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SOME ASPECTS OF QUANTITATIVE MODELLING IN THE AUSTRALIAN BUREAU OF AGRICULTURAL ECONOMICS

by

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1 Introduction

Given the major theme of this Conference, namely the use of quantitative methods for forecasting and economic analysis in agriculture, we have largely tailored our paper to a broad description of the various programs of economic modelling initiated in the Australian Bureau of Agricultural Economics (BAE) in recent years. We have, in the process, also found it necessary to touch on the philosophy of application of quantitative methods in the BAE.

The BAE is the (semi-autonomous) research agency of the Australian Federal 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 of regular agricultural surveys and recommendations/analysis 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 (6).

As seen from the outline above, we concentrate attention mainly on three classes of models. First, production models are discussed (Section 3) 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 (Section 4) which are used for projection work and, where structurally sound, 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 (Section 5).

The three classes of models, taken together, provide a range of methodology capable of addressing a wide 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 macroeconomic policies or in the structure of other sectors in the economy.

A challenging task facing economists in government organisations such as the Bureau, is (a) 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 (b) how best to introduce and utilise the results of quantitative research into government decision making, in order to effect consistent rural policy. To this end, some suggestions are made in Section 6 on how quantitative models used in the Bureau might be extended and linked to give greater insight into contemporary rural issues. Emphasis is on flexibility in construction and use of these models, and on tailoring of their further development to the research environment of government. As such 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 (3, 64).

Only the Bureau's major programs of quantitative Research are reviewed below. The large numbers of 'one-off' quantitative studies conducted by the Bureau in recent years, ranging from exploration of specific problems at the farm level to examination of market retailing systems, are listed in the BAE bibliography (10).

2 The Bureau's Research Program

The 1970s mark a period where 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.

(a) 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 where, although still expanding, agriculture is small relative to other sectors of the economy. The Australian rural sector cannot now be viewed in isolation. Inter-sectoral and macroeconomic isses extending well beyond the traditional rural focus have become important, with the Bureau being increasingly asked to provide judgements in areas outside agriculture.

(b) The magnitude of structural change required of the rural sector in the seventies 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, the Bureau resources have been mobilised to meet requirements of these IAC inquiries, which have ranged from adjustment of prices of individual inputs and outputs to the examination of entire industries and rural institutions.

(c) There has been a marked improvement in the quality of research workers and graduates over time, and in the comprehensiveness of their training. As noted by Gruen (34) this can be attributed to a substantial upgrading and expansion of staff in Australian universities in the seventies, the fact that economics has been one of the pronounced recent growth 'industries' in Australia and (until recently) given 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 numbers of Honours graduates in economics (as opposed to agriculture) and researchers with post-graduate qualifications, particularly Ph. D.'s.

(d) Linked to (c), the seventies mark a period of development, uptake and use of a wide range of quantitative tools by universities and institutions such as the BAE. There are two polar schools of thought on the ultimate usefulness of some of these quantitative methods. However, there can be no doubt about the impact which these techniques have had on the structure of the Bureau, its operation and methods of executing research. Continued participation by institutions like the BAE in policy requires consistency in approach which can be achieved in part by use of quantitative methods.

As a perspective to later sections, the Bureau's current research program can be summarised as follows:

(i) Export dependence of the rural sector means that attention is given to the 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, US, EC and New Zealand, and assessment of the general trading potential of the ASEAN and OPEC countries (42). Issues in stabilisation, access and transient as opposed to long term fluctuations and downturns 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.

(ii) 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- and long-term studies of the supply and demand for rural commodities - invariably researched using quantitative methods (Section 4) but also 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 (7), rural credit (4) etc., and second, broader micro- and macro-economic policies and trends such as changes in the tariff structure and analysis of 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.

(iii) Downward trending and fluctuating rural terms of trade imply continual change and adjustment of resources in agriculture. This involves investigating the extent to which farmers are able to accommodate and adjust to change, and the major impediments involved in this process (55). Analyses involve (1) maintenance of a comprehensive farm data base: (b) methodological research and modelling to provide a consistent framework to handle resource allocation problems, and (c)development of appropriate criteria and an analytical framework for evaluating policy and broader socio-economic 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.

