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VALAM AND ARLAM: TWO COMPUTER PROGRAMS FOR ESTIMATING HYPOTHETICAL PETROLEUM RESOURCES USING PROSPECT AREAS AND FIELD SIZES

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CONTENTS

SUMMARY

Computer programs VALAM and ARLAM are available on BMR's HP-1000 computer. They were developed from program LAMDA (Hinde, 1984a). All three programs use projections of historic data to provide probabilistic estimates of the amounts of oil and gas that may be discovered, in a petroleum province, as a result of drilling a specified number of new-field wildcat wells. VALAM and ARLAM, however, use pre-drill area of prospect in addition to field size.

Input data for both programs includes: the predrill area of closure of every prospect drilled; the field sizes of the discoveries; and the success rate likely to result from drilling future prospects. The input data are printed out followed by the parameters of the linear least squares fit to the data and some statistics. The input data is also used to produce graphic plots on the HP printer/plotter.

The assessments are given in the same way as program LAMDA: a histogram and a cumulative probability distribution of resources; the mean, standard deviation, and some percentiles of the distribution of resources; a seriation of average size and standard deviation of the undiscovered fields, and a histogram of the number of new discoveries.

INTRODUCTION

Projection of identified field sizes (Forman and Hinde, in press) may be used to indicate how much oil or gas is likely to be discovered by future drilling of an area. Hinde (1984a) has described a computer program, called LAMDA, for carrying out assessment by this method. There are, however, many prospective areas where this method can not be applied, because few or no petroleum fields have been discovered within them.

Forman and Hinde (in prep.) have outlined two methods by which projections of historic data can be used to estimate the field sizes, their order of discovery, and the total potential in an area with a history of drilling but few or no discoveries. Instead of field size (V), these methods model a decline in predrill area of prospect (A). One method, using computer program ARLAM, converts the prospect (A) to field size (V) using a correlation between V and A that may be derived from an area of similar geology and economics.

Forman and Hinde point out, however, that this method is likely to yield overestimates of undiscovered potential. The other method, using computer program VALAM (Forman and Hinde, in prep.), converts the area of prospect (A) to field size (V) using a projection of log V/A versus discovery number. The data for this projection may be derived from the area of study or, if insufficient field size data are available, they may be derived from an area of similar geology and economics. This paper documents the two computer programs ARLAM and VALAM.

DESCRIPTION OF PROGRAMS ARLAM AND VALAM

Programs ARLAM and VALAM were written to model the tendency to drill the areally larger prospects early during petroleum exploration (Forman and Hinde, in prep.). They model the decline in predrill area of prospect (A), and VALAM also models a decline in field size divided by predrill area of closure (V/A). The parameters λ_A and $\lambda_{V/A}$ are powers to which A and V/A are raised to model their declines in a similar way to which the decline in V was modelled in program LAMDA.

It is assumed that a straight line is a reasonable fit to the plot of log A versus new-field wildcat number and to the plot of log V/A versus discovery number. The programs calculate the correlation coefficient, z-statistic, and recursive residuals to test these assumptions.

Program ARLAM fits a straight line to the plot of log predrill area of closure (log A) versus new-field wildcat number. This line is extrapolated by the method used in program LAMDA (Hinde, 1984a; Forman and Hinde, in press) to obtain estimates of the areas of closure of a specified number of prospects.

The success rate, likely to result from drilling these prospects, is specified by the user. It is used in the program to estimate which prospects are likely to be discoveries.

For these discoveries, predrill area of prospect is converted to field size using a straight line regression between log area of closure (log A) and log field size (log V); the slope, intercept, and standard deviation of the residuals of this regression are supplied as input data. The amounts of petroleum in each hypothetical discovery are summed to obtain the total volume of petroleum for each extrapolation.

Program VALAM also fits a straight line to the plot of log predrill area of closure (log A) versus new-field wildcat number. In addition, a straight line is fitted to the plot of log(V/A) versus discovery number. Both lines are extrapolated independently of each other by the method used in program LAMDA (Hinde, 1984a; Forman and Hinde, in press). Estimates of the areas of closure are obtained for a specified number of prospects. A specified success rate is used in the program to estimate which prospects are likely to be discoveries. For these, the estimated ratio of V/A is used to determine hypothetical field sizes. These are summed to obtain the total volume of petroleum for each extrapolation.

