11})$, and $Y_2 = g(X_{12})$. Here, X_{11} denotes the amount of X_1 used in producing Y_1 and X_{12} denotes the amount of X_1 used in producing Y_2. Thus, the profit function can be defined simply as:

$$\pi = p_{y1}Y_1 + p_{y2}Y_2 - p_1X_{11} - p_1X_{12}.$$ [2]

Rearranging this equation gives the to-be-anticipated rule that use of the input X_1 should be increased until the cost of an additional unit (p_1) is equated with the value of the marginal output (i.e. $p_{y_1}MP_{11}$). To maximise profit, set the increased cost, called the marginal factor cost of using X_1 (MFC), equal to the marginal value product (MVP):

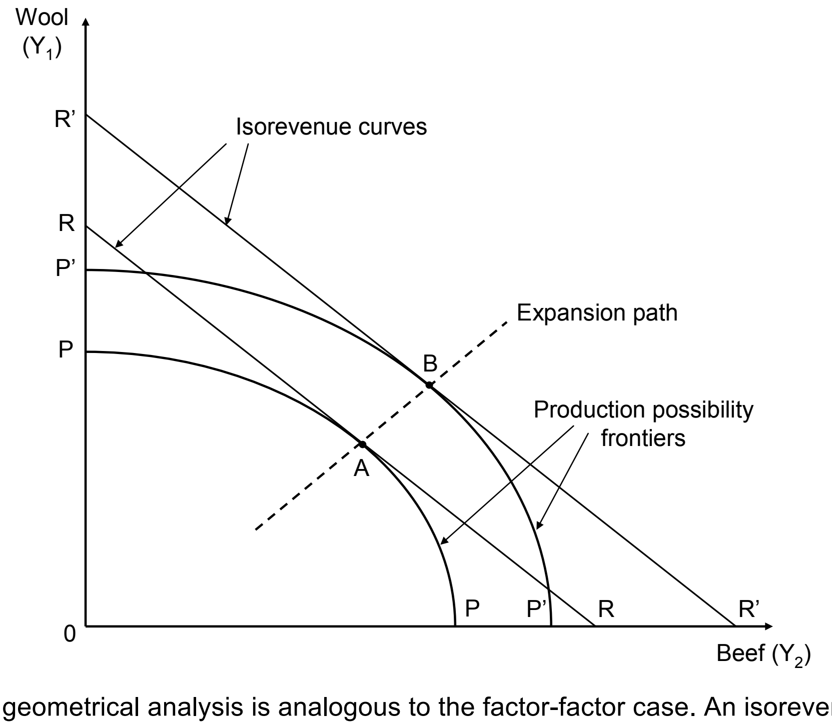
$$MVP_{11} = MFC_1, \text{ and}$$
$$MVP_{12} = MFC_1$$

This condition applies for each response process. Further rearrangement of these equations gives:

$$-p_{y_2}/p_{y_1} = -MP_{11}/MP_{12} = MRT_{21},$$

which specifies that a necessary condition for efficiency is that MRT equals the (negative) appropriate price ratio. This enables us to define an expansion path in product-product space, shown in Figure 8.19 for wool and beef output.

Figure 8.19 Optimisation along the expansion path in product-product space.



The geometrical analysis is analogous to the factor-factor case. An isorevenue curve is defined as:

$$R = p_{y_1}Y_1 + p_{y_2}Y_2.$$

---

[2] For those interested in mathematical optimisation, the first-order conditions for maximum profit are found by partially differentiating with respect to X_{11} and X_{12}, and setting these to zero

$$\partial \pi / \partial X_{11} = p_{Y1}\, \partial Y_1 / \partial X_{11} - p_1 = 0$$
$$\partial \pi / \partial X_{12} = p_{y_2}\, \partial Y_2 / \partial X_{12} - p_1 = 0.$$

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For a specific level of revenue, R*, the isorevenue curve can be rearranged as:

$$Y_1 = R^*/p_{y_1} - (p_{y_2}/p_{y_1})Y_2$$

which is a linear function with the intercept on the Y_1 axis of R^*/p_{y_1} and a slope of $-p_{y_2}/p_{y_1}$. Optimisation involves equating the slope of the isorevenue curve with the slope of the production possibilities curve at point A as in Figure 8.19. At that point, the isorevenue curve RR is tangential to the production possibilities curve (*PP*) and the condition, $MRT_{21} = -p_{y_2}/p_{y_1}$ is satisfied. This relationship will form the expansion path for the firm in the product-product case, as is also shown in Figure 8.19.

Assuming that the resource input level is such that the firm is operating on the production frontier *PP*, the most efficient combination of Y_1 and Y_2 will be achieved at point A. In order to maximise profits, the firm will increase the resource input level and move up along the expansion path until a point is reached, say B, where the additional revenue earned from Y_1 and Y_2 is just matched by the costs of an additional unit input of resource.

8.5.6 An example of optimisation involving two sheep products (ANPR450 students only)

Consider two alternative sheep enterprises:

(a) production based on first-cross terminal meat sire breeds crossed with Merinos; and

(b) specialist prime lamb production using terminal meat sire breeds over crossbred ewes.

Moving from (a) to (b) results in greater production and income from meat compared with wool. This movement is demonstrated in Figure 8.20 where the production possibilities frontier is represented by the curve, *PP*. As indicated above and shown in Figure 8.15, a production possibilities frontier that is concave to the origin is considered the most likely situation in sheep production.

Suppose the option of first-cross terminal meat sire breeds crossed with Merinos produces W_1 of wool and L_1 of lamb at point A on the production possibilities frontier. The option of specialist prime lamb production using terminal meat sire breeds over crossbred ewes produces W_2 of wool and L_2 of lamb at point B on the production possibilities frontier. Now, as shown above, the relative prices of wool and lamb are represented by the slope of the isorevenue curves. The relevant isorevenue curve is R_1R_1 for a farm running first-cross terminal meat sire breeds crossed with Merinos and operating at point A. This farm would be both allocatively efficient (the isorevenue curve is tangent to the production possibilities frontier, or $-p_{y_w}/p_{y_b} = MRT_{wb}$) and technically efficient (it is operating on the frontier). Therefore, it is economically efficient (that is, undertaking profit-maximising behaviour).

On the other hand, a specialist prime lamb producer using terminal meat sire breeds over crossbred ewes is operating at point B. This producer would also be technically efficient, indicated by the fact that he or she is operating on the frontier. But production would be allocatively inefficient in that the relevant isorevenue curve for this producer would be $R_1'R_1'$. As can be seen in Figure 8.20, this isorevenue curve lies below R_1R_1 and is not tangent to the frontier. Therefore, production is economically inefficient (the producer is not maximising profit) at the prevailing product prices because it is allocatively inefficient.

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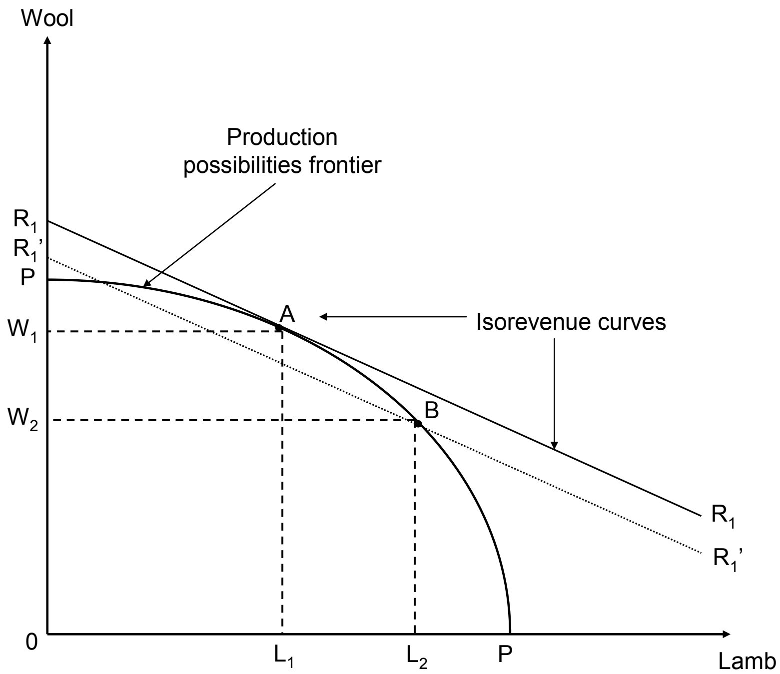
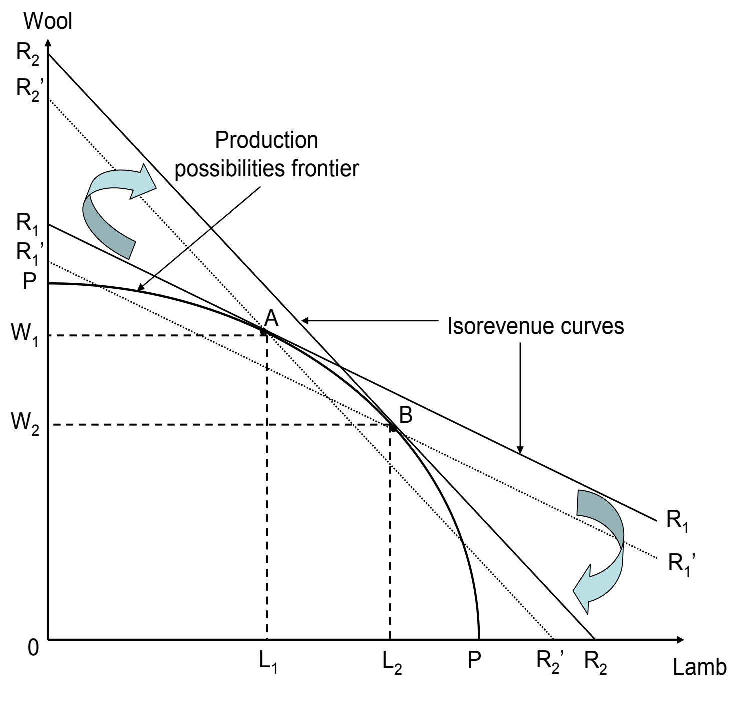
Figure 8.20 Optimising the production of wool and lamb.



