

What is the difference between productivity and profit?

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Foreword

This report has been written to explain the difference between productivity and profit. A focus of the work program of the Economics Branch in recent years has been on productivity measurement and explanation. Further, the Branch's empirical research evaluation process focuses on productivity-change measurement. Yet scientists and research managers commonly ask Branch members questions such as "is profit the same as productivity?" and "what is the difference between profit and productivity?".

This report has been written to explain these two terms and to promote discussion in NRE about profit and productivity. We give non-technical definitions of profit and productivity, and use a case study to show how different economic changes — to prices, sector-wide knowledge, and farm-specific knowledge — affect both productivity and profit.

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Preface: How to Read this Report

With this report, we intend to service the needs of several different users. Therefore, different parts of the report will be valuable to different people. This is hardly surprising given the breadth of people in NRE, and externally, that may be interested in this topic.

As is common for reports of this nature, we have included an Executive Summary for the reader who is only interested in the main points.

The next two chapters (Introduction and Definitions) will deliver most of the messages we hope to convey in some detail. These two, read in conjunction with Chapter 4 (Summary) will provide a good foundation for understanding the topics discussed, without much technical detail.

Chapter 3 contains some technical detail. We have relegated most of the equations and mechanics of the model we use in Chapter 3, to the Appendix. However, Chapter 3 does rely on the model laid out in detail in the Appendix, and hence some readers may find Chapter 3 hard going. However, we have not moved Chapter 3 itself into an Appendix because we feel it is an integral part of our main message—productivity and profitability react differently to changes in prices, firm-specific technology and sector-wide technology.

Executive Summary

Farmers and research administrators are concerned with both profit and productivity. These are two related but distinct concepts.

Profit is a measure of receipts less costs. Economists splits costs into two broad categories, those that vary with output (variable costs) and those that do not (fixed costs). Different profit measures use different definitions of 'receipts' or 'costs'. For example, some profit measures — like farm gross margin — take account of variable costs, but exclude fixed costs.

Profit will change when something affects either receipts or costs. For example, an output price change will alter profit because it affects receipts (price of output times the quantity of output). If costs stay constant, and output price rises, then by definition, profit will rise.

Productivity is a measure of the units of (physical) output that can be produced from a given amount of (physical) inputs. We can most easily measure productivity when a production process requires only one input, and one output. For example, if a farm produces milk, and only uses labour, then productivity is measured by the amount of milk per labour unit (for some defined time period).

Productivity will not be affected by a change in output price, because price is not part of the productivity equation; a change in output price does not affect the ability of the farm to transform inputs into outputs. Anything that alters the ability of a farm to transform inputs into outputs (for example, something that lets us get more milk per labour unit) will improve productivity. This is usually the focus of research: to alter production processes so that productivity improves.

Generally, prices (of inputs or outputs) will affect profit, but they will not affect productivity. However, technical change (via research or other means) will affect both productivity and profit since it affects the ability of farms to convert inputs to outputs (productivity) and hence affects receipts (output price times output quantity) or costs (input price times input quantity) or both.

Farmers are concerned with profit because it provides the means for current consumption (food, clothing, education, etc.) and investment (which provides future

consumption). They are concerned with productivity to the extent that it helps them create higher profits, or to counter the inexorable cost-price squeeze.

Research administrators know that for an industry to survive, it has to continually improve its productivity. Otherwise, international competition will displace domestic production on the world market, and at home. This could lead to the demise of an industry.

1.0 Introduction

The Department of Natural Resources and Environment (NRE) uses a wide range of instruments to help the Victorian economy generate wealth from its natural resources, without excessively degrading the environment. These instruments include amongst other things: regulation, policy and research.

NRE uses these instruments to wide effect: it can have an impact upon many different natural resource industries, from forestry through fishing. NRE's actions can also affect the health, and speed of adjustment, of rural areas. Therefore, to use these instruments properly, NRE must understand how industries play their part in contributing to overall prosperity, and how they interact with the environment.

One of NRE's key aims is to allow natural resource industries to live up to their full potential: NRE hopes to provide settings such that natural resource industries can expand and thrive. In other words, NRE often wants to put in place a system that lets businesses find profitable opportunities. Profit — which, is a measure of the excess of receipts over costs — is useful because it allows the profiteer to buy goods and services now, or to invest for the future; increased profits increase prosperity.

But prospering is not easy. Generally, farmers are involved in a game of survival: farms are constantly on a 'treadmill', where they must improve performance to survive, but just as they reach their short-term performance target, the goalposts shift. National and international forces constantly move the goalposts: international farms improve their performance and push prices down; new technologies revolutionise the way commodities are bought and sold, the speed of their delivery, and the safety of their handling, etc.

So how do farms and industries remain profitable? Farms do this both individually, and as part of an industry.

At the farm-level, managers stay on the treadmill by using resources better: rearranging production processes; expanding scale; investing in new machines; undertaking their own research and development; hiring new and well-trained staff; retraining existing staff, etc.

At the industry level, managers try to help their industry by commissioning industry-wide research, and lobbying for changes in government policy. Both of these help the industry to overcome the ‘cost-price squeeze’ in agriculture¹.

Actions by farmers or industry-bodies to improve profitability, or overcome the cost-price squeeze, are often aimed at altering the production process so that more output can be produced per unit of input, that is, many actions are aimed at improving *productivity*.

NRE plays a part both at the farm and industry level, particularly the latter. It does this, for example, by improving policy, and allocating funds to research. Over recent years, a large part of the Economics Branch’s work in both these areas — policy development and research evaluation — has been to better understand ‘productivity’. The Economics Branch views industries as being on a treadmill, constantly trying to improve ‘performance’, where performance is often synonymous with productivity.