In both programs, the extrapolation of the straight lines is carried out assuming a partial dependency among the average slope and intercept, the average standard deviation of the residuals of the fitted lines, and the value of lambda (λ). Two values of lambda are required in the model for program VALAM, one for A (λ_A) and one for V/A ($\lambda_{V/A}$), and they are assumed to be independent of each other.

The programs extrapolate a whole family of possible straight-line fits to the log A versus new-field wildcat number data as a basis for estimating the areas of closure of undrilled prospects. A random sampling technique is used to generate the straight lines and future areas and field sizes to produce the assessment in terms of a cumulative probability distribution of hypothetical petroleum resources. The user is required to specify the wildcat success rate, as a triangular distribution, and the number of future new-field wildcat wells.

Printing and plotting of input data

The input data are printed out followed by the parameters of the linear least squares fit to the data, the correlation coefficient, the z-statistic, and the maximum likelihood estimate of lambda.

The input data are used to produce graphic plots on the HP printer/plotter. ARLAM displays the wildcat success rate, cumulative predrill area of closure (A) versus new-field wildcat number, log A versus new-field wildcat number, and a normal plot of the recursive residuals for the model fitted to log A versus new-field wildcat number. VALAM displays the cumulative values of V/A versus discovery number, log(V/A) versus discovery number, and a normal plot of the recursive residuals for the model fitted to log (V/A) versus discovery number. The recursive residuals are also written onto a file which can be read by another program. This program, program 'W' (Hinde 1984a), tests whether or not the residuals are normally distributed.

Estimating hypothetical resources

The two programs estimate the total amount of oil or gas that may be discovered by drilling a particular number of new-field wildcat wells. The user must specify the number of wells, a triangular distribution for the success rate, and the number of iterations required. The assessment is carried out in two parts: firstly, the maximum likelihood estimates of lamda, and the distributions of the possible values of lambda are obtained; secondly, the straight lines are projected and the computer simulates drilling the specified number of new-field wildcat wells.

Estimating lambda and its distribution

The distribution of the possible values of lambda and the average value are obtained using maximum likelihood theory as described by Hinde (1984). The average value of λ_A is obtained using the predrill areas of closure for every prospect drilled. The average value of $\lambda_{V/A}$ is estimated using the values of V/A for every new-field discovery (program VALAM only).

Assessment of hypothetical resources

For each iteration, a random value of the success rate is selected from the specified triangular distribution. The success or failure of each of the future new-field wildcat wells is simulated by comparison of this sampled success rate with a random number.

During each iteration one of the straight lines fitted to the log A versus new-field wildcat number plot (and for program VALAM only, the log V/A versus discovery number plot) is projected for a specified number of new-field wildcat wells. Each projection is carried out using one random value of λ_A, selected from the distribution of its estimate and, for program VALAM only, one random value of $\lambda_{V/A}$, selected independently from the distribution of its estimate. The corresponding expected values of slope, intercept, and standard deviation of the residuals of the straight lines are determined using empirical equations (Hinde, 1984a; Forman and Hinde, in press). Only positive values of lambda are accepted.

The distribution of log predrill area of prospect (log A) for each simulated discovery is estimated using the average log A and the standard deviation of the residuals. A value of log area is chosen by random sampling of this distribution. Similarly in program VALAM, values of log(V/A) are estimated for each discovery, using the average value of log(V/A) and the calculated standard deviation of the residuals. Log field size (log V) is calculated from these values of log A and log V/A and is then converted to actual field size. In program ARLAM, a value of log V is generated using the specified regression of log A versus log V; the value of log V is converted to actual field size.

The field sizes are summed for each iteration and when a large number of iterations have been carried out the results are expressed as a histogram and cumulative probability distribution of resources. The distribution of the number of discoveries and a seriation of the average field size and standard deviation of the undiscovered fields are also produced.

FORMAT OF INPUT DATA

The following table details the input required for programs ARLAM and VALAM. It should be typed into a file called 'DATAL', for program ARLAM, or DATAV for program VALAM. The input in lines 1 to 10 are the same as for program LAMDA. The data listed in line 10a are only required for program VALAM. Field sizes, predrill areas of closure, and various well data are entered in line 11.

Files DATAL, DATAV, and DATL (for program LAMDA) may be created automatically from data base AUSTCO. The programs to do this (ASARL and ASRL1 for program ARLAM, ASVAL and ASVL1 for program DATAV, and ASLAM and ASLM1 for LAMDA) are documented by Hinde (in prep.). Program ASLAM is also documented in Hinde (1984b).

