A REVIEW OF THREE RESEARCH PROGRAMS IN QUANTITATIVE MODELLING IN THE BUREAU OF AGRICULTURAL ECONOMICS*

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Elements of three of the BAE's research programs in economic modelling of the rural sector, namely, the modelling of agricultural production systems, rural commodity markets and agriculture within a general equilibrium framework, are reviewed with emphasis on the use of such models in policy work. Suggestions are made for further modelling in these areas.

Introduction

The BAE is the (semi-autonomous) research agency of the Australian Commonwealth Department of Primary Industry. It employs some 150 economists plus back-up staff and has responsibilities to both government and industry in the preparation and publication of economic outlook information, results from regular agricultural surveys, and recommendations on or analyses of contemporary economic issues. Details of the structure of the BAE, and of individual research projects, can be found in the Bureau's Annual Report (BAE 1980*a*). However, little has been published in the way of reviews of the various programs of economic research carried out in the Bureau from year to year.

The aim in this paper is to make a modest start on such a review process. The multiplicity of Bureau studies published in recent years makes an all-encompassing review difficult. Therefore, we concentrate attention in this paper on only three programs of quantitative modelling. First, we discuss *production models*, in which whole farms or regional aggregates of farms are modelled using mathematical programming and systems simulation techniques. Second, we outline the Bureau's *econometric commodity models* which are used for projection work and for policy evaluation. Finally, efforts within the Bureau to develop *general equilibrium models*, which subsume much of the detail of the production and commodity models, are outlined. The three classes of models, taken together, provide a range of methods capable of addressing a spectrum of questions ranging from issues in structural adjustment at the farm level, or supply response for one or several enterprises, to the impact on the rural sector as a whole of changes in either macroeconomic policies or the structure of other sectors in the economy.

Two challenges facing economists in government organisations such as the Bureau are how to ensure that 'basic' and long-term research continues in the face of a barrage of day-to-day *ad hoc* policy work and how best to utilise the results of quantitative research in government decision

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making, in order to put consistent rural policy into effect. To this end, some suggestions are made on how quantitative models used in the Bureau might be extended to give greater insight into contemporary rural issues. Emphasis is on flexibility in construction and use of these models, and on tailoring their further development to the research environment of government. The following gives some guidance on how parts of the Bureau's research program might develop in the next few years, in concert with the changing policy issues discussed by the BAE (1978*a*) and Miller (1979*b*).

In this paper, it has not been possible to review the Bureau's large number of 'one-off' quantitative studies which range from exploration of specific problems at the farm level to examination of market retailing systems. These studies have (in varying degrees) provided valuable input to the modelling programs discussed below.

The Bureau's Research Program

The 1970s marked a period during which four major influences transformed the Bureau's program of work from one essentially concerned with provision of information specific to the rural sector to a fully fledged research program aimed at the analysis of a broad range of policy issues.

The *subject matter* to be analysed has changed, due to the rapid development of the rural sector from a situation of dominance in the economy, with attendant policies to boost agriculture, to one in which agriculture, although still expanding, is small relative to other sectors of the economy. The Australian rural sector cannot now be viewed in isolation. Intersectoral and macroeconomic issues extending well beyond the traditional rural focus have become important and the Bureau is being asked more frequently to provide judgments in areas outside agriculture.

The magnitude of structural change required of the rural sector in the 1970s brought with it *increased demands for analysis* of policies for adjustment. These demands came from both industry and government, but most importantly from the *public inquiry process* instituted in the Industries Assistance Commission (IAC). Since 1974, BAE resources have been mobilised to meet requirements of IAC inquiries which have ranged from adjustment to prices of individual inputs and outputs to the examination of entire industries and rural institutions.

Over time, there has been a marked improvement in the comprehensiveness of the training of graduates and research workers. Gruen (1979) has noted that, apart from factors relating to increased competition for limited job opportunities, this improvement can be attributed, in part, to a substantial upgrading and expansion of staff in Australian universities in the 1970s. In addition, in recent years economics has been one of the 'industries' in Australia to experience pronounced growth, and, until recently, there has been a substantial proportional increase in intake of graduates by the Public Service. Within the Bureau, these trends have been translated into a greater-than-proportional increase in the number of honours graduates in economics (as opposed to agriculture) and researchers with post-graduate qualifications, particularly Ph.Ds.

Also, the 1970s marked a period of development, uptake and use of a wide range of quantitative tools by universities and institutions such as the BAE. There is controversy over the ultimate usefulness of some of these quantitative methods, but there can be no doubt about the impact which these techniques have had on the structure of the Bureau, its operation and its methods of executing research. Continued participation in policy work by institutions like the BAE requires consistency in approach, which can be achieved in part by the use of quantitative methods.

As a background to later sections, the Bureau's current research program is summarised below.

Export dependence of the rural sector means that attention is given to *overseas developments* and their consequences for Australian farmers. Developments in Australia's trade with the rest of the world are monitored, since these affect the competitiveness of Australian rural industries. An example here is the rapid expansion of Australia's mineral exporting industries in terms of providing an alternative source of foreign exchange. Sector-wide issues include monitoring and interpretation of *trade policies* of countries such as Japan, the U.S.A., the EEC and New Zealand, and assessment of the general trading potential of the ASEAN and OPEC countries (Hussey 1979). Issues such as stabilisation, access to overseas markets, and transient (as opposed to long-term) fluctuations for individual industries are also important. Research in these areas provides a basis for examining the scope for trading and for providing better briefs for negotiation and development of trade.

The monitoring and analysis of markets and trends in the rural sector continues to be a crucial part of the research program. Commodity research programs involve both short-term and long-term *studies of the supply and demand for rural commodities*, with increasing use of quantitative methods as well as institutional analysis (e.g. the marketing institutions within which supply and demand are equated). Monitoring and analysis is also undertaken in relation to, first, specific policy measures in the rural sector, e.g. adjustment schemes (BAE 1981), rural credit (BAE 1978*b*) etc. and, second, broader microeconomic and *macroeconomic policies and trends*, such as changes in the tariff structure, and issues such as tariff compensation, taxation measures and exchange rates. Projects in this area contribute to a greater understanding of these relationships, often making use of results from sectoral and economy-wide models.