3 Modelling Production Systems

Models of production systems developed in the Bureau can be subdivided according to time dependency, stochastic elements and treatment of the goal function - and a large number of Bureau studies can be identified which have modelled each or a combinatinon of these features. Models which retain a high degree of flexibility in terms of adaptability to diffeinvolved random selection of one of a number of discrete climatic patterns and attendant levels of livestock performance each quarter (44). Later versions (40, 58) incorporated more sophisticated inter-relationships between the pasture base and the animal, and included a larger number of 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, given present large holdings of grain, and are being expanded to incorporate optimising techniques.

The research into whole-farm modelling for beef, wheat and sheep properties has been reported by Kingma and Kerridge (53, 54) and in essence takes the form of recursive LP models with simulation components, for non viable, potentially viable and viable properties in the Wheat Sheep and High Rainfall Zones in Australia. Transformation matrices/vectors in this recursive formulation are really simulation modules expressing the financial structure of the firm, expectations, stochastic elements of the environment both within and between years, and utility and risk aversion on the part of the farmer.

The models were initially used in the Bureau's report on income stabilisation to explore the influence of price and output variation on the farmer's 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 to provide analytical backing to the Bureau's Report on Rural Credit (4). In this study, emphasis was on examining the effects on farm growth of the addition of varying amounts of land and/or capital, and the consequence of farms having to increase their debts to finance the increased size of operation, large liability costs and access to further credit (and the cost of credit) both during and after adjustment. This analysis was extended by Kingma and Kerridge (54) to provide a more comprehensive study of the ability of various types of farms to cope with economic pressures over time. Finally, the models have been used to assess the impact of constraints on expansion of the sheep meat enterprise (48).

The papers cited in relation to this model document some evidence that absolute output and changes in output from the models, both in terms of physical and financial variables, conform reasonably well to historical series. We have found that these models can 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 these 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, and more generally improvements in productivity growth, farm viability etc.. Further research in this area is being directed towards more rigorous specification of technical and behavioural relationships within the models (61).

Regional Production Models. As was the case for initiation of whole-farm modelling, regional production models were first used in the evaluation of input subsidies in the broadacre industries. This first attempt, reported by Kingma (50), 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 (a) to separately represent five major geographic regions in Australia, namely the three major zones with subdivision of the Pastoral and Wheat Sheep Zones into north and south representing, respectively summer and winter rainfall areas, and (b) to incorporate much more detail within these regional matrices. The model has been described in its general form by Easter and Kingma (30) and was used by Kingma et al. (52) 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, optimal use of variable inputs (e.g. fertilizer, labour) and the optimal pattern of land use development for any year. Stochastic features were introduced into the model through (a) parameters of the objective function, particularly prices and costs of variable inputs - thus allowing stochastic specification of prices; (b) technical coefficients - thus allowing introduction of stochastic feed supply and demand, and livestock performance. Dynacid features were introduced through linear difference equations operating on resource capacities and flexibilities.

Having developed the dynamic regional framework, we were confronted with the usual economic decisions on further modelling effort. The options were between either (a) having a small number of sub-regions with a relatively detailed configuration of land types, livestock and cropping activities together with comprehensive labour supply and demand and financial submodels, or (b) increasing the number of sub-regions with much less emphasis on specification of dynamic components. The five-region model was used in 1977 in an analysis of productivity change (15, 28, 51) without recourse to the dynamic structure. These analyses were based on use of the (static) LP matrix, given research time constraints and the learning time required for operation of the model by other research staff.

With this experience in mind, modelling since 1977 has been directed towards (a) above, namely a significantly 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 also increased in all 13 sectors. 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. (56). Diagrams and discussion in the paper by Cornell and Hone (20) give some idea of the detail built into the farm enterprises.

