

A comprehensive agricultural system simulation model: The case of broiler growers

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ABSTRACT

CHICKSIM is a comprehensive whole-farm dynamic and stochastic simulation model for contract broiler growers. The model simulates annual production, farm policy, marketing, financial management, growth and income tax aspects of a typical or representative broiler farm over a multiple year planning horizon. Several options are available in the model to simulate various regional production practices and contractual arrangements characterizing the broiler industry. KEYWORDS: Simulation, Broiler Growers, Economics, Profitability.

INTRODUCTION

The use of computer simulation models has been very popular with economists and management scientists during the last two decades. The range of simulation applications has covered both firm and economy-wide problems (Naylor). In recent years, simulation models have also been used in agricultural problems to analyze production, marketing and financial responses to policy and technological changes (Csaki). However, most of these models have either been static or deterministic. A major limitation of these types of simulation models is that future changes in the model variables are assumed constant through time. An alternative approach to specifying simulation models is to assume a dynamic (recursive) and stochastic process for key model variables.

There have been several agricultural simulation models developed for use in both mainframe and microcomputers. Examples of mainframe computer simulation models include FLIPSIM V (Richardson and Nixon), REPFARM (Baum), and FEEDSIM (Holland and Sharples). Examples of microcomputer farm simulation models are FFSM (Schnitkey, Barry and Ellinger), FINPACK (Hawkins), and PACKSIM (Falk, Tilley and Schatzer). The mainframe models are generally large in scope and have long term planning horizons. The microcomputer models are relatively smaller in scope and have shorter planning horizon. A review of other farm sector simulation models is given by Walker and Helmers.

The purpose of this paper is to describe the development and application of CHICKSIM, a comprehensive whole-farm agricultural system simulation model for contract broiler production. Prior to the development of CHICKSIM, there was no comprehensive dynamic and stochastic farm simulation model

specifically developed to address the simulation of representative broiler farms. One major reason for this is the highly complex production, marketing and financial processes involved in broiler production compared to other agricultural products. For instance it would be easier to model annual crops such as corn or soybeans because revenues and expenditures can be specified on an annual basis. Broilers, on the other hand, take only seven to eight weeks before the birds are delivered and sold to processing plants. In addition, the broiler industry is different from other agricultural production in that it is vertically integrated and with different regional contract pricing schemes.

BROILER PRODUCTION

Broilers are young chickens seven-to eight-weeks old weighing an average of 4.21 pounds per bird. Annual production of broilers in the U.S. has increased from one billion birds to over four and a half billion birds during the last three decades. Per capita consumption of broiler meat has also increased from nine pounds to over fifty-five pounds in three decades. Changes in consumer preferences, new production and marketing technologies, and increases in real disposable income have brought along these tremendous increases in broiler production and consumption.

The broiler industry is also characterized by an extensive vertical network of production practices. A typical integrated broiler operation consists of the hatchery, feed mill, processing plant, field and management staff and several hundred contract broiler growers. This paper deals with the development and application of a simulation model for contract broiler growers. Almost all commercial broilers produced at present are under contract except for a small portion of integrator-owned farms and small scale independent production. Contract broiler production is carried out between an integrator who owns the hatchery, feed mill and processing plant and the contract grower. The terms of the contract varies with grower location, market returns of the integrator, changes in input prices and financing terms, and production efficiency. In general, however, the integrator provides the baby chicks, feed, medication, field supervision and part of the fuel requirements while the grower provides the bird housing, litter, water, electricity, labor, and fuel for heating and brooding.

There are numerous contract pricing schemes which vary by region and production practices. Bird prices are set on a per pound or per bird produced. Premiums are usually given for feed efficiency and relative production efficiency ranking of the grower among all the integrator's contract growers. Guaranteed prices are also given for birds produced in new broiler houses. Growers face the risk of high mortality due to different respiratory diseases, fluctuations in market prices which affect contract prices, production inefficiency and high input costs.

DESCRIPTION OF CHICKSIM

CHICKSIM is a recursive Monte Carlo simulation model which simulates the production, financial management, farm policy and income tax aspects of a broiler grower operation over a ten year planning horizon. The simulation model is programmed in FORTRAN code and consists of over 6000 source statements and requires 2M of total storage space under the VM/CMS system using an IBM 3081d mainframe computer. The model recursively simulates the case farm by using the ending financial position in year one as the beginning position in year two and so on. CHICKSIM is capable of simulating an enterprise with one to ten broiler houses with five placements (sets) per house each year and a maximum of eight broiler houses with six placements per house each year. If seven placements are used, a maximum of seven broiler houses are allowed.