Downward trends and fluctuations in rural terms of trade imply continual *change and adjustment* of resources in agriculture. Investigations are undertaken of the extent to which farmers are able to accommodate and adjust to change, and the major impediments involved in this process (Kingma and Samuel 1977). Analyses involve maintenance of a comprehensive *farm data base*; methodological research and modelling to provide a consistent framework to handle *resource allocation* problems; and *development of appropriate criteria* and an analytical framework for *evaluating policy* and broader socioeconomic problems since efficiency criteria provide no solution to welfare issues, and given the increasing emphasis on household income as distinct from income from farm produce only.

Modelling Production Systems

Models of production systems developed in the BAE can be subdivided according to time dependency, stochastic elements and treatment of the goal function – and a large number of Bureau studies which have modelled each, or a combination, of these features can be identified. Models which retain a high degree of flexibility in terms of adaptability to different policy problems, while still giving strong expression to economic theory, have been found to be most suited to Bureau work. Combinations of systems simulation techniques and mathematical programming methods have been used and, in this regard, two parallel streams of model building have been pursued in the past few years within the Bureau – the modelling of *representative farms* or groups of farms, and the modelling of *regions* (beef, sheep, crops). These two classes of models are outlined briefly below.

Farm models. Since 1975, linear programming (LP) matrices have been developed for most production systems in Australian agriculture. Thus, Easter and Kingma (1975), Plain (1978) and Ockwell (1979) concentrated on whole-farm livestock and cropping systems in the Wheat-Sheep and High Rainfall Zones. Hall and Ockwell (1979) have constructed LP matrices for typical dairy farms in Australia and are currently using these to assess the impact, at farm level, of alternative marketing arrangements in the dairy industry. An added objective of that study is to interface these dairy sector models with the larger regional models discussed later. LP formulations for horticultural properties are also now being used (Khan 1979) to evaluate adjustment alternatives for this class of property.

The broader problems of farm adjustment in the highly uncertain Australian production environment, and the need to identify factors which enhance productivity, have stimulated the development and use of dynamic, stochastic farm-level models in the Bureau (e.g. Reeves et al. 1974; Kingma and Kerridge 1977; Holman and Love 1978). Reeves et al. and Holman and Love concentrated on models of a specific enterprise, namely beef production, while Kingma and Kerridge developed whole-farm models.

The systems simulation models initially represented feed supply and demand for the growing of cattle on pasture, with and without supplementary feeding. Stochastic elements involved random selection of climatic patterns and attendant levels of livestock performance each quarter (Reeves et al. 1974). Later versions (e.g. Love 1979) incorporated more sophisticated interrelationships between the pasture base and the animal, and included alternative production strategies. Such models are currently being used to test the feasibility of supplementing feeding of grain, as part of a wheat stabilisation scheme.

Research into whole-farm modelling for beef, wheat and sheep properties has been reported by Kingma and Kerridge (1977, 1978) and in essence takes the form of recursive LP models with simulation components, for nonviable, potentially viable and viable properties in the Wheat-Sheep and High Rainfall Zones in Australia. The models are neoclassical in terms of production response, but this response is circumscribed or dampened in several ways: first, through use of adaptive expectations models which give expression to the fact that farmers are generally unwilling to adjust their enterprise mix in the short run but will adjust at an increasing rate, given continued occurrence of some event; second, through modelling of risk aversion or the unwillingness to operate at the point of (expected) profit maximisation; and third, through modelling of strategies for household decisions relating, for example, to use of the annual cash surplus.

The models were used initially in the Bureau's report on income stabilisation to explore the influence of price and output variation on farmers' operations and income streams over time. Results indicated the futility of attempts at price stabilisation in an environment where climatic (output) variability is extensive. The models were used in 1977 in the Bureau's report on rural credit (BAE 1978*b*) to study the effects on farm growth of the addition of varying amounts of land and/or capital and debt. The models have also been used to examine the ability of various types of farms to cope with economic pressures over time (Kingma and Kerridge 1978) and to assess the impact of constraints on expansion of the sheep meat enterprise (Kerridge 1980).

The papers cited in relation to this model document some evidence that absolute output and changes in output predicted by the models, both in terms of physical and financial variables, conform reasonably well to historical series. These models simulate output series for individual farms if (highly variable) individual farm data are used. If State (regional) conditions are approximated, then, because rainfall and price series are 'averaged', close conformation to State conditions is also achieved. This means that the models potentially lend themselves to aggregate analyses of policy alternatives, changes in incomes (prices), the impact of new enterprises, improvements in productivity growth, etc.

Despite all this, much can be done to improve the specification of technical and behavioural relationships within the models and to conduct analyses of a validatory nature as reported in McKay et al. (1978). Scope also exists for further extension of the models to encompass decision-theoretic techniques as a framework for simulating major decisions such as land purchase and sale, and Becker-type formulations to simulate allocation of operator and family time and funds between production, the household and leisure.

Regional production models. Regional models were first used in the evaluation of input subsidies in the broadacre industries. The first attempt (Kingma 1975) involved use of recursive LP to generate and analyse cash flows over time, under a variety of price and resource situations, for the national sheep, beef and cropping industries. This highly aggregated model was subsequently expanded to represent separately five major geographic regions in Australia and to incorporate more detail within these regional matrices. The model was described in its general form by Easter and Kingma (1976) and was used by Kingma et al. (1976) in a benefit-cost analysis of a resource subsidy. The model provided a framework for simulating the allocation of resources within any year for the broadacre industries, generating information on the optimal mix of livestock and cropping activities, the optimal use of variable inputs (e.g. fertiliser, labour) and the optimal pattern of land use for any year. Stochastic features were introduced into the model through the objective function, particularly for prices and costs of variable inputs and for technical coefficients such as feed supply and demand, and livestock performance. Dynamic features were introduced through linear difference equations operating on resource capacities and flexibilities. Examples of the classical 'phasing' in output from this type of model are contained in

Kingma et al. (1976). Flexibility constraints in these models change the (otherwise normative) LP solutions to allow prediction of actual (positive) short-run behaviour of farm firms.