An industry’s productivity improvements may indeed improve profit. But they may not. It depends on what else is happening domestically and globally to commodity prices; it depends on what the goalposts are doing. For example, if domestic farms increase productivity but so do other (international) farms, then profitability might not change at all. In this instance, world prices may fall. Rather, the productivity improvement just helps farms to stay on the treadmill, rather than fall off it.

In this report, we will talk about profit and productivity in the context of agricultural industries. However, the report’s main messages are relevant to all industries. We shall illustrate that profit and productivity are closely linked, but they are different; and their uses differ accordingly. We shall give some examples throughout the report, about how these concepts can be put to different uses.

In Section 2 we provide formal definitions of profit and productivity. In Section 3 we will provide some worked examples of what happens to profit and productivity when there are several economic changes: price changes; industry-wide knowledge changes; and farm specific knowledge changes. In Section 4 we summarise.

¹ The ‘cost-price’ squeeze is where the price of inputs (eg labour, capital, materials, etc) increases whereas the price of outputs decline. This phenomenon has been observed in all developed economies.

2.0 Profitability and Productivity: Definitions

Profitability and productivity of agricultural farms are two related but distinct concepts. In this chapter, we will explain the fundamental differences between these concepts.

2.1 Profitability

Profit measures the financial performance of farms. It is a measure of receipts less costs. Different profit measures include different definitions for ‘receipts’ and ‘costs’.

Economists generally split costs into fixed and variable. Fixed costs are those that do not vary with output produced (for example, an annual lease payment on a tractor does not vary with the quantity of crop harvested). Variable costs do, as their name suggests, vary with output (a larger area of crops will generally require more fertiliser, all else constant).

The accountant’s method of calculating costs differs from the economist’s. For example, an accountant may not consider family labour as a cost because it does not involve a cash outflow. However, the economist considers family labour a resource that could have been used elsewhere, if it were not used on the farm; the labour has an *opportunity cost*². This opportunity cost is included in the economist’s calculation of profit³.

For a given definition of receipts and costs, there are two ways of measuring profitability: in an absolute or a relative sense. We now look at each of these in turn.

² *Opportunity cost* is defined as the cost of the next best alternative use of that resource. For example, land that is being used for wheat production but can also be used to run sheep. Therefore, the opportunity cost of growing wheat is equal to the income foregone from running sheep on that parcel of land.

³ Another example of opportunity cost is depreciation (the ‘wearing down’ of an asset). While accountants include depreciation in calculating profit it often differs from the economists’ definition. For example, there may be tax advantages to farmers from accelerated depreciation. But economists are usually concerned with the economic life of an asset, not its life as noted in accounting records..

2.1.1 Absolute Profitability

Measures of absolute profitability are based on the level of profit. Absolute profitability can be measured on a farm basis or on a per unit of output or input basis⁴.

Absolute farm profit is a measure of ‘whole of farm’ performance, and it may be calculated as total farm receipts less total (fixed plus variable) costs; or total farm receipts less variable costs (which we call variable profit, or farm gross margin).

Absolute farm profit may obscure how a farm was able to generate profits. For example, a farm may undertake several agricultural activities, where one generates a loss, but another earns a profit. A farm level profit measure may not contain any information on the profitability performance of the farm’s different activities. Therefore, farm-level profit may provide a partial evaluation of the profitability of the farm.

Farm profit can usually be disaggregated into different farming activities. For example, in a mixed sheep-cropping farm, we may be able to determine how much profit the farm derives from crops, and how much it derives from sheep. However, this is only true to the extent we know how to attribute the farm’s costs between crops and sheep. This allocation of costs is complicated by interactions between outputs. For example, cropping activities may depend on rotating land use between different cropping activities and livestock activity in order to maintain a nutrient balance in the soil. Therefore, the allocation of costs is not clear-cut in practice. Nevertheless, disaggregated farm profit may still be a useful management tool in identifying potential profitability problems.

Absolute profitability measured on a per unit or per output basis — such as gross margin per hectare — may be useful to compare intra-farm activities. If we ignore cross-activity interactions (mentioned above), then a relatively low per-unit profit result may suggest that a farm is badly using the relevant inputs; it could reallocate some of these inputs to other uses, and increase overall farm profit. A farm that

⁴ In this report, we take inputs to mean land, labour, capital, materials and any other resource used in the production process.

chooses the profit maximising input mix, given input prices, is called *allocatively efficient*.

However, we need to judge allocative efficiency in the light of factors such as risk. Some farmers are relatively more risk averse (they will more actively try to avoid risk). They might do this, for example, by diversifying production to several output classes. This allows the farmer to lower his risk of a large loss in any one year from (say) bad weather or prices; but this comes at the cost of a potentially huge return if all goes well. Specifically, in (say) a mixed wheat-wool farm, the impact of a fall in wheat prices may be buffered by the farm's wool output. An analyst needs to take account of this; if an analyst assumes all farmers have the same risk aversion, they may judge a more risk averse farmer as allocatively inefficient when in fact he is efficient *given his risk preferences*.

2.1.2 Relative Profitability

Absolute farm profit may be a misleading indicator of performance across farms. For example, one farm may have a lower level of absolute profit because it has a smaller scale of operation, that is, it may still place its resources in high-valued uses, but its overall profit simply reflects the fact that it uses less resources to produce less output. Relative profitability, on the other hand, is readily amenable to comparisons between farms with different scales. Usually, relative profitability measures are expressed as percentages of assets, costs or revenues and therefore take account of different farm scales. For example, two relative measures include total farm profit over total farm asset values (return on assets), or farming gross margin over total farm asset values.