Options are available in the model to run either deterministic or stochastic analysis. A maximum of 300 iterations is available if the stochastic option is elected. At the end of each iteration, the model stores the results and reinitializes the broiler farm to the original situation used at the outset of the first iteration. Upon completion of the desired number of iterations, the model performs a descriptive statistical analysis and computes for the mean, standard deviation, coefficient of variation, maximum value for 179 output variables. The model also develops the cumulative probability distribution functions (CDF) for these variables and estimates the probability of economic success and survival of the broiler farm. The probability of economic success is defined as the probability of the farm having a positive net present value while the probability of survival is defined as the probability of the farm remaining solvent each year of the planning horizon.

Bird prices and survival fractions (one minus the mortality rate) per placement are determined by the analyst for the deterministic mode. If the stochastic option is selected, bird prices, survival fractions, variable input prices, and feed costs are drawn from analyst specified probability distributions. Inasmuch as contract broiler growers do not pay any feed cost, the stochastic feed cost option is normally not used unless an analysis of an independent broiler grower is conducted. The analyst can select five different probability

distributions in selecting the stochastic survival fractions and bird prices (multivariate normal, independent normal, multivariate empirical, independent empirical, and independent triangular). Variable input prices can be modelled using either the independent normal or independent triangular probability distribution while feed costs are assumed to follow an independent empirical probability distribution.

The model has three primary pricing options. The first option is used when analyzing contractual arrangements where stochastic bird weights and payments are based on a per thousand heads basis. The second option is to specify stochastic bird weights and prices per thousand pounds. The third option, which is a slight modification of the second option, selects stochastic bird prices per thousand pounds based on a stochastic feed conversion efficiency procedure. This pricing mechanism allows for higher (lower) bird prices per thousand pounds given efficient (inefficient) stochastic feed conversion rate.

An option is also available in the model for premium pricing based on survival fractions. If the stochastic survival fraction selected is greater than an analyst specified survival rate, the stochastic bird prices selected are increased by an analyst-specified percentage. Variable input costs may be randomly selected and the model allows for a premium pricing scheme based on a target maximum level of variable cost. The model permits both variable costs and bird prices to increase (decrease) annually during the planning horizon by an analyst-specified percentage rate. There is also an option in the model that allows for farm growth through the purchase of new broiler houses. The immediate cost of the expansion is the minimum downpayment for the house plus the downpayment for additional equipment necessary to handle the proposed larger size operations. Prior to finalizing the purchase, the model checks the equity ratios that would exist after the purchase. The proposed sale is cancelled if the purchase overextends the debt bearing capacity of the operation. Once the purchase is made, the model updates the farm's total debts and assets to reflect the expansion.

Cash receipts for the broiler farm are the sum of receipts from each placement for all houses and other farm income the analyst determines exogenously. Annual cash withdrawals for family living expenses can be estimated through the model supplied consumption functions or the analyst can specify a separate consumption function. Cash flow deficits are financed through bank borrowings using farmland equity as collateral. If the farm is not able to cover its cash flow deficit, the farm is declared insolvent. Cash flow surpluses are used to prepay principal payments on current debts or can be invested as a source of off-farm income.

The model calculates the variable cost of production for the broiler farm per placement and then sums up the placement costs

to obtain total enterprise annual variable cost. The analyst must provide the initial broiler costs for chicks, fuel, electricity, repairs, labor, and other miscellaneous costs. The analyst must also provide initial values for fixed costs such as machinery costs, depreciation method (straight line, double declining or accelerated), property tax, accountant fees and other fixed costs. After simulating the last iteration of an analysis, the model prints a summary of the input data, projected income statement, cash flow statement, and balance sheet. Additional information is also reported on a per house basis for the number of chicks placed, chicks actually sold, survival fractions and bird prices used, cash receipts by set, and variable production cost by set. An abbreviated output is also provided covering the income statement and several financial ratios calculated from the projected financial statement. The model prints descriptive statistics for all the output variables (e.g., net present value, net farm income, total production cost, internal rate of return among others) by year and the cumulative probability distributions for these variables.

A complete description of CHICKSIM is available in Gempesaw, Munasinghe and Richardson. Many of the options in the model are independent so the available number of combinations and permutations is large. This flexibility enhances the usefulness of CHICKSIM to simulate various scenarios of broiler grower operations.