The five-region model was used to analyse productivity change (Bond 1977; Easter 1977; Kingma 1977) without recourse to the dynamic structure. Because of research time constraints and the learning time required for operation of the model by other research staff, these analyses were based on use of the (static) LP matrix only. With this experience in mind, modelling since 1977 has been directed towards development of a larger matrix of input-output coefficients but with no recursive and stochastic components. The number of regions was increased to 13 and the degree of detail, particularly with regard to livestock enterprises, was increased in all sectors. Some further work on the recursive formulation for this model is being undertaken (C. Easter, personal communication, 1979). However, the (static) 13-sector regional programming model (RPM) represents the most recent phase in the Bureau's research on regional modelling, and has been described, together with examples of validation, by Longmire et al. (1979). Diagrams and discussion in the paper by Cornell and Hone (1978) give some idea of the detail built into the farm enterprises.

Regional stratification in the RPM is based on the traditional three major production zones in Australia, but also on a more detailed analysis of climate (temperature, rainfall, evaporation), enterprise specialisation and geographical location. Bureau researchers have taken care to preserve the flexibility of the model. Thus, price indexing methods to allow rapid forward estimation of returns and variable costs in the objective function are included in the model 'package'. Accompanying FORTRAN routines provide a variety of summary tables, depending on detail required and the nature of the problem.

Four levels of input intensity or productivity were specified for sheep, beef and cropping activities. Thus, the model allows substitution between activities of differing capital-labour intensities. The model gives expression to the concept of 'extensification', implying a reduced livestock carrying capacity coupled with a commensurate reduction in other inputs such as capital investment and variable costs (but excluding land) per unit output. In the recent situation of continuing inflation and the attendant 'cost-cutting' or reduced use of variable inputs by many farmers, the ability of a model to simulate several levels of productivity is important. In a rapidly changing environment, this characteristic means that such models have an advantage over econometric models which cannot adequately handle unprecedented situations.

To date, the model has been used in further analyses of likely (*ex ante*) productivity change in the beef, sheep and cropping industries; the Bureau's medium-term (five-year) supply projections; general (continuing) supply response work; and analyses of the sheep meat enterprise. Growth in the trade in live sheep to the Middle East in recent years is an example of a new industry which can easily be integrated into the model. The first study in the Bureau relating to the Middle East trade was reported by Cornell and Hone (1978) who derived supply elasticities which indicated that a run-down in the national flock was not likely to occur as a result of live sheep exports. Analyses using the model were also prepared for a task force on the Middle East market (Cornell et al.

1978) and results were integrated with an analysis conducted at the University of New England with that University's regional model, APMAA (Wicks, Mueller and Crellin 1978). During 1978, the Bureau was requested to conduct an inquiry into the impact of union-imposed restrictions on the export of live sheep from Australia. The report, BAE (1980*b*), used data generated from the model to show the national losses, repercussions within the farm production sector, and rural employment implications resulting from such restrictions.

In summary, the Bureau now has farm-level and regional models of the Australian broadacre industries. An analysis of the costs of this modelling program indicates that approximately five man-years and $6000 for computing have been used (excluding the costs of the various analyses). Further work in both the farm adjustment (farm-level) and supply response (national) areas is likely to be directed towards refinement of parameters, on the one hand, and overhaul and improved modelling of various components as required for policy work, on the other.

Availability of relevant data will continue to be a constraint in this work. Major sources of data have been the farm surveys conducted by the Bureau and data held by State departments responsible for agriculture, the Australian Bureau of Statistics and CSIRO. One-off research projects aimed at collection and analysis of specialised data are likely to become increasingly important.

Modelling Commodity Markets

Recently, considerable research effort has been devoted to developing econometric models of Australia's agricultural commodity markets, reflecting the Bureau's increasing involvement in commodity forecasting and analysis. The Bureau now has a regular commitment to present annual forecasts of production, utilisation (domestic consumption and exports) and prices at the National Agricultural Outlook Conference (NAOC). Forecasts are published annually in BAE Situation and Outlook reports. As well, quarterly updates of forecasts of gross value and volume of production and exports are published in *BAE Trends* and the Bureau's journal, *Quarterly Review of the Rural Economy*. The Bureau now also prepares regular medium-term (five-year) projections of the Australian agricultural sector, the latest projections being for 1982/83 (BAE 1979*b*).

Forecasting now depends increasingly on econometric models, but these models have also been used in analyses of policy proposals relating to agricultural commodity markets. Models have been updated or modified as these policy problems have emerged, and this has often required substantial (background) development costs. The usual trade-offs between marginal improvements in predictive ability and marginal cost of development apply. However, the necessity for these trade-offs is diminishing as more comprehensive models of markets, in which the major structural relationships are explicit, are developed.

In the 1960s, commodity models developed in the Bureau were typically aggregated to the State or national levels, usually employed annual time series data and were single-equation formulations. The multi-equation models of Taylor (1963) and Pender and Erwood (1970) were exceptions. Updating was infrequent and depended on the policy analyses required. Linkages between models or industries were only on an informal basis, given limited compatible data. The small country assumption was generally adopted, although some effort was explicitly directed towards modelling of overseas markets. This situation, however, reflected the state of the art, the only major Australian study available at that time being the Monash study reported by Gruen et al. (1967).

Wool was one commodity in Australia for which there was a pressing need for quantitative forecasting and policy analyses in the early 1970s. Two approaches to the analysis and forecasting of wool prices were developed in the Bureau at that time. The first, by Duane (1973), was a traditional market equilibrium study in which the major addition was the modelling of interfibre competition in demand functions for wool, and the simultaneous determination of consumption, stocks, supplies and prices. However, the model was not employed for forecasting because of its size and because it could not be used to simulate the impact of changes in world business activity on Australian wool prices.

The other approach to wool price forecasting, instigated by Hussey (1972), specifically addressed these difficulties. Using interest rates in important OECD wool-using countries as leading indicators of changes in business activity overseas, a single-equation price forecasting model was developed. The model was successfully employed for forecasting in the Bureau. Dalton (1974) and Dalton and Taylor (1975) updated this original model and introduced a number of innovative components, including a diffusion index as an index of leading indicators of overseas economic activity. The diffusion index leads future changes in income in major industrialised trading nations. More recently, updated versions of the model have been employed to analyse policy related to setting a minimum price and to the wool stockholding behaviour of the Australian Wool Corporation (Campbell et al. 1980).