To date the model has been used in (a) further analyses of likely (ex ante) productivity change in the beef, sheep and cropping industries, (b) the Bureau's medium-term (5-year) supply projections (Section 6.2), (c) general (continuing) supply response work, and (d) 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 by the Bureau, relating to the Middle East trade, was reported by Cornell and Hone (20) who through derivation of response surfaces and supply elasticities relating to sheep meat production, helped to offset the unjustified panic in the sheep industry which developed in 1977-78 concerning a possible rundown in the national flock. Analyses using the model were also prepared during 1977 for a task force on the Middle East market (21) and results were integrated with a parallel analysis conducted at the University of New England with that university's regional model, APMAA. 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. This situation had reached such proportions that, because of industrial disputes, no live sheep were leaving the country. With the help of analyses of data generated from the model the Bureau was able to show the substantial national losses, repercussions within the farm production sector and rural employment implications resulting from such restrictions. The Report, the edited version of which is now in press (9), led to an eventual defusing of the confrontation.

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 computer funds 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 an overhaul and improved modelling of various components as required for policy work on the other. These production models are therefore likely to become more comprehensive over time as they are increasingly used to provide analytical results and as research staff become more competent in their use.

4. Modelling Commodity Markets

Considerable research effort has recently been devoted to developing (positive) 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 forecasts of gross value and volume of production and exports are published in issues of "Trends" and Bureau's new journal, "Quarterly Review of the Rural Economy". The Bureau now also prepares regular medium-term (five-year) projections of the Australian agricultural sector, the last projections being for 1982-83 (8).

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

In the 1960s those 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 (85) and Pender and Erwood (68) were rare exceptions. Updating was infrequent, depending on the policy analyses required and linkages between models or industries was 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. (35).

Wool was the commodity in Australia with the most pressing need for quantitative forecasting and policy analyses in the early seventies. Two approaches to the analysis and forecasting of wool prices were developed in the Bureau at that time. The first, by Duane (27) was a traditional market equilibrium study with the major addition being the modelling of inter-fibre competition in demand functions for wool and the simultaneous determination of consumption stocks, supplies and prices. The model was not, however, employed for forecasting because of its size and its inability to simulate the impact of changes in world business activity on Australian wool prices.

The other approach to wool price forecasting, instigated by Hussey (41) specifically addressed these difficulties. Using leading indicators (interest rates) of changes in business activity overseas and treating domestic production and competitive fibre prices as predetermined, a single equation price forecasting model was developed. The model was successfully employed for forecasting in the Bureau. Dalton (22) and Dalton and Taylor (25) updated this original model, introducing a number of innovative components including a diffusion index to replace the leading indicator in Hussey's study. The diffusion index incorporated 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 wool stockholding behaviour of the Australia Wool Corporation (18).

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 model which originated prior to this development in the market has lost some of its applicability. Current studies of the wool market are therefore focussing more on structural aspects of demand and supply of wool in Australia, including factors influencing levels of stocks (19, 39).

Livestock - In the early 1970s a major switch from sheep to sheep and beef occurred in the grazing livestock sectors. At that time a number of single-equation models, such as those of Malecky (60) and Dalton and Lee (24) were employed for analysis and forecasting of livestock numbers and the supply of meat and wool. 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-70s emphasis has been on modelling livestock supply in a multi-equation, multi-enterprise system using extensions of the models developed by Reutlinger (72), Freebairn (32) and Jarvis (43) which cast livestock supply in terms of traditional capital and investment theory. These models permit explicit modelling of the dynamic links between livestock numbers, production and 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 recently been developed in the Bureau and used in the five-year projections (8). 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 was a feature of these supply models. Further use and analysis of these models is reported in Longmire and Main (57), Reynolds and Gardiner (74) and West (88). The econometric supply models have at times been used in conjunction with the demographic or inventory (simulation) models developed for beef (71) and sheep (90).

Changing levels of domestic consumption of meats in Australia in the mid 1970s encouraged research on domestic demand for meat. Main, Reynolds and White (59) and, more recently, Reynolds (78) employed a demand systems approach to analysing retail demand for meat. The meats included in the demand system were beef, sheep meats, pig meat and poultry meat.