Now, suppose the relative prices of wool and lamb change with an increase in the price of lamb relative to wool. This change results in a swivelling of the isorevenue curve from R_1R_1 to R_2R_2 in Figure 8.21. (It means that more wool now needs to be given up in exchange for an extra unit of lamb.) The specialist prime lamb producer at point B is now allocatively efficient as the new isorevenue curve, R_2R_2, is tangent to the production possibilities frontier. On the other hand, the producer of first-cross terminal meat sire breeds crossed with Merinos is now allocatively inefficient because the highest isorevenue curve that this producer can reach is $R_2'R_2'$, which is lower than R_2R_2. This case study shows how changes in market conditions can affect how economically efficient a sheep producer is at any time.

Figure 8.21 Optimising the production of wool and lamb following a change in their relative prices.



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8.6 Price theory

8.6.1 An introduction to price theory

The main purpose of this section of the topic is to develop an understanding of price theory and skills in price analysis within the context of the sheep enterprise. In studying agricultural prices we are concerned with the processes of price formation, including particularly the nature of the various supply and demand functions, their own-price elasticities and cross-price elasticities of demand, and factors that shift these functions. We are interested in the efficiency of the price system and the ways in which policy might be used to improve that efficiency or, as is often the case, diminish it. Note that policy has its impact on a variety of functions of prices and quantities traded in markets.

The price system solves three problems: which products are to be produced and in what quantities; how the products will be produced; and for whom they will be produced. You should have a reasonable understanding of the way in which economic theory suggests how the price system enables the 'invisible hand' to guide the economic system towards the optimal mix of products and the optimal technique in production together with the optimal distribution of the resultant output in consumption.

Similarly, you should have some knowledge of the way in which imperfections affect the invisible hand such that, in a welfare sense, the above three problems result in sub-optimal solutions. Sometimes it is possible to correct these imperfections by public policy while still retaining the advantages of the price system (for example, by imposing a tax on the producer who imposes external costs on others). On other occasions it may be that an alternative system of allocation, such as a 'command system' involving a reliance on centralised direction, is preferred to the price system (for example, in the provision of public goods such as the maintenance of law and order).

The price system acts as a coordinator between the decentralised decisions of producers and consumers and, in doing so, fulfils two functions. One is the production objective whereby desired production is stimulated while unwanted production is impeded. The other is the allocative objective whereby prices tend to encourage the efficient division of resources in production and the rationing of goods among consumers.

If these objectives are to be satisfied, four functions must be performed:

(a) the capital attraction function;
(b) the distribution function;
(c) the efficiency-incentive function; and
(d) the consumer-rationing function.

The first two of these functions relate to the production objective while the latter two relate to the allocative objective.

The perfectly competitive model of economic theory postulates that the price mechanism performs these four functions effectively, thereby fulfilling the dual objectives. In this way, the price mechanism provides information for the decision as to what to produce (capital-attraction function) and also determines how the benefits from production are to be divided among the participants (distribution function). The mechanism also establishes by whom goods and services will be produced (efficiency-incentive function) as well as who will consume the products (consumer-rationing function). These objectives and functions in a perfectly competitive system are summarised in Table 8.1.

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Table 8.1 The Functions of Prices in a Perfectly Competitive Market Model.

Objectives		Functions
1.	Production	The producer-motivation or capital attraction function. The investment test – what to produce. The distribution function – produced by whom (i.e. rewards).
2.	Allocation	The efficiency-incentive function – use of resources in production. The demand-control or consumer-rationing function – allocation of commodities in consumption.

At the long-run competitive equilibrium, the operating capacity of a sheep enterprise is optimal when any additional cost of production equals the additional revenue earned (MC = MR). This position is usually cited as the ideal position of the farm.

If the assumptions of the perfectly competitive utopia are dropped, the symmetry of the above objectives and functions will be lost. Various types of uncertainty also lead to market failure and require intervention by the government in an attempt to correct the problems of under- or over-production that might occur (see Topic 11 on the effects of risk on decision making).

8.6.2 Price formation in the sheep industry

The specific objectives in price analysis in the sheep industry are to:

(1) explain price formation and quantities traded
(2) predict or forecast future prices and quantities
(3) study the implications and consequences of government intervention in the markets for sheep products.

In this section, the orientation is towards prices and quantities traded in a competitive market environment. Product prices in the sheep industry perform the broad functions of:

- resource allocation and direction of economic activity (both production and consumption);
- rationing resources and products among farms, firms and consumers; and
- rewarding economic activities through their impact on revenue flows to sheep producers.

The rationing and rewarding functions of prices are frequently given little attention, and similarly the quantity reactions of the market place to institutionally affected prices generally receive limited explicit attention. Prices perform multiple functions and their allocative effects should not be viewed in isolation. Policies designed to affect one function of price inevitably interfere with its other functions. For example, where government policies are introduced to influence the resource allocation function by controlling prices, this may well force quantities to become the adjustment mechanism in the determination of rewards to factors of production. The types of government intervention in agriculture involve policies such as tariffs and export subsidies, protective devices and regulations, price support and stabilisation policies. Stabilisation policies used to be implemented in the wool industry.

Price and quantity outcomes in a competitive market are generally presumed to result from the interaction of supply and demand. The so-called 'Marshallian cross' diagram, reproduced in Figure 8.9, results in equilibrium price (P_e) and quantity (Q_e) where the wool supply and demand functions intersect. In the real world, we generally observe equilibrium points and only by employing assumptions or data on other factors can we identify the supply and demand functions. Using the *ceteris paribus* assumption (that all other factors remain constant), the demand curve (or function) represents all combinations of price and quantity demanded by wool buyers, while the supply curve (or function) represents all combinations of price and quantity supplied by wool sellers.

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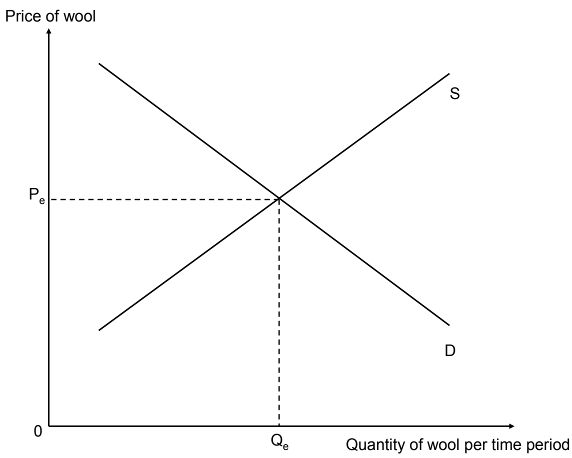
Figure 8.9 The 'Marshallian cross'.

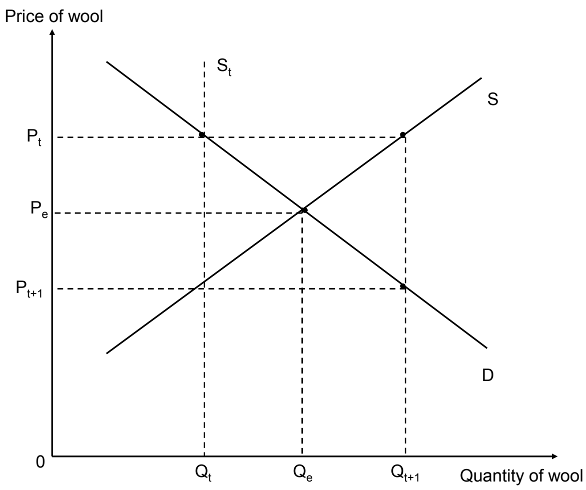


In practice, the demand for and supply of a particular product, such as wool or lamb, depend on the commodity's own price, as shown in Figure 8.9, and on a number of other factors that vary depending on the product concerned. These other factors cause shifts in supply or demand functions, described later in this section and in section 8.7, respectively. The effects of changes in variables affecting supply and demand are usually summarised in terms of elasticities. For example, the 'own-price elasticity of demand' for lamb is the percentage change in the quantity of lamb demanded given a one per cent change in the price of lamb. The 'cross-price elasticity of demand' for lamb with respect to the price of beef is the percentage change in the quantity of lamb demanded given a one per cent change in the price of beef.

The discussion above tells us very little about the forces underlying supply and demand, or about the determination of prices and quantities over time. Forces underlying supply and demand may be respectively explained by the economic theories of production (supply) and consumers' utility, or satisfaction, reflected in their 'willingness to pay' (demand).