With active intervention in the wool market by the Australian Wool Corporation, a major change in the factors affecting wool prices for producers has occurred. As a consequence, the single-equation wool price forecasting models, which originated prior to or in the early stages of this development in the market, have lost some of their applicability. Current studies of the wool market are therefore being focused more on structural aspects of demand for, and supply of, wool in Australia, including factors influencing levels of stocks (Carland 1979; Hinchy and Simmons 1979).

Livestock. In the early 1970s, a major switch from sheep to sheep and beef occurred in the grazing livestock sector. At that time a number of single-equation models, such as those of Dalton and Lee (1975) and Malecky (1975), were employed for analysis and forecasting of the supply of meat and wool and of livestock numbers. The models were typically Nerlovian, with livestock numbers or supply of livestock products modelled as a single equation and related to supply in the previous period, own price, price of other grazing enterprises and a proxy for seasonal conditions.

Since the mid-1970s, emphasis has been on modelling livestock supply in a multi-equation, multi-enterprise system, using extensions of the models developed by Reutlinger (1966), Freebairn (1973) and Jarvis (1974) which cast livestock supply in terms of traditional capital and investment theory. The livestock inventory and supply system that flows from the central identity (closing numbers equal opening numbers plus births less deaths and slaughterings) in these models contains five subsets of equations: inventory identities describing opening livestock numbers; production identities; and stochastic equations explaining natural increases, slaughterings and rates of production per head. Models become more complex as differential age categories are introduced, since natural increase applies only to the youngest age category while promotions are relevant only to older age categories.

The above supply models permit explicit modelling of the dynamic links between livestock numbers, production and the factors affecting changes in numbers over time. Major variables hypothesised to influence slaughterings, natural increase and production are opening livestock numbers, relative profitability and seasonal conditions. An important feature is the ability of these models to simulate changes in the direction of supply response according to the length of production run. For example, short-run negative supply response, coupled with longer term positive supply response, can be explicitly simulated, given the dynamic links between slaughterings and livestock numbers.

Models of beef, sheep and pig supply along these lines have been developed recently in the Bureau and used in the five-year projections (BAE 1979*b*). In these supply models, stochastic equations were used to explain slaughterings and other endogenous variables affecting livestock numbers through time. Although linear and employing simple expectations operators, short-run negative supply response and longer run positive supply response were features of these supply models. Further use and analysis of these models is reported in Longmire and Main (1980), Reynolds and Gardiner (1980) and West (1980). The econometric supply models have been used at times in conjunction with the demographic or inventory (simulation) models developed for beef (Reeves 1975) and sheep (Williams 1980).

Earlier in the decade, models of price determination in the saleyard markets for lamb and cattle were developed by Bain (1972) and Papadopoulos (1973), respectively. These models of price formation at the State level indicated the importance of export demand and domestic production in the price formation process for livestock. More recent analysis of the price formation process for meats, however, has involved the development of wider structural models of the beef and pig meat markets although a wider structural model of the market for sheep meat is still being constructed.

Changing levels of domestic consumption of meats in Australia in the mid-1970s encouraged research on domestic demand for meat. Main et al. (1976) and, more recently, Reynolds (1978) employed a demand systems approach to analysing retail demand for meat. The meats included in the demand system were beef, sheep meat, pig meat and poultry meat.

With the accumulated knowledge gained from separately modelling the price formation process, domestic supply and demand, and the U.S. market (Bain 1977), Longmire and Main (1980) have developed an aggregative annual model of the Australian beef market. The model is simultaneous, with the main endogenous variables being livestock numbers, production, consumption, exports and prices at the saleyard and retail levels. It simulates over a period which can be both historical and into the mid-1980s. As well, the impact, interim and long-run multipliers of the model have been calculated. Further insight into the various overseas markets is also being obtained through complementary studies in the Bureau, such as that by Hinchy (1978) who used spectral techniques to investigate lead-lag relationships between prices in the U.S. manufacturing beef market and Australian beef prices.

The highly institutionalised nature of the markets for other livestock products leaves limited scope for econometric analysis. Price forecasting for eggs, and retail demand studies for fluid milk, butter and cheese have been undertaken with varied results. Not only do institutional constraints and structural changes infringe greatly on these analyses, but data for these products are somewhat limited. Other approaches may be of use here — in particular, cross-sectional analysis of demand, consumption and expenditure surveys and/or using a 'food demand matrix' approach, along the lines pioneered by Brandow (1961). The modelling of the supply of these products will remain difficult.

Grains and oilseeds. In Australia there has been little need for public forecasts of wheat prices because of a variety of factors, such as the way returns to producers have traditionally been determined for wheat delivered to the Australian Wheat Board and the stabilising effect on wheat prices which the U.S.A. had for a long period as a result of its loan rate system and stockholding policies. Quantitative modelling of world wheat prices in the Bureau has been limited, therefore, to time series analysis of prices and trend extrapolation. Recently, however, the method by which producers are paid for wheat delivered has changed so that producer returns will move more in line with international wheat prices. Interest in the forecasting of prices of Australian wheat has consequently increased.

Econometric analysis has been employed recently in the Bureau to model and project the domestic supply of wheat and coarse grain production (as opposed to fodder production) (BAE 1976, 1979*b*). Crops have been modelled in a recursive supply system, with the grain cropping supply system conceptualised as a series of decisions which flow from the aggregate to the disaggregate in a whole-farm decision sequence, namely: (a) determine total cultivated area (area under crops, fallow and sown pastures), (b) determine area sown to pasture and area sown to grains, (c) determine area sown to wheat, and (d) determine area sown to other crops, barley, oats, sorghum, maize, oilseeds and field peas.

A model of domestic utilisation of grains for stock feed was developed by Bain (1973). More recently, a similar model of domestic utilisation of grains for stock feed has been combined with equations explaining food/factory demand for wheat and for coarse grains, to derive total domestic disappearance of grains. The residual between total domestic production and consumption was assumed to be exported.