Relative profit measures give the analyst an indication of the wealth being generated across disparate industries. Whereas absolute profit measures (for example, gross-margin per cow) could be useful within an industry, relative profit measures (return on assets) can be used within and across industries.

Although measuring relative profitability is one part of an analyst's exercise, the important part is usually disentangling the reasons for differences in relative profitability, which is more difficult. A range of variables can (and have) been used to try and do this in the past. For example, it would appear that dairy farms with large herds have higher absolute and relative profitability than smaller farms. Some

variables that are commonly used to explain relative profitability include farm size, manager's education, access to information, and whether the manager is full-time.

Another variable that is commonly used to explain relative farm profit is geographical location. Location may explain differences in relative profitability within an agricultural industry. For example, climatic disturbances, such as drought, are usually confined to a region; some regions have more fertile soil; regions can sometimes face different policies, etc. These can have a significant effect on relative farm profit. We would expect however, that disadvantaged regions would also have lower land prices; the demand for land of this type would be lower, and this would be reflected in land prices.

2.1.3 Choice of Profitability Measures

The choice of using an absolute or relative profitability measure depends on the task at hand. Absolute profitability is appropriate for analysing the financial performance of a farm in terms of *levels* or dollars. Relative profitability, on the other hand, is more relevant for *comparisons* between farms or between group of farms. Using both measures would improve profitability analysis by providing more information on the financial performance of farms than is possible by one measure alone.

2.2 Productivity

Productivity is a measure of the output produced per unit input. It is a *physical* rather than a financial measure, using data on physical quantities of inputs (labour hours, hectares of land, etc.) and outputs (tonnes of wheat, kilograms of wool, etc). We can most easily measure productivity when there is one output and one input. For example, when the output is wheat, and the input labour. Then, a measure of productivity could be tonnes of wheat per hour of labour. Note that productivity is quite different to profit. The latter would take account of receipts (which incorporates the price of wheat) and costs (which would incorporate the price of labour).

Productivity is *usually* measured as a relative concept⁵; either across farms or across time. The rate of productivity *growth* (usually the excess of output growth over input growth) is also an important indicator of economic viability of a farm or an

agricultural industry. If the productivity growth of an international competitor (like the New Zealand dairy industry) were far outstripping Australia's, then we would expect the competitor to win existing and new markets on the basis of their price per unit, thereby displacing Australia's sales on the world market.

An important concept of productivity analysis is *technical efficiency*. This is a farm-level concept. It measures how efficient one farm is, relative to the best farm around at the time (the market leader, if you like). The market leader(s) could be seen as the yardstick(s) for all other farms.

However, the market leader can only be as good as the local setting (policy, land quality, etc.) and technology (determined by research) allows it. A farm doing the absolute best it can given the local settings is said to be on the local production frontier (the term frontier is used to show it is at the forefront of technology). Conversely, the further away a farm is from the frontier (the further behind the market leader), the less technically efficient it is, and the greater scope it has to improve its technical efficiency (it has greater scope for 'catch up'). If a farm is not technically efficient, it is unlikely to be viable in the long-term.

In contrast to the farm-level concept of technical efficiency, *technological progress* represents a shift outwards of the frontier; it allows all farms (including the previous market leader) to improve productivity. In other words, the boundary (the goalposts for the farm) has moved. Technological progress is an *aggregate* concept; it is relevant to an industry rather than a farm. Technological progress changes the scope of *all farms* to transform inputs into outputs. It does not depend on how many farms adopt the new technology but the fact that the potential for more efficient use of inputs is now possible for all farms. Whereas a farm could improve its technical efficiency without the other farms being affected, technological progress redefines best practice for everyone. For example, a new crop variety may affect the ability of all crop farms to increase yield per hectare without increasing input use. The rate of technological progress is an important indicator of long-term economic viability of an industry.

⁵ We can only measure the absolute value of productivity in the simple one-input, one-output case.

This section will discuss two ways of measuring productivity: partial and total factor productivity measures. We will discuss partial productivity measures first.

2.2.1 Partial Productivity

When total output or a subset of total output is measured in relation to a subset of inputs, this is called a partial productivity measure. Crop yields per hectare and milk per cow are two examples of partial productivity measures. However, these measures, as their name suggests, are incomplete depictions of productivity changes that may be occurring on a farm. To interpret these measures as total farm productivity changes would be misleading because partial productivity measures, by definition, do not include the full set of inputs (or sometimes outputs). For example, a crop-wool farm may experience an increase in crop productivity but also a large decrease in wool productivity, if the latter effect dominates, total farm productivity may fall.

While partial productivity measures may be *inadequate* to analyse overall productivity changes occurring on a farm, these measures are potentially useful in identifying sources of changes. This is because their partial nature allows these measures to focus on specific parts of the farm. Further, partial measures are often easy to calculate.

For partial productivity measures to be useful they should be carefully defined so as to take account of the most relevant information. For example, if we are interested in dairy production, we may want to consider how much feed is used to produce a litre of milk. However, we would be less interested in knowing fuel costs per litre of milk, since fuel is relatively less important in dairy production.

2.2.2 Total Factor Productivity

Total factor productivity (TFP) measures how much farm output is produced in relation to total inputs. By analysing TFP changes we are able to determine the relative economic viability of a farm or agriculture industry. TFP analysis implicitly analyses both the technical efficiency (movements towards the frontier) *and* the rate of technological progress of farms (movements of the frontier).

