Chapter Two

THE DYNAMIC COMPUTER MODELS

2.1 - Introduction

Usually, computer programs for optimization of flock structures only suit the situations in which the populations are established with respect to the ideal proportion of different classes of animals involved. Meanwhile, no annual trend for different aspects of breeding are usually presented by means of a *year-by-year* scheme. Also, for rotational crossings it is assumed that the related populations are at equilibrium, in terms of the established gene frequencies of the breeds in subsequent years of crossing.

In practice, there are many questions confronting the breeder especially about the details of the previous stages of breeding. For instance, what is the age structure of the flocks at the start; how long does it take for the crossbreeding system to get established so as we will have the proposed proportions of animals possessing the corresponding gene frequencies.

Additionally, in case of the rotational crossings, how long does it take for a system to reach an equilibrium for the whole number of the population, not just for a few number of the progeny, yet after a relatively long period of time i.e., 12-14 years.

This can be illustrated another way by saying that, for instance in sheep, due to the 50% ratio of male lambs for each lambing, most of which going out of reproduction cycle, and existence of a generation interval of about 2 years, and also due to keeping ewes in the production systems

for 5-6 years, it takes for rotational crossing systems (e.g., 2-breed rotation), a long time to reach an equilibrium for the whole number of the ewes. It follows that, assuming 1 lamb produced per ewe per year in a flock consisting of 100 ewes, about 60-70 ewes (which have genes from the 100 dams at the start) can be produced within 5 years duration. Accordingly, about 1 or 2 ewes out of this number will have the expected gene proportions from each sire as presented in Table 4, Chapter One. Therefore in practice, rotational crossing systems before equilibrium will have a great deal of details which are not usually outlined through theoretical discussions by the researchers.

Furthermore, how should we start to crossbreed to get the flocks ready for the proposed system and finally, what is the annual trend of the genetic and economic consequences of the proposed crossbreeding system?

In order to answer these questions, it was intended to produce computer models to identify the optimal management of population structure in crossbreeding systems, as well as for the prediction of the economic aspects of such systems in meat sheep for quite a long period of time, e.g. the time at which the rotational crossing systems reach equilibrium. But, due to the software incompatibility and time limitations, the models were developed only for a total of 10 years (from year -1 to year 8), a reasonable period of time in crossbreeding without application of selection.

2.2 - Materials and methods

General information on the models

Eight different optimum design dynamic models for self-contained populations were envisaged, seven of which were investigated to various extents during the research work, by developing the algorithm using Microsoft Excel's Solver software. These models are introduced in Table 8. Due to the software problems for a proper comparison of the four relatively advanced models of this group and the time limitation, two of them were chosen for further improvements and the final conclusions, being introduced later in this chapter. The relevant models are A) a) 1 and B) b) 1.

In the latter, number of the ewes in each flock is allowed to vary from one year to another. The variation in number of the ewes in this model is because of two reasons. The first and the main reason, due to the

changeable number of hoggets as replacements in each year (this phenomenon could exist with a stable ewe replacement rate), and the second, due to the possible use of a smaller number of the surviving ewes from earlier years, by the model in the following year for a particular flock or for all the flocks in special conditions, depending on the input data. Notwithstanding, this is not a main feature of the model. As can be seen in the worked example (DYNCVRBL.XLS in Chapter Three), a full proportion of the surviving ewes has been used.

Table 8. The initial optimum design crossbreeding models for optimization of population structure in self-contained meat sheep crossing systems.

A) No. of ewes stable in all years and flocks		B) No. of ewes may vary whenever necessary	
a) all the ewes survived are used as replacements:	b) a proportion (or all) of the ewes survived may be used as replacements:	a) all the ewes survived are used as replacements:	b) a proportion (or all) of the ewes survived may be used as replacements:
1) Dynamic strategy	1) Dynamic strategy	1) Dynamic strategy	1) Dynamic strategy
2) Static strategy	2) Static strategy	2) Static strategy	2) Static strategy

There are 2 deterministic models called DYNCSTBL.XLS and DYNCVRBL.XLS models, both using a dynamic strategy to identify optimal management of population structure. Also, these models use a so-called *year-by-year* scheme. By means of these models, the breeder can identify the best choice of the available breeds consisting of 2 breeds of sheep to use for crossing, together with the corresponding optimal population structure with the highest profitability possible.

Also, each model may propose either a single terminal crossing, a rotational crossing, or a terminal-rotation crossing system for an optional set of the input parameters given by the breeder. There is also the possibility of recommending no crossing by the models for 2 particular breeds of sheep, when no crossing is as profitable as a purebreeding program.

The flock structures, and most of the important phenotypic, genotypic and economic parameters are presently displayed diagrammatically on the computer screen, for easier handling of the management actions, and for consideration of those breeders who are interested in further information and scientific speculations.

The computer models predict the following:

1) Phenotypic parameters, including the production performances of different traits, most important of which being:

- slaughter weight of the lambs
- body weight of the ewes
- greasy fleece weight
- fibre diameter
- weaning rate
- ewe replacement rate

2) Management parameters i.e.:

- number of the ewes in the flocks
- number and source of the migrant hoggets as replacements
- number of the slaughter lambs
- number of the salvage animals (implicitly)
- number of the losses

3) Genetic parameters including:

- degree of heterozygosity
- breed difference
- gene proportion of the breed (usually) superior in meat production, in the ewes and hoggets
- gene proportion of each breed in the slaughter lambs.

4) The economic consequences for the proposed systems i.e., the cumulative discounted net profit, applying the standard cash-flow discounting method (optional) for each economic year, and other economic details.

To predict the corresponding output data i.e., the genetic, phenotypic and economic parameters, the input data should be given to the models by the breeder. These data include:

- weaning rate of the ewes
- weaning rate of the maidens
- slaughter weight of the lambs
- body weight of the culling ewes
- ewe replacement rate
- greasy fleece weight of the ewes
- greasy fleece weight of the hoggets
- greasy fleece weight of the yearlings

- clean fleece weight : greasy fleece weight ratio (= yield)
- fibre diameter
- ewe mortality
- weaning to hogget mortality
- weaning to slaughter mortality
- costs of husbandry per ewe per year
- costs of feed per ewe per year
- costs of feed and husbandry per slaughter lambs
- costs of feed and husbandry from birth to yearling
- costs of feed and husbandry from yearling to hogget
- costs of marketing per ewe
- costs of wool harvesting and marketing
- price of 1 kilogram of clean wool of 21 microns in diameter
- extra price (negative and/or positive) per 1 kilogram of clean fleece for each micron deviating from 21 microns
- price of purebred replacements for Year -1 and Year 0
- price of purebred ewes for Year -1
- price of ewes per kilogram body weight
- price per kilogram live weight of lambs
- discount factor
- total number of the ewes for commencement of the system, and finally;
- heterosis for the most important traits in the reciprocal crosses.

These input parameters are given to the programs on Sheet 1 for each model.

Because price of wool might not have a linear relationship with fibre diameter as it is the case in Australia, therefore the profit of wool computed in the worked examples will contain reasonable errors. As these models are in the first instance produced for crossbred meat production, therefore, development of special algorithm for rectifying this matter has been beyond the scope of this thesis. This would be worth of consideration in future work.

Functional aspects of the models

The general *year-by-year* scheme presenting the general basis of the crossbreeding models is illustrated in Figure 4. This is a simplified figure of a series of 10 consecutive years of crossbreeding for an enterprise.

A generation interval of 2 years was assumed for the sheep in the models; 19 months for the first mating of the hogget ewes, and 5 months for conception length.

There are 2 breeds of sheep and up to 3 flocks. As a general clue to help accelerate testing crosses of the candidate breeds, breed A should be good in prolificacy and mothering ability, and breed B superior in meat characteristics.

The models are aimed at the maximal cumulative (discounted) net profit in the final year, which correspondingly maximizes the cumulative (discounted) net profit for the previous years.

One of the advantages of these models is that they calculate numbers of the hoggets, ewes and the slaughter lambs for each year based on the phenotypic and genetic make-up of the related flocks, when applying the standard cash-flow discounting (optional) simultaneously. Application of the standard cash-flow discounting could in special circumstances affect the composition of the flocks to a certain degree.

There are predictable numbers of animals, N_1-N_{12}. The N_1-N_5 and N_{10}-N_{12} (the latter for the model with variable numbers of ewes i.e., DYNCVRBL.XLS), form the main elements for optimization of the population's structure. The other numbers and output parameters are affected by their values i.e., numbers N_6-N_9 are determined indirectly, once the numbers N_1-N_5 (and N_{10}-N_{12}) are specified by the models. At this stage, all of the output parameters can be computed. In other words, numbers of the migrant hoggets and those of ewes are central to optimization of the flock structures.

It follows that, numbers of the migrant hoggets and those of ewes are directly specified by adjusting the "Variable"s being part of the equations concerned, both of which shall be introduced later on. The main numbers mentioned above, determine how many of the female lambs should be sold, and how many of them should be raised as the hoggets for replacement purposes in the corresponding flocks in the future.

In prediction of the numbers, there is a set of the fixed elements or formulas in the equations which produce the predictable numbers N_1-N_5 and N_{10}-N_{12} of the animals, as well as a number of the adjustable elements, in the same equations i.e., the adjustable parameters, or "Variable"s. In other words, the aforementioned numbers are directly affected by the relevant Variables which are adjusted to the certain levels by iteratively calculating of all the combinations possible of the Variables, to specify an

optimal population structure by the computer models, in order to result in the maximum profitability of the enterprise. The Variables under title "Adjustable parameters" in each year will be presented in the year-by-year diagrams in the worked examples in Chapter Three. Also, the modeling equations can be considered later in this Chapter.

As an illustrative note, in Year 3, the numbers $N_1 + N_3 = N_6$ of Year 1, and $N_2 + N_4 = N_7$ of the same year. This is because it has been assumed that the first mating of hoggets occurs at 19 months of age, and thus, the replacement hoggets are provided from the flocks 2 years previously.

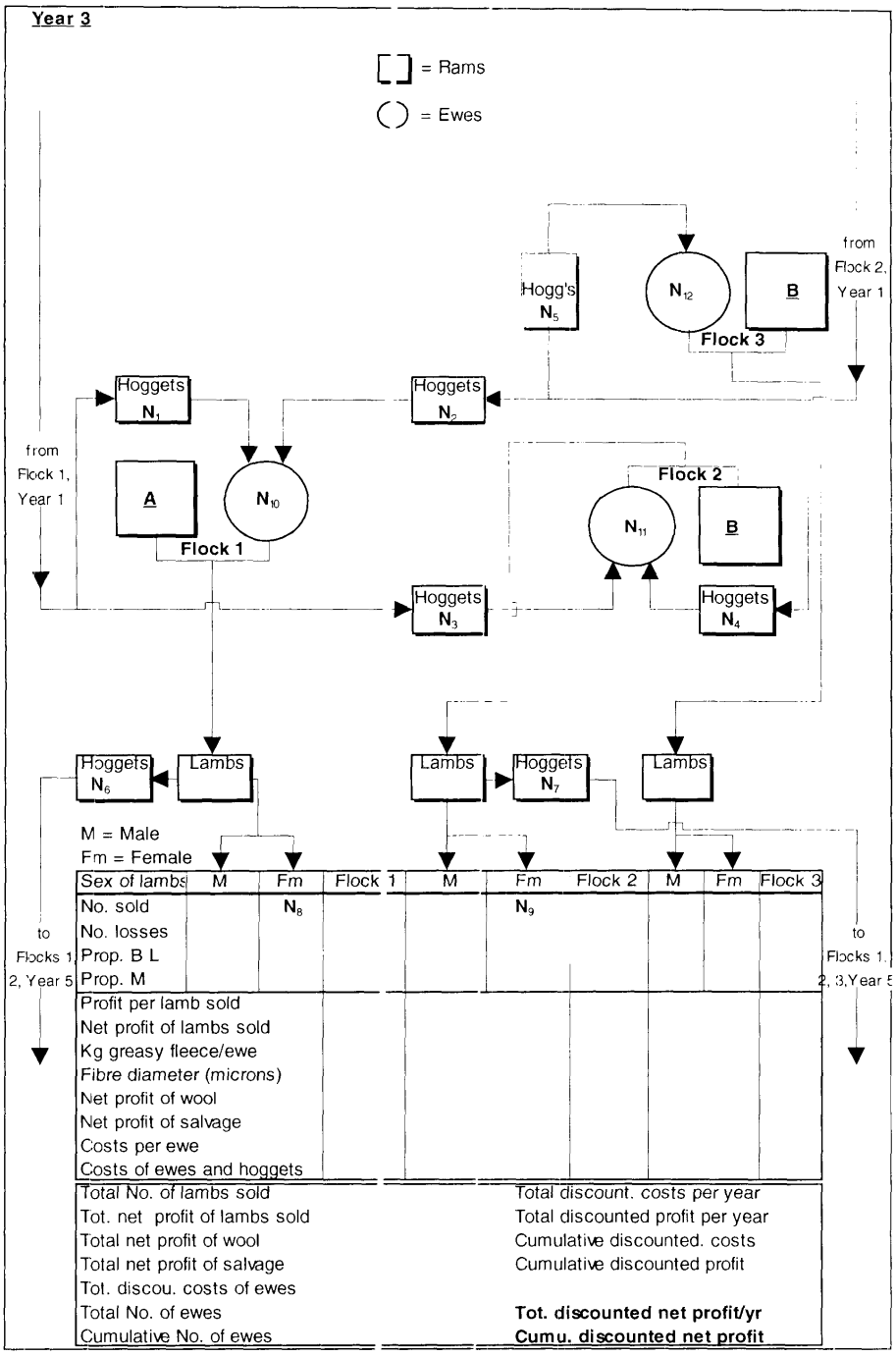

Figure 4, illustrating part of the "year-by-year" scheme and the population's structural elements i.e., the predictable numbers N_1-N_{12} of the migrant hoggets and of the slaughter female lambs and ewes in the flocks, together with most of the output parameters for prediction.