Quantitative modelling of markets for *other crops* in Australia (those besides wheat, coarse grains and oilseeds, and including sugar, rice, cotton and horticulture) has generally been undertaken in relation to medium-term supply projections (BAE 1979*b*) or specific government inquiries into policies affecting these crops. As a rule, in the analyses of demand for and supply of these crops, single-equations techniques, often with a time trend explanatory variable to provide forecasts of future production or consumption, were used. Exceptions are the models for grapes (Miller and Roberts 1972) and citrus fruit (BAE 1976).

The Bureau has become involved in 'marketing' studies intended to provide insight into the structure and operations of firms at levels from the farm gate to retail. Studies have been concerned with resource allocation in processing, distribution and retail firms, and the (normative) question of whether price formation is 'efficient'. These studies have complemented the (positive) commodities research. Some topics which are receiving increasing attention in this regard are the operation of the wool reserve price scheme, market intervention for beef and other products, and the auction system and livestock selling techniques.

Because econometric modelling in the Bureau has gained momentum only recently, modelling has tended to be approached on single-commodity lines. Given the relationships between cropping and grazing livestock in Australian agriculture, the ties between domestic feed-grain consumption and the intensive livestock sector, and the cross effects between different foods at the retail level, inconsistencies can arise between the projections made with individual models of commodity markets. These sources of inconsistency are likely to be overcome in future by further integration of individual models.

Only recently have attempts been made to combine structural models of demand and supply in wider market models. For beef and pigs, the Bureau has wider econometric models in which linkages between demand, supply and price are explicit. Scope exists for developing structural models of other markets in which linkages are explicit. Models of this nature are likely to be superior for modelling alternative policy situations and for furthering understanding of the major forces in the market. Whether the structural models produce superior forecasts is still open to question.

The dynamics of the models of commodity markets require further investigation. Given that forecasting has been a principal reason for developing many of the models, relatively little research has been devoted to assessing the forecasting ability of the models developed. The work of Freebairn (1975), Bourke (1979) and Gellatly (1979) offers guidelines as to ways in which alternative forecasting methods can be evaluated. Scope exists for more regular review of past forecast accuracy, which would act as a guide for development of alternative forecasting models.

Modelling Macroeconomic Systems

A relatively recent avenue of agricultural economics research in the Bureau has been the development of macroeconomic models, where the rural sector is treated as part of the overall economy. The greater attention given to intersectoral competition for resources in the economy has been described as the most significant development in agricultural policy discussion in recent years (Edwards and Watson 1978).

There are two broad approaches to macroeconomic modelling. The first, macroeconometric modelling, involves specifying a multipleequation system in which macroeconomic concepts are of a derived nature and deduced from their microeconomic components by means of aggregation rules. Examples of these sorts of models used in Australia are the Treasury's NIF7 (National Income Forecasting) model (see later) and the Reserve Bank's RBA76 model (Jonson et al. 1977). The former model has been used largely for forecasting purposes. The latter has greater structural content. No such model is available in the Bureau, although use has been made of the Treasury's NIF model and the MACRO module of the IMPACT Project (see later). One difficulty with the NIF model, from the Bureau's viewpoint, is that the rural sector is treated as exogenous. However, a new project to attempt to endogenise this sector is being initiated.

The second broad approach to macroeconomic modelling is the use of (structural) general equilibrium (GE) systems, in which there is explicit recognition that individual actions are at the heart of every collective social phenomenon observed. Producers are generally modelled as maximising profits subject to technical constraints, while consumers maximise utility subject to budget constraints. Equilibrium is reached when all excess demands in the economy are zero. Such a GE model has been used in the Bureau. It is a five-sector model portraying agriculture, mining, manufacturing exports, manufacturing import-competing and services. The first three sectors are export sectors, the fourth is import-competing, while the services sector is nontraded. This model has been used to examine intersectoral issues such as the impact of mining growth on the economy, technological change, tariff reductions and subsidies (Stoeckel 1979*a*,*b*). The model has been described in detail by Stoeckel (1978) and in more general form by Stoeckel (1979*a*).

The ORANI module of the IMPACT Project is another GE model of the Australian economy that has been used by the Bureau. A novel feature of the latest (1978) version of the model is that specification of the agricultural production functions allows for joint production. In this formulation, a scalar index defines the generalised capacity to produce and this then serves to locate the multi-product transformation schedule. This two-level specification was empirically estimated using data from the Bureau's grazing industry surveys (Vincent et al. 1979).

A common set of deficiencies in both ORANI and the Bureau's GE model is that money, interest and intertemporal aspects are not specified. The models use comparative statistics and examine only the change from one equilibrium position to another in response to some exogenous shock or disturbance. This deficiency or lack of realism for some aspects is returned to later when issues such as the incorporation of expectations and money phenomena are touched on.

GE analysis and the mining boom. The five-sector model described above was developed initially to analyse issues of competition for resources between agriculture and other sectors of the economy. One such issue was the impact of the mining boom in Australia on agriculture. Australia is the world's largest exporter of iron ore and bauxite and a large supplier of coal; these mineral groups expanded in value terms by 25 per cent between 1966 and 1974. It was argued by Gregory (1976) that this mineral boom caused both the agricultural and import-competing sectors to contract. Gregory's argument was that the traded goods sectors are interrelated through the balance of payments and the exchange rate. A tendency for the balance of payments to improve through large sales of mineral exports would cause the exchange rate to appreciate. This appreciation lowers the relative prices of export and import-competing goods as measured in Australian currency. The lower prices for exports and relatively lower priced imported goods would cause the traditional export and import-competing sectors to decline. However, by using the GE model, with explicitly modelled terms of trade and income effects and inter-industry flows, Stoeckel (1979*a*) was able to show that, as a result of increases in domestic supplies, output of the import-competing sector in fact expands, at least in the long run.