Interaction between supply and demand over time implies changes in the equilibrium points P_e and Q_e through time. In any one time interval, it could be argued that the supply function in Figure 8.9 is vertical. Further, suppose that some external factor resulted in the supply function, S_t, in Figure 8.10. The equilibrium observed in period t would thus be P_t, Q_t. Assuming that producers expected P_t to prevail in the following period (t + 1), the outcome in period t+1 would be P_{t+1}, Q_{t+1}. Such adjustments would continue in successive time periods until the market returned to equilibrium at P_e and Q_e, or another shock to the system initiated further adjustments.

Figure 8.10 Supply-demand equilibrium.



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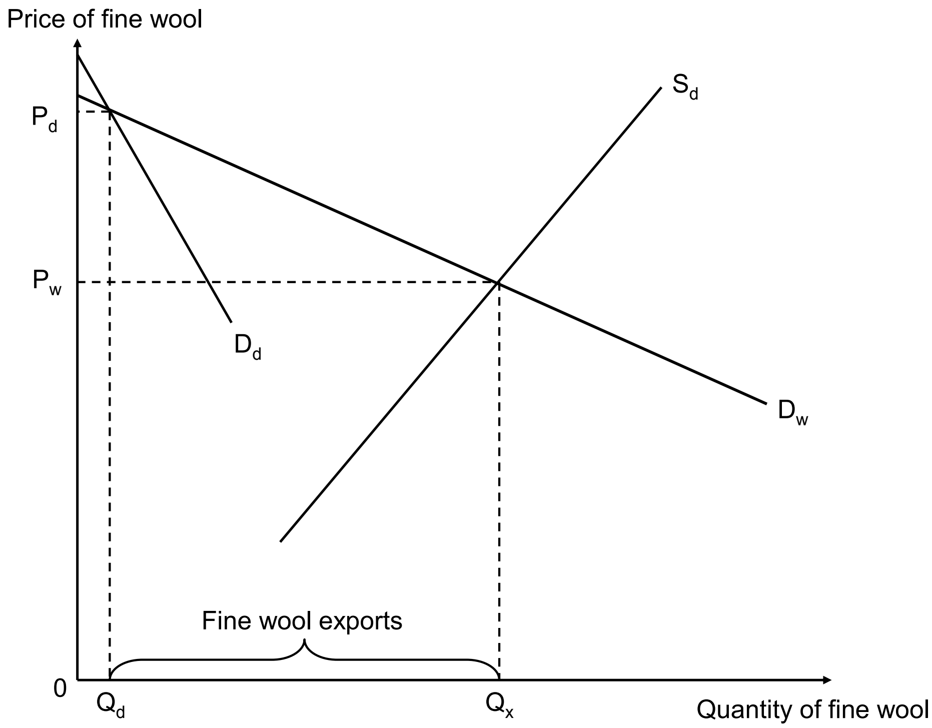
The situation described above is what is generally known as the 'cobweb cycle' for obvious reasons. Such cyclical behaviour has been statistically observed for a number of agricultural markets, the best examples being pigs (the 'hog cycle') and cattle. The length of these cycles is related to the length of the production cycle from the initial decision of producers to mate sows or cows to the point in time when the progeny of that mating are evident in the market. Such a model is appropriate for sheep products as well. For example, analysts of the wool market have identified 'textile cycles'.

The general notion of cyclical behaviour is introduced here to emphasise the point that a market in which prices are formed is a dynamically changing entity rather than a static closed structure. In analysing the market for sheep products, we need to combine economic theory and prior knowledge of the characteristics of products and markets to construct models for empirical analysis. Such models aid in the identification of forces operating to determine prices and quantities in a dynamic and changing sheep economy.

The demand and supply diagrams shown in Figures 8.9 and 8.10 are for a closed economy, and are not representative of the situation for the major products in the sheep industry. Figure 8.11 shows a more realistic situation where the bulk of the greasy fine wool output is exported. A new demand curve is now introduced, the export demand curve (D_w), which is downward-sloping to reflect the fact that fine wool producers in Australia are price-makers in the world market. For many Australian agricultural exports, this is not the case because producers are price-takers and a horizontal export demand curve is close to the true situation. The domestic demand curve (D_d) is small, to reflect the low level of demand for greasy fine wool for domestic processing, and steeply downward-sloping, to reflect price-inelastic demand (see below). A small amount of wool, $0Q_d$, is destined for the domestic market at price P_d while the bulk of the clip, Q_dQ_x, is exported at price P_w.

Figure 8.11 Supply and demand curves for Australian greasy fine wool.



8.7 Analysis of supply

The main issues in supply analysis are:

- identification of short-run and long-run supply functions, and their derivation from cost theory;
- estimation of the elasticity of supply, and lags in supply;
- identification of supply shifters and the distinction between supply functions and supply response, and estimation of aggregate supply response; and
- differences in supply response due to the availability of alternative production opportunities.

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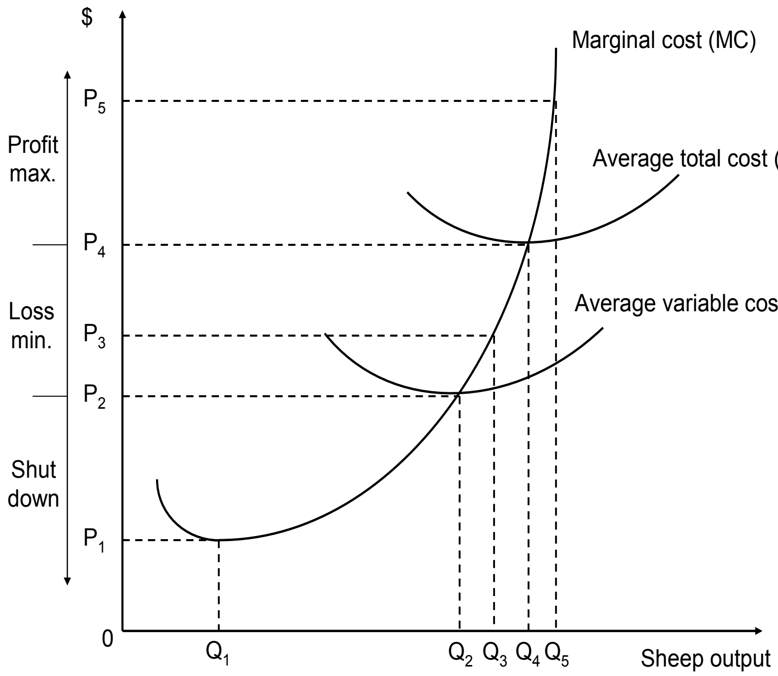
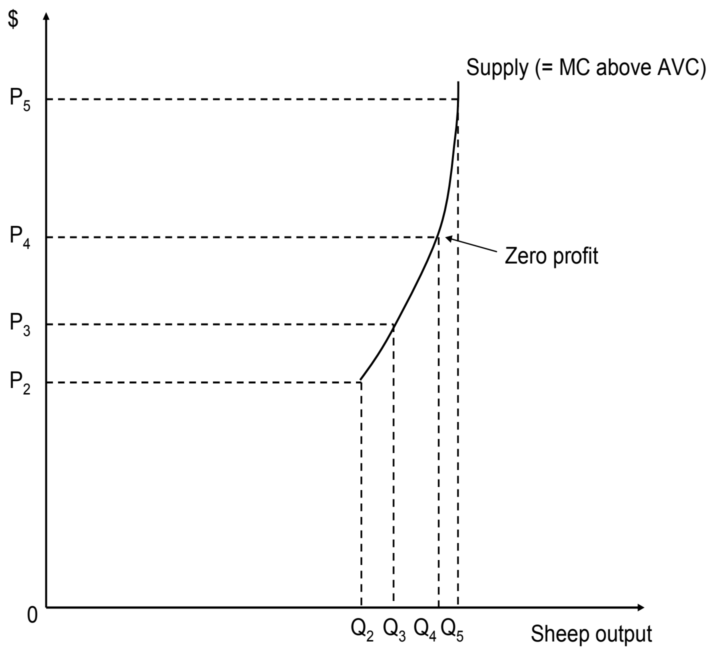
8.7.1 Deriving supply functions from cost theory

The following diagrams in Figure 8.12 are used to analyse the relationships between average cost, marginal cost and supply. Average total cost (*ATC*) is *C*/*Q*, where *Q* is output and *C* is total cost, including both variable and fixed costs per unit of output. Average variable cost (*AVC*) is *VC*/*Q*, where *VC* is variable cost. Marginal cost is defined as the increase in total cost as a small change is made in *Q*, or $MC = \Delta C/\Delta Q$. The marginal cost is, in effect, the slope of the total cost curve at a given point. The MC curve cuts both the *ATC* and *AVC* curves at their minimum points. The farm's short-run supply curve is derived from the short-run marginal cost curve above the average variable cost curve, as shown in part (b) of Figure 8.12.