With the experience of separately modelling the price formation process, domestic supply and demand, and the US market (13), Longmire and Main (57) have developed an aggregative annual model of the Australian beef market. The model is simultaneous and the main endogenous variables are livestock numbers, production, consumption, exports and prices at the saleyard and retail levels. As well as simulating over an historical period and projecting into the mid 1980s, the impact, interim and long-run multipliers of the model have been calculated using a BAE computer package. Further insight into the various overseas markets is also being obtained through complementary studies in the Bureau, such as that by Hinchy (38) who used spectral techniques to investigate lead-lag relationships between prices in the US (manufacturing) beef market and Australian beef prices.

The highly institutionalised nature of the markets for other livestock products has limited scope for econometric analysis. Price-forecasting for eggs, retail demand studies for fluid milk, butter, cheese have been undertaken with varied results. Not only do intitutional constraints and structural changes infringe heavily 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. The modelling of the supply of these products will remain difficult.

Grains and oilseeds - Approximately 80 per cent of wheat grown in Australia enters the export market, which means that price forecasting involves difficult and resource intensive modelling of the international grain economy. In Australia, because of the way returns to producers have traditionally been determined for wheat delivered to the Australian Wheat Board, there has been little informational need for public forecasts of wheat prices. Quantitative modelling of world wheat prices has therefore been limited to simple 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 now consequently increased.

Econometric analysis has recently been employed in the Bureau to model and project the domestic supply of wheat and coarse grain production (as opposed to fodder production). 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 (12). More recently a similar model of domestic utilisation of grains for stockfeed 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 including sugar, rice, cotton and horticulture) generally has been undertaken in relation to medium term supply projections (18) or specific government enquiries into policies affecting these crops. As a rule the analyses of demand and supply of these crops employed single equations techniques, often with a time trend explanatory variable to provide forecasts of future production or consumption. Exceptions have been the models for citrus fruit (2) and grapes (65).

5 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. This 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 (31).

There are two broad approaches to macroeconomic modelling. The first, macroeconometric modelling involves specifying a multiple equation system in which macroeconomic concepts are of a derived nature and deduced by means of aggregation rules from their microeconomic components. Examples of these sorts of models used in Australia would be the Treasury's NIF (National Income Forecasting) Model (Section 6.3) and the Reserve Bank's RBA76 model (45). The former model is used largely for forecasting purposes whereas the latter has a greater structural content. To date there has been no such model developed in the Bureau, although use has been made of the Treasury's NIF model and the MACRO module of the IMPACT Project (Section 6.3). 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 endogenise this sector is being initiated.

The second broad approach to macro-economic 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, namely, 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 non-traded. 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 (82, 83). The model has been described in detail by Stoeckel (81) and in more general form by Stoeckel (82). The ORANI module of the IMPACT Project is another GE model of the Australian economy that has been used by the Bureau.

GE analysis and the mining boom - The five-sector model described above was initially developed 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 is a large supplier of coal and these mineral groups expanded in value terms by 25% between 1966 and 1974. It was argued by Gregory (33) 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 (82) 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 - Australia maintains a tariff on imported goods which is high by world standards. However, the large rural and mining export industries are unprotected and are therefore placed at a relative disadvantage to the import-competing (manufacturing) sector. 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 highly suitable to 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 (63) and the five-sector GE results reported in Stoecke et al. (84) are broadly similar in effect with the agricultural sector benefiting from a 10% across-the-board tariff cut, by an increase in the (real) value of farm produce (at the farm gate) in the range of 1-2 per cent.

6 Potential Linkages Between Models and Possibilities for Integrating Research

The pressures for increased involvement by the Bureau in policy work were described in Section 2. 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 deal with a diversity of on-going 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 (6). 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 task and the diversity of (necessary) projects undertaken (6) mean that management, coordination and sustained provision of a conducive environment for 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 to either 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-sub-units, learning time is reduced for research staff and the cost of individual analyses is reduced.

6.1 Regional Models and Socioeconomic Analysis

The RPM depicts a comparative static production model embodying implicit demand equations for agricultural factors of production, and aggregate supply equations for the broad-acre full products. The structure includes exogenous prices and 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 on production. Linkages to the overall economy are through the prices of capital, labour and purchased inputs and through various institutional constraints (56).