TFP analysis is potentially a useful tool in analysing economic viability of farms, but an analyst needs to take care with how she or he measures outputs and inputs. Since TFP includes all outputs and inputs, but productivity is a physical measure, then the

analyst must add things that are in different units. For example, labour hours and tonnes of fertiliser. There are several techniques economists use to do this: index numbers, linear programming, and regression. Coelli, Rao and Battese (1998) contains information on all these techniques.

Economists also need to be careful about how they measure output and input quality. Consider, for example, if we want to measure the productivity of wool specialist farms. Wool is an output that comes in varying degrees of quality. To capture quality improvements, an analyst would need to make sure he had disaggregated data on different wool types; the quantity of production of each of these types; and the price of each of these types. Unless these data were available, the analyst would struggle to measure quality improvements. Therefore, different quality outputs and inputs need to be treated, essentially, as different outputs and inputs. This may place quite costly demands on the analyst.

2.3 Summary of Chapter 2: Productivity versus Profitability

In this Chapter, we have explained the difference between productivity and profitability. Productivity is a measure of output per unit inputs. It is a physical concept. Profit is a measure of receipts minus costs. It is a financial concept. Both concepts are important when evaluating the health of a farm/industry. They analyse different aspects of performance. In Figure 1, we graphically represent the relationship between productivity and profitability.

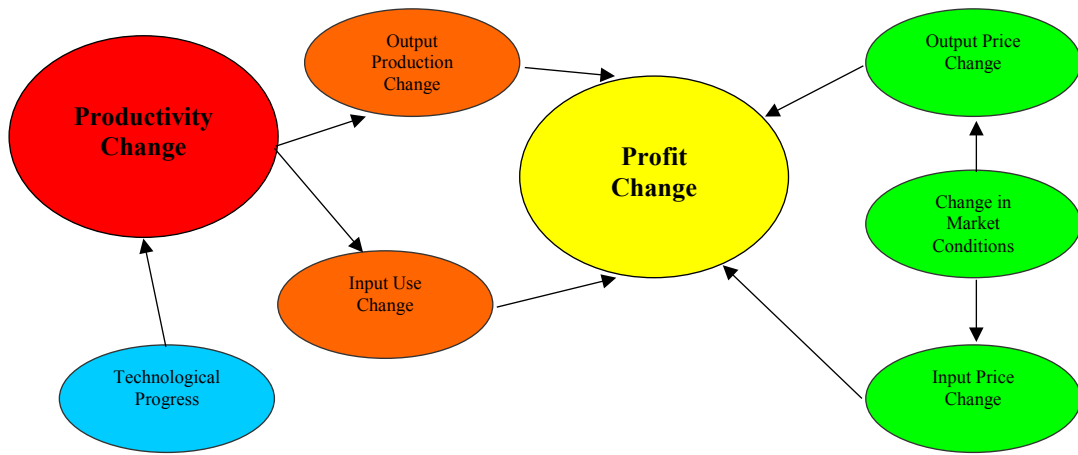
All else held constant, a productivity improvement will increase profit, through its effect on the way inputs are transformed into outputs: more output (and hence revenue) will be produced from the same inputs (same costs).

Usually, productivity improvement occurs over a period of time (like 5 to 10 years). This means it will be happening concurrently with other changes. For example, output prices may be falling relative to input prices. If the latter effect is very large, it may negate or overturn the positive effect that a productivity improvement would have had on profit. Conversely, if output prices are rising relative to input prices, then this will enhance the effect of a productivity improvement, giving a farm two sources of profit gain over the relevant time period.

All else held constant, a rise in output prices relative to input prices will improve profit. The farm's revenues will increase at a faster rate than its costs. Hence, revenue minus costs (profit) will increase. This increase in profit, on its own, will not improve productivity. However, higher profits *could be* invested in new technologies that would improve productivity. For example, if a farm were to experience several profitable years in a row, it could probably afford better technology, and therefore have greater scope to improve its productivity. By contrast, if a farm were to have several unprofitable years, it would probably view an investment in new technology as unaffordable.

An analyst may look at a farm's profitability to determine if it is viable in the short term. However, to investigate other questions—for example, the impact of technological change on an industry—an analyst may need to consider productivity. The reason for this should be straightforward given the above discussion. Technological progress may have a very large impact on an industry and significantly improve its productivity. However, if foreign firms have improved their productivity at the same rate, then there may be little or no change in the domestic industry's financial performance (international competition would have pushed the price of the commodity downwards). This is not to say that technological progress had no impact. Quite the contrary, without technological progress domestically, the industry would decline in size relative to its international competitors, since it would have been outperformed in international and domestic markets. Rather, in this case technological progress should be judged to have maintained the viability of the industry; technological progress allowed the industry to remain on the treadmill.

Figure 1: Graphical Presentation of the Relationship Between Productivity and Profitability



3.0 A Model of Productivity and Profitability

We developed a farm model to analyse the impact of four changes — output price, input price, farm-specific knowledge, and sector-wide knowledge — on the farm’s productivity and profitability. We call the initial situation that of a farm the ‘base scenario’, and we call the post-change situation the ‘alternative scenario’.

Our model farm maximises gross margin — the surplus between revenue and variable costs — and takes output and input prices as given⁶. The farm maximises gross margin by choosing its output and input levels.

We assumed that the farm has one output and four inputs — hired labour, materials, land and capital. However, the farm treats the amount of land and capital as fixed inputs (in economic parlance, this is a ‘short-run’ analysis). This means the farm cannot adjust land and capital in reaction to the change (in price, etc). Hence, the farm can only vary hired labour and materials. The Appendix provides a more technical exposition of the model.