Figure 8.12 Cost curves and their relationship to the short-run supply curve of the farm.
(a) Cost functions



(b) Supply function



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As stated above, the profit-maximising, or loss-minimising, output level is where MR = MC. In a competitive market, price is equal to marginal revenue for each producer, who is a price-taker, and therefore output is determined by the marginal cost curve. Think about a typical example of a lamb producer moving out along the expansion path by increasing the stocking rate. Outputs of lamb and wool are increased by raising the stocking rate, but increasingly more resources (and therefore higher marginal costs) will be used in doing so. So long as the additional revenue derived from a higher stocking rate (*MR*) is greater than the additional costs incurred (*MC*), it will pay the producer to continue to expand the stocking rate. But, with diminishing returns to inputs, a point will eventually be reached where the additional cost incurred in purchasing sheep and variable inputs outweighs the additional revenue. The optimal stocking rate will be reached when the revenue earned from an additional DSE/ha is just equal to its additional cost (*MR = MC*). It is often said that stocking rate is the chief 'driver' of profit. In a recent study of a sample of lamb producers in Eastern Australia (Sheep CRC Project 1.2.6), it was estimated that an additional 1 per cent increase in DSE/ha results in a 0.75 per cent increase in gross margin (as a measure of profit). Clearly, these lamb producers had not yet reached a point on their expansion path where they should stop increasing their stocking rate.

If the output price is above P_4 in Figure 8.12(a), the farmer makes a profit and aims to maximise that profit. For an output price of P_5, he or she would produce at Q_5 where the marginal cost (*MC*) equals the output price (*MR*). If the output price is between P_2 and P_4, at say P_3, the farmer is making a loss, and aims to minimise that loss by producing at Q_3, where $MC = P_3$. Because revenue is still covering variable costs, it pays this farmer to keep producing. The farm makes lower losses by producing than by ceasing production because total revenue exceeds total variable cost and so some (unavoidable) fixed costs are covered. If the price falls below P_2, it pays the farmer to cease production as revenue is insufficient to cover total variable cost under these conditions and he or she will increase indebtedness by staying in production.

8.7.2 Supply responsiveness

The price elasticity of wool supply refers to the relative change in quantity of wool supplied divided by the relative change in wool price. The steepness of the supply function in Figure 8.12 gives a guide as to the ease (or in this case of a very steep supply curve, lack of ease) with which producers can move along the curve. This definition can be represented as:

$$EQ_S = \frac{\Delta Q_S / Q_S}{\Delta P / P}.$$

The industry supply curve is the (horizontal) sum of the individual supply curves of sheep producers. In the long run, when all fixed capital becomes variable, fixed costs are zero so that the marginal cost curve becomes flatter. The aggregate or industry supply curve therefore also becomes flatter and more elastic with respect to price. That is, short-run elasticities of supply are generally less than long-run elasticities.

The distinction between short-run and long-run supply functions is important because, in the sheep industry, there is usually a lag between the decision to change supply in response to a market incentive and its achievement. Consider, for example, a decision to respond to a rise in the price of wool by increasing the stocking rate, which relies on the farm manager increasing the number of DSEs on the property through breeding. It is likely to take a considerable period to expand the stocking rate to the point where the increase in wool output is achieved.

There may be asymmetric supply response, due to differences in response for price increases and price decreases. In particular, it is likely to take longer to respond to a price increase than to a price decrease when, for example, producers can reduce wool supply quickly by selling sheep.

Some medium-run estimates of the price elasticity of supply in sheep production in Australia are presented in Table 8.2. Observe that they tend to be around unity, being slightly less in the pastoral zone where opportunities to switch between enterprises are more limited.

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Table 8.2 Estimates of Medium-Run Price Elasticities of Supply in Australian Sheep Production. Source: Mounter (2007).

Breed	Zone	Estimate
Non-merino		1.2
Merino	High rainfall	1.0
Merino	Wheat-sheep	1.2
Merino	Pastoral	0.8

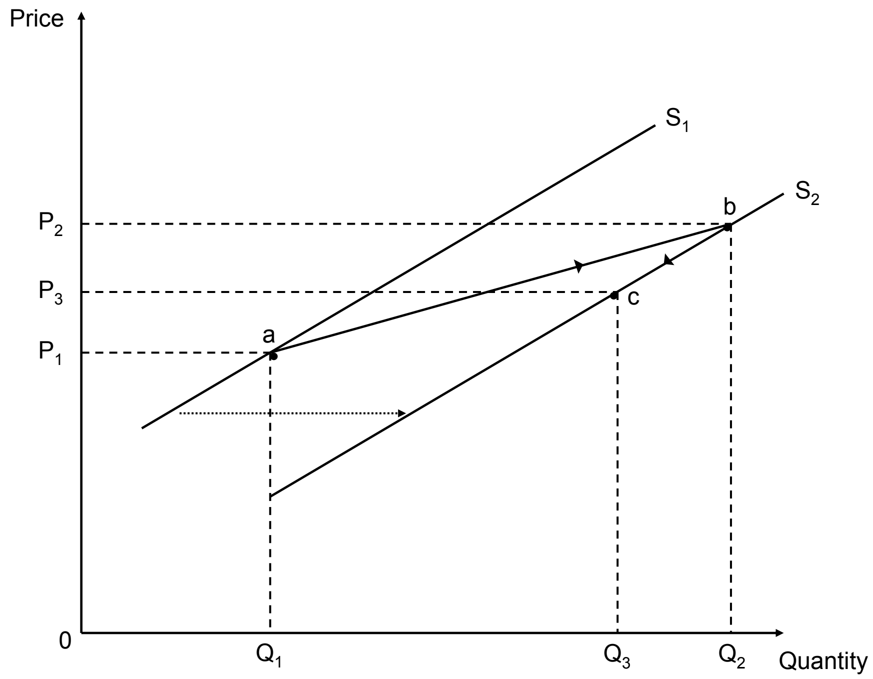
8.7.3 Supply shifters and the supply response function

Major supply shifters of the industry supply curve in the sheep industry include changes in input costs, prices of substitute products (typically, crops and beef in Australia), technological change, joint product prices (for example, lamb and wool), external factors such as weather, and institutional factors.

Supply shifters may be seen as shifting the supply function horizontally backwards and forwards. That is, following a change in supply conditions, different quantities will be supplied at each price. In some cases, such as the imposition of a tax, it makes sense to consider the movement as a vertical shift by the amount of the tax.

Supply response functions are usefully distinguished from ordinary supply functions as described above. In supply response functions, as opposed to supply functions, a price change causes a movement of the supply function *as well as* a movement along the function. The reason for this response is that some producers will respond to price increases by adopting new production technologies that are now more profitable. On adoption, these new technologies are highly unlikely to be replaced by the old technology once prices fall again. Such as situation is shown in Figure 8.13 where a producer is producing $0Q_1$ at point *a*, and receiving a price of P_1. A price increase to P_2 induces an increase in output to $0Q_2$, due in part to a movement along the supply function but also due to an outward shift of the supply function from S_1 to S_2 as the producer adopts the new, more productive, technology. If the output price were then to drop to P_3, the farmer would produce at point *c* and output would be reduced to Q_3. This output is greater than would have occurred had the farmer not adopted the new technology when the output price increased from P_1 to P_2.

Figure 8.13 Supply functions and supply response.



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8.8 Analysis of demand

8.8.1 Demand concepts

The theory of demand is built on the notion that consumers maximise their utility (satisfaction) derived from selecting goods from the bundle available, given prices for the products and their level of income. It is not required to be studied in detail in this topic. But you do need to understand the concepts of own-price elasticity of demand and relationship to revenue, cross-price elasticity of demand and income elasticity of demand. Also, an outline is presented of demand function shifters and lag effects.

The own price elasticity of wool demand refers to the relative change in quantity of wool demanded divided by the relative change in wool price. The steepness of the demand function also gives a guide as to the ease (or in this case of a very steep demand curve, lack of ease) with which consumers can move along the curve. This definition can be represented as:

$$EQd = \frac{\Delta Q_d / Qd}{\Delta P / P}.$$

The price elasticity of demand is normally negative. That is, as wool quantity increases then consumers are willing to pay less for wool. Similarly, as wool quantity decreases then wool prices increase (for a normal good). In recent years wool supply has contracted but prices have not risen in real terms.

Table 8.3 includes some selected price elasticity of demand estimates for sheep products taken from Mounter (2007). Note that the own-price elasticity estimates are all negative, as expected, indicating that an increase in price leads to a lower quantity demanded. For example, an increase of 1 per cent in the price of greasy wool in the export market results in a 2 per cent decline in the quantity of this wool category demanded.

Table 8.3 Some Own-Price Elasticities of Demand for Sheep Products. Source: Mounter (2007),

Sheep product	Market	Elasticity estimate
Wool greasy	Export ≥28 micron	-2.0
Wool greasy	Export 24-27 micron	-1.9
Wool greasy	Export 20-23 micron	-1.2
Wool greasy	Export ≤ 19 micron	-1.0
Wool scoured	Export ≥28 micron	-2.0
Wool scoured	Export 24-27 micron	-1.9
Wool scoured	Export 20-23 micron	-1.2
Wool scoured	Export ≤ 19 micron	-1.0
Wool top and noil	Export	-1.5
Live sheep	Export	-2.0
Lamb	Export	-2.5
Lamb	Domestic	-1.5
Lamb with respect to mutton price	Domestic	0.13
Mutton	Export	-5.0
Mutton	Domestic	-1.4
Mutton with respect to lamb price	Domestic	0.82

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The cross-price elasticity estimates are positive, as expected, indicating that an increase in the price of a competing product results in an increase in the quantity demanded of the product in question. That is, the competing product is now more expensive, encouraging the consumer to switch to consumption of the product being analysed. The following equation shows the cross price elasticity relationship between lamb price (*Pl*) and the quantity of mutton (*Qm*):

$$EQlm = \frac{\Delta Q_m / Qm}{\Delta Pl / Pl}.$$

If the relationship is positive then lamb and mutton are substitutes and if the relationship is negative then the two goods complement one another. Consider the example of two products that compete for the consumer's dollar: lamb and mutton. The results in Table 8.3 show that a one per cent increase in the price of mutton results in a 0.13 per cent increase in the quantity of lamb demanded in the domestic market. The positive sign indicates that lamb and mutton are substitutes, but not perfect substitutes. This elasticity is considerably less than the cross-price elasticity of demand for mutton with respect to the lamb price of 0.82. That is, the price of lamb has a much greater effect on the domestic demand for mutton than the price of mutton has on the domestic demand for lamb. This result is not surprising: it reflects the fact that lamb is a more important meat than mutton in the domestic market, and therefore its price has a much larger impact on demand for mutton than does the price of mutton on the demand for lamb.