Tariff changes and commercial policy. The tariffs maintained by Australia on imported goods are high by world standards. However, the large rural and mining export industries are unprotected and therefore are placed at a relative disadvantage to the import-competing (manufacturing) sector (Gregory 1976). Tariff and commercial policies are of major importance to overall economic policy and the structure of the Australian economy. Since the GE models referred to are 'real' models with resources and consumption optimally allocated by relative price changes, they are useful for longer run analyses of tariff changes. Both the five-sector and ORANI models have been used in the Bureau in this context. The ORANI results reported in Miller (1979*a*) and the five-sector GE results reported in Stoeckel et al. (1979*a*) are broadly similar in effect, with the agricultural sector benefiting from a 10 per cent across-the-board tariff cut, by an increase in the (real) value of farm produce (at the farm gate) in the range of 1 to 2 per cent.

Other GE analyses. Despite their shortcomings, GE models, by including many price and quantity interactions between industries and sectors, can provide insights into policy issues that otherwise would not be evident. Examples of where such added insights might be useful in the near future are the effects of oil price rises on agriculture and the economy; the effects of increasing real wages on the economy; changes in government spending; changes in international terms of trade; and the effects of booms in the rural sector on the national economy.

Possibilities for Integrated Research in Modelling

The pressures for increased involvement by the Bureau in policy work were described early in this paper. In this section, some possible advances in quantitative analysis which may enhance the Bureau's ability to respond to these policy questions are put forward.

Bureau resources are invariably allocated to those projects judged of greatest policy relevance and urgency at any time. Because these scarce resources must also be used to deal with a diversity of ongoing research, briefing tasks, in-house review of documents and development of the data base, there is restricted scope for new 'basic' research. Allocation of resources is carried out at several levels within the Bureau, such as via the Executive, review meetings, research seminars, and by individual Branch and Section Heads (BAE 1980*a*). This process is carried out on a year-round basis. Branch Heads are responsible for management of the research programs and, together with Section Heads, they allocate personnel to projects and integrate priorities. Responsibility for determining balance and composition of the program, and reconciling overlaps in research, rests with the Executive. For wool and meat, there is further scrutiny of research through review meetings with industry representatives.

The magnitude of the above tasks and the diversity of (necessary) projects undertaken mean that the management, co-ordination and sustained provision of an environment conducive to team research on quantitative models is difficult. Resources are just not available on a full-time basis for such sustained modelling efforts. Hence, the key to this research is either to develop the models over an extended time period, gradually increasing complexity while the models are in use, or to develop components of models as distinct projects, with eventual integration by specialised researchers. Examples of both these approaches can be found in the Bureau.

The suggestions below are tailored to the 'piecemeal' research environment just discussed. Emphasis is on additivity in research, or a 'building block' approach, making full use of models already in place and attempting to explore extensions of these models and areas where linkages between models might be possible. The result is a flexible suite of models with linkages functioning or not, depending on the nature of the problem at hand. By retaining operational small subunits, learning time is reduced for research staff and the costs of individual analyses are reduced.

Regional models and socioeconomic analysis

The regional programming model (RPM) is a comparative static production model which provides (profit maximising) outcomes of farmers' decisions in production and investment; i.e. it gives a simultaneous equation solution of products and factors used, given prices, technical coefficients and neoclassical assumptions about production. Linkages to the overall economy are through the prices of capital, labour and purchased inputs and through various institutional constraints (Longmire et al. 1979).

The RPM can be broadened by incorporating simulation components which model the bioeconomic and socioeconomic environments in greater detail. Such a broader model might operate as follows. With expectations for time period t formulated and with physical resources for t representing the outcome of production/investment from previous time periods, farmers will make decisions on production and investment for t. These (expected) levels of production and investment will be adjusted upwards or downwards, with attendant windfalls or costs, depending on the actual (simulated) outcomes for stochastic variables such as prices and yields in t. Actual outcomes and previous experience then influence household decisions on spending in t and savings for future investment, as well as farmers' expectations for the following time period.

Important research questions here are: (a) How should the RPM framework ultimately be structured and operated? What does it add to understanding if the model is expanded and what is the 'best' operational size? (b) How should outcomes, i.e. the stochastic environment, be modelled at the regional level? (c) How do farmers form expectations, react to risk and use information? (d) How does the socioeconomic environment affect decision making, involving both the reaction of the individual to his environment and the question of interaction within the rural/urban environment?

Technical structure. Experience has shown that increased detail in relation to production systems is a worthwhile investment — meaning that, for a given budget, we are better off with fewer 'farms' more accurately depicted than with more farms with highly aggregated activities. Increased detail is, however, not always warranted in analyses and thus often unnecessarily increases complexity and cost. The RPM is embodied in a FORTRAN package which improves flexibility in operation. One method of incorporating added (problem-specific) detail, therefore, is to build a number of 'blocks' of detailed activities which can be switched readily in or out of the model, depending on the problem at hand. An example of this is the work on exports of live sheep (Cornell and Hone 1978).

Expansion of the LP matrix to incorporate a number of farm sizes would be low cost and would allow a more accurate representation of overall resource use in agriculture. A highly aggregated production structure assumes away interfarm restrictions, to the extent that these result in actual production below the level of efficiency that it is possible to achieve on larger farms. While survey results show that lower productivity cannot confidently be correlated with farm size alone (BAE 1978*a*), at a minimum, some research on farm size to analyse one case study region should be conducted, given the finding that, in validation experiments, differences in matrix structure (i.e. technical coefficients) become evident for small and large farms (Kingma and Kerridge 1978, Appendix B).

Socioeconomic structure. The multiplicity of issues relating to the way in which farmers respond to their economic and wider environment has received some attention in the Bureau. Again, a full review of these studies is a paper in itself. However, it is useful to indicate briefly how these studies relate to the broader modelling program. Studies in labour demand (e.g. Bhati 1978), off-farm employment (e.g. Riethmuller and Spillman 1978), migration rates (e.g. Sexton 1976), time lags in adjustment (e.g. Monday 1981) and productivity change (e.g. Lawrence and McKay 1980) all potentially provide criteria or rules of thumb for determining rates of change or movement of resources, to be built into regional models. Similarly, the Bureau's microeconomic studies in investment behaviour (e.g. Waugh 1977*a*,*b*), use of information by farmers (e.g. Riethmuller 1978), values held by farmers (e.g. Kerridge 1978), attitudes of farmers to change (e.g. Robinson and Gibbs 1979), and determination of expectations (see our discussion of the industry econometric work) provide insight into the structure of agricultural production, hence allowing modification of models for policy advice (Kingma and Samuel 1977). In all the above, it is research into the formation and modification of expectations that requires the most urgent attention. Another area worthy of much more intensive investigation for modelling purposes is the microeconomics of change in the rural-urban complex (Kelly et al. 1978).