In our base scenario, we assumed a given set of parameters (output prices, input prices, farm knowledge and sector-wide knowledge). Then, we ran four alternative scenarios to compare with the base scenario. The four alternative scenarios that we ran were:

1. fall in output price;
2. rise in hired labour wage rate;
3. a movement towards inefficiency for a farm (eg, a farm moving to an inefficient scale); and
4. an improvement in agricultural practices.

Except for the third scenario, all of these scenarios represent events beyond the control of the farm. We compared each alternative scenario to the base in terms of:

1. farm gross margin; and

⁶ Taking output and input prices as given is a realistic assumption for an individual farm. Individual farms are not able to influence prices. Economists call this the *price-taking* assumption.

2. farm productivity (using a Fisher total factor productivity index).

The Fisher TFP index measures takes a value of one in the base scenario. If an alternative scenario does not change farm productivity, the index remains at one. If an alternative scenario increases productivity, the Fisher index rises above one. If an alternative scenario decreases productivity the Fisher index falls below one.

3.1 Base Scenario

Before we proceed with discussion of the results, we will make some important points about the base scenario. We assumed a particular form of technical relationship between inputs into output, that is, we assumed a particular form of the ‘production function’.

We included a parameter in the production function that represented the industry’s level of technology and knowledge. This parameter also includes the managerial expertise of the farmer. The appendix provides more details on this variable. This was an assumed value.

As stated above, our model farm produces one output. This is relatively more accurate in the case of dairy and specialist livestock farms, but is probably not an adequate representation of cropping or mixed cropping-livestock farms. However, this does not alter the results of our subsequent analysis.

Table 3.5, at the end of this Chapter, contains information on selected variables used in the farm model for the base and alternative scenarios. It also provides a comparison of the base to each of the alternative scenarios.

3.2 Fall in Output Price

The impact of a 25 per cent fall in output is given in Table 3.1. The fall in output price lowered the farm's gross margin. The farm's gross margin fell by nearly 20 units. This represents a fall of gross margin of around 27 per cent. The farm responded to the fall in output price by both lowering labour input use and materials use from 0.4 to 0.3 to reduce total costs (Table 2.5). This caused output to fall from 3.5 to 3.41 units and compounded the decline in total revenue (Table 3.5). This new output level was the new profit maximising level because the fall in output price made production less profitable.

From Table 3.1, we can see that a 25 per cent fall in output price had *no effect* on productivity. This is because the change in output prices does not change the *technical ability* of the farm to transform inputs into outputs. Yet, even with the same ability to get outputs from inputs, the farm's profit falls because it receives less revenue from each output unit.

Table 3.1: Change in Profitability and Productivity in 'Fall in Output Price' Scenario

Variable/Scenario	Base	Fall in Output Price	Change (%)
Gross Margin	63.98	46.69	27.02↓
Productivity Index	1	1	No Change

Note that a fall in output price is *not* the same as a change in the quality of output (like, for example, a fall in the protein content of milk). A change in output quality alters the ability of the farm to convert inputs to outputs and therefore, it affects productivity (similar to a change in Agricultural Practices — see below).

3.3 Wage Rise

We can see from Table 3.2 that gross margin fell — by 1.4 per cent — in response to a 25 per cent wage rise. The farm responded to the increase in wages by reducing the quantity of hired labour input from 0.4 to 0.32 units (Table 3.5). The other variable input, materials, was left unchanged at 0.4 units (Table 3.5). The farm's total variable costs remain unchanged. Since hired labour falls, output also falls slightly (to 3.45 units) which in turn generates less revenue (Table 3.5). This causes a fall in the farm's gross margin.

A 25 per cent increase in wages has no an effect on productivity (Table 3.2). Like a fall in output price, a *fall in wages (or other input prices) does not affect the technical relationship between outputs and inputs.*

Table 3.2: Change in Profitability and Productivity in 'Wage Rise' Scenario

Variable/Scenario	Base	Wage Rise	Change (%)
Gross Margin	63.98	63.09	1.4↓
Productivity Index	1	1	No Change

3.4 Inefficient Farm

We simulated a model farm's move towards inefficiency, by moving it from fully efficient in the base scenario, to 75 per cent efficient in the alternative scenario. This assumption allows us to simulate *technical inefficiency*. Essentially, our model farm in the alternative scenario produces 75 per cent less output from the same inputs. More details on how this scenario was run is in the Appendix.

This case could represent, for example, a change in ownership of the farm from an experienced, well-trained person, to a less-experienced manager; a change in farm-specific knowledge. The new manager may not use all the land to the maximum possible extent (does not spread fixed costs as well as he should) or just combine variable inputs in a poor manner.

From Table 3.3 we can see that the farm gross margin falls nearly 20 units. The inefficient farm uses the same quantity of inputs as the base farm (Table 3.5). Therefore, total variable costs remain the same. Production falls from 3.5 to 2.62 units (Table 3.5). This results in lower revenue of 52.49 compared to 70 in the base (Table 3.5). Constant costs combined with lower revenue lead to a fall in gross margin.

The productivity index also falls by nearly 0.2 index points (Table 3.3). A 25 per cent reduction in the output that can be produced from given inputs is clearly a productivity loss (by definition!)⁷.

Table 3.3: Change in Profitability and Productivity in 'Inefficient Farm' Scenario

Variable/Scenario	Base	Inefficient Farm	Change (%)
Gross Margin	63.98	46.49	27.34↓
Productivity Index	1	0.87	13.4↓

⁷ The fall in productivity is not equal to 25 per cent because the production function is in log form.