8.8.2 Demand shifters

Major demand function shifters in the sheep industry are prices of substitute (competing) products, income and income distribution, population, tastes and institutional factors. Positive and negative shifters of the demand function can occur.

The first two shifters are particularly important. As indicated above, mutton is one a number of meats that is competitive with lamb, albeit not strongly so. Other examples of prices of substitutes in the lamb demand function are beef, chicken and pork, and they tend to be stronger competitors than mutton. Examples of substitutes for wool are synthetics and cotton.

Estimates of the income elasticity of demand for lamb at the retail level in Australia have varied quite markedly. The estimates in three recent studies (Griffith et al. 2001) are in the range from 0.22 to 0.77. These estimates mean that a 1 per cent increase in income leads to a less than 1 per cent increase in the demand for lamb. There are few estimates for mutton demand but those that have been undertaken in the past suggest that the income elasticity of demand for mutton is negative. That is, mutton is an inferior good, meaning that its demand declines as consumers' incomes increase. As most greasy wool is exported, the income elasticity of demand for wool in importing countries is the most relevant estimate. It tends to be more elastic than for other fibres, greater than one in developing countries but between zero and one in developed countries. For all sheep products (as for virtually all agricultural products), the income elasticities of demand for services associated with further processing and marketing tend to be higher than those for the raw product.

8.8.3 The market effects of international trade

The tables included in the ABARE publication, *Commodity Statistics*, give details of the proportion of production that is exported for a number of our main products. Such tables show that wool and live sheep are highly dependent on overseas markets. Lamb producers also depend on export markets, but less so. Australia has exported large amounts of these commodities for many decades, although the export dependence of lamb has increased in more recent years.

Although the export of agricultural products is very important to Australian agriculture, Australian production and export is relatively small in the global setting with the notable exception of wool where Australia maintains a prominent market position.

Points to think about when examining the market effects of international trade in wool, live sheep and lamb are:

(a) Note the relationship between home country and world market prices, where Australia is a net exporter of the products of concern in this unit.

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(b) Equilibrium requires imports to equal exports on a global basis in addition to domestic demand being equal to domestic supply.
(c) Note the difference between the situation when the small country assumption (producers as a whole are price takers) applies and when it does not. Think about the problem of applying the small country assumption to Australian wool exports (see Figure 8.11).
(d) A further piece of important information is that most agricultural production in the world is produced and consumed in the same country. Only relatively small amounts are traded internationally although wool is an exception.
(e) Arising from (d), it means that relatively small changes in world production or consumption affect world markets. Various factors cause world market prices for sheep products to be very unstable. You can check some evidence for Australian commodities by consulting the ABARE commodity reports.

8.8.4 The effects of exchange rates

In addition to markets for commodities, there is a 'market' for international currencies. In the case of Australia, there is no foreign exchange market as such where traders buy and sell various foreign currencies. Individuals and traders can exchange A$ for other currencies via financial institutions.

Exchange rates fluctuate from day to day, and sometimes there may be a major trend in exchange rates, either a devaluation or a revaluation (sometimes referred to as an appreciation) in response to a situation where the balance of payments is in persistent disequilibrium (either deficit or surplus). Operators in the sheep industry can benefit from knowing how variations in exchange rates affect prices of their exports and imported inputs.

The important factor about exchange rates is that if they vary, they may cause variations in domestic prices. Remember that devaluations are associated with balance of payments deficits and are designed to encourage exports while discouraging imports.

8.8.5 Agricultural price instability

Agricultural prices are very often highly unstable. This instability can be traced to instability in underlying demand and supply functions. Supply fluctuations can be due to weather and natural hazards (floods, fire and diseases), disruption to transport and normal marketing procedures and legislative changes. On the demand side, instability can be generated particularly in relation to the demand for exports which in turn can be caused by political instability, protection policies, exchange rate fluctuations and changes in supply in importing countries. Instability may be of a cyclical nature, depending on the nature of demand and supply elasticities. As mentioned above, analysts of the wool market have identified 'textile cycles'. Woollen mill margins and outputs rise faster than wool supply during periods of expansion, causing stock depletion. In a recession, the opposite outcomes occur as stocks accumulate.

The instability in prices for agricultural products, especially food products, frequently induces governments to take action to protect producers, consumers or both from the full effects of those fluctuations. This generally falls under the heading of stabilisation policy. Wool was subject to stabilisation scheme for a number of decades.

8.8.6 Marketing margins

The marketing margin for a product is the difference between the price paid to the producer and the price paid by the final consumer. It measures the total cost plus profit of all marketing functions performed on the product. There can be a number of marketing margins at different stages in the supply chain, measuring the difference between the price paid to the producer at one level and the price paid by the user at the next level in the chain.

Issues for consideration in relation to marketing margins for sheep products include:

- changes in the farmer's share of the consumer's dollar – it has been declining over time for wool producers (note that this does not mean that the absolute amount received by producers has declined)
- long-term changes in margins, e.g. effects of wage rates
- price levelling and price averaging
- effects of different price elasticities of demand.

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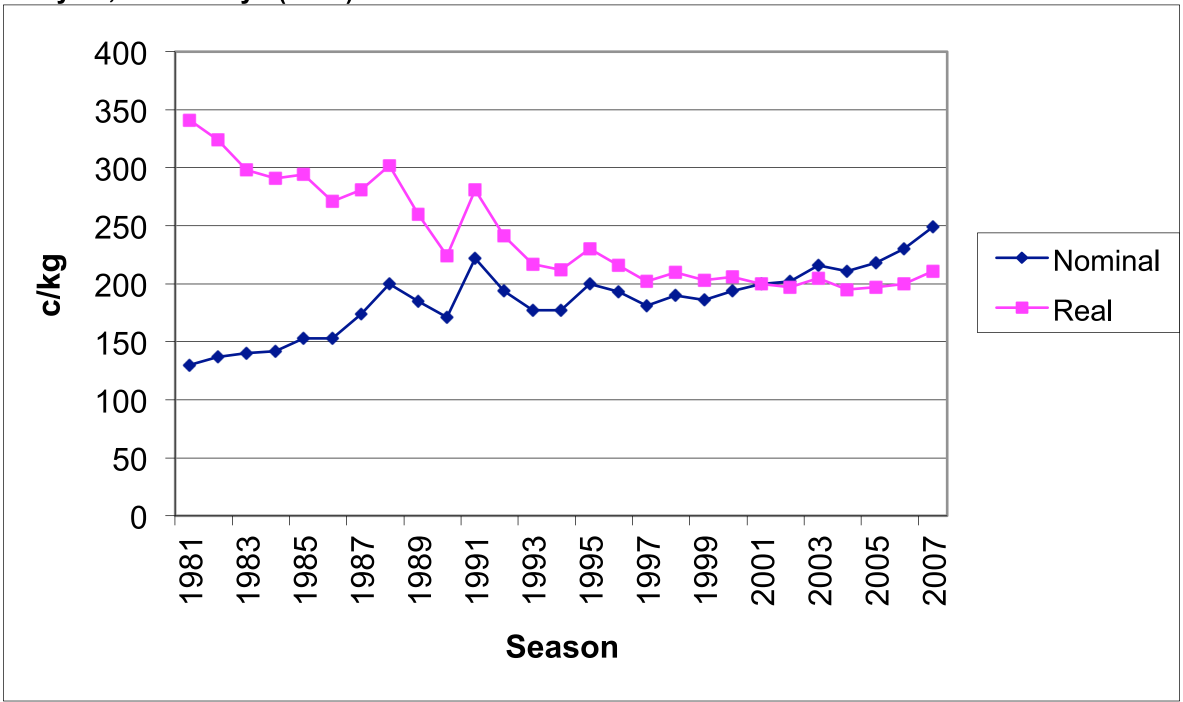
The practices of price levelling and price averaging are common in the retail meat trade throughout Australia, suggesting that the markets for meats 'are not perfectly competitive, at least in the short run' (Idstein and Griffith 1999). Price levelling is a 'practice adopted by retailers in meat markets of varying margins to smooth retail prices over time in the face of fluctuating saleyard and wholesale prices'. Price averaging is the practice of averaging margins by spreading costs across all types of a product in order to minimise the extent of an individual price change (Idstein and Griffith 1999).

Costs associated with each section of the wool supply chain from farm to mill were documented by Mac Stats and Analysis, and Gabrys (2007). In that study industry costs were shown to have decreased by 2 to 3 per cent per year since the 2002-03 season. Costs, however, were still 2.7 per cent above the long-run cost proportion of revenue, which was 44 per cent. The major cost reductions were in storage costs and wool shipping rates to China. Most other costs, particularly on-farm costs, had increased during the period. The cost of finance to brokers was reported to be a higher proportion of costs; however, the finance costs to industry were reported to be lower. Economist's use the term "real" as opposed to "nominal" to describe costs and incomes that have been deflated by the consumer price index which is a measure of inflation. The real costs over all sectors of the supply chain had increased by 6 per cent in 2006-07 to approximately 211 cents per kilogram. In real terms, therefore, the industry had not saved real costs. The real and nominal costs to mill are shown in Figure 8.14 for the period from 1980 to 2007.