Econometric models, forecasting and policy analysis

In this section, approaches to forecasting and policy analysis within an econometric framework are put forward. Emphasis is on integration of both the individual models and the methods used to apply these models. Suggestions are not meant to be exhaustive but to give some indication of the direction of econometric work in the Bureau.

The changing approach to forecasting. Until recently, forecasting in the Bureau has tended to be undertaken on an individual commodity basis without formal integration until after preparation and review. Scope exists for both more comprehensive surveying of the economic environment within which agricultural forecasts are made, and for formalising the forecasting process, as has been done in the USDA (Boutwell et al. 1976).

As an export-oriented agricultural producer, Australia is heavily influenced by major economic changes overseas. Forecasts of the overseas economic environment prepared by institutions like OECD and USDA have been relied upon as an input to the Bureau's agricultural forecasts. Similarly, forecasting of Australian macroeconomic variables has been left largely to other Australian institutions. While not implying that the BAE is embarking on a macroeconomic modelling venture, the above situation is now changing as the BAE becomes increasingly involved in macroeconomic issues.

Efforts are being made at present to introduce improvements in methods used to arrive at forecasts, along the lines adopted by USDA (Boutwell et al. 1976). For example, co-ordination between commodity forecasts is increasing through more regular commodity meetings, availability of more comprehensive models and operation of better and more integrated data banks. Also, greater attention is now being given to consistency of specification of models between institutions, an example here being the much more regular liaison in technical modelling with USDA (A. Womack, USDA, personal communications, 1978 and 1979).

Feasibility of aggregate forecasts generated from individual commodity models has traditionally been achieved *ex post* and subjectively. In the most recent Bureau projections (BAE 1979*b*), however, consistency has been achieved in three additional ways. First, researchers increasingly have taken account of interrelationships between commodities in the modelling process. Second, the forecasting process has become progressively formalised and thus greater care is automatically taken in making consistent assumptions across industries. Third, industry assumptions have been combined into the 13-region regional programming model (RPM) of the beef, sheep and cropping industries to obtain a simultaneous solution for agricultural output, and consistency in utilisation of rural resources. As well as a consistency check on (aggregate) econometric results, the RPM has also provided a framework for projections in its own right.

Results from the RPM differ in nature from output from the econometric models, the former stating what farmers should do under profit maximising conditions and the latter stating what farmers actually do under the assumed conditions. Consistency can, however, be achieved through appropriate setting of flexibility constraints in the RPM. In addition, the RPM, as presently formulated, is used to project forward for a single period of one to five years, while the econometric results reflect recursive annual output over the same period. Therefore, projections from the two classes of model differ, especially for products with lengthy production cycles. A comparison of such projections is given in BAE (1979*b*).

Linking econometric models. In the interests of achieving greater consistency between forecasts from separate econometric models, attempts are currently being made to put together the essential elements of a multisector econometric model of Australian agriculture. Cross-commodity effects of importance within such a framework are the grazing livestock/grain complex; the feed-grain/intensive livestock complex; meat marketing margins; and domestic demand for meats. Details of this model have been discussed by us elsewhere (Kingma et al. 1980). However, it is important to note that many associated developments would be necessary for effective operation of such a model and, indeed, for operation of a suite of (integrated) econometric commodity models. The most important of these is attention to data requirements of the models and establishment of more systematic methods for handling data within the Bureau. A start has been made on development of such a data-handling system.

Policy evaluation and commodity models. A component of the Bureau's evaluation of agricultural policy relates to schemes of general market intervention such as international commodity agreements, international commodity stabilisation schemes, EEC agricultural policy, the U.S. meat import laws, the Australian beef export diversification scheme, and, in particular, domestic stabilisation schemes. The schemes have been developed and evaluated with two broad questions in mind – first, which of a number of alternative schemes is best suited to the particular problem and, second, given that policy makers have decided that a certain scheme will be introduced, how can this scheme be most efficiently implemented. A number of additional questions are usually raised; e.g. who gains and who loses from the scheme? what degree of stability can be achieved? what level of funding or stocks might be involved? what are the effects of alternative operating formulae for the schemes? and what administrative costs are involved? The Bureau's econometric models can play, and have played, an important role in the development and evaluation of such market intervention schemes.

Both optimal control and simulation approaches have been used in the Bureau for these evaluations. Dalton (1976) introduced the *optimal control approach* to derive stockholding policies for stabilising the wool market. The variables to be stabilised were price and production separately, rather than stabilisation of incomes in aggregate, and it was assumed that stabilisation policies should attempt to counteract the effect only of factors which cause short-term fluctuations in the wool market. A two-equation model of the wool market was estimated, with the price of wool and the numbers of sheep shorn as the endogenous variables. Instruments to achieve greater market stability, namely the purchase, stockholding and sale of wool by the intervention agency (Australian Wool Corporation) were superimposed on this market model.

The optimal control problem was set up to minimise the deviations of price and production from their long-run trends over a rolling five-year planning horizon. Trade-offs between the reduction in price variation and the average size of the stockpile were estimated, as well as the average capital requirement and the average rate of return on the intervention agency's trading operations.

A similar approach has been adopted in the Bureau for setting stabilisation prices by formula for buffer funding and bilateral commodity pricing arrangements. Considerable scope exists for employing current econometric models within such an optimal control framework. Research being conducted on wool stockholding by Hinchy and Simmons (1979) is likely to provide the Bureau with considerable experience of applying optimal control theory within the framework of a structural econometric model.

The second approach to evaluation and development of stabilisation and other market intervention policies with an econometric model is *policy simulation*. Unlike the two other approaches, which are normative, the simulation approach is positive. Thus, the simulation approach is not bound to the difficulties of specifying either targets or a welfare function. Furthermore, the simulation approach need not be constrained to linear models as is necessary for solution of the optimal control model. As well, the simulation approach is much more flexible, in that a number of policy instruments and operating rules can be introduced. However, by not having some optimality criterion superimposed, the analysis can expand quickly without some well-constructed procedures for policy experimentation.