DATA FILES AND SUPPORT PROGRAMS

The files and programs associated with CHICKSIM are summarized in Figure 1. The first input data file, Main Data, contains all the information needed by the analyst to simulate a broiler enterprise using a per thousand head bird pricing option. However, if the analyst wants to use the per thousand pound bird pricing option, the second input data file, Option Data, has to be used. The third input data, Title Data, contains a summary title of the broiler enterprise being simulated.

Runchick Exec is an IBM VM-CMS macro program designed to load the CHICKSIM Fortran programs. It also creates and opens files to receive the output files generated by CHICKSIM such as Table Result, Model Result, Cmatrix Results, Stoc Result, Iror Result, Grow Result, Option Result, and Debug Result. Runchick Exec also identifies the input data files for CHICKSIM to read.

For purposes of analyzing the simulation results, the analyst has two options. The analyst can either check the results or the analyst can use two support Fortran programs, UDTAB40 and UDTABLE, which provide a summary of the main output file. UDTAB40 is a program designed to read and summarize into a table format the first 40 output variables generated by CHICKSIM. The analyst can select which variables to include in the table by specifying the variable number in the input data file UDTAB40 Data. UDTABLE is

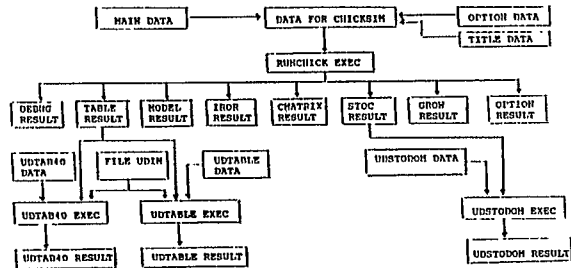


Figure 1. Schematic of the Program Files Used in the CHICKSIM Model.

a program designed to read and summarize into a table format the remaining output variables which can be selected through the input data file UDTABLE Data. Both UDTAB40 and UDTABLE have their own exec macro programs (UDTAB40 Exec and UDTABLE exec) and title data file (File Udin). The difference between UDTAB40 and UDTABLE is that UDTAB40 prints the averages (means) of the key output variables over the ten year planning horizon while UDTABLE prints the key output variables on an annual basis.

A third support program, UDSTODOM, is also available to the analyst to conduct stochastic dominance analysis of different broiler farms or scenarios. Stochastic dominance with respect to a function, as explained by Meyer, allows the analyst to set assumptions about risk behavior of the broiler grower and then ranks the uncertain investment scenarios which are considered optimal for the different risk attitudes. UDSTODOM also has its own data file, UDSTODOM Data, and execution program, UDSTODOM Exec.

MODEL APPLICATION AND VALIDATION

Since the completion of the first version of CHICKSIM in 1987, the model has been used in three major applications. Hunter used the model to evaluate the impacts of higher mortality rates and fluctuating bird prices on the profitability of broiler farms in Delaware, Maryland and Virginia (Delmarva) region. Results of his study showed that the broiler farms were more sensitive to higher mortality rates than to bird price changes. In another study, Gempesaw et al. used CHICKSIM to analyze the probable impacts of growth regulators (biotechnology) on broiler farm profitability in two major broiler producing areas, Delmarva and Georgia. They found that broiler grower profits would likely increase if the impact of the growth regulator is measured solely in terms of growout efficiency. However, farmers would probably be better off not adopting the new technology if its use was accompanied by a corresponding decrease in bird prices due to overproduction or lower survival rates due to management problems associated with shorter production cycle.

In addition, the model has been used to evaluate the impacts of interest rates and

debt financing levels on Delmarva, Georgia and Arkansas contract broiler growers. Gempesaw, Bacon, and Richardson used CHICKSIM to analyze the effect of financial variable changes on interregional competition in broiler production. They found the Delmarva growers to be highly sensitive to increases in interest rates and debt-financing levels due to higher investment requirements.

Several steps have been and are being followed to ensure the validity of CHICKSIM's simulation results. First, personal interviews and farm visits of broiler grower operations were conducted. Discussions were conducted with these growers ranging from contractual arrangements to variable costs of production. Second, data on representative farm budgets were collected from various producing regions. Third, extensive discussions were made with poultry extension specialists on data requirements and viability of results. Most of the options installed on CHICKSIM resulted from these discussions and collection of data from various broiler producing regions. In addition, peer review has been and will continue to be a major part of CHICKSIM's validation and verification.

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