Figure 8.14 Nominal and real costs for the period 1980-2007. Source: Mac Stats and analysis, and Gabrys (2007).



8.9 Derived demand for factors of production

8.9.1 Nature of farm inputs and factors influencing their use

The derived demand for factors of production (or inputs) is the demand for an input used in production in an enterprise that is derived from the demand for the final product. Short-term input demand at the farm level can be influenced by the category in which particular expenditures fall. In large part, this is due to the nature of the derived demand for the different inputs. The main factors affecting current (or recurrent) farm input use in the short run are:

- the level of economic activity
- seasonal conditions
- livestock numbers and demography (size, sex, breed and ages of the sheep flock)
- ease of short-run substitution between inputs.

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The main factors affecting current farm input use in the long run are:

- the effect of technological change on production methods
- changes in the relative prices of inputs
- changes in the relative prices of outputs
- livestock numbers and demography (size, sex, breed and ages of the sheep flock)
- ease of long-run substitution between inputs
- land degradation
- changes in government policy.

The main factors affecting farm capital expenditure are:

- real net farm income and savings
- uncertainty of expected income
- changes in the relative prices of capital and current inputs
- changes in the cost of capital (interest rates)
- level of farm debt
- government investment policy.

To illustrate how some of these factors have influenced farm capital expenditure in the past, declining capital expenditure during the 1980s was a result of three main factors. First, a high degree of uncertainty prevailed in the rural sector, leading to a readjustment following the excesses of the late 1970s and early 1980s. Second, lower net returns made investment in farming less attractive and reduced the capacity for internal funding. The final factor was the high cost of capital purchases (high interest rates and prices of capital items). This decline was reversed in the 1990s when interest rates fell, prices of capital items remained static as inflation rates remained low and net returns to farming increased, making investment more attractive and increasing the capacity for internal funding.

8.9.2 Input use and production technologies

A technology is a branch of knowledge concerning a particular production system, and may be either embodied in inputs or disembodied. Embodied technologies are those that can only be acquired by purchasing a commodity or service, such as improved drenches and pasture seed varieties. Disembodied technologies are those whose application does not require the purchase of a commodity, such as the knowledge and skills applied by the farmer in animal husbandry and pasture management.

Non-exclusive use of a farm input occurs where an individual producer cannot be excluded from using it. Non-rival use is where the marginal cost of providing the input to an additional user is zero. Its use does not restrict further use by others. Embodied technologies are price-excludable and the product in which they are embodied is rival, despite the fact that the technology itself remains non-rival. Whether the private sector will produce a particular farm input depends on whether the input is non-rival and non-exclusive.

Private markets are likely to exist for some embodied technologies used in the sheep industry. Examples are agricultural chemicals, seeds and machinery markets. Disembodied technologies are likely to be non-price-excludable and are usually non-rival. Private markets in such services are either non-existent or operating at sub-optimal levels. Examples abound in research information markets.

Fertiliser is an interesting example to demonstrate the difference between embodied and disembodied technologies. To gain the benefits in pasture growth by applying improved fertilisers, a farmer needs to purchase the fertiliser (embodied technology). But the farmer can also make better use of fertiliser through precise and well-timed application by applying his or her knowledge and skills in its application (disembodied technology).

8.9.3 Analysing derived demand (ANPR450 students only)

There are two kinds of problems involved in analysing derived demand. First, there is the demand by farmers for inputs (factors of production) such as machinery, labour and fertiliser. Second, there

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is the notion that most agricultural outputs are indeed inputs used by other sectors. For example, sheep are an input to the sheepmeat industry.

The theory of derived demand is based on marginal productivity concepts that determine the quantities of particular inputs used. It is an extension of production theory. Begin by assuming that the prices of inputs are determined in a competitive environment. For the individual farm, the optimising condition is:

$$P_y \, MP_i = P_i$$

where $P_y \, MP_i$ is the value of the marginal product (VMP_i) of the *i*-th input. Thus, the VMP_i curve becomes the farm's demand curve for that particular factor (input), given a fixed quantity of other factors. If the price of one factor varies, then optimum factor combinations change and a new factor demand curve emerges. It is possible to identify effects for factor price changes that are similar to the income and substitution effects in consumer demand.

You should pay particular attention to aspects of elasticity of the derived demand curves. Some general results of the factor (input) demand theory developed for the perfectly competitive case are:

(1) The elasticity of demand for factors will be greater in absolute value the more elastic the demand for the final product.
(2) The demand for a factor is more elastic the more readily other factors can be substituted for it. This relates to the elasticity of substitution (E_S) between factors defined above. Whether factors are substitutes or complements has implications for the adjustment to new equilibria.
(3) The elasticity of demand for a factor is more elastic the more elastic is the supply of other productive services.
(4) The smaller the fraction of total cost represented by payments to a factor, the less elastic its demand will be.
(5) Elasticity of demand for a factor is greater in the long run than in the short run because, in the long run, farms can vary resource combinations more readily.

These rules give a guide to the variables that are relevant in building models of factor demand, and in hypothesising what the expected signs of coefficients of those variables might be. Consider the following example of a derived-demand effect. With the switch to first-cross or composite breed ewes for prime lamb production by many producers who have traditionally run self-replacing Merino flocks, the price of replacement first-cross and composite ewes has increased as a consequence of the increased demand.

Estimates by Mounter (2007) of medium-run cross-price elasticities of input demand (where the medium run is defined as 3 to 5 years) are presented in Table 8.4 at different levels in the sheep industry. These elasticities can be interpreted in the same way as the concept of cross-price elasticity of demand mentioned above in section 8.7, and therefore Mounter (2007) reported all estimates with the expected positive signs. These estimates give a guide as to the ease of substitution between inputs. As an example of how to read the table, the elasticity of demand for sheep (measured in DSEs) in respect of the price of other production inputs is 0.1: a 1 per cent increase in the prices of other inputs is associated with a 0.1 per cent increase in sheep numbers. As the prices of other inputs increase, sheep inputs are substituted for them to a limited extent. This low estimate reflects the fact that it is very difficult for farmers to substitute between sheep and other inputs, as you might have guessed.

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Table 8.4. Estimates of Medium-Run Cross-Price Elasticities of Input Demand (Elasticities of Substitution) in the Australian Sheep Industry. Source: Mounter (2007),

Industry level	Elasticity between:	Estimate
Farm	Sheep and other farm inputs	0.1
Wool warehouse	Wool and other warehouse inputs	5.0
	Same fibre diameter categories of wool	5.0
	produced from the same agricultural zone	2.0
	Same fibre diameter categories of wool	
	produced different agricultural zones	
Wool processing	Wool and other processing inputs	0.1
	Different fibre diameter categories of wool	0.1
Wool export	Wool and other export inputs	0.1
Sheepmeat	Lamb and other processing inputs	0.1
processing	Non-merino lambs produced from	5.0
	different agricultural zones	
	Merino lambs produced from different	5.0
	agricultural zones	2.0
	Non-merino and merino lambs	0.1
	Mutton (sheep) and other processing	5.0
	inputs	
	Mutton produced from different	
	agricultural zones and/or enterprises	
Sheepmeat	Lamb and other marketing inputs	0.1
marketing	Mutton and other marketing inputs	0.1

Mounter (2007) also provided some general medium-run estimates of own-price elasticities of input supply at various levels in the sheep industry, shown in Table 8.5. Note that these elasticities are also positive, indicating that an increase in the price of sheep outputs brings about greater input use, again as you would expect. The estimates are at least unity, indicating an increase in output price induces a substantial effect on input usage.

Table 8.5 Some Medium-Run Elasticities of Input Supply in the Australian Sheep Industry. Source: Mounter (2007),

Industry level	Estimate
Farm	3.0
Wool warehouse	2.5
Wool processing	2.5
Wool export	1.0
Sheepmeat processing	2.0
Sheepmeat marketing	2.0

8.10 Case study of the profitability of different ways of producing wool and meat

8.10.1 Background

This case study entails a comparison of the profitability of 14 different activities within the sheep enterprise. Moore et al. (1997) modelled the profitability of these activities using the computer program *GrassGro*. Simulations were run from 1 January 1965 to 31 December 2002 at four case study locations in southern NSW, Victoria and South Australia where wool and sheepmeat production are major industries: Cowra, Rutherglen, Mortlake and Naracoorte. The sites for the case studies are shown in the appendix in Topic 7.

As explained in Topic 7, Warn et al. (2005) modelled the following activities:

- Merino wethers (superfine 17.5 µm, and fine wool 19.0 µm)
- Self-replacing Merino ewes (fine 19.0 µm, and medium wool 21µm) turning off store Merino lambs (4 months old) or yearlings (12 months old)

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- Dual-purpose Merino ewes (fine and medium wool) turning off first-cross store lambs (4 months old) or lambs finished to 44 kg liveweight with grain (up to 6 months of age)
- Prime lamb first-cross ewes turning off second-cross store lambs (4 months old), or lambs kept up to 6 months of age and finished on grain to reach 44 kg or 53 kg liveweight.