Simulation of alternative pricing mechanisms has been employed in the BAE analysis of buffer funding arrangements for wheat and beef. These simulations involved examination of stabilisation mechanisms under predetermined price and domestic production conditions, as well as situations where supply was assumed to respond to (stabilised) price. Alternative formulae for setting price were simulated for these schemes (see, for example, BAE 1979*a*), and a number of trade-offs were highlighted, including the trade-off between size of buffer fund on average and the degree of stability that can be achieved.

This, then, gives a brief summary of the Bureau's approach in one area of policy analysis. Considerable conceptual and technical difficulties remain. However, as experience is gained, econometric models are likely to play an increasing role in the examination of problems where dynamics of the system must be captured.

Aggregate models of the agricultural sector

The rationale for attempting to make in-house models more comprehensive derives from the arguments presented earlier, the important issue being development of an analytical framework which also expresses the essence of economic activity in other sectors and the macroeconomy generally. Larger models do not necessarily provide better results and we do not mean to imply that a new ambitious modelling program is being initiated — the stress is on gradual development of models in a way which ensures a 'building block' approach to research.[1]

We have discussed the alternatives for development of aggregate models elsewhere (Kingma et al. 1980). However, briefly, four classes of models can be identified, depending on whether the viewpoint of modelling is micro-oriented or macro-oriented.[2] In the *micro-oriented* models, an adaptation of the RPM might form the core of the aggregate model with a less detailed institutional structure, based on GE principles, superimposed.[3] Alternatively, in *macro-oriented* models, where the aim is to explore the broader effects of changes in the macroeconomy and national institutions on the rural sector without detail on agricultural production and resource movements, then the aggregative model can best be viewed as a microeconomic system with perhaps some RPM features[4], or a GE system embedded in a time-recursive RPM framework.[5] The modelling of dynamic GE phenomena, with the formidable problems of specification of the dynamics, adaptation of expectations, the rate of interest/time preference and, indeed, whether solutions exist, constitutes a growing body of international economic research. The Bureau does not have the resources to enter this field competitively. However, given the investment in recursive programming methods as well as GE models, a logical extension is to attempt to combine these into a framework in which a GE model is solved for each time period, with recursive linkages through a set of dynamic equations.

In all this, modelling and data problems should not be underestimated. There is a large gap, for example, between the applied Walrasian models described above and theoretical GE analysis (Schwodiauer 1977). The *applied* modelling of transactions costs, imperfect adjustment and expectations is still in its infancy, as is the application of alternative typologies, such as game-theoretic Edgeworth models, to Walrasian systems. A greater *theoretical* focus on transactions costs and the exchange process

[1] Lest our enthusiasm in advocating quantitative research on seemingly ever-growing models be misunderstood, we stress here our attitude towards use of these quantitative models. Utility or total human welfare is derived from characteristics embodied within goods, implying that there is a qualitative hierarchy of goods with 'intermediate' market goods at one end of the spectrum and non-measurable goods yielding satisfaction in a psychic sense at the other. In quantitative analyses (as in the national accounts), only (material) goods and services exchanged in the market are counted, the implication being that, if only quantitative measures are used to gauge success of the system, there is likely to be a bias in apparent economic welfare, perhaps leading to incorrect policy decisions. Quantitative models can generate valuable information on various aspects of a wide range of policy measures. However, results from quantitative work must be used responsibly and be presented within a broader judgmental framework.

[2] Part of a commitment to extending in-house models involves keeping abreast of, and where possible, using models developed by other institutions. To this end there are six Australian models which the Bureau could use or has profitably used: the APMAA model of Australian agriculture (Wicks et al. 1978), the IMPACT model (Dixon et al. 1977; Powell 1977), the AREA model in which Australia is modelled as part of a world system (MacRae and Mula 1978), and the three macroeconomic models NIF7 (Higgins and Fitzgerald 1973), IMP (Brain 1977) and RBA76 (Jonson et al. 1977).

[3] See, for example, the 'multilevel' LP models developed by Goreux and Manne (1973), and in a recursive dynamic context the models of Day and Cigno (1978).

[4] This formulation would approach that of the ORANI module of the IMPACT project (Dixon et al. 1977; Powell 1977). The Bureau's attitude in this context is likely to remain one of contributing to and using ORANI where possible.

[5] An example of a model similar in concept to this is the dynamic GE model developed by Adelman and Robinson (1978).

has led to a large recent literature on the role of money in the economy. The GE models described above cannot handle these monetary issues, since exchange is treated as completely anonymous and costless. There is then no need for a special medium of exchange, and no problem of liquidity and, hence, no particular monetary rates of interest. Before money phenomena can be captured in large GE (or disequilibrium) models, intertemporal behaviour, market uncertainty and transactions costs should, ideally, be modelled.

Despite such difficulties, it seems certain that work on general (dis)equilibrium models will continue to hold a place in international economic research (Schwodiauer 1977), with potential payoffs to the Bureau's modelling program.

Summary

We have attempted to summarise the essential elements of the BAE's research as it relates to the use of quantitative methods in three modelling programs. The use of quantitative methods has increased sharply in the Bureau in response to the need to accommodate pressures for analytical work relating to formulation of improved rural policy, in the areas of trade with overseas countries, intersectoral competition/stabilisation within the Australian economy, and structural adjustment within the agricultural sector itself. We traced three major threads in the Bureau's quantitative work – first, the modelling of agricultural production systems using simulation and mathematical programming techniques; second, the modelling of rural industries (e.g. beef, wool) within an econometric framework; and third, with increasing emphasis on macroeconomic issues, the modelling of general equilibrium systems where the rural sector is treated as part of the overall economy. An attempt was then made to explore possible linkages between these groups of models and possible refinements of the models themselves, in ways which ensure additivity in research. Emphasis was on further development of structural models in the sense that they relate to action by particular agents in the economy. Suggested modelling developments were tailored to the inevitable 'piecemeal' nature of research, characteristic of organisations such as the Bureau, where long-term research must find a place amidst the often dominant and urgent day-to-day responses to industry and government.

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