Meanwhile, $N_8 + N_6$ and $N_7 + N_9$ (plus the number of losses) add to the total number of the lambs weaned in the flocks concerned.

If the numbers N_2, N_3 >= 1, and N_5 = 0 $\Rightarrow$ the system is a rotational crossing. When N_2,N_3 >= 1, and N_5 >= 1 $\Rightarrow$ the system is a terminal-rotation crossing. Also, when N_1, N_3 >= 1, and N_2 = 0 $\Rightarrow$ the system is a terminal crossing. The same will be for the situation in which N_2, N_4 >= 1 and N_3 = 0. Some other combinations may be proposed by the models as well.

It must be noted that in any proposed crossing system by these models the replacement hoggets are provided from within the flocks and no hoggets are purchased for this purpose from outside the population.

As can be seen in Figure 4, the models do not account for the product and value of the mature rams, and therefore for simplicity, the related economic aspects are not included in the calculations.

It must be emphasized that it is assumed all the purebred animals being intended for crossbreeding are from populations at equilibrium, and no selections, mutations and unusual changes in the population occur until end of the crossbreeding term.

The very general directions which should be observed for optimization of a population's structure in a year-by-year scheme are as follows:

1) build up the required equations accommodating all of the relationships between the flock structures, the phenotypic and genotypic parameters, and the economic factors.

2) determine numbers of the hoggets as regular replacements required for each flock as well as for the flocks in the following 2 years (because of 2 years generation interval).

3) compute numbers of the surviving ewes allowed to retain in the flocks concerned. If the model has a variable number of ewes, propose additional numbers of the replacement hoggets and/or lessen number of the survivals (ewes) as well as of the migrant hoggets, for the coming year.

4) nominate the relevant flocks in the second last year for providing the trial numbers of the hoggets. Also, in the present year, the flocks from which the proper numbers of hoggets for the following 2 years are supplied, should be suggested.

5) calculate number of the available female progeny as replacements in each flock.

6) recommend some reasonable numbers of hoggets from the candidate flocks for the recipient flocks.

7) continue with computing of the equations having the existing values which are the recommended "Variables" based on the above rules. Then repeat all the previous stages for all combinations possible of the population's structural elements by changing the Variables' values. And finally, select the most profitable structure while considering the economic consequences for a certain time period.

With a proper algorithm and an appropriate set of the initial arbitrary values for the Variables, all of the computations for optimization of the flock structures are performed automatically, while following the above rules. The required equations in relation to the rule 1) above for the program shall be presented later in this chapter. Also, the technical details of the programming can be seen from Answer Report 1 and Answer Report 2 given in the Appendices.

As said earlier, both of the models use a dynamic strategy for optimization of flock structures. It seems to be worth noting that in a variable strategy, the values of Variables can vary from one year to the following year while in a static strategy, the same values are used in the equations concerned for optimization of a population structure every year i.e., the common Variables for different years.

For more details of the functional aspects of the models, see the complementary information or these models in Chapter Three.

Cash-flow discounting

Basically, cash-flow discounting is usually applied where two or more production systems or selection programs are to be compared.

From the economic standpoint, it is clear that there is an inflation rate for any currency which causes a reduction in the value of money in the following years. The reason is that the price of goods, and wages are increased. Subsequently, an additional amount of money is needed to be paid for the same quantity and quality of goods and services in the following year. For instance, if we now pay \$100 to provide forage, and the inflation rate is 10 % in the next year, the amount of \$100 (1 + 10 %) = \$110 is needed to be paid for the same unit of forage, and after 5 years it will be $\$100 \times (1+ 0.1\%)^5 = \$161$.

Similarly, if we have for instance, a profit of $1000 in the next 5 years, the present value of that will be $1000 / (1 + 10 %)^5 = $621. The general formula (Nicholas, 1987) for discount factor is : $(1+ d)^t$ where d is discount rate, and t the unit of time, e.g., year.

Different production programs have different costs and returns in each stage of production and in each economic year. Accordingly, due to the interaction between inflation rate and the comparable costs and returns, a proper comparison of the profitability of say, two production systems becomes a critical task. Therefore, if we are to compare some particular production systems, we have to standardize the corresponding costs and returns for each system. This is done by way of dividing all the related costs and returns by the annual inflation rate at the end of each economic year. Figures 11 and 12, together with Tables 9 and 10 in Chapter Four serve to illustrate this concept more clearly.

As different crossing systems with varying sets of input data can be compared by the models offered in this thesis in different trials, therefore a cash-flow discounting procedure will increase the accuracy of adopting a proper crossing system. In the models concerned all the costs and profit for each year can be converted into the present value of money by incorporation of the standard cash-flow discounting method. This results in the computed cumulative net profit in each year for the models.

Discounting usually delays the break-even point, increases the cost of primary input, and reduces the value of future returns (Kinghorn, 1994).

Preliminary information on the prediction of the flock structures and performance levels

Two of the models which have successfully been tested, will be introduced here. So, preliminary information on due aspects of the models seems to be relevant.

All of the input data as a complex, affect the flock structures and the performance of the following generation of the crossbred animals. Also, as there are many different traits involved in the models, therefore, from the economic standpoint of view, accurate prediction of the aggregate production performances in a population with an optimal structure is of paramount importance. Accordingly, despite some technical limitations while using the software, a tolerance of 0.1% for the output parameters has been allowed for the optimal solutions by the software in these models.

For prediction of the desired parameters and the flock structures, the phenotypic and economic parameters together with the percent expressions of heterosis for the separate reciprocal crosses of the 2 purebred sheep have been used. In cases where the heterosis of some traits are not explicitly mentioned in the literature, they have been derived using the relevant data. In the meantime, the economic aspects shall be discussed later in Chapter Four

It follows that, for prediction of the production performances, the heterosis has been a basic parameter. Recalling from Chapter One, the expression of heterosis is directly dependent on the allelic heterozygosity of the parents in a cross with respect to the breed-of-origin i.e., it is proportional to the breed difference in a cross. Accordingly, the phenotypic parameters have been calculated by adding the extra level of production of the progeny, to the mean performance level of the parents considering the degree of the breed difference and heterosis when crossing. The following equation illustrates this concept:

$$P_{F1} = (M_{P1} + M_{P2}) / 2 (1 + dH) \qquad \text{(equation 8)}$$

where P_{F1} represents the progeny's expected performance, M_{P1} and M_{P2} parental mean performances, d breed difference, and H percent heterosis already obtained in a trial cross using purebred animals.

This will be more clarified in the following by a hypothetical example:

mean performance of breed A = 100 Kg
mean performance of breed B = 80 Kg
heterosis = 0.12
breed difference = 100%

Mean performance of the progeny = (100 + 80) / 2 (1 + 1 x 0.12) = 100.80 Kg.

Here, the heterosis has been fully exploited, because of 100% breed difference due to the full allelic heterozygosity of the breeds.

In the more complicated cases, the performance of the flocks for each trait has been predicted based on the general equation which comes in the following. It has been assumed that there are 2 breeds of sheep being breeds X and breed Y. Also, the replacements for flock 1 are provided from flocks 1 and 2 of the previous year, and are mated to the rams of breed X in flock 1.

Mean performance of a flock for a particular trait =

total proportion of the replacements
x {proportion of the replacements from flock 1 x (mean performance of breed X + (gene proportion of breed X in the flock x performance of breed X + gene proportion of breed Y in the flock x performance of breed Y)) / 2 x (1 + breed difference of the replacements in comparison with the sire breed used in the existing flock x proportion of heterosis resulting from the X x Y cross) + proportion of replacements from flock 2 x (mean performance of breed X + (gene proportion of breed X in the flock x performance of breed X + gene proportion of breed Y in the flock x performance of breed Y)) / 2 x (1 + breed difference of the replacements in comparison with the sire breed used in the existing flock x proportion of heterosis resulting from the X x Y cross)} + proportion of the ewes survived coming from the previous year x performance level of the same ewes.

It must be emphasized that this method of computing the performance levels relates to the progeny traits and the "weaning rate after crossing". For calculating the ewe trait performances, a similar way has been employed with reference to the previous year and the year before that. In other words, for computing the ewe trait performances, the mean product levels of the survivals have been determined using the related data of the ewes in the previous year, and that of the replacements has been derived using their parental performances in the past two years' flocks. A hypothetical example serves to illustrate the above equation more clearly:

proportion of replacements from flock 1 = 0.12
gene proportion of breed X in replacements from flock 1 = 0.40
gene proportion of breed Y in replacements from flock 1 = 0.60

proportion of replacements from flock 2 = 0.82
gene proportion of breed X in replacements from flock 2 = 0.20
gene proportion of breed Y in replacements from flock 2 = 0.80

mean performance level of breed X = 50 kg
mean performance level of breed Y = 45 kg

breed difference (compared with the purebred rams in flock 1) of the replacement hoggets coming from flock 1 = 0.60

breed difference (idem) of the replacement hoggets coming from flock 2 = 0.80

heterosis of the X x Y cross = 0.10

proportion of the total replacements = 10%
proportion of the ewes survived, from the previous year = 90%
performance level of the ewes survived, for a particular trait = 47.5 Kg

Accordingly, the mean performance of the flock is computed as follows:

Mean performance of flock 1 =
0.10 x {0.12 x (50 + (0.40 x 50 + 0.60 x 45)) / 2 x (1 + 0.60 x 0.10) + 0.82 x (50 + (0.20 x 50 + 0.80 x 45)) / 2 x (1 + 0.80 x 0.10)} + 0.90 x 47.5
= 47.617 Kg.

The modeling equations

For prediction of the desired output parameters, development of a comprehensive complex of equations including phenotypic and genotypic parameters as well as the cost and return equations with the standard cash-flow discounting covering almost all of the important economic traits, is deemed to be necessary.

Below are the original equations used in the algorithm for the two models. These include half of the equations incorporated in the algorithm (from Year -1 to end of Year 3). As from Year 4 on, no more changes in any of the equations occur, except for the reference numbers and characters in the equations concerned therefore, they are built up in a manner similar to the first half and are not presented in this manuscript. For the reader's comfort, the cell references for each of the models are given on the related Worksheets. Also, as the Microsoft Excel 5 doesn't accept brackets other than the round ones in the equations in the Formula Bar, therefore, some symmetrical spaces between brackets in some of the equations have been created whenever necessary (e.g., in equation F211) in addition to the descriptions and special arrangements of the equations concerned. In the meantime, those equations which are not described, are either simple ones to follow, or the comparable equations with similar locations on the Worksheets are described somewhere else in the earlier stages. For instance, ewe replacement rate in Year 3 is computed applying same method used in the rest of the Years.

There are two Worksheets used to develop the algorithm for each model. As such, the terms "Sheet1!" and "Sheet2!" are used as parts of the equations for reference. Similarly, the dollar signs "$" are incorporated in the equations just for the technical use. Further, most of the equations are common between the two models, and whenever changes occur, the related equations shall be specifically presented for each model. A final point should be made in relation to the symbols used in the description of the equations. As the worked examples use the data attributed to the Border Leicester and the Merino sheep breeds thus, BL and M stand for the Border Leicester and the Merino, respectively.

Sheet 1:

L55 (total costs of a BL ewe per year) = D34+D33
M55 (total costs of a Merino ewe per year) = E34+E33

Sheet 2:

B31 (No. of the migrant hoggets from Year -1, flock 1 to Year 1) = total no. of replacement ewe hoggets in Year 1, from Year -1, flock 1 = C127+G135

B87 = C182+G190

B142 = C237+G245

B197 = C292+G300

B252 = C347+G355

C28 (degree of heterozygosity of the lambs compared with the pure BL lambs) = proportion of the Merino genes in the ewe population when crossed to the BL rams = 1-F19

C29 (proportion of the BL genes) = average proportion of the BL genes in the paraents = 0.5*(1+F19)

C72:
in the DYNCSTBL.XLS model = F20*E19
in the DYNCVRBL.XLS model = Q73 * F20 * E19

C84 = 1-F75

C85 = 0.5*(1+F75)

C127:

in the DYNCSTBL.XLS model = (1-Q130)*F76*E75

in the DYNCVRBL.XLS model = Q129*0.5*D31

C139 = F130

C140 = 0.5*F130

C182:

in the DYNCSTBL.XLS model = (1-Q183)*F131*E130

in the DYNCVRBL.XLS model = Q184*0.5*D87

C194 = F185

C195 = 0.5*F185

C237:

in the DYNCSTBL.XLS model = (1-Q238)*F186*E185

in the DYNCVRBL.XLS model = Q239*0.5*D142

C249 = F240

C250 = 0.5*F240

D13 = 0

D14 = 0

D15 = 1

D31 (No. of lambs weaned in flock 1, Yea -1) = E19 *(F17
No. of ewes * (mean weaning rate of the M pop.
+Sheet1!$D$5) / 2*(1+ F21 *(F20
+wean. rate of the BL) / 2 * (1 + breed difference * (proportion of maiden ews
*Sheet1!$K$4 + (1-F20) * Sheet1!$K$5))+10^-10!
*"BL*M" heterosis of maiden ewes + prop. of mature ewes * "BL*M" heterosis of mature ewes)).

! This infinitesimal additional data and the like hereinafter are included in some of the equations just for the technical purposes.

D36 (No. of the male lambs sold) = (0.5*D31) *(1-(D38
(No. of the males weaned) * (1 - (prop. of the BL genes
* Sheet1!$D$30 +Sheet2!D39* Sheet1!$E$30))
* the BL mortality rate from wean. to slaught.+ prop. of the M * mortality of the M; wean. to slaughter)).

D38 = C29

D39 = 1-C29

D69 = 0

D70 = 0

D71 = 1

D87 (No. of the lambs weaned in flock 1, Year 0) =
E75*(F73+Sheet1!$D$5)/2*(1+(F77*(F76*Sheet1!$K$4
+(1-F76)*Sheet1!$K$5)))+10^-10

D92 = (0.5*D87)*(1-(D94*Sheet1!$D$30+Sheet2!D95*Sheet1!$E$30))

D94 = C85

D95 = 1-C85

D124 = C28

D125 = C29

D126 = D125

D142 (No. of the lambs weaned, flock 1, Year 1) = E130*F128+10^-10

D147 = (0.5*D142)*(1-(D149*Sheet1!$D$30
+Sheet2!D150*Sheet1!$E$30))

D149 = C140

D150 = 1-C140

D179 = C84

D180 = C85

D181 = D180

D197 = E185*F183+10^-10

D202 = (0.5*D197)*(1-(D204*Sheet1!$D$30
+Sheet2!D205*Sheet1!$E$30))

D204 = C195

D205 = 1-C195

D234 = C139

D235 = C140

D236 = D235

D252 = E240*F238+10^-10

D257 = (0.5*D252)*(1-(D259*Sheet1!$D$30
+Sheet2!D260*Sheet1!$E$30))

D259 = C250

D260 = 1-C250

E19 (No. of ewes in flock 1) = Q20 * Sheet1!D50
Variable 1, Year -1 * Total No. of ewes in Year -1.

E36 (No. of the female lambs sold) = (0.5*D31-B31 - B31 *(D38
(No. of the lambs left after hoggets moved (disregarding losses) - number of losses

*Sheet1!$D$29 + D39 * Sheet1!$E$29))
from weaning to hogget))
*(1-(E38 * Sheet1!$D$30 +Sheet2!E39*Sheet1!$E$30))
* (1 - (proportion of the female lambs deceased from weaning to slaughter)).

E38 = C29

E39 = 1-C29

E75:
in the DYNCSTBL.XLS model = E19*(1-F20)+C72+G72
in the DYNCVRBL.XLS model = Q75*E19*(1-F20)+C72+G72

E92 = ((0.5*D87-B87)-(((B87*(1+(D94*Sheet1!$D$29
+D95*Sheet1!$E$29)))) -B87))
*(1-(E94*Sheet1!$D$30+Sheet2!E95*Sheet1!$E$30))

E94 = C85

E95 = 1-C85

E130:
in the DYNCSTBL.XLS model = E75*(1-F76)+C127+G127
in the DYNCVRBL.XLS model = Q133*E75*(1-F76)+C127+G127

E147 = ((0.5*D142-B142)-(((B142*(1+(D149*Sheet1!$D$29+D150
*Sheet1!$E$29))))-B142))
*(1-(E149*Sheet1!$D$30--Sheet2!E150*Sheet1!$E$30))

E149 = C140

E150 = 1-C140

E185:
in the DYNCSTBL.XLS model = E130*(1-F131)+C182+G182
in the DYNCVRBL.XLS model = Q188*E130*(1-F131)+C182+G182

E202 = ((0.5*D197-B197)-(((B197*(1+(D204*Sheet1!$D$29+D205
*Sheet1!$E$29))))-B197))
*(1-(E204*Sheet1!$D$30--Sheet2!E205*Sheet1!$E$30))

E204 = C195

E205 = 1-C195

E240 :
in the DYNCSTBL.XLS model = E185*(1-F186)+C237+G237
in the DYNCVRBL.XLS model = Q243*E185*(1-F186)+C237+G237

E257 = ((0.5*D252-B252)-(((B252*(1+(D259*Sheet1!$D$29+D260
*Sheet1!$E$29))))-B252))
*(1-(E259*Sheet1!$D$30-Sheet2!E260*Sheet1!$E$30))

E259 = C250

E260 = 1-C250

F17 (average weaning rate of flock 1) = F20 * Sheet1!E4
proportion of hogget ewes * weaning rate of the hoggets
+ (1-F20) * Sheet1!E5
+ proportion of mature M ewes * weaning rate of the ewes.

F18 (proportion of heterozygosity of flock 1) = proportion of BL genes in ewe population
in fllock 1 = F19

F19 = 0

F20 = Sheet1!E15

F21 (breed difference) = proportion of the M genes in the ewe pop. = 1-F19 = 1-0 = 1

.

F36 (No of the lambs sold from flock 1) = D36 + E36
No. of the male lambs sold + No. of the female lambs sold.

F37 (No. of losses of flock 1) = D31- B31 - D36 - E36
Total No. of lambs weaned - No. of hoggets moved - No. of the male lambs sold - No. of the female lambs sold.

F40 (Profit per lamb sold) = (Sheet1!$D$7 +(F19 * Sheet1!$D$7
(slaughter wt of the BL lambs + (prop. of the BL genes*slaughter wt of the BL

+ (1-F19) * Sheet1!$E$7))/2 *(1+ F21 * Sheet1!$K$7)
+ prop. of the M genes * slaughter w t of the M)) / 2 * (1+ breed difference * "M*BL" heterosis)
*(D38 * Sheet1 !$D$9 + D39 * Sheet1!$E$9)
* (prop. of the BL genes * price/kg li e lamb BL+ prop. of the M genes * price/kg M live lamb).

F41 (net profit of lams sold) = F36 * (F40 -(D38 * Sheet1!D37
No. of the lambs sold * (profit/lamb sold - (prop. of the BL genes* the BL lambs' costs to slaughter
+ D39 * Sheet1!E37))
+ prop. of the M genes * costs of the M slaughter lambs)).

F42 = Sheet1!E17

F43 = Sheet1!E25

F44 (net profit of wool) =
(E19-(E19*Sheet1!E28))*(F42 * Sheet1!$E$21*(Sheet1!$H$20
No. of the M ewes * (clean fleece weight * (price/kg
+ (Sheet2!F43- 21) * Sheet1!$HS24)- Sheet1!$E$46)
+ change in value due to diamete change) - costs of harvesting and marketing/ewe)
+ B31 *((Sheet1!D19+Sheet1!E19)/2
+ No. of the female lambs raised as hoggets for Year 1 * c l e a n
*(1+Sheet1!K19)*Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$D$25
f l e e c e w e i g h t *(p r i c e + c h a n g e i n
+Sheet1!$E$25)/2*(1+Sheet1!K25)-21)*Sheet1!$H$24)
v a l u e d u e t o c h a n g e i n d i a m e t e r)
- Sheet1!$E$46)
- costs of marketing/ewe).

F45* (net profit of salvage) = (E19 * F20-(E19*(F19*Sheet1!$D$28+(1- F19)
(No. of the salvage ewes disregardin losses - No. of the ewes
* Sheet1!$E$28))) *(F19*Sheet1!$D$12*Sheet1!D13
deceased in the flock * sale value of
+(1-F19)*Sheet1!$E$12*Sheet1!$E$13 - Sheet1!$E$43)
the cull for age ewe - costs of marketing/ewe).
*
1) No. of the salvage ewes equals No. of the ewes multiplied by the ewe replacement rate less No. of the losses.
2) "Costs of salvage ewes" is not deducted fro n the profit here as the salvage value is considered as a ewe trait like wool production. "Costs of ewes" for producir g lambs, wool and salvage ewes are computed as a single comprehensive component covering all of the ewes cots in ea h economic year.

F46 (costs per ewe) = costs of husbandry + costs of feed = Sheet1!M55 = E34 + E33

F47 (costs of ewes and hoggets) = (E19-
E19*F20)*F46+E19*F20*F46*Sheet1!E6/12
costs of feed and husbandry of the ewes retained for 12 months+ these same costs of the old, cull for age ewes (which are replaced with hogget ewes in the next year) sold after weaning their lambs
+(E19-(E19*F20))* Sheet1!E42 + (E19*F20) *Sheet1!E41
+ No. of mature ewes *price of the mature M ewes + No. of the M hoggets *price of the M hoggets
+ B31 *(C29*Sheet1!D38
+ No. of the female lambs raised as replacements for Year 1 * (costs of feed and husbandry
+(1-C29)*Sheet1!E38)
from birth to yearling) .

F48 (total No. of lambs sold) = F36 + I36

F49 (total net profit of the lambs sold) = sum of the net profit of lambs sold = F41 + I41

F50 (total net profit of wool) = sum of the net profit of wool in the flocks = F44 + I44

F51 (total net profit of salvage) = sum of the net profit of salvage in the flocks = F45 + I45

F52 (total discounted costs of ewes and hoggets) =
(F47 + I47) /Sheet1!$C$48^*I*
total costs of the ewes and hoggets in the 3flocks / discount factor powers to *I*
*
I is an exponent for "Year -1" being the first economic year. In each economic year the aforementioned exponent equals the No. of the years past since the system has commenced.

F53 (total No. of ewes) = sum of the 3 flocks' ewe No.'s = E19 + I20

F54 (cumulative No. of ewes) = F53

F73 (weaning rate of ewes in flock 1) = F76 * Sheet1!E4 + (1-F76) * Sheet1!E5
proportion of the maidens* wean. rate + proportion of mature ewes * wean. rate.

F74 = F75

F75 = 0

F76 = Sheet1!E15

F77 = 1

F92 = D92+E92

F93 = D87-B87-D92-E92

F96 = ((Sheet1!$D$7+(F75*Sheet1!$D$7+(1-F75)*Sheet1!$E$7))/2
*(1+F77*Sheet1!$K$7))*(D94*Sheet1!$D$9+D95*Sheet1!$E$9)

F97 = F92*(F96-(D94*Sheet1!D37+Sheet2!D95*Sheet1!E37))

F98 = Sheet1!E17

F99 = Sheet1!E25

F100 (net profit of wool) =
(E75-(E75*Sheet1!E28))*(F98*Sheet1!$E$21 * (Sheet1!$H$20
No. of ewes * (clean fleece weight * price/kg
+(F99-21) * Sheet1!$H$24)- Sheet1!$E$46)
+ change in value due to change in diameter) - costs of harvesting and marketing)
+ B87 *((Sheet1!D19+Sheet1!E19)/2
+ No. of the female lambs raised for Year 2 * (c l e a n
*(1+Sheet1!K19)*Sheet1!E21*(Sheet1!H20+((Sheet1!D25
+Sheet1!E25)
f l e e c e w e i g h t)*(price/kg + change in value due
/2*(1+Sheet1!K25)-21)*Sheet1!H24) - Sheet1!E46)
to change in diameter) - costs of harvesting and marketing/ewe)
+ B31 *((Sheet1!D18+Sheet1!E18)/2
+ No. of the yearlings from Year -1 raised for Year 1 * (c l e a n
*(1+Sheet1!K18)*Sheet1!E21*(Sheet1!H20+((Sheet1!D25
+Sheet1!E25)
f l e e c e w e i g h t)*(price/kg + change in value due
/2*(1+Sheet1!K25)-21)*Sheet1!H24) - Sheet1!E46)
to change in diameter) - costs of harvesting and marketing/ewe).

F101 =(E75*F76-(E75*(F75*Sheet1!$D$28+(1-F75)*Sheet1!$E$28)))
*(F75*Sheet1!$D$12*Sheet1!D13+(1-F75)*Sheet1!$E$12
*Sheet1!$E$13-Sheet1!$E$43)

F102 = Sheet1!M55

F103 (costs of ewes and hoggets, fock 1, Year 0) =
(E75-E75*F76) * F102 + E75*F76*F102*Sheet1!$E$6/12
(costs of feed and husbandry of the ewes retained for 12 months+ these same costs of the old, cull for age ewes (which are replaced with hogget ewes in the next year) sold after weaning their lambs

+ C72*Sheet1!$E$41+B87*(C85*Sheet1!$D$38
+ osts of replacement hogges + costs of the hoggets raised
+(1-C85)*Sheet1!$E$38)
as replacements for Year 2
+B31*(C29*Sheet1!$D$39 + (1-C29)*Sheet1!$E$39)
+ costs of the hoggets from Year -1 being raised as replacements for Year 1).

F104 =F92+I92

F105 = F97+I97

F106 = F100+I100

F107 = F101+I101

F108 = (F103+I103)/Sheet1!$C$48^2

F109 = E75+I76

F110 = F109+F54

F124 = G28

F125 = G29

F126 = F125

F128 (weaning rate after crossing, flok 1, Year 1) =
(C127+G127)/E130 * (C127/(C127+G127)
proportion of the hoggets * (proportion of the hoggets from flock 1
*(Sheet1!$E$4+(D125*Sheet 1!$D$4+(1- D125)*Sheet1!$E$4))/2
*mean weaning rate of the BL and the hoggets
*(1+D126*Sheet1!$L$4)
* (1 + *amount* of heterosis)
+ G127/(G127+C127) *(Sheet1!$E$4+(F125*Sheet1!$D$4
+ proportion of the hoggets from flock 2 * mean weaning rate of
+(1-F125)*Sheet1!$E$4))/2*(1+F126*Sheet1!$L$4))
the BL and the hoggets * (1 + *amount* of heterosis))
+(E130-C127-G127)/E130 *(Sheet1!$E$5+(F75*Sheet1!$D$5+(1
+ proportion of mature ewes * (mean weaning rate of the
-F75) * Sheet1!$E$5))/2*(1+ F77*Sheet1!$L$5)
BL and the ewes survived, Year 0 * (+ *amount* of heterosis).

F129 =(C127+G127)/E130*(D124*C127/(C127+G127)
+F124*G127/(G127+C127))+(E130-C127-G127)/E130*F74

F130 = (C127+G127)/E130*(D125*C127/(C127+G127)+F125
*G127/(G127+C127))+(E130-C127-G127)/E130*F75

F131 (ewe replacement rate, flock 1, Year 1) =
(C127+G127)/E130* (C127/(C127+G127)
proportion of the hoggets * (proportion of the hoggets from flock 1
*(Sheet1!$D$15+(F19*Sheet1!$D$15+(1- F19)*Sheet1!$E$15))/2
* (mean parental ewe replacement rate
*(1+F21*Sheet1!$K$15)+ G127/(G127+C127)
* (1 + *amount* of heterosis) + proportion of the hoggets from flock 2
*(Sheet1!$D$15+(H20*Sheet1!$D$15+(1- H20)*Sheet1!$E$15))/2
* (mean parental ewe replacement rate
*(1+H22*Sheet1!$K$15))+ (E130-C127-G127) /E130
* (1 + *amount* of heterosis)) + proportion of the mature ewes survived, Year 0
* F76
* ewe replacement rate.

F132 = F130

F147 = D147+E147

F148 = D142-B142-D147-E147

F151 (profit per lamb sold) =
((Sheet1!$E$7+(F130*Sheet1!$D$7+(1-F130)*Sheet1!$E$7))/2
*(1+F132*Sheet1!$L$7))*(D149*Sheet1!$D$9+D150*Sheet1!$E$9)

F152 (net proit of lambs sold, flock 1, Year 1) =
F147*(F151-(D149*Sheet1!D37+Sheet2!D150*Sheet1!E37))

F153 (Kg greasy fleece per ewe, flock 1, Year 1) =
(C127+G127)/E130*(C127/(C127+G127)*(Sheet1!$D$17+(F19
proportion of the hoggets * (proportion of the hog's from flock 1* g r e a s y
*Sheet1!$D$17+(1-F19)*Sheet1!$E$17))/2*(1+F21*Sheet1!$K$17)
f l e e c e w e i g h t
+ G127/(G127+C127) *(Sheet1!SD$17+(H20*Sheet1!$D$17
+ prop. of the hog's from flock 2* g r e a s y

+(1-H20)*Sheet1!$E$17))/2*(1+H22*Sheet1!$K$17))
f l e e c e w e i g h t)
+ (E130-C127-G127)/E130 * F98
+ proportion of the mature ewes survived, Year 0 * greasy fleece weight.

F154 (fibre diameter, flock 1, Year1) =
(C127+G127)/E130* (C127/(C127+G127)
proportion of the hoggets*(proportion of the hoggets fom flock 1
*(Sheet1!$D$25+(F19*Sheet1!$D$25+(1-F19)
* m e a n f i b r e
*Sheet1!$E$25))/2*(1+F2 *Sheet1!$K$25)
d i a m e t e r
+ G127/(G127+C127) *(Sheet1!$D$25+(H20*Sheet1!$D$25
+ proportion of the hoggets from flock 2 * m e a n f i b r e
+(1-H20)*Sheet1!$E$25))/2*(1+H22*Sheet1!$K$25))
d i a m e t e r)
+ (E130-C127-G127)/E130 * F99
+ proportion of the ewes survived, Year 0 * fibre diameter.

F155 (net profit of wool, flock 1, Year 1) =
(E130-(E130*(F130*Sheet1!D28+(1-F130)*Sheet1!E28)))
No. of ewes
*(F153*Sheet1!$E$21*(Sheet1!$H$20
* (clean fleece weight * (price/kg
+(F154-21) * Sheet1 $H$24)- Sheet1!$E$46)
+ change in value due to change in diameter) - costs of harvesting and marketing/ewe)
+ B142 *((Sheet1!E19+(F130*Sheet1!$D$19+(1
+ No. of the female lambs raised for Year 3 * (c l e a n
-F130)*Sheet1!$E$19))/2*(1+F132* Sheet1!$L$19) *Sheet1!$E$21
f l e e c e w e i g h t
*(Sheet1!$H$20+ ((Sheet1!E25+(F130*Sheet1!$D$25+(1-
* (price/kg + change in value
F130)*Sheet1!$E$25))/2*(1+F132*Sheet1!$L$25)-21)*
Sheet1!$H$24)
due to change in diameter)
- Sheet1!$E$46)
- costs of harvesting and marketing/ewe)
+ B87 *(Sheet1!$D$18+Sheet1!$E$18)/2*(1
No. of the yearlings from Year -1 *(c l e a n
+Sheet1!$K$18)*Sheet1!$E$21*(Sheet1!$H$20
f l e e c e w e i g h t * (price/kg
+((Sheet1!$D$25+Sheet1!$E$25)/2*(1+Sheet1!$K$25)- 21)
+ change in value due to change
*Sheet1!$H$24)- Sheet1!$E$46)

in diameter) - costs of harvesting and marketing/ewe).

F156 (net pofit of salvage) =
(E130*F131-(E130*(F130*Sheet1!$D$28+(1-F130)*Sheet1!$E$28)))
(No. of the salvage ewes disregarding losses - No. of the ewes deceased in the flock
(((C127+G127)/E130 (C127/(C127+G127)
* ((proportion of the hoggets * (proportion of the hoggets from flock 1
*(Sheet1!$D$12+(F19*Sheet1!$D$12+(1- F19)*Sheet1!$E$12))/2
*m e a n b o d y
*(1+F21*Sheet1!$K$12)
w e i g h t
+ G127/(G127+C127) *(Sheet1!$D$12+(H20*Sheet1!$D$12
+ proportion of the hoggets from flock 2 * mean
+(1-H20)*Sheet1!$E$12))/2*(1+H22*Sheet1!$K$12))
body weight)
+ (E130-C127-G127)/E130 *(F75*Sheet1!$D$12+(1-F75)
+ proportion of the ewes survived, Year 0 * mean body
*Sheet1!$E$12))*(F130*Sheet1!$D$13+(1-F130)
weight) * price per kilogram body weight of the
*Sheet1!$E$13)- Sheet1!$E$43)
cull for age ewes) - cost of marketing/ewe).

F157 (costs per ewe, flock 1, Year 1) =
(C127+G127)/E130*(C127/(C127+G127) *(Sheet1!$L$55
proportion of the hoggets* (proportion of the hoggets from flock 1* mean
+(F19*Sheet1!$L$55+(1-F19)*Sheet1!$M$55))/2
costs per
*(1+F21*Sheet1!$K$35)+ G127/(G127+C127)
ewe + proportion of the hoggets from flock 2
*(Sheet1!$L$55+(H20*Sheet1!$L$55+(1- H20)*Sheet1!$M$55))/2
*mean costs
*(1+H22*Sheet1!$K$35))+ (E130-C127-G127)/E130 * F102
per ewe) + proportion of the ewes survived, Year 0 * costs/ewe

F158 = (E130-E130*F131)*F157+E130*F131*F157*Sheet1!$E$6/12
+B142*(C140*Sheet1!$D$38+(1-C140)*Sheet1!$E$38)
+B87*(C85*Sheet1!$D$39+(1-C85)*Sheet1!$E$39)

F159 = F147+I147+L147

F160 = F152+I152+L152
F161 = F155+I155+L155

F162 = F156+I156+L156

F163 = (F158+I158+L158)/Sheet1!$C$48^3

F164 = E130+I131+J122

F165 = F164+F110

F179 = G84

F180 = G85

F181 = F180

F183 = (C127+G127)/E130*(C182/(C182+G182)*(Sheet1!$E$4
+(D180*Sheet1!$D$4+(1-D180)*Sheet1!$E$4))/2
*(1+D181*Sheet1!$L$4)+G182/(G182+C182)
*(Sheet1!$E$4+(F180*Sheet1!$D$4+(1-F180)*Sheet1!$E$4))/2
*(1+F181*Sheet1!$L$4))+(E130-C127-G127)/E130*(Sheet1!$E$5
+(F130*Sheet1!$D$5+(1-F130)*Sheet1!$E$5))/2
*(1+F132*Sheet1!$L$5)

F184 =
(C182+G182)/E185*(D179*C182/(C182+G182)+F179*G182/(G182
+C182))+(E185-C182-G182)/E185*F129

F185 = C182+G182)/E185*(D180*C182/(C182+G182)+F180*G182/(G182
+C182))+(E185-C182-G182)/E185*F13

F186=(C182+G182)/E185*(C182/(C182+G182)*(Sheet1!$D$15+(F75
*Sheet1!$D$15+(1-F75)*Sheet1!$E$15))/2*(1+F77*Sheet1!$K$15)
+G182/(G182+C182)*(Sheet1!$D$15+(H76*Sheet1!$D$15
+(1-H76)*Sheet1!$E$15))/2*(1+H78*Sheet1!$K$15))+(E185
-C182-G182)/E185*F131

F187 = F185

F202 = D202+E202

F203 = D197-B197-D202-E202

F206 = ((Sheet1!$E$7+(F185*Sheet1!$D$7+(1- F185)*Sheet1!$E$7))/2
*(1+F187*Sheet1!$L$7))*(D204*Sheet1!$D$9+D205*Sheet1!$E$9)

F207 = F202*(F206-(D204*Sheet1!$D$37+Sheet2!D205*Sheet1!$E$37))

F208 = (C182+G182)/E185*(C182/(C182+G182)*(Sheet1!$D$17
+(F75*Sheet1!$D$17+(1-F75)*Sheet1!$E$17))/2
*(1+F77*Sheet1!$K$17) +G182/(G182+C182)*(Sheet1!$D$17
+(H76*Sheet1!$D$17+(1-H76)*Sheet1!$E$17))/2
*(1+H78*Sheet1!$K$17))+(E185-C182-G182)/E185*F153

F209 = (C182+G182)/E185*(C182/(C182+G182)*(Sheet1!$D$25
+(F75*Sheet1!$D$25+(1-F75)*Sheet1!$E$25))/2
*(1+F77*Sheet1!$K$25)+G182/(G182+C182)*(Sheet1!$D$25
+(H76*Sheet1!$D$25+(1-H76)*Sheet1!$E$25))/2
*(1+H78*Sheet1!$K$25))+(E185-C182-G182)/E185*F154

F210 = (E185-(E185*(F185*Sheet1!$D$28+(1-F185)*Sheet1!$E$28)))
No. of ewes
*(F208*Sheet1!$E$21*(Sheet1!$H$20+(F209 - 21)
* (clean fleece weight * (price/kg + change in value
* Sheet1!$H$24)- Sheet1!$E$46)
due to change in diameter) - costs of harvesting and marketing/ewe)
+ B197 *((Sheet1!$E$19+(F185*Sheet1!$D$19
+ No. of the female lambs raised for Year 4 * (c l e a n
+(1-185)*Sheet1!$E$19))/2*(1+F187*Sheet1!$L$19) *Sheet1!$E$21
f l e e c w e i g h t
*(Sheet1!$H$20+ ((Sheet1!$E$25+(F185*Sheet1!$D$25+(1
* (price per Kg + change in value
-F185)*Sheet1!$E$25))/2*(1+F187*Sheet1!$L$25) -21)
due to change
*Sheet1!$H$24) - Sheet1!$E$46)
in diameter) - costs of harvesting and marketing/ewe)
+ B142 * ((Sheet1!$E$18+(F130
+ No. of the yearlings from Year 0 * (c l e a n
*Sheet1!$D$18+(1-
F130)*Sheet1!$E$18))/2*(1+F132*Sheet1!$L$18)
f l e e c e
*Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$E$25+(F130
*Sheet1!$D$2 5

weight * (price/kg + change in
+(1- F130)*Sheet1!$E$25))/2*(1+F132*Sheet1!$L$25)
value due to change in
-21)*Sheet1!$H$24) - Sheet1!$E$46)
d i a m e t e) - costs of harvesing and marketing /ewe).

F211 = (E185*F186-(E185*(F185*Sheet1!$D$28+(1-
F185)*Sheet1!$E$28)))*((C182+G182)/E185*(
C182/(C182+G182)*(Sheet1!$D$12+(F75*Sheet1!$D$12+(1-
F75)*Sheet1!$E$12))/2
*(1+F77*Sheet1!$K$12)+G182/(G182+C182)
*(Sheet1!$D$12+(H76*Sheet1!$D$12+(1-H76)*Sheet1!$E$12))/2
*(1+H78*Sheet1!$K$12))+(E185-C182-G182)/E185
*(F130*Sheet1!$D$12+(1-F130)*Sheet1!$E$12))
*(F185*Sheet1!$D$13+(1-F185)*Sheet1!$E$13)-Sheet1!$E$43)

F212 = (C182+G182)/E185*(C182/(C182+G182)
*(Sheet1!$L$55+(F75*Sheet1!$L$55+(1-F75)*Sheet1!$M$55))/2
*(1+F77*Sheet1!$K$35)+G182/(G182+C182)
*(Sheet1!$L$55+(H76*Sheet1!$L$55+(1-H76)*Sheet1!$M$55))/2
*(1+H78*Sheet1!$K$35))+(E185-C182-G182)/E185*F157

F213 = (E185-E185*F186)*F2 2+E185*F186*F212*Sheet1!E6/12
+B197*(C195*Sheet1!$D$38+(1-C195)*Sheet1!$E$38)
+B142*(C140*Sheet1!$D$39+(1-C140)*Sheet1!$E$39)

F214 = F202+I202+L202

F215 = F207+I207+L207

F216 = F210+I210+L210

F217 = F211+I211+L211

F218 =(F213+I213+L213)/Sheet1!$C$48^4

F219 = E185+I186+J177

F220 = F219+F165

F234 = G139

F235 = G140

F236 = F235

F238 = (C182+G182)/E185*(C237/(C237+G237)*(Sheet1!$E$4+(D235
*Sheet1! $D$4+(1-D235)*Sheet1!$E$4))/2
*(1+D236*Sheet1!$L$4)+G237/(G237+C237)
*(Sheet1!$E$4+(F235*Sheet1!$D$4+(1-F235)*Sheet1!$E$4))/2
*(1+F236*Sheet1!$L$4))+(E185-C182-G182)/E185
*(Sheet1!$E$5+(F185*Sheet1!$D$5+(1-F185)*Sheet1!$E$5))/2
*(1+F187*Sheet1!$L$5)

F239 =
(C237+G237)/E240*(D234*C237/(C237+G237)+F234*G237/(G237
+C237))+(E240-C237-G237)/E240*F184

F240 =
(C237+G237)/E240*(D235*C237/(C237+G237)+F235*G237/(G237
+C237))+(E240-C237-G237)/E240*F185

F241 (ewe replacement rate, flock 1, Year 3) =
(C237+G237)/E240 *(C237/(C237+G237) * (Sheet1!$E$15
proportion of the hoggets * (proportion of the hoggets from flock 1* ewe
+(F130*Sheet1!$D$15+(1 - F130)*Sheet1!$E$15))/2
replacement
*(1+F132*Sheet1!$L$15)
rate
+ G237/(G237+C237) *(Sheet1!$D$15+(H131*Sheet1!$D$15
+ proportion of the hoggets from flock 2 * ewe
+(1-H131)*Sheet1!$E$15)/2*(1+H133*Sheet1!$K$15))
replacement rate)
+ (E240-C237-G237)/E240 * F186
+ proportion of the ewes survived, Year 2 * ewe replacement rate.

F242 = F240

F257 =D257+E257

F258 = D252-B252-D257-E257

```
F261 = ((Sheet1!$E$7+(F240*Sheet1!$D$7+(1-F240)*Sheet1!$E$7))/2
      *(1+F242*Sheet1!$L$7))*(D259*Sheet1!$D$9+D260*Sheet1!$E$9)

F262 = F257*(F261-(D259*Sheet1!$D$37+Sheet2!D260*Sheet1!$E$37))

F263 = C237+G237)/E240*(C237/(C237+G237)*(Sheet1!$E$17
      +(F130*Sheet1!$D$17+(1-F130)*Sheet1!$E$17))/2
      *(1+F132*Sheet1!$L$17)--G237/(G237+C237)*(Sheet1!$D$17
      +(H131*Sheet1!$D$17+(1-H131)*Sheet1!$E$17))/2
      *(1+H133*Sheet1!$K$17))+(E240-C237-G237)/E240*F208

F264 = (C237+G237)/E240*(C237/(C237+G237)*(Sheet1!$E$25
      +(F130*Sheet1!$D$25+(1-F130)*Sheet1!$E$25))/2
      *(1+F132*Sheet1!$L$25)--G237/(G237+C237)*(Sheet1!$D$25
      +(H131*Sheet1!$D$25+(1-H131)*Sheet1!$E$25))/2
      *(1+H133*Sheet1!$K$25))+(E240-C237-G237)/E240*F209

F265 = (E240-(E240*(F240*Sheet1!$D$28+(1-F240)*Sheet1!$E$28)))
      *(F263*Sheet1!$E$21*(Sheet1!$H$20+(F264-21)
      *Sheet1!$H$24)-Sheet1!$E$46)
      +B252*((Sheet1!$E$19+(F240*Sheet1!$D$19
      +(1-F240)*Sheet1!$E$19))/2*(1+F242*Sheet1!$L$19)
      *Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$E$25+(F240*Sheet1!
      $D$25+(1-F240)*Sheet1!$E$25))/2*(1+F242*Sheet1!$L$25)-21)
      *Sheet1!$H$24)-Sheet1!$E$46)
      +B197*((Sheet1!$E$18 +(F185*Sheet1!$D$18
      +(1-F185)*Sheet1!$E$18))/2*(1+F187*Sheet1!$L$18)
      *Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$E$25
      +(F185*Sheet1!$D$25+(1-F185)*Sheet1!$E$25))/2
      *(1+F187*Sheet1!$L$25)-21)*Sheet1!$H$24)-Sheet1!$E$46)

F266 = (E240*F241-(E240*(F240*Sheet1!$D$28+(1-F240)
      *Sheet1!$E$28)))*( (  (C237+G237)/E240*(    C237/(C237+G237)
      *(Sheet1!$E$12+(F130*Sheet1!$D$12+(1-F130)*Sheet1!$E$12))/2
      *(1+F132*Sheet1!$L$12)+G237/(G237+C237)*(Sheet1!$D$12
      +(H131*Sheet1!$D$12+(1-H131)*Sheet1!$E$12))/2
      *(1+H133*Sheet1!$K$12)      )+(E240-C237-G237)/E240
      *(F185*Sheet1!$D$12+(1-F185) *Sheet1!$E$12)   )
```

*(F240*Sheet1!$D$13+(1-F240)*Sheet1!$E$13)-Sheet1!$E$43)

F267 = (C237+G237)/E240*(C237/(C237+G237)*(Sheet1!$M$55
+(F130*Sheet1!$L$55+(1-F130)*Sheet1!$M$55))/2
*(1+F132*Sheet1!$L$35)--G237/(G237+C237)*(Sheet1!$L$55
+(H131*Sheet1!$L$55+(1-H131)*Sheet1!$M$55))/2
*(1+H133*Sheet1!$K$35))+(E240-C237-G237)/E240*F212

F268 = (E240-E240*F241)*F267+E240*F241*F267*Sheet1!$E$6/12
+B252*(C250*Sheet1!$D$38+(1-C250)*Sheet1!$E$38)
+B197*(C195*Sheet1!$D$39+(1-C195)*Sheet1!$E$39)

F269 = F257+I257+L257

F270 = F262+I262+L262

F271 = F265+I265+L265

F272 = F266+I266+L266

F273 (total discounted costs of ewes, Year 3) =
(F268+I268+L268)/Sheet1!$C$48^(B221+2)
total costs of ewes/ discount factor powers to the No. of the years past.

F274 = E240+I241+J232

F275 = F274+F220

G16 = 0

G24 = 0

G28 = 1-H20

G29 = 0.5*(1+H20)

G31 (No. of lambs weaned in flock 2) = I20 *(H18
No of ewes * (avg. wean. rate of the M ewes in flock 2
+Sheet1!$D$5) / 2 * (1+ H22 * (H21
+ wean. rate of the BL) / 2 * (1 + breed difference * (proportion of maiden hoggets

*Sheet1!$K$4 + (1-Sheet2!H21) *Sheet1!$K$5))+10^-10
* "BL*M" heterosis of maidens + (proportion of mature ewes) * "BL*M" heterosis of mature ewes)).

G36 = (0.5*G31)*(1-(G38*Sheet1!$D$30+Sheet2!G39*Sheet1!$E$30))

G38 = G29

G39 = 1-G29

G72 = 0

G80 = 0

G87 = I76*(H74+Sheet1!$D$5)/2*(1+(H78*(H77*Sheet1!$K$4
+(1-Sheet2!H77)*Sheet1!$K$5)))+10^-10

G94 = G85

G95 = 1-G85

G127:
in the DYNCSTBL.XLS model = Q130*F76*E75
in the DYNCVRBL.XLS model = Q132*(1-Q131)*0.5*G31

G135:
in the DYNCSTBL.XLS model = (1-Q131)*H77*I76
in the DYNCVRBL.XLS model = Q130*(1-Q129)*0.5*D31

G139 = 1-(H131)

G140 = 0.5*(1+H131)

G142 (No. of the lambs weaned, flock 2, Year 1) = I131*H129+10^-10

G147 = (0.5*G142)*(1-
(G149*Sheet1!$D$30+Sheet2!G150*Sheet1!$E$30))

G149 = G140

G150 = 1-G140

G182 :
in the DYNCSTBL.XLS model = Q183*F131*E130
in the DYNCVRBL.XLS model = Q187*(1-Q186)*0.5*G87

G190:
in the DYNCSTBL.XLS model = (1-Q184)*H132*I131
in the DYNCVRBL.XLS model = Q185*(1-Q184)*0.5*D87

G194 = 1-(H186)

G195 = 0.5*(1+H186)

G197 = I186*H184+10^-10

G202 = (0.5*G197)*(1-
(G204*Sheet1!$D$30+Sheet2!G205*Sheet1!$E$30))

G204 = G195

G205 = 1-G195

G237:
in the DYNCSTBL.XLS model = Q238*F186*E185
in the DYNCVRBL.XLS model = Q242*(1-Q241)*0.5*G142

G245:
in the DYNCSTBL.XLS model = (1-Q239)*H187*I186
in the DYNCVRBL.XLS model = Q240*(1-Q239)*0.5*D142

G249 = 1-(H241)

G250 = 0.5*(1+H241)

G252 = I241*H239+10^-10

G257 = (0.5*G252)*(1-(
G259*Sheet1!$D$30+Sheet2!G260*Sheet1!$E$30))

G259 = G250

G260 = 1-G250

H18 = H21*Sheet1!$E$4+(1-H21)*Sheet1!$E$5

H19 =H20

H20 = 0

H21 = Sheet1!E15

H22 = proportion of the M genes in the population = 1-H20 = 1-0 = 1

H31 (No. of the migrant hoggets from Year -1 flock 2 to Year 1) = K135+G127+H123
= total No. of replacements in Year 1 from Year -1, flock 2.

H36 =((0.5*G31-H31)-(((H31*(1+(G38*Sheet1!$D$29
+G39*Sheet1!$E$29))))-H31))*(1-(H38*Sheet1!$D$30
+Sheet2!H39*Sheet1!$E$30))

H38 = G29

H39 =1-G29

H74 = H77*Sheet1!$E$4+(1-H77)*Sheet1!$E$5

H75 = H76

H76 = 0

H77 = Sheet1!E15

H78 = 1

H87 = G182+H178+K190

H92 = ((0.5*G87-H87)-(((H87* (1+(G94*Sheet1!$D$29
+G95*Sheet1!$E$29))))-H 87))
*(1-(H94*Sheet1!$D$30+ Sheet2!H95*Sheet1!$E$30))

H94 = G85

H95 = 1-G85

H129 (weaning rate after crossing, flock 2, Year 1) =
(G135+K135)/I131
(G135/(G135+K135)(Sheet1!$D$4+(H136*Sheet 1!$D$4
+(1-H136)*Sheet1!$E$4))/2*(1+H137*Sheet1!$K$4)
+K135/(K135+G135)*(Sheet1!$D$4+(J136*Sheet1!$D$4
+(1-J136)*Sheet1!$E$4))/2*(1+J137*Sheet1!$K$4))
+(I131-G135-K135)/I131*(Sheet1!$D$5+(H76*Sheet1!$D$5
+(1-H76)*Sheet1!E5))/2*(1+H78*Sheet1!$K$5)

H123 :
in the DYNCSTBL.XLS model = Q129*0.5*G31+10^-10
in the DYNCVRBL.XLS model = Q135*(1-Q132)*(1-
Q131)*0.5*G31+10^-10

H130 = (G135+K135)/I131*(H135*G135/(G135+K135)
+J135*K135/(K135+G135))+(I131-G135-K135)/I131*H75

H131 =(G135+K135)/I131*(H 36*G135/(G135+K135)
+J136*K135/(K135+G135))+(I131-G135-K135)/I131*H76

H132 (ewe replacement rate, flock 2, Yea 1) =
(G135+K135)/I131*(G135/(G135+K135)*(Sheet1!$D$15
+(F19*Sheet 1!$D$15+(1- F19)*Sheet1!$E$15))/2
*(1+F21*Sheet1!$K$15)+K135/(K135+G135)*(Sheet1!$D$15
+(H20*Sheet1!$D$15+(1- H20)*Sheet1!$E$15))/2
*(1+H22*Sheet1!$K$15))+(I131-G135-K135)/I131*H77

H133 = 1-H131

H135 = C28

H136 = C29

H142 = G237+K245+H233

H137 = 1-H136

H147 = ((0.5*G142-H142)-((H142*(1+(G149*Sheet1!$D$29
+G150*Sheet1!$E$29))))-H142))
*(1-(H149*Sheet1!$D$30+Sheet2!H150*Sheet1!$E$30))

H149 = G140

H150 = 1-G140

H178:
in the DYNCSTBL.XLS model = I123*J122
in the DYNCVRBL.XLS model = Q190*(1-Q187)*(1
-Q186)*0.5*G87+10^-10

H184 = (G190+K190)/I186*(G190/(G190+K190)*(Sheet1!$D$4
+(H191*Sheet1!$D$4+(1-H191)*Sheet1!$E$4))/2
*(1+H192*Sheet1!$K$4)+K190/(K190+G190)*(Sheet1!$D$4
+(J191*Sheet1!$D$4+(1-J191)*Sheet1!$E$4))/2
*(1+J192*Sheet1!$K$4))+(I186-G190-K190)/I186*(Sheet1!$D$5
+(H131*Sheet1!$D$5+(1-H131)*Sheet1!E60))/2
*(1+H133*Sheet1!$K$5)

H185 = (G190+K190)/I186*(H190*G190/(G190+K190)+J190
*K190/(K190+G190))+(I186-G190-K190)/I186*H130

H186 = (G190+K190)/I186*(H191*G190/(G190+K190)+J191
*K190/(K190+G190))+(I186-G190-K190)/I186*H131

H187 = (G190+K190)/I186*(G190/(G190+K190)*(Sheet1!$D$15
+(F75*Sheet1!$D$15+(1-F75)*Sheet1!$E$15))/2
*(1+F77*Sheet1!$K$15)+K190/(K190+G190)*(Sheet1!$D$15
+(H76*Sheet1!$D$15+(1-H76)*Sheet1!$E$15))/2
*(1+H78*Sheet1!$K$15))+(I186-G190-K190)/I186*H132

H188 =1-H186

H190 = C84

H191 = C85

H192 = 1-H191

H197 = G292+K300+H288

H202 = ((0.5*G197-H197)-(((H197*(1+(G204*Sheet1!$D$29
+G205*Sheet1!$E$29))))-H197))
*(1-(H204*Sheet1!$D$30+Sheet2!H205*Sheet1!$E$30))

H204 = G195

H205 = 1-G195

H233:
in the DYNCSTBL.XLS model = I178*J177
in the DYNCVRBL.XLS model = Q245*(1-Q242)*(1-Q241)
*0.5*G142+10^- 10

H239 = (G245+K245)/I241*(G245/(G245+K245)*(Sheet1!$D$4
+(H246*Sheet1!$D$4+(1-H246)*Sheet1!$E$4))/2
*(1+H247*Sheet1!$K$4)+K245/(K245+G245)
*(Sheet1!$D$4+(J246*Sheet1!$D$4+(1-J246)*Sheet1!$E$4))/2
*(1+J247*Sheet1!$K$4))+(I241-G245-K245)/I241
*(Sheet1!$D$5+(H186*Sheet1!$D$5+(1-H186)*Sheet1!$E$115))/2
*(1+H188*Sheet1!$K$5)

H240 = (G245+K245)/I241*(H245*G245/(G245+K245)
+J245*K245/(K245+G245))+(I241-G245-K245)/I241*H185

H241 = (G245+K245)/I241*(H246*G245/(G245+K245)
+J246*K245/(K245+G245))+(I241-G245-K245)/I241*H186

H242 = (G245+K245)/I241*(G245/(G245+K245)*(Sheet1!$E$15

```
      +(F130*Sheet1!$D$15+(1-F130)*Sheet1!$E$15))/2
      *(1+F132*Sheet1!$L$15)--K245/(K245+G245)*(Sheet1!$D$15
      +(H131*Sheet1!$D$15+(1-H131)*Sheet1!$E$15))/2
      *(1+H133*Sheet1!$K$15))+(I241-G245-K245)/I241*H187

H243 = 1-H241

H245 = C139

H246 = C140

H247 = 1-H246

H252 = G347+K355+H343

H257 = ((0.5*G252-H252)-(((F252*(1+(G259*Sheet1!$D$29
      +G260*Sheet1!$E$29))))
      -H252))*(1-(H259*Sheet1!$D$30+Sheet2!H260*Sheet1!$E$30))

H259 = G250

H260 = 1-G250

I20 = Q21*Sheet1!D50+10^-1

I36 = G36+H36

I37 = G31-H31-G36-H36

I40 = ((Sheet1!D7+(H20*Sheet1!D7+(1-H20)*Sheet1!E7))/2
      *(1+H22*Sheet1!K7))*(G38*Sheet1!D9+G39*Sheet1!E9)

I41 = I36*(I40-(G38*Sheet1!D37+G39*Sheet1!E37))

I42 = Sheet1!E17

I43 = Sheet1!E25

I44 = (I20-(I20*Sheet1!E28))*(I42*Sheet1!$E$21*(Sheet1!$H$20
```

```
      +(Sheet2!I43-21)*Sheet1!$H$24)-Sheet1!$E$46)
      +H31*((Sheet1!D19+Sheet1!E19)/2*(1+Sheet1!K19)
      *Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$D$25+Sheet1!$E$25)/2
      *(1+Sheet1!K25)-21)*Sheet1!$H$24)-Sheet1!$E$46)

I45 = (I20*H21-(I20*(H20*Sheet1!$D$28+(1-H20)*Sheet1!$E$28)))
      *(H20*Sheet1!$D$12*Sheet1!D13
      +(1-H20)*Sheet1!$E$12*Sheet1!$E$13-1*Sheet1!$E$43)

I46 = Sheet1!M55

I47 = (I20-I20*H21)*I46+I20*H21*I46*Sheet1!E6/12+(I20-(I20*H21))
      *Sheet1!E42+(I20*H21)*Sheet1!E41+H31*(G29*Sheet1!D 38
      +(1-G29)*Sheet1!E38)

I76:
      in the DYNCSTBL.XLS model = I20*(1-H21)+G80+K80
      in the DYNCVRBL.XLS model = Q76*I20*(1-H21)+80 + K80

I92 = G92+H92

I93 = G87-H87-G92-H92

I96 = ((Sheet1!$D$7+(H76*Sheet1!$D$7+(1-H76)*Sheet1!$E$7))/2
      *(1+H78*Sheet1!$K$7))*(G94*Sheet1!$D$9+G95*Sheet1!$E$9)

I97 = I92*(I96-(G94*Sheet1!D37+Sheet2!G95*Sheet1!E37))

I98 = Sheet1!E17

I99 = Sheet1!E25

I100 = (I76-(I76*Sheet1!E28))*(I98*Sheet1!$E$21*(Sheet1!$H$20+(I99
      -21)*Sheet1!$H$24)-Sheet1!$E$46)
      +H87*((Sheet1!D19+Sheet1!E19)/2*(1+Sheet1!K19)*Sheet1!$E$21
      *(Sheet1!$H$20+((Sheet1!$D$25+Sheet1!$E$25)/2*(1+Sheet1!K25)
      -21)*Sheet1!$H$24)-Sheet1!$E$46)
      +H31*((Sheet1!D18+Sheet1!E18)/2*(1+Sheet1!K18)*Sheet1!$E$21
      *(Sheet1!$H$20+((Sheet1!$D$25+Sheet1!$E$25)/2*(1+Sheet1!K25)
```

-21)*Sheet1!$H$24)-Shee 1!$E$46)

I101 = (I76*H77-(I76*(H76*Sheet1!$D$28+(1-H76)*Sheet1!$E$28)))
*(H76*Sheet1!$D$12*Sheet1!D13+(1-H76)*Sheet1!$E$12
*Sheet1!$E$13-Sheet1!$E$43)

I102 = Sheet1!M55

I103 = (I76-I76*H77)*I102+I76*H77*I102*Sheet1!E6/12
+K80*Sheet1!$E$41+H87*(G85*Sheet1!$D$38+(1-G85)
*Sheet1!$E$38)+H31*(G29*Sheet1!$D$39+(1-G29)*Sheet1!$E$39)

I116 = G28

I117 = G29

I118 = 1-I117

I120 = (Sheet1!D4+(I122*Sheet1!D4+(1-I122)*Sheet1!E4))/2
*(1+I124*Sheet1!K4)

I121 = I116

I122 = I117

I123 = (Sheet1!$D$15+(H20*Sheet1!$D$15+(1-H20)*Sheet1!$E$15))/2
*(1+H22*Sheet1!$K$15)

I124 = 1-I122

I131:
in the DYNCSTBL.XLS model = I76*(1-H77)+G135+K135
in the DYNCVRBL.XLS model = Q134*(1-H77)*I76+G135+K135

I147 = G147+H147

I148 = G142-H142-G147-H147

```
I151 = ((Sheet1!$D$7+(H131*Sheet1!$D$7+(1-H131)*Sheet1!$E$7))/2
     *(1+H133*Sheet1!$K$7))*(G149*Sheet1!$D$9+G150*Sheet1!$E$9)

I152 = I147*(I151-(G149*Sheet1!D37+Sheet2!G150*Sheet1!E37))

I153 = (G135+K135)/I131*(G135/(G135+K135)*(Sheet1!$D$17+(F19
     *Sheet1!$D$17+(1- F19)*Sheet1!$E$17))/2*(1+F21*Sheet1!$K$17)
     +K135/(K135+G135)*(Sheet1!$D$17+(H20*Sheet1!$D$17
     +(1-H20)*Sheet1!$E$17))/2*(1+H22*Sheet1!$K$17))+(I131-G135
     -K135)/I131*I98


I154 = (G135+K135)/I131*(G135/(G135+K135)*(Sheet1!$D$25
     +(F19*Sheet1!$D$25+(1- F19)*Sheet1!$E$25))/2
     *(1+F21*Sheet1!$K$25)+K135/(K135+G135)
     *(Sheet1!$D$25+(H20*Sheet1!$D$25+(1- H20)*Sheet1!$E$25))/2
     *(1+H22*Sheet1!$K$25))+(I131-G135-K135)/I131*I99

I155 = (I131-(I131*(H131*Sheet1!D28+(1-H131)*Sheet1!E28)))
     *(I153*Sheet1!$E$21*(Sheet1!$H$20+(I154-21)*Sheet1!$H$24)
     -Sheet1!$E$46)
     +H142*((Sheet1!D19+(H131*Sheet1!D19+(1-H131)
     *Sheet1!E19))/2*(1+H133*Sheet1!K19)*Sheet1!$E$21*(Sheet1!
     $H$20+ ((Sheet1!D25+(H131*Sheet1!D25+(1-H131)
     *Sheet1!E25))/2*(1+H133*Sheet1!K25)-21)*Sheet1!H24)
     -Sheet1!$E$46)
     +H87*((Sheet1!D18+Sheet1!E18)/2*(1+Sheet1!K18)*Sheet1!$E$21
     *(Sheet1!$H$20+((Sheet1!$D$25+Sheet1!$E$25)/2*(1+Sheet1!K25)
     -21)*Sheet1!$H$24)-Sheet1!$E$46)

I156 = (I131*H132-(I131*(H131*Sheet1!$D$28+(1-
     H131)*Sheet1!$E$28)))*( (   (G135+K135)/I131
     *(     G135/(G135+K135)*(Sheet1!$D$12+(F19*Sheet1!$D$12
     +(1- F19)*Sheet1!$E$12))/2
     *(1+F21*Sheet1!$K$12)+K135/(K135+G135)
     *(Sheet1!$D$12+(H20*Sheet1!$D$12+(1-H20)*Sheet1!$E$12))/2
     *(1+H22*Sheet1!$K$12)     )+(I131-G135-K135)/I131
     *(H76*Sheet1!$D$12+(1-H76)*Sheet1!$E$12)   )
     *(H131*Sheet1!$D$13+(1-H131)*Sheet1!$E$13)-Sheet1!$E$43 )
```

I157 = (G135+K135)/I131*(G135/(G135+K135)*(Sheet1!$L$55
+(F19*Sheet1!$L$55+(1- F19)*Sheet1!$M$55))/2
*(1+F21*Sheet1!$K$35)+K135/(K135+G135)
*(Sheet1!$L$55+(H20*Sheet1!$L$55+(1-H20)*Sheet1!$M$55))/2
*(1+H22*Sheet1!$K$35))+(I131-G135-K135)/I131*I102

I158 = (I131-I131*H132)*I157+I131*H132*I157*Sheet1!$E$6/12
+H142*(G140*Sheet1!$D$38+(1-G140)*Sheet1!$E$38)
+H87*(G85*Sheet1!$D$39+(1-G85)*Sheet1!$E$39)

I171= G84

I172 = G85

I173 = 1-I172

I175 = (Sheet1!$D$4+(I177*Sheet1!$D$4+(1-I177)
*Sheet1!$E$4))/2*(1+I179*Sheet1!$K$4)

I176 = (H178/J177)*I171+(J177-H178)/J177*I121

I177 = (H178/J177)*I172+(J177-H178)/J177*I122

I178 =(H178/J177)*(Sheet1!$D$15+(H76*Sheet1!$D$15
+(1-H76)*Sheet1!$E$15))/2*(1+H78*Sheet1!$K$15)
+(J177-H178)/J177*I123

I179 = 1-I177

I186:
in the DYNCSTBL.XLS model = I131*(1-H132)+G190+K190
in the DYNCVRBL.XLS model = Q189*(1-H132)*I131+G190+K190

I202 = G202+H202

I203 = G197-H197-G202-H202

```
I206 = ((Sheet1!$D$7+(H186*Sheet1!$D$7+(1-H186)*Sheet1!$E$7))/2
      *(1+H188*Sheet1!$K$7))*(G204*Sheet1!$D$9+G205*Sheet1!$E$9)

I207 = I202*(I206-(G204*Sheet1!$D$37+Sheet2!G205*Sheet1!$E$37))

I208 =(G190+K190)/I186*(G190/(G190+K190)*(Sheet1!$D$17
      +(F75*Sheet1!$D$17+(1-F75)*Sheet1!$E$17))/2
      *(1+F77*Sheet1!$K$17)+K190/(K190+G190)
      *(Sheet1!$D$17+(H76*Sheet1!$D$17+(1-H76)*Sheet1!$E$17))/2
      *(1+H78*Sheet1!$K$17))+(I186-G190-K190)/I186*I153

I209 = (G190+K190)/I186*(G190/(G190+K190)
      *(Sheet1!$D$25+(F75*Sheet1!$D$25+(1-F75)*Sheet1!$E$25))/2
      *(1+F77*Sheet1!$K$25)+K190/(K190+G190)
      *(Sheet1!$D$25+(H76*Sheet1!$D$25+(1-H76)*Sheet1!$E$25))/2
      *(1+H78*Sheet1!$K$25))+(I186-G190-K190)/I186*I154

I210 = (I186-(I186*(H186*Sheet1!$D$28+(1-H186)*Sheet1!$E$28)))
      *(I208*Sheet1!$E$21*(Sheet1!$H$20+(I209-21)*Sheet1!$H$24)
      -Sheet1!$E$46)
      +H197*((Sheet1!$D$19+(H186*Sheet1!$D$19+(1-H186)
      *Sheet1!$E$19))/2*(1+H188*Sheet1!$K$19)*Sheet1!$E$21
      *(Sheet1!$H$20+ ((Sheet1!$D$25+(H186*Sheet1!$D$25+(1-H186)
      *Sheet1!$E$25))/2*(1+H188*Sheet1!$K$25)-21)*Sheet1!$H$24)
      -Sheet1!$E$46)
      +H142*((Sheet1!$D$18+(H131*Sheet1!$D$18+(1-H131)
      *Sheet1!$E$18))/2*(1+H133*Sheet1!$K$18)*Sheet1!$E$21
      *(Sheet1!$H$20+((Sheet1!$D$25+(H131*Sheet1!$D$25
      +(1-H131)*Sheet1!$E$25))/2*(1+H133*Sheet1!$K$25)
      -21)*Sheet1!$H$24)-Sheet1!$E$46)

I211 = (I186*H187-(I186*(H186*Sheet1!$D$28+(1-
      H186)*Sheet1!$E$28)))*( (   (G190+K190)/I186
      *(     G190/(G190+K190))*(Sheet1!$D$12
      +(F75*Sheet1!$D$12+(1-F75)*Sheet1!$E$12))/2
      *(1+F77*Sheet1!$K$12)+K190/(K190+G190)*(Sheet1!$D$12
      +(H76*Sheet1!$D$12+(1-H76)*Sheet1!$E$12))/2
      *(1+H78*Sheet1!$K$12)     )+(I186-G190-K190)/I186*(H131
```

*Sheet1!$D$12+(1-H131)*Sheet1!$E$12))*(H186*Sheet1!$D$13
+(1-H186)*Sheet1!$E$13)-Sheet1!$E$43)

I212 = (G190+K190)/I186*(G190/(G190+K190)*(Sheet1!$L$55
+(F75*Sheet1!$L$55+(1-F75)*Sheet1!$M$55))/2
*(1+F77*Sheet1!$K$35)+K190/(K190+G190)*(Sheet1!$L$55
+(H76*Sheet1!$L$55+(1-H76)*Sheet1!$M$55))/2
*(1+H78*Sheet1!$K$35))+(I186-G190-K190)/I186*I157

I213 = (I186-I186*H187)*I212+I186*H187*I212*Sheet1!E6/12
+H197*(G195*Sheet1!$D$38+(1-G195)*Sheet1!$E$38)
+H142*(G140*Sheet1!$D$39+(1-G140)*Sheet1!$E$39)

I226 = G139

I227 = G140

I228 = 1-I227

I230 = (Sheet1!$D$4+(I232*Sheet1!$D$4
+(1-I232)*Sheet1!$E$4))/2*(1+I234*Sheet1!$K$4)

I231 = (H233/J232)*I226+((J232-H233)/J232)*I176

I232 = (H233/J232)*I227+((J232-H233)/J232)*I177

I233 = (H233/J232)*(Sheet1!$D$15+(H131*Sheet1!$D$15
+(1-H131)*Sheet1!$E$15)/2*(1+H133*Sheet1!$K$15)
+(J232-H233)/J232*I178

I234 = 1-I232

I241:
in the DYNCSTBL.XLS model = I186*(1-H187)+G245+K245
in the DYNCVRBL.XLS model = Q244*(1-H187)*I186+G245+K245

I257 = G257+H257

I258 = G252-H252-G257-H257

```
I261 = ((Sheet1!$D$7+(H241*Sheet1!$D$7+(1-H241)*Sheet1!$E$7))/2
     *(1+H243*Sheet1!$K$7))*(G259*Sheet1!$D$9+G260*Sheet1!$E$9)

I262 = I257*(I261-(G259*Sheet1!$D$37+Sheet2!G260*Sheet1!$E$37))

I263 = (G245+K245)/I241*(G245/(G245+K245)*(Sheet1!$E$17
     +(F130*Sheet1!$D$17+(1-F130)*Sheet1!$E$17))/2
     *(1+F132*Sheet1!$L$17)--K245/(K245+G245)*(Sheet1!$D$17
     +(H131*Sheet1!$D$17+(1-H131)*Sheet1!$E$17))/2
     *(1+H133*Sheet1!$K$17))+(I241-G245-K245)/I241*I208

I264 = (G245+K245)/I241*(G245/(G245+K245)*(Sheet1!$E$25
     +(F130*She et1!$D$25+(1-F130)*Sheet1!$E$25))/2
     *(1+F132*Sheet1!$L$25)--K245/(K245+G245)*(Sheet1!$D$25
     +(H131*Sheet1!$D$25+(1-H131)*Sheet1!$E$25))/2
     *(1+H133*Sheet1!$K$25))+(I241-G245-K245)/I241*I209

I265 = (I241-(I241*(H241*She et1!$D$28+(1-H241)*Sheet1!$E$28)))
     *(I263*Sheet1!$E$21*(Sheet1!$H$20+(I264-21)*Sheet1!$H$24)
     -Sheet1!$E$46)
     +H252*((Sheet1!$D$19+(H241*Sheet1!$D$19
     +(1-H241)*Sheet1!$E$19))/2*(1+H243*Sheet1!$K$19)
     *Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$D$25
     +(H241*Sheet1!$D$25 +(1-H241)*Sheet1!$E$25))/2
     *(1+H243*Sheet1!$K$25)-21)*Sheet1!$H$24)-Sheet1!$E$46)
     +H197*((Sheet1!$D$18+(H186*Sheet1!$D$18
     +(1-H186)*Sheet1!$E$18))/2*(1+H188*Sheet1!$K$18)
     *Sheet1!$E$21*(Sheet1!$H$20+((Sheet1!$D$25
     +(H186*Sheet1!$D$25+(1-H186)*Sheet1!$E$25))/2
     *(1+H188*Sheet1!$K$25)-21)*Sheet1!$H$24)-Sheet1!$E$46)

I266 = (I241*H242-(I241*(H241*Sheet1!$D$28+(1-
     H241)*Sheet1!$E$28)))*( (  (G245+K245)/I241
     *(  G245/(G245+K245)*(Sheet1!$E$12  +(F130*Sheet1!$D$12+(1-
     F130)*Sheet1!$E$12))/2
     *(1+F132*Sheet1!$L$12)--K245/(K245+G245)*(Sheet1!$D$12
     +(H131*Sheet1!$D$12+(1-H131)*Sheet1!$E$12))/2
     *(1+H133*Sheet1!$K$12)  )+(I241-G245-K245)/I241
```

```
      *(H186*Sheet1!$D$12+(1-H186)*Sheet1!$E$12)  )*(H241
      *Sheet1!$D$13+(1-H241)*Sheet1!$E$13)-Sheet1!$E$43 )

I267 = (G245+K245)/I241*( G245/(G245+K245)*(Sheet1!$M$55
      +(F130*Sheet1!$L$55+(1-F130)*Sheet1!$M$55))/2
      *(1+F132*Sheet1!$L$35)+K245/(K245+G245)*(Sheet1!$L$55
      +(H131*Sheet1!$L$55+(1-H131)*Sheet1!$M$55))/2
      *(1+H133*Sheet1!$K$35)  )+(I241-G245-K245)/I241*I212

I268 = (I241-I241*H242)*I267+I241*H242*I267*Sheet1!$E$6/12
      +H252*(G250*Sheet1!$D$38+(1-G250)*Sheet1!$E$38)
      +H197*(G195*Sheet1!$D$39+(1-G195)*Sheet1!$E$39)

J24 = 0

J25 = 0

J26 = 1

J80 = 0

J81 = 0

J82 = 1

J122 = H123

J135 = G28

J136 = G29

J137 = 1-J136J142 = J122*I120

J147 = (0.5*J142)*(1-(J149*Sheet1!$D$30+Sheet2!J150*Sheet1!$E$30))

J149 = (1+I122)/2

J150 = 1-J149
```

J177:
in the DYNCSTBL.XLS model = (1-I123)*J122+H178+10^-10
in the DYNCVRBL.XLS model = Q183*(1-I123)*J122+H178

J190 = G84

J191 = G85

J192 = 1-J191

J197 = J177*I175

J202 = (0.5*J197)*(1-(J204*Sheet1!$D$30+Sheet2!J205*Sheet1!$E$30))

J204 = (1+I177)/2

J205 = 1-J204

J232:
in the DYNCSTBL.XLS model = (1-I178)*J177+H233+10^-10
in the DYNCVRBL.XLS model = Q238*(1-I178)*J177+H233

J245 = G139

J246 = G140

J247 = 1-J246

J252 = J232*I230

J257 = (0.5*J252)*(1-(J259*Sheet1!$D$30+Sheet2!J260*Sheet1!$E$30))

J259 = (1+I232)/2

J260 = 1-J259

K80:
in the DYNCSTBL.XLS model = H21*I20
in the DYNCVRBL.XLS model = Q74*H21*I20

K135:
in the DYNCSTBL.XLS model = Q131*H77*I76
in the DYNCVRBL.XLS model = Q131*0.5*G31

K147 = (0.5*J142)*(1-
(K149*Sheet1!$D$30+Sheet2!K150*Sheet1!$E$30))

K149 = (1+I122)/2

K150 = 1-K149

K190:
in the DYNCSTBL.XLS model = Q184*H132*I131
in the DYNCVRBL.XLS model = Q186*0.5*G87

K202 = (0.5*J197)*(1-
(K204*Sheet1!$D$30+Sheet2!K205*Sheet1!$E$30))

K204 = (1+I177)/2

K205 = 1-K204

K245:
in the DYNCSTBL.XLS model = Q239*H187*I186
in the DYNCVRBL.XLS model = Q241*0.5*G142

K257 = (0.5*J252)*(1-
(K259*Sheet1!$D$30+Sheet2!K260*Sheet1!$E$30))

K259 = (1+I232)/2

K260 = 1-K259

L48 (total discounted costs per year) = (to al discounted profit/yr - total net discounted profit/yr) =
L49 - L53

L49 (total discounted profit per year) = (F49+F50+F51) / Sheet1!$C$48^1
(total net profit of lambs sold, of wool and of salvage) / discount factor powers to 1

L50 (cumulative discounted costs) = total discounted costs per year + total discounted costs of the previous years = L48 + 0

L51 (cumulative discounted profit) = (total discounted profit per year + total discounted profit of the previous years = L49 + 0

L53 (total net discounted profit per year) = total discounted profit per year - total disounted costs of ewes and hoggets = (L49 - F52)

L54 (cumulative net discounted profit) = cumulative discounted profit - cumulative discounted costs = L51-L50

L104 = L105-L109

L105 = (F105+F106+F107)/Sheet1!$C$48^2

L106 = L104+L50

L107 = L105+L51

L109 = (L105-F108)

L110 = L107-L106

L147 = J147+K147

L148 = J142-J147-K147

L151 (profit per lamb sold, flock 3, Year) =
(sheet1!$D$7+(I122*Sheet1!$D$7+(1-I122)*Sheet1!$E$7))/2
*(1+I124*Sheet1!$K$7)*(J149*Sheet1!$D$9+J150*Sheet1!$E$9)

L152 (net profit of lambs sold, flock 3, Year 1) =
L147*(L151-(J149*Sheet1!$DS37+J150*Sheet1!$E$37))

L153 (kg greasy fleece/ewe, flock 3, Year 1) =
H123 / J122 *(Sheet1!$D$17+(H20*Sheet1!$D$17
proportion of the hoggets *(m e a n

+(1-H20)*Sheet1!$E$17))/2*(1+H22*Sheet1!$K$17)
greasy fleece weight
+ (J122-H123)/J122 * L98
+ proportion of the ewes survived, Year 0 * greasy fleece weight.

L154 (fibre diameter, flock 3, Year 1) =
H123 / J122 *(Sheet1!$D$25+(H20*Sheet1!$D$25
proportion of the hoggets * (mean
+(1- H20)*Sheet1!$E$25))/2*(1+H22*Sheet1!$K$25)
fibre diameter)
+ (J122-H123)/J122 * L99
+ proportion of the ewes survived, Year 0 * mean fibre diameter.

L155 (net profitof wool, flock 3, Year 1) =
(J122-(J122*(I122*Sheet1!D28+(1-I122)*Sheet1!E28)))
No. of the ewes
*((L153*Sheet1!$E$21) *(Sheet1!$H$20+(L154-21)
* (clean fleece weight* price/kg + change in value
*Sheet1! $H$24)- Sheet1!$E$46)
due to change in diameter) - costs of harvesting and marketing/ewe).

L156 (net profit of salvage, flock 3, Year 1) =
(J122*I123-(J122*(I122*Sheet1!$D$28+(1-I122)*Sheet1!$E$28)))
No. of the cull for age ewes
*((Sheet1!$D$12+(H20*Sheet1!$D$12+(1-H20)
* (body weight of the cull
*Sheet1!$E$12))/2*(1+H22*Sheet1!$K$12)*(I122*Sheet1!$D$13
for age ewes * price per kilogram
+(1-I122)*Sheet1!$E$13) - Sheet1!$E$43)
body weight - cost of marketing /ewe).

L157 (costs per ewe) =
H123 / J122 * (Sheet1!$L$55+(H20*Sheet1!$L$55
proportion of the ewe hoggets* total costs
+(1-H20)*Sheet1!$M$55))/2*(1+H22*Sheet1!$K$35)
per ewe
+(J122-H123) / J122 * L102
+ proportion of the ewes survived, Year 0 * costs per ewe.

L158 = (J122-J122*I123)*L157+J122*I123*L157*Sheet1!$E$6/12

L159 = L160-L164

L160 = (F160+F161+F162)/Sheet1!$C$48^3

L161 = L159+L106

L162 = L160+L107

L164 = L160-F163

L165 = L162-L161

L202 = J202+K202

L203 = J197-J202-K202

L206 = (Sheet1!$D$7+(I177*Sheet1!$D$7+(1-177)*Sheet1!$E$7))/2
*(1+I179*Sheet1!$K$7)*(J204*Sheet1!$D$9+J20*Sheet1!$E$9)

L207 = L202*(L206-(J204*Sheet1!$D$37+J205*Sheet1!$E$37))

L208 = H178/J177*(Sheet1!$D$17+(H76*Sheet1!$D$17+(1-H76)
*Sheet1!$E$17))/2*(1+H78*Sheet1!$K$17)+(J177-H178)/J177*L153

L209 = H178/J177*(Sheet1!$D$25+(H76*Sheet1!$D$25+(1-H76)
*Sheet1!$E$25))/2*(1+H78*Sheet1!$K$25)+(J177-H178)/J177*L154

L210 = (J177-(J177*(I177*Sheet1!$D$28+(1-I177)*Sheet1!$E$28)))
*((L208*Sheet1!$E$21)*(Sheet1!$H$20+(L209-21)
*Sheet1!$H$24)-Sheet1!$E$46)

L211= (J177*I178-(J177*(I177*Sheet1!$D$28+(1-I177)*Sheet1!$E$28)))
((H178/J177(Sheet1!$D$12+(H76*Sheet1!$D$12+(1-H76)
*Sheet1!$E$12))/2*(1+H78*Sheet1!$K$12)
+(J177-H178)/J177*(I177*Sheet1!$D$12+(1-I177)*Sheet1!$E$12))
*(I177*Sheet1!$D$13+(1-I177)*Sheet1!$E$13)-Sheet1!$E$43)

L212 = H178/J177*(Sheet1!$L$55+(H76*Sheet1!$L$55+(1-H76)
*Sheet1!$M$55))/2*(1+H78*Sheet1!$K$35)+(J177-H178)/J177*L157

L213 = (J177-J177*I178)*L212+J177*I178*L212*Sheet1!E6/12

```
L214 = L215-L219

L215 = (F215+F216+F217)/Sheet1!$C$48^4

L216 = L214+L161

L217 = L215+L162

L219 = L215-F218

L220 = L217-L216

L257 = J257+K257

L258 = J252-J257-K257

L261 = (Sheet1!$D$7+(I232*Sheet1!$D$7+(1-I232)*Sheet1!$E$7))/2
      *(1+I234*Sheet1!$K$7)*(J259*Sheet1!$D$9+J260*Sheet1!$E$9)

L262 = L257*(L261-(J259*Sheet1!$D$37+J260*Sheet1!$E$37))

L263 = H233/J232*(Sheet1!$D$17+(H131*Sheet1!$D$17
      +(1-H131)*Sheet1!$E$17 )/2*(1+H133*Sheet1!$K$17)
      +(J232-H233)/J232*L208

L264 = H233/J232*(Sheet1!$D$25+(H131*Sheet1!$D$25
      +(1-H131)*Sheet1!$E$25 )/2*(1+H133*Sheet1!$K$25)
      +(J232-H233)/J232*L209

L265 = (J232-(J232*(I232*Sheet1!$D$28+(1-I232)*Sheet1!$E$28)))
      *((L263*Sheet1!$E$21)*(Sheet1!$H$20+(L264-21)
      *Sheet1!$H$24)-Sheet1!$E$46)

L266 = (J232*I233-(J232*(I232*Sheet1!$D$28+(1-I232)*Sheet1!$E$28)))
      *((H233/J232*(Sheet1!$D$12+(H131*Sheet1!$D$12
      +(1-H131)*Sheet1!$E$12 )/2*(1+H133*Sheet1!$K$12)
      +(J232-H233)/J232*(I232*Sheet1!$D$12+(1-I232)*Sheet1!$E$12))
      *(I232*Sheet1!$D$13+(1-I232)*Sheet1!$E$13)-Sheet1!$E$43)
```

L267 = H233/J232*(Sheet1!$L$55+(H131*Sheet1!$L$55
+(1-H131)*Sheet1!$M$55))/2*(1+H133*Sheet1!$K$35)
+(J232-H233)/J232*L212

L268 = (J232-J232*I233)*L267+J232*I233*L267*Sheet1!$E$6/12

L269 = L270-L274

L270 (total discounted pofit per year) =
(F270+F271+F272)/Sheet1!$C$48^ (B221+2)
total profit per year / discount factor powers to the No. of the years past.

L271 = L269+L216

L272 = L270+L217

L274 = L270-F273

L275 = L272-L271