3.5 Improvement in Agricultural Practices

We simulated an improvement in agricultural practices as a 25 per cent increase in the industry's technology and knowledge or the farmer's human capital. This scenario can be seen as a simulation of *technological progress*. More details on how this scenario was simulated is explained in the Appendix.

This change might represent, for example, a new breakthrough by one of the rural research corporation projects; a change in knowledge that affects the whole sector (industry). A higher yielding or better quality crop variety, better pasture management, or an improvement in livestock genetics could all be represented as a shift of the production function that this scenario emulates.

Table 3.4 shows that an improvement in agricultural practices increases gross margin by nearly 5 units. Output rises (from 3.5 to 3.72) and hence so does revenue (70 to 74.45) (Table 3.5). However costs remain the same. Therefore, gross margin rises.

The productivity index increases by nearly 7 per cent in this scenario (Table 3.4). The improvement in agricultural practices allows the model farm to produce more output with the same inputs (Table 3.5).

Table 3.4: Change in Profitability and Productivity in 'Improvement in Agricultural Practices' Scenario

Variable/Scenario	Base	Improvement in Agricultural Practices	Change (%)
Gross Margin	63.98	68.45	6.98↑
Productivity Index	1	1.06	6.38↑

Table 3.5: Summary of selected variables, Base versus Alternative Scenarios

Variable	Scenario				
	Base	Fall in Output Price	Wage Rise	Inefficient Farm	Improvement in Ag. Practices
<i>Price</i> ^a	20	15	20	20	20
<i>Output</i> ^b	3.5	3.41	3.45	2.62	3.72
<i>Total Revenue</i> ^b	70	51.19	69.09	52.49	74.45
<i>Labour units hired</i> ^b	0.4	0.3	0.32	0.4	0.4
<i>Wages</i> ^a	10	10	12.5	10	10
<i>Labour Cost</i> ^c	4	3	4	4	4
<i>Materials units used</i> ^b	0.4	0.3	0.4	0.4	0.4
<i>Unit cost of Materials</i> ^a	5	5	5	5	5
<i>Materials Cost</i> ^d	2	1.5	2	2	2
<i>Total Variable Cost</i> ^e	6	4.5	6	6	6
<i>Gross Margin</i> ^f	63.98	46.69	63.09	46.49	68.45
Gross Margin Changes (%)	NA	-27.02	-1.4	-27.34	6.98
Productivity Index	NA	1	1	0.87	1.06
Change in Productivity (%)	NA	0	0	-13.4	6.38

Notes to Table:

^a assumed to be determined external to the farm

^b determined by the farm model

^c Labour units hired multiplied by Wages

^d Material units used multiplied by unit cost of Materials

^e sum of Labour Cost and Materials Cost

^f Total Revenue minus Total Variable Cost

NA not applicable.

4.0 Summary

In this document, we have highlighted the difference between productivity and profitability. Productivity is a measure of the output produced per unit input. ‘Productivity change’ is a measure of the change in this ratio. Profit is a measure of the excess of receipts over costs. Often it is measured as a ratio. For example, profit relative to total assets.

There are many different productivity and profitability measures. Each of these has a particular use. The user needs to ensure that he uses the right statistic for the task at hand.

This report shows that a productivity change, all else constant, will raise profit. By improving productivity, a farm is able to produce the same output using less input, or more output for the same input. If prices remain constant, this will increase profit. Productivity is one of the main drivers of profit and, therefore, the viability of farms.

However, an increase in profits (due, say, to an output price rise) will not improve productivity if all else is constant. For example, if output or input prices change then profit will also change, but productivity will not; prices have no effect on the way a farm transforms inputs into output.

If a farmer re-invests newly acquired profits in new technology, training or expansion, then this may — subsequently — improve productivity. Farmers who finance new investment through retained earnings need to build up their investment funds over some time period. A large gain due to (say) a sudden price rise may provide the farmer with enough funds to bring forward their investment plans, and hence invest in new technology relatively early. However, a farmer always has the option of using retained earnings for other things (a new car, his children’s education, etc.).

The Economics Branch is often interested in productivity measurement and the effect of research on productivity. Research affects the ability of farms to transform inputs into outputs. Therefore, to evaluate research the economist needs to know how it affects the production function, or productivity.

However, economists are not the only ones that are interested in productivity. Research administrators who allocate resources to agricultural R&D can think of the

benefit from their work being derived from improvements in productivity. If research administrators focus on relative productivity gains (and hence benefits) from different research projects, they can better allocate research funds, and hence increase the returns to the community from their investment.

Policy makers that are mindful of the important role that productivity plays in the economy can help ensure the viability of Victoria's agriculture industry. Because prices, and the competitiveness of international competition, do not remain constant, improvements in productivity are needed to ensure that Victorian farms survive. An improvement in an exporting industry's productivity may not improve profits if, for example, international prices fall because overseas competitors are also improving their productivity. Agricultural farms are on a treadmill. Productivity improvements are needed not only to thrive, but in many circumstances to survive.

Appendix: A Technical Explanation of Methodology

A.1 The Model

We use a logarithmic Cobb-Douglas⁸ production function with four inputs. Two are variable and the other two are fixed. We restrict our analysis to how the farm behaves in the short-run. The production function can be written as:

$$Q = \ln A + \alpha \ln L + \beta \ln K + \gamma \ln M + \delta \ln H + \varepsilon \quad (1)$$

Where, Q is output;

A is an exogenous variable representing the human capital of the farmer or the state of technology;

L is the quantity of hired labour units used;

K is the quantity of physical capital units used;

M is the quantity of materials units used;

H is the quantity of land units used;

α , β , γ and δ are the technical coefficients of L , K , M and H respectively; and

ε is a stochastic error term with a mean of zero.