8.10.2 Comparison of the profitability of activities

When Warn et al. (2005) used meat and wool prices for 1999–2003 to simulate mean gross margins for the period 1966–2002, the dual-purpose (first-cross lambs) enterprise was found to be most profitable, followed by prime lambs (second-cross lambs). With the exception of superfine-wool (17.5 μm) yearlings, the self-replacing flocks (lambs and yearlings) were least profitable. Fine-wool (19.0 μm), wethers were less profitable than ewes, but the superfine-wool wethers compared favourably with the fine-wool Merino lamb enterprise. The relative profitability of each enterprise at the four locations was similar. An effect of micron premiums was apparent for the Merino enterprises.

These differences in gross margin are consistent with benchmarking studies, which indicate that dual-purpose flocks performed better than wool (Merino) or prime lamb flocks over the past few years (Holmes, Sackett and Associates, 2005). Although the Victorian Farm Monitor Project does not differentiate between dual-purpose Merino flocks and cross-bred ewe flocks, data from this project also confirm the superior profitability of prime lamb flocks relative to wool flocks since 2001 (Department of Primary Industries Victoria, 2005).

Similar examples could be given involving sheep production at a more aggregate level on mixed farms. The most obvious ones that are commonly found in the wheat-sheep zone involve crops such as wheat and beef production. Sheep and beef production is also common on farms in the pastoral zone.

When the mean price for 1999–2003 was used, there was no advantage in keeping Merino lambs to shear and sell as yearlings. Around 6 kg/ha (18 per cent) of additional wool was produced in the yearling system, and a similar amount of meat was produced per ha. The price discount for yearling meat relative to that of lamb (30 per cent) limited the income from meat in the yearling system. If the price for meat from lambs was the same as that from yearlings, the yearling enterprise would be marginally more profitable than the Merino lamb enterprise.

Finishing first-cross lambs to 44 kg liveweight was less profitable than store lambs, and this was most pronounced for the Cowra location. The length of the growing season and the extent of the spring peak in pasture supply affected the relative value of finishing lambs. Finishing first-cross lambs (medium-wool ewes) to a liveweight of 44 kg was less profitable than lambing later, retaining more ewes and turning off store lambs: a loss of \$6–\$7/ha resulted for Mortlake, Rutherglen and Naracoorte, and a loss of \$77/ha resulted for Cowra. The mean sale weight of first-cross store lambs ranged from 39 kg (Cowra) to 41 kg (Rutherglen). Grain-feeding reduced production risk by adding an additional 4–6 kg liveweight to the lambs. However, this small gain in meat production per ha was associated with a decrease in the number of ewes per ha and wool production per ha.

Compared with turning off stores, finishing second-cross lambs to a liveweight of 44 kg with grain costing \$150/t increased gross margin by \$26/ha for Mortlake, \$6/ha for Rutherglen, \$3/ha for Naracoorte, and decreased gross margin by \$20/ha at Cowra. Compared with turning off stores, finishing second-cross lambs to 53 kg liveweight would have increased gross margin by \$87/ha at Mortlake, \$64/ha at Naracoorte, \$45/ha at Cowra and \$34/ha at Rutherglen.

The dual-purpose enterprise appeared to be relatively resilient to price changes, as it was the most profitable enterprise under the price scenario. The dual-purpose and prime lamb enterprises produced more meat per ha than the self-replacing Merino enterprises and consequently delivered a greater income per ha from meat (Figure A8.1). As all ewe replacements were purchased, not bred, in the dual-purpose and prime lamb enterprises, more joined ewes were run per ha and thus more meat was produced per ha than in the self-replacing Merino enterprises. The fine- and medium-wool dual-purpose enterprises delivered higher wool incomes than the prime lamb enterprises because of the slightly higher wool production per ha and the higher value of the wool. The wether enterprises produced slightly more wool per ha but substantially less meat per ha than the ewe enterprises, which resulted in the lowest profitability.

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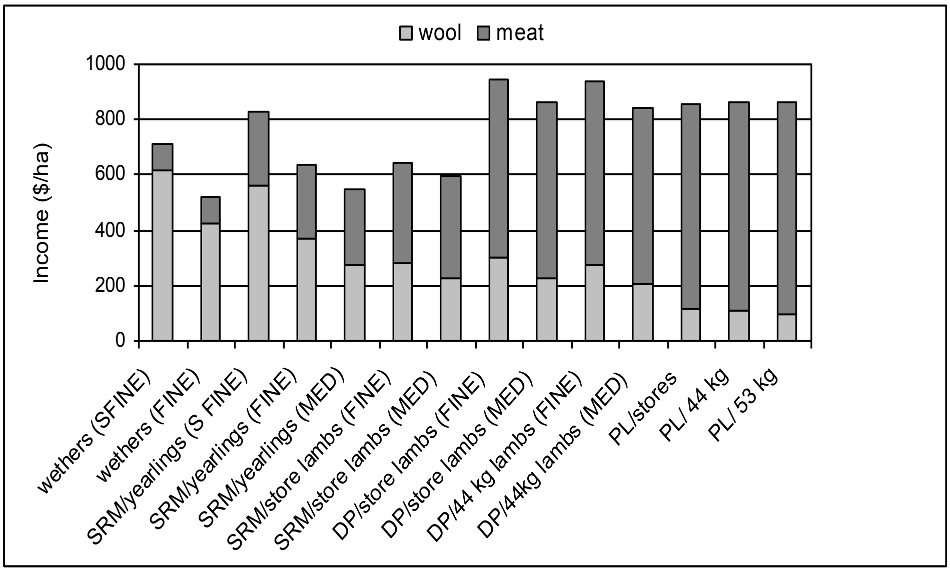
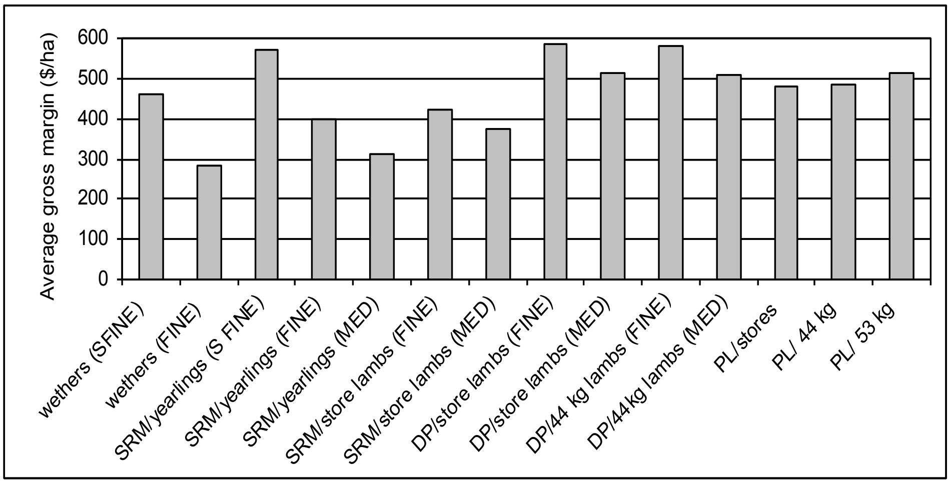
Figure 8.15 Proportions of income from wool or meat for a range of sheep enterprises at Rutherglen, northern Victoria, using five-year average prices (1999-2004). Source: Warn et al. (2005).



Note: SRM – self-replacing Merino flock; DP – dual-purpose flock with terminal sire and Merino ewes; PL – prime lamb flock with terminal sire and crossbred ewes).

In Figure 8.16, the self-replacing Merino and dual-purpose activities fit the definition of a minimum of 25 per cent of income from each of wool and meat for dual-purpose sheep enterprises. Self-replacing Merino enterprises had greater reliance on wool income, ranging from 37 per cent to 67 per cent compared with dual-purpose with a range of 24 per cent to 32 per cent. As would be expected in the specialist enterprises, wether systems are dominated by wool income and prime lamb by meat. These enterprises are much more susceptible to commodity price swings for either wool or meat whereas the dual-purpose enterprises are insulated with more equal dual-product incomes.

Figure 8.16 Comparison of gross margins for a range of sheep enterprises simulated for Rutherglen, northern Victoria, using five-year (1999-2003) average wool and meat prices. Source: Warn et al. (2005).



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Note: SRM – self-replacing Merino flock; DP – dual-purpose flock with terminal sire and Merino ewes; PL – prime lamb flock with terminal sire and crossbred ewes.

The effect on gross margin of producing heavier lambs was investigated for a first-cross lamb enterprise at Mortlake. Table A1.1 shows the effect of time of lambing and lamb sale age on the number of ewes/ha that can be carried and the associated gross margins for a first-cross lamb (FINE ewes) enterprise at Mortlake. In this example, rather than feed lambs grain to increase sale weight, the option of lambing earlier (in June) and keeping lambs for a longer time (until the end of December) was explored. This option was compared with the store lamb option: lambing in September, ewes stocked at 20/ha, and selling lambs at 4 months of age (end of December). Lambing earlier meant lambs were sold at a higher average liveweight but fewer ewes/ha could be carried, resulting in less meat and wool income per ha. A price grid was used in the simulation, allowing lambs of different sale weights over the 35 years to receive the appropriate sale price. Although the 44 kg lambs would have received a price premium of 20 c/kg (liveweight) on average compared with the 38 kg lambs, this was not high enough to make up for the lower meat and wool production per ha.

Table 8.6 Effect of time of lambing and lamb sale age on the number of ewes/ha that can be carried. Source Warn et al. (2005).

System	Ewes/ha	Gross margin ($/ha)	Lamb sale weight (kg)	Wool income ($/ha)	Meat income ($/ha)	Maintenance feed costs ($/ha)
Lamb June/sell end Dec	12	704	44	323	797	71
Lamb Sept/sell end Dec	20	1042	38	593	1086	101

Acknowledgments

To Kimbal Curtis, Department of Agriculture and Food, WA for survey information on the Australian sheep industry and Lisa Warn, Mackinnon project, University of Melbourne, for material on enterprise comparisons.

Readings

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2. *Sackett, D. and Francis, J. 2006, 'Integration of wool, meat and cropping systems', in P.B. and D. Maxwell (eds), Wool Meets Meat, Proceedings of the 2006 Australian Sheep Industry CRC Conference, Orange.
3. Warn, L.K., Webb Ware, J., Salmon, L., Donnelly, J. and Alcock, D. 2005, Analysis of the profitability of sheep wool and meat enterprises, Report to the Australian Sheep Industry CRC.

* Denotes compulsory reading.

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Summary

Summary PowerPoint slides are available on CD
This topic provides an overview of the economics of sheep production. The main purpose is to develop an understanding of the principles of production and price theory, and how these principles can be applied to problems in sheep production and the optimisation of production to maximise profit. The main topics to be covered are the:

- input-output relationships
- relationships between inputs in producing outputs
- profit maximisation
- price theory
- relationships between supply and demand
- derived demand for factors of production
- product-product relationships.

This topic does not claim to be comprehensive as the subject is enormously broad and complex. It provides an introduction to the array of economic principles.

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Glossary of terms

Allocative efficiency in outputs	Occurs where the marginal rate of product transformation equals the (negative) appropriate price ratio of the products
Average product	The output produced per unit of a particular input used in an enterprise
Average cost	The cost of producing a single unit of output in an enterprise
Capital	Buildings, plant, equipment, livestock and improvements that can be used to produce output that generates a future stream of cash inflows
Competitive products	Where an amount of one product will have to be surrendered to increase marginally the production of another product, input use remaining unchanged
Complementary products	Where the amount produced of one product increases with a marginal increase in the production of another product, input use remaining unchanged
Cost	The expenditure on economic resources used in production, measured as the opportunity cost
Cross-price elasticity of demand	The percentage change in the quantity of a product demanded given a one per cent change in the price of a related product
Demand	The amount of a product that is demanded by buyers in a market
Demand curve (function)	A schedule or curve showing the quantity of a good that an individual consumer (individual demand curve) or consumers in aggregate (market demand curve) would buy at each price, holding other things constant
Demand shifter	A factor that shifts a demand function leftwards or rightwards
Demand theory	Built on the notion that consumers maximise their utility derived from selecting goods from the bundle available, given prices for the products and level of income
Depreciation	The decline in value of a farm capital item through wear-and-tear
Derived demand	The demand for an input used in production in an enterprise that is derived from the demand for the final product
Diminishing returns	The decline in successive increments of output with constant increments of inputs
Disembodied technologies	Are those technologies that are not embodied in an input and whose application does not require the purchase of an input
Dual-purpose sheep enterprise	An enterprise in which at least 25 per cent of income is derived from each of wool and meat products
Economic analysis	Study of the allocation of scarce resources among competing wants
Economic optimisation	Maximisation of an objective function, such as profit maximisation or cost minimisation
Economies of scale	The doubling of output for less than double the cost, inputs being used in constant proportions at each level of output
Economies of size	The doubling of output for less than double the cost
Elasticity of input substitution	A measure used to describe the ease with which one input can be substituted for another
Elasticity of production (output)	A measure used to describe the ease with which one input can be used to increase output
Embodied technologies	Are those technologies that can only be obtained by buying an input in which they are embodied
Enterprise	The production of a particular output, or group of related outputs, for sale or domestic use
Equilibrium price	A price that equates the quantity of a product supplied with the quantity demanded in a market

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Exchange rate	The rate at which one currency is exchanged for another
Expansion path	A line joining points of efficient combinations of the variable factors for different levels of output
Factor-factor relationship	The mathematical relationship between two inputs used in the production of an output in an enterprise
Factor-product relationship	The mathematical relationship between an input and an output in production in an enterprise
Farm activity	A specific method of production within a farm enterprise
Farm enterprise	The production of a particular farm output, or group of related farm outputs, for sale or domestic use
First-cross lambs	Usually progeny of an English long wool breed, e.g. Border Leicester, or a specialist meat sire, e.g. Suffolk, crossed with Merino ewes
Fixed (durable) capital	Capital that can be used over a long period (usually a number of years) to yield returns over that period
Fixed cost	The cost of using a fixed input in production in an enterprise
Fixed input	An input used in the production of an output, or group of related outputs, the level of which does not vary with the level of output
Gross margin	Gross revenue minus variable costs
Homogeneous function	A function in which the output elasticity is constant for all levels of input
Input	A factor used in the production of an output, or group of related outputs, in an enterprise
Isocost line	A line that joins up all points of constant budget outlay
Isoprofit line	A line joining all points of equal profit
Isoquant	A line that joins up all points of constant output
Isorevenue curve	A line joining points of equal revenue
Marginal analysis	A study of the effects of a small change in a variable
Marginal cost	The additional cost that is incurred in an enterprise when one additional unit of output is produced.
Marginal factor cost	The cost incurred in using in producing an additional unit of output
Marginal product	The additional output that is produced in an enterprise when an input is increased by one unit
Marginal rate of (product) transformation	The amount of change in output of one product in response to a marginal change in the production of another product (shown by the slope of a production possibilities frontier)
Marginal rate of substitution	Measures how well one input substitutes for another along a given isoquant
Marginal revenue	The additional revenue that is earned in an enterprise when output is increased by one unit.
Market price	The sale price received for selling output, net of any costs not included in the cost estimate such as marketing costs beyond the 'farm gate'
Marketing margin	The difference between the price paid to the producer and the price paid by the final consumer
Mixed enterprise farm	One in which there is more than one enterprise as part of the normal operations of the farm
Non-exclusive use	Occurs where an individual cannot be excluded from using an input
Non-rival use	Occurs where the marginal cost of providing an input to an additional user is zero and its use does not restrict its further use by others
Opportunity cost	The revenue forgone by not using an input in its next best alternative use

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Optimisation in product-product relationships	The process of maximising profit maximisation at the point where the production possibilities frontier is tangential to the isorevenue curve
Output	The amount of a product produced in a given time period (normally one year).
Own-price elasticity of demand	The percentage change in the quantity of a product demanded given a one per cent change in its price
Price averaging	The practice of averaging margins by spreading costs across all types of a product in order to minimise the extent of an individual price change
Price levelling	A practice adopted by retailers of varying margins to smooth retail prices over time in the face of fluctuating saleyard and wholesale prices
Price elasticity of supply	The percentage change in the quantity of a product supplied given a one per cent change in its price
Prime lamb production	Using terminal meat sire sheep breeds over crossbred ewes
Product-product relationship	The relationship between amounts produced of two products in the same production system
Production function	The technical relationship that effectively limits the options of the manager of an enterprise, and specifies the relationship between the inputs a farm uses and the outputs it produces
Production possibilities frontier	A line representing all feasible combinations of products produced by fully employing all available inputs
Profit	The surplus remaining after the opportunity costs of all inputs have been met, formally calculated as the total revenue earned minus the total cost of production
Profit maximisation	Pursuit of the maximum profit, achieved when marginal revenue is equal to marginal cost
Public good	A good that is non-excludable and non-rival in consumption
Returns to scale	A measure of the responsiveness of output to changes in inputs along a scale line
Revenue	Amount of money earned from production for sale or domestic use in an enterprise
Scope economies	When two or more products can be produced within a production system at a lower cost than producing each of the products in separate production systems
Second-cross lamb	Progeny of a second sire breed, e.g. Suffolk, crossed with a crossbred ewe, e.g. Border Leicester x Merino
Self-replacing merino flock	A purebred Merino flock breeding its own Merino ewe replacements
Semi-durable input	A good that is used in production for several years before being traded in the market
Sheep enterprise	The production of a sheep output, or group of sheep outputs, for sale or domestic use
Substitutes	Goods that 'compete' with each other in supply and demand

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Supplementary products	Where the amount produced of one product remains constant with a marginal increase in the production of another product, input use remaining unchanged
Supply	The amount of a product produced for sale in the market
Supply curve (function)	A schedule or curve showing the quantity of a good that an individual firm (individual supply curve) or firms in aggregate (market supply curve) would produce at each price, holding other things constant.
Supply response curve (function)	A relationship showing how the quantity demanded of a product responds to a change in its price when the price change causes a movement of the supply function as well as a movement along the function
Supply shifter	A factor that shifts a supply function leftwards or rightwards
Textile cycle	A distinct cyclical pattern in textile prices and quantities, similar to a cobweb in structure
Value of the marginal product	The output price times the marginal product of a particular input used in an enterprise
Variable cost	The cost of using a variable input in production in an enterprise
Variable input	An input used in the production of an output, or group of related outputs, the level of which varies according to the level of output
Working capital	Capital needed on a month-by-month basis for operating an enterprise (usually less than a year)

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