The RPM can be linked to the bio- and socioeconomic environment through simulation components. A completed socioeconomic framework might portray that at the start of time period t, with expectations for t formulated and with physical resources for t representing the outcome of investment/disinvestment over previous time periods, farmer decisions (modelled through linear programming techniques) will flow through to factor and product markets. Actual outcomes for t (i.e. the influence of stochastic variables such as prices, yields etc.) are 'revealed' reinforcing or disappointing expectations held on returns from production and investment costs. Actual outcomes and experiences from previous time periods then influence, first, household decisions on spending in t and savings for investment in t+1, and second, expectations regarding the next time period, t+1.

Important research questions here are: (a) how should the RPM framework be ultimately 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, this 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 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 is therefore to build a number of 'blocks' of detailed activities which can be readily switched in or out of the model, depending on the problem at hand. An example of this is the work on exports of live sheep (20).

Expansion of the LP matrix to incorporate a number of sizes of farms would be low cost and would allow a more accurate representation of overall resource use in agriculture.

A highly aggregated production structure assumes away inter-farm restrictions, to the extent that these result in actual production below the level of efficiency possible to achieve on larger farms. While survey results show that lower productivity cannot confidently be correlated with farm size alone (3), at 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 (54, App.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 briefly indicate how these studies relate to the broader modelling program.

Thus we have at regional level, studies in labour demand (e.g. 14), off-farm employment (e.g. 76), migration rates (e.g. 79), time lags in adjustment (e.g. 66), and productivity change (e.g. 62), all of which provide criteria or rules of thumb for determining the rates of change or movement of resources to be built into agricultural models. Similarly the Bureau's microeconomic studies in investment behaviour (e.g. 87), use of information by farmers (e.g. 75), values held by farmers (e.g. 47), attitudes of farmers to change (e.g. 77), and determination of expectations (see Section 4), provide insight into the structure of agricultural production, hence allowing modification of models for policy advice (55). 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 is the microeconomics of change in the rural-urban complex (46).

6.2 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 give some indication of the direction of econometric work in the Bureau.

6.2.1 The Changing Approach to Forecasting

Forecasting in the Bureau has until recently 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 formalising the forecasting process as has been done in the USDA (17).

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 largely left to other Australian institutions. This situation is now changing as the BAE becomes increasingly involved in macroeconomic issues.

Improvements in the procedures used to arrive at forecasts along the lines adopted by USDA (17) are presently being introduced. Coordination between commodity forecasters is increasing through more regular commodity meetings, availability of more comprehensive models (see Section 6.2.2), operation of better and more integrated data banks and the greater availability of alternative in-house forecasts. Greater attention is now also being given to consistency of specification of models between institutions, an example here being the much more regular liaison in technical modelling, with USDA.

Feasibility of aggregate forecasts generated from individual commodity models has traditionally been achieved ex post and subjectively. In the most recent Bureau projections (8), however, consistency was achieved in three additional ways. First, researchers increasingly took account of interrelationships between commodities in the modelling process. Second, the forecasting process has progressively become formalised thus greater care is automatically taken in selecting consistent assumptions between industries. Third, industry assumptions were 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 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 whereas the latter state 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 1-5 year period while the econometric results reflect recursive annual output over the 1-5 year series. Projections from the two classes of model thereafter differ, especially for products with lengthy production cycles. A comparison of such projections is given in BAE (8).

6.2.2 Linking Econometric Models

In the interests of achieving greater consistency between forecasts from separate econometric models we are currently attempting to put together the essential elements of a multi-sector econometric model of Australian agriculture. Cross-commodity effects of importance within such a framework are (a) the grazing livestock-grain complex; (b) the feedgrain-intensive livestock complex; (c) meat marketing margins; (d) domestic demand for meats.

Year-to-year linkages, which would partly determine the dynamics of the model, would be specified for major capital stock variables (livestock numbers, land areas and stocks on hand of livestock products and grain). Other lagged endogenous variables such as lagged prices, will also affect the dynamics of the model through lags in formation of expectations affecting major supply variables, and through adjustment delays in the setting of marketing margins and in consumer response to price. Key endogenous variables in this model will be land area, crop yield, grain production, farm-level grain prices, domestic grain utilisation, grain exports, livestock numbers, natural increases, livestock slaughterings, output per head of livestock, livestock production, marketing margins for domestic and export markets, livestock product prices at farm/retail/export level, and exports of livestock products. The principal exogenous variables in the model will be input prices an index (or indices) of seasonal conditions, population, income, prices of other foods, inflation, an index of costs in the marketing sector, export prices and constraints on shipment of exports.