The production function is assumed to have constant returns to scale so α , β , γ and δ sum to one. L and M are assumed to be variable inputs. K and H are assumed to be fixed inputs because of the short-run nature of the analysis. K and H cannot be adjusted in the short-run because we assume it would take more than one period to change and for the effects to become observable.

Now, we turn our attention to the profit function. Profit can be written as:

$$\Pi = PQ - wL - rK - qM - zH \quad (2)$$

Where, Π is profit;

⁸ For more information on the Cobb-Douglas production function see (for example) A.C. Chiang's (1984) *Fundamental Methods of Mathematical Economics*, B.R. Binger and E. Hoffman's (1988) *Microeconomics with Calculus*, M. Wisniewski's (1996) *Introductory Mathematical Methods in Economics* and Coelli et al (1998).

P is the price of output;
 w are wages for hired labour;
 r is the price of physical capital;
 q is the price of materials; and
 z is the price of land.

Substitute (1) into (2) yields the following profit function:

$$\Pi = P(\ln A + \alpha \ln L + \beta \ln K + \gamma \ln M + \delta \ln H) - wL - rK - qM - zH \quad (2')$$

Because we assumed that the farm is a profit-maximiser, the first order partial derivatives for the variable inputs L and M were obtained to determine the optimal quantity of variable input use:

$$\frac{\partial \Pi}{\partial L} = \frac{\alpha P}{L} - w = 0 \quad (3)$$

$$\frac{\partial \Pi}{\partial M} = \frac{\gamma P}{M} - q = 0 \quad (4)$$

Equations (3) and (4) implies that the marginal productivity of labour and materials is equal to wages or the price of materials respectively. Because we assumed that the farmer is profit-maximising, these equations say that the farm will buy labour and materials inputs until their respective marginal product equals their respective marginal costs. Rearranging equations (3) and (4) yields the farm's demand for labour and materials respectively:

$$L = \frac{\alpha P}{w} \quad (3')$$

$$M = \frac{\gamma^P}{q} \quad (4')$$

Equations (3') and (4') state that the farm's demand for labour and materials depends on the price of output, the respective technical coefficients and the respective price of the input. The farm will buy hired labour and materials until the quantity of the respective inputs equals the ratio of the input's share of average gross revenue (or output price) to its marginal cost (or its input price).

The inputs K and H are assumed to have been fixed as explained previously. The farmer, therefore, maximises profit given the initial quantities of K and H . The choice variables are L and M which are selected to produce a level of Q that will maximise equation (2').

A.2 The Productivity Index

A variation of the Fisher index was used to analyse the change in total factor productivity (TFP) from the base to the alternative scenarios. We will take TFP to mean the ratio of the quantity of output to the quantity of inputs.

To construct the Fisher index, the Laspeyres and Paasche indexes need to be constructed. The Laspeyres index calculates TFP assuming that the level of input use in the alternative scenario is the same as in the base. Conversely, the Paasche TFP index assumes that the level of input use in base scenario is same as in the alternative one. This allows us to isolate productivity changes arising from technological progress.

We can write the Laspeyres and Paasche indexes respectively as:

$$TFP^L = \frac{Q^s(L^b, M^b)}{X^b} \div \frac{Q^b(L^b, M^b)}{X^b} = \frac{Q^s(L^b, M^b)}{Q^b(L^b, M^b)} \quad (5)$$

$$TFP^P = \frac{Q^s(L^s, M^s)}{X^s} \div \frac{Q^b(L^s, M^s)}{X^s} = \frac{Q^s(L^s, M^s)}{Q^b(L^s, M^s)} \quad (6)$$

Where, TFP^L and TFP^P are the TFP index for Laspeyres and Paasche respectively;

Q^b and Q^s are the production function for the base and alternative scenario respectively;

(L^b, M^b) and (L^s, M^s) are the variable inputs used in the base and alternative scenario respectively; and

X^b and X^s are the total inputs used in the base and alternative scenario respectively.

We can use equations (5) and (6) to construct a Fisher index of TFP (TFP^F):

$$TFP^F = \sqrt{TFP^L} \times \sqrt{TFP^P} \quad (7)$$

We analyse percentage changes in TFP^F relative to the base for each alternate scenario.

A.3 Profitability

We analyse profitability using gross margin. Gross margin was used rather than economic profit⁹ because of the ease in analysing changes using gross margin. Economic profit equals zero in the base scenario because we assume the farm is producing in equilibrium on the production possibilities frontier. As a result, relative changes of economic profit in the alternative scenarios would be divided by zero.

We use gross margin because we do not have to impose any assumptions on this measure. We know gross margin will never equal zero in this model because we assume that fixed costs are always greater than zero. Furthermore, gross margins are comparable between the base and alternative scenarios because we have assumed that the stock of K and H are the same for every scenario.

Gross margin (GM) can be written in algebra form as follows:

$$GM = TR - wL - qM \quad (8)$$

We analyse changes in gross margin in percentage form.

A.4 The Scenarios

This section will describe how we simulated the base and alternative scenarios. We can divide the scenarios into three groups: the base, price shock scenarios and the production shock scenarios. We will discuss the base scenario first.

A.4.1 The Base Scenario

There are five variables in the production function that are exogenously determined in the production function. Table A1 contains the assumed values we gave each of the exogenous variables in the production function.

⁹ 'Economic profit' is defined as total revenue less variable and fixed costs.