Line	Cols	Variable	Description	Format for entire line
1	1-80	ITITLE	Used to identify the computer run.	(40A2)
2	1-11	BASIN	Basin name	(A11)
3	1-9	SUBAS	Sub-basin or infrabasin	(A9)
4	1-80	ITITL2	Date the data was compiled	(40A2)
5	1-80	ITITL2	Who compiled the data	(40A2)
6	1-80	ITITL2	The characters 'OIL', 'GAS', or 'BOE' (See Note 1)	(40A2)
7	1-10	IUNIT	The units of volume (see Note 2)	(5A2)
8	1-80	ITITL2	Remarks (eg date of last well)	(40A2)
9	1-5	N	Number of new-field wildcat wells	(5I5,A1, 3F10.0)
	6-10	NRUNS	Number of iterations to be carried out (suggested values: 2000 or 5000). If no assessment is required, leave blank.	

	11-15	NFIRST	The well number, in the data, to be considered the first well. If not required, leave blank.	
	16-20	MDRILL	The number of additional wells to be drilled. If no assessment is required, leave blank.	
	21-25	ISEED	A 5-digit number to seed the random number generators. If omitted, 12345 is used.	
	26	IFPLT	If 'Y' - allows the graph plots to be produced. If 'N' or blank - stops the graphs plots.	
	27-36	FLDMIN	A cut-off specifying the minimum size for future generated fields; if a field is generated smaller than FLDMIN it is ignored and another generated. If not required, leave blank.	
	37-46	HMAX	Maximum value to be used for the the range in the histogram of undiscovered resources. If left blank the program calculates a value.	
	47-56	SDMAX	A cut-off specifying the maximum sizes allowed for future generated fields. SDMAX is the number of standard deviations a log field size is allowed above its average. (Default is 2).	
10	1-10	XTH1	Minimum value of the success ratio for the triangular distribution of success ratios.	(3F10.0)
	11-20	XTH2	Most likely value of the success ratio for this distribution.	
	21-30	XTH3	Maximum value of the success ratio for this distribution.	

If no assessment is required, line 10 may be left blank.

The next line is for program ARLAM only:

10a	1-10	ASLOPE	Slope of the line fitted to log A as a function of log V.	(3F10.0)
	11-20	AINTC	Intercept of this line.	
	21-30	ASRES	Standard deviation of the residuals about this line.	
11	1-5	IWELL(I)	Sequence number of the I'th new-field wildcat, ie IWELL(I)=I for I=1 to N.	(I5,F10.5, A2,1X,10A2)
	6-15	CAREA(I)	Predrill area of closure of the I'th new-field wildcat.	
	16-17	IYEAR(I)	Year I'th new-field wildcat was drilled.	
	19-38	INAME(I, J),J=1, 10	Name of the I'th new-field wildcat.	
	39-48	FSIZE(I)	Size of the field if the well was a discovery well, otherwise, leave blank.	

Line 11 is repeated until all new-field wildcats have been entered

Note 1: Program LAMDA (Hinde, 1984a) now allows units of BOE.

Note 2: The units for volume, variable IUNIT, are usually $10^6 m^3$ for oil, 10^6BBL for barrels of oil equivalents (BOE), and $10^9 m^3$ for gas. The program converts these to 10^6BBL (MMB), 10^6BBL (MMB), and $10^{12} ft^3$ (TCF) respectively for output.

RUNNING THE PROGRAM

Programs ARLAM and VALAM reside in the BMR's Hewlett-Packard 1000 computer. To run program ARLAM, after the data file 'DATAL' has been prepared, use the commands:

```
RP,ARLAM       (to restore program ARLAM)
RU,ARLAM       (to run program ARLAM)
```

The output will be sent back to the terminal. To send the output to the printer instead, use:

```
RU,ARLAM,6     (to run program ARLAM; output to LU6)
LP,-N          (to print the output file)
```

or

```
RU,ARLAM,16    (to run program ARLAM; output
                directly to the printer)
```

To run program VALAM, after the data file 'DATAV' has been prepared, use the same commands substituting VALAM for ARLAM. An example terminal session was given for program LAMDA (Hinde, 1984a). Because programs ARLAM and VALAM are similar to LAMDA, an example is unnecessary.

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