Many associated developments related to the Bureau's quantitative modelling efforts would be necessary for effective operation of an integrated econometric model. For example, a systematic data-handling system would be an essential component as well as development of procedures for regularly assessing the model's predictive ability. Flexibility of model construction is crucial so that the structure of the model may be altered and commodities added/deleted as markets change.

6.2.3 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 US meat import laws, the Australian beef export diversification scheme, and, in particular, domestic stabilisation schemes. Generally, the schemes have been developed and evaluated with two broad questions in mind: (1) which of a number of alternative schemes is best suited to the particular problem, and (b) given that policy makers have decided that a certain scheme will be introduced, how can this scheme be most efficiently implemented. In the process, a number of additional questions are usually raised, namely, 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 (23) 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 sheep numbers 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. Tradeoffs 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.

The second approach to evaluation and development of stabilisation and other market intervention policies with an econometric model is policy simulation. Unlike the other two approaches, which are normative, the simulation approach is (conditionally) positive. Thus the simulation approach is not bound to the difficulties of specifying either targets or a quadratic 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 quickly expand without some well constructed policy experimentation procedures.

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 5), and a number of tradeoffs were highlighted, including the tradeoff between size of buffer fund on average and the degree of stability that can be achieved.

6.3 Linking Regional and Macroeconomic Models

Some ideas on linkages between the Bureau's GE model and the (static and time based) RPM are explored below [1]. We are

[1] Note that we do not mention the econometric commodity models of Section 4 in this Section. However, because of the insight these models give into the dynamics of market equilibrium they have a potential role to play in any future formulations of the above RPM-GE models.

conscious of the fact that larger models do not necessarily provide better results. However, the rationale for attempting to make in-house models more comprehensive links back to the arguments presented in Section 2, the important issue being development of an analytical framework which also expresses the essence of economic activity in other sectors and the macroeconomy generally. Equally, we do not imply that a new over-ambitious modelling program is being initiated. The stress is on gradual development of models with a 'blueprint' in mind to guide research and to ensure additivity of individual research projects. Exposure of elements of such a blueprint to professional scrutiny is important. The following is not an exhaustive list of possible models.

Four classes of models can be identified depending on whether the viewpoint of modelling is micro- or macro-oriented. In the micro-oriented models an adaptation of the RPM might form the core of the aggregative model with a less detailed institutional structure based on GE principles superimposed (Models 2 and 4 below). Alternatively, in macro-oriented models, where the aim is to explore the broader effects of change 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 (Model 1), or a GE system imbedded in a time recursive RPM framework (Model 3).

Model 1 essentially involves expansion of the GE model of Section 5 to either (a) accommodate specific policy problems while retaining the present perspective between sectors, or (b) expanding the agricultural sector only, as a means of gaining greater insight into the interplay of agricultural and non-agricultural markets. Data derived from the RPM might provide an input to this latter formulation. Development according to (b) would approach the IMPACT formulation, thus effort in this area might be mis-spent.

Model 2 really reflects the RPM framework, developed to include linkages between the rural sector and the macroeconomy.

The well known example of this class of model is Goreau and Manne's "multilevel" LP model which generates results under both perfect competition and monopoly conditions for variables such as employment, sector output, income levels, regional distribution of income, price levels, exports and imports and resource use. The appealing feature of Model 2 from the Bureau's viewpoint is that the detail already modelled for (regional) agricultural processes can be explicitly retained while allowing agriculture to be modelled as part of the economy. Experience gained and data analysed in development of the Bureau's GE model would be of direct relevance to modelling the macroeconomic 'balance' equations for such a model.

Model 3. The modelling of dynamic GE phenomena with its formidable problems of specification of the dynamics, adaptation of expectations, the rate of interest/time preference, and indeed whether solutions exist, is a growing body of international economic research. The Bureau does not have the resources to competitively enter this field. 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. Adelman and Robinson (1) have provided a comprehensive account of their modelling experiences using these concepts. Solution of their model for each time period involves three phases, (a) determination of investment by producers, based on expectations; (b) solution of a static GE system in which investment from (a) is exogenous; and (c) updating of variables, formation of expectations etc. for t+1. As such their model is similar in concept to the farm models of Section 3.

Model 4 might involve an activity analysis framework with the clearing of markets in time t taking place with reference to either (a) dynamic (Bellman) equilibrium principles, or (b) a series of temporary equilibria over time. Conceptualisation of production and consumption in this way brings to the fore many similarities with von Neumann's notion of dynamic equilibrium. A realistic and intuitively appealing empirical adaptation of von Neumann's model has been developed by Day and Cigno (26). In their model firms are conceptualised as operating according to the von Neumann criteria. Duality theory is used to show that firms' optimal choices of activities and activity levels for a sequence of periods can be a solution of a one-period program in which accounting prices, p, of closing stocks (resource valuations) are parameters. This introduces expectations into their model in a specific way. Firms' productivity and investment plans are then combined with (aggregate) consumption and employment decisions of households to give a general equilibrium choice of activity levels in t, for given expectations on p_{t+1}, and subject to the usual von Neumann constraints on capital and current output. Consumption, production and prices of inputs and outputs are endogenously determined. The model can simulate constant proportional growth in consumption of goods over time (i.e. the von Neumann ray is a special case in their formulation). However the authors concentrate mainly on the type of disequilibria phenomena which would be of interest to an applied institution such as the BAE.

In all the above, modelling problems should not be underestimated. There is a large gap, for example, between the applied Walrasian models of Section 5 and theoretical GE analysis (78). 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 has led to a large recent literature on the role of money in the economy. The GE models of Section 5 cannot handle these monetary issues since exchange is completely anonymous and costless. There is 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, intemporal 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 (78), with potential payoffs to the Bureau's modelling program.

Other Australian Models: Part of a commitment to extending in-house models involves keeping abreast of and using where possible, models developed by other institutions. To this end four Australian models are described below as analytical frameworks, which the Bureau could (has) profitable use(d).

APMAA is a model of the Australian agricultural sector based on some 500 representative farms stratified according to size, type and region. Individual representative farms are modelled using linear programming (89). Because of its highly disaggregated structure and hence flexibility in modelling features of (regional) policy problems, APMAA can be regarded as complementary to the Bureau's models. Liaison to this end has taken place on two projects, namely the analysis of the export potential for live sheep and the effect of rising oil prices on agriculture.

IMPACT provides a comprehensive framework for studying the implications of economic and social change (70). The medium-term component of this model, ORANI, is a GE system (Section 3) with some 110 industries and commodities. The Bureau economy of changes in tariffs, exploitation of mineral resources, a fiscal stimulus, pricing of oil products, assistance to industries etc.

The NIF model is a macroeconometric quarterly Keynesian model of the Australian economy developed by the Treasury (37). Hopefully, agriculture will ultimately be made endogenous in the equation system, providing a greater potential for joint analysis between the Bureau and Treasury.

The AREA Model of the Australian Department of Science and Environment is being developed as an Australian (econometric) model for the UK Department of Environment's 'Systems Analysis Research Unit Model' (SARUM) which is aimed at providing an analytical framework to assist in guiding long-term policy and planning decisions in the areas of international trade and resource use. AREA is of potential use to the Bureau in studying world and regional food supply and demand problems, environmental problems relating either directly to agriculture, such as the analysis of the effects of toxic agricultural chemicals, or indirectly through, for example, changing relative prices, energy conservation, ecological legislation etc.

7 Summary

We have attempted to summarise the essential elements of the BAE's research program as this relates to use of quantitative methods in economics. 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 refinement 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 response to industry and government.

Finally, lest our enthusiasm in advocating quantitative research on seemingly ever-growing models be misunderstood, we stress 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 quantitative measures only are used to gage success of the system there is likely to be a bias in apparent economic welfare, perhaps leading to wrong 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 judgemental framework.

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