Table A1: Variables and Results from the Model

Variable	Scenario				
	Base	Fall in Output Price	Wage Rise	Inefficient Farm	Improvement in Ag. Practices
α^a	0.2	0.2	0.2	0.2	0.2
β^a	0.5	0.5	0.5	0.5	0.5
γ^a	0.1	0.1	0.1	0.1	0.1
δ^a	0.2	0.2	0.2	0.2	0.2
A^a	10	10	10	10	12.5
L^b	0.4	0.3	0.32	0.4	0.4
K^b	11.35	11.35	11.35	11.35	11.35
M^b	0.4	0.3	0.4	0.4	0.4
H^b	3.61	3.61	3.61	3.61	3.61
<i>Efficiency</i> ^a	1	1	1	0.75	1
Output	3.5	3.41	3.45	2.62	3.72
Profit Function					
P^a	20	15	20	20	20
w^a	10	10	12.5	10	10
r^a	5	5	5	5	5
q^a	5	5	5	5	5
z^a	2	2	2	2	2
Gross Margin	63.98	46.69	63.09	46.49	68.45
Change from Base (%)	NA	-27.02	-1.4	-27.34	6.98
Fisher TFP Index	1	1	1	0.87	1.06
Change from Base (%)	NA	0	0	-13.4	6.38

Notes to Table:

^a exogenous variable

^b endogenous variable

NA not applicable.

These technical coefficients can be viewed as the inputs' technical relationship to output. The variable, A represents the state of technology.

Table A1 also contains the values for the endogenous variables L , K , M and H . The variable inputs L and M were determined using equations (3') and (4'). K and H were determined by solving (2') for $\Pi = 0$ and satisfying the first order conditions (3) and (4).

Table A1 also contains information on the variables of the profit function. All of these variables were exogenously determined. We assumed that the farm is a price taker so prices are given. These values are hypothetical and should be treated as such. Obviously, a change in these variables is likely to change the way the farm allocates resources as described in the model section.

Table A1 contains the initial production level and gross margin for the base scenario. Production is 3.5 units and gross margin is 63.98.

A.4.2 Price Shocks

We ran two price shock scenarios: a 25 per cent fall in output price and a 25 per cent rise in wages. These two scenarios were run to analyse the impact of changes in output and input prices respectively.

The fall in output price was simulated by reducing P from 20 to 15 (table A1). The farm's profitability fell by over 27 per cent. Input use fell in response to lower profitability. The resulting lower output also contributed to the farm's reduced profitability. However, the productivity index did not change because the farm did not change the way it transformed inputs into output.

We simulated the wage rise scenario by increasing w from 10 to 12.5 (table A1). Profitability fell by around 1.4 per cent for the hypothetical farm. This was mainly because of higher wages the farmer had to pay. However, the fall in profitability was relatively low. Recall from equation (3) that the marginal productivity of labour is equal to the wage. By raising the wage, the marginal unit of labour became more productive. The increase in wages here is almost fully offset by the farmer reducing hired labour inputs and higher labour productivity.

The increase in marginal labour productivity does not imply that the farm had a higher TFP index value. Productivity change was zero for this hypothetical farm because the farm did not undertake technical change of its production function.

A.4.3 Production shocks

The remaining two scenarios were shocks to the production function. This meant that the production function was changed in an exogenous fashion.

The first scenario we ran, the inefficient farm was simulated by assuming it was 75 per cent less efficient in transforming inputs into output than the base case (table A1). This meant we simply multiplied the base case production function by 0.75. Equation (1) can be rewritten as:

$$Q \times Efficiency = Efficiency \times (\ln A + \alpha \ln L + \beta \ln K + \gamma \ln M + \delta \ln H) \quad (9)$$

Where, *Efficiency* is the degree to how efficient the farm was. If *Efficiency* was less than 1, then the farm is inefficient.

By simulating inefficiency this way, we are assuming that the farm is not operating on the production possibilities frontier of the base scenario. We effectively imposed the restriction that it uses the same inputs for given output and input prices than the base scenario to produce 75 per cent less output; ie the farm is technically inefficient. This scenario can be seen as a simulation of a farm managed by an inexperienced farmer.

The inefficient farm experienced a decline of profitability of over 27 per cent than the base case. This was from using the same quantity of variable inputs and therefore unchanged costs but from reduced output. Output fell from around 3.5 to approximately 2.6 units. As a result, total revenue fell while variable costs remain the same. The fall in output caused the fall in gross margin.

The TFP index fell by over 13 per cent. Given that we have imposed the restriction that the farm is not producing on the production frontier, this result is the correct one

from a theoretical perspective. The hypothetical farm did not produce at the production frontier and did not achieve the productivity level as in the base case. As Coelli et al (1998) point out, the Cobb-Douglas production function assumes that the farm is producing at the production frontier.

We simulated the next scenario, improvement in agricultural practices, by assuming that A increased from 10 to 12.5. This simulates that technological breakthrough regarding agricultural production has occurred. Thus, the farm moves to a higher production possibilities frontier. This assumes that the farm is moves to the frontier. Again, we impose the condition that the farm uses the same level of inputs for given output and input prices as the base. This causes a change in the production function. Output increases from around 3.5 to over 3.7 whereas variable inputs remained the same.

Gross margins increased by nearly seven per cent. This gain was entirely made up by higher production. Productivity also increased over six per cent. Again, this was entirely made up by increased production. That is, the farm is now able to produce higher output with the same level of inputs. It has shifted to a higher production function.

References

Coelli, T., Rao, D. S. P. and Battese, G. E., 1998, *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers.