Review of the TRYM Model, June 1997

# *COMMENTS ON SOME MODELLING ISSUES*[1]

by

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## *1. Introduction*

The Treasury is to be congratulated for the openness and accessibility of TRYM. The documentation of theory and data, and the availability of a documented computer system to run the model, establish TRYM as a major public asset for practical economic policy analysis. Recent documentation gives intuitively appealing explanations of TRYM results, identifying the key controversial conceptual issues (expectations, policy lags etc.), and honestly stating the limitations of the model. All of this augers well for further development of the model, for interaction with the wider profession, and for the dissemination of knowledge.

This paper addresses in order four modelling issues on which we have been asked to comment: the treatment of expectations in TRYM; the scope for more use of systems estimation of its behavioral equations; the treatment of taxes; and finally, whether there are gains to be made by further disaggregation of the model. These topics are discussed in turn in Sections 2 through 5.

## *2. Expectations in TRYM*

### *2.1 General considerations*

The treatment of expectations in macroeconometric models poses special problems for model builders. First, the long-run convergence properties of a model are not independent of the assumed expectations formation process. For example, an expectations formation process that allows agents to make avoidable forecasting errors in the foreground and middle distance of a planning horizon will be inconsistent with the model's long-run postulates (typically neutrality and super-neutrality of money, plus purchasing power parity) *unless* (as in TRYM) there is an error correction mechanism that progressively eliminates forecast errors over time so that the model does indeed converge to its correct steady state.

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Second, despite the existence of a large empirical literature, there is little consensus about how agents in the various markets form their expectations. While there is little contention that investors, arbitragers, consumers, producers and governments are forward looking, the issue of what information about the future these agents use is contentious. Indeed, even the empirical standing of the Lucas critique (1976) itself has been called into question (Ericsson and Irons, 1995).

In common with many of the modern macroeconometric models used for short-run forecasting and for policy analysis, forward-looking behaviour in TRYM is confined to financial markets. Agents operating in the goods and labour markets are assumed to be backward looking. This dichotomy in the treatment of expectations can be traced back at least as far as Dornbusch (1976) and is consistent with the observation that financial markets adjust quickly relative to goods and to labour markets.[4]

Apart from theoretical and empirical considerations, there are also good practical reasons for confining forward-looking expectations to financial markets. Typically, forward-looking expectations are assumed to be model-consistent or *rational*[5] and models with rational expectations are more difficult to solve than are models with backward-looking (usually adaptive) expectations. This difficulty is a non-linearly increasing function of the number of forward-looking variables. In addition, the imposition of rational expectations often produces short-run results (such as large jumps in the values of variables) that are seen as implausible.

These jumps arise because the behaviour of agents in the short run is linked to the model's projections of future behaviour. Such behaviour will follow some rule for intertemporal optimality in which the paths of endogenous variables depend on the information set containing what the market believes about the future evolution of exogenous variables.

Shocks to the model consist of a discontinuous change in this information set. The size of the induced jumps in the endogenous variables at the time of (or in discrete-time models, just after) the shock is magnified considerably in models with forward looking behaviour, and it is this that leads to difficulties with the plausibility of projections. As a consequence, the credibility of the model for short-run forecasting may appear to be compromised, although perhaps not fairly so.

The fundamental difficulty is that the shock, by assumption, is a discrete change in the expectations (about current and future exogenous variables) held (according to the model framework) by *all* market participants. Such discrete jumps in the information set can seldom, if ever, be identified with historical events. This means that the thought experiment conducted using the model asks a 'what if' type question

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4 It is also often argued that agents in financial markets are more likely to seek and use information about the future when forming their expectations than are agents in other markets because the payoffs for doing so are greater in relation to the costs.

5 Rational expectations will be used below interchangeably with *model-consistent* expectations.

for which the observer's intuition is poorly prepared by casual historical observation. Thus claims about implausibility of jumping variables in models with rational expectations may be exaggerated.

If the argument in the last paragraph is accepted, then the production of 'plausible' forecasts from a model containing forward-looking (and especially, rational) expectations may require an intermediate task in scenario writing. If expectations of all agents in a particular market do not undergo an identical instantaneous change (such as the belief, say, that real government spending will be 2 per cent less than previously supposed), then the shock cannot be injected into the model in the usual manner. Instead it may be necessary to hypothesize an 'as-if' time path for the evolution of the shock, allowing time for the realization by the market as a whole that its previously held forecasts must be revised. Of course this involves arbitrary decisions in modelling, and the end result in practice may not look very different from an approach in which expectations are adaptive rather than rational.

Notwithstanding any of the above, the acceptability of short-run forecasts may be improved if expectations are assumed to be backward-looking in most markets with variants of model-consistency confined to financial markets.

*2.2 TRYM's current modelling of financial markets*

The modelling of financial markets in TRYM is atypical in two key respects. Firstly, uncovered interest parity (UIP) is assumed to hold in the long run but not in the short run. An ad hoc term-structure equation relates short- and long-run interest rates.[6] Secondly, while agents in financial markets do not form their expectations rationally, they do use some information about the future.

TRYM's financial agents must form expectations about the exchange rate and the price level 40 quarters hence. They are assumed to be able to predict the effects that a particular shock will have on the exchange rate and the price level in the steady state; they are unable, however, to predict with certainty the effects that a particular shock will have on the exchange rate and the long-term inflation rate 40 quarters hence.

Expectations about these two variables are formed on the basis that the economy will have reached its steady state within 40 quarters of the time that a shock is experienced. Since there is nothing in TRYM to ensure that the economy does reach a reasonable approximation to its steady state within 40 quarters, expectations about the exchange rate and price level are not necessarily realized. Hence forward-looking agents can make systematic forecasting errors that persist through the foreground and middle distance of a projection but which are eliminated asymptotically over time, so that such errors do not occur in the steady state.

This expectations formation process is described as quasi model-consistent (hereafter referred to as QMC) by the developers of TRYM. Relative to rational

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[6] The developers of TRYM justify the model's ad hoc term structure equation on the basis that it "... emulates movements in bonds in history while preserving sensible simulation properties for the model as a whole" (Commonwealth Treasury, 1996a, p. 6.6).

expectations, it has the considerable computational advantage that solutions of the model can be obtained recursively.

This is in tension with the standard approach to macroeconometric modelling where expectations are assumed to be either adaptive or model-consistent.[7] Several analysts, including Fair (1979 and 1984), Murphy (1988) and Fisher *et al.* (1992), have shown that the simulation properties of macroeconometric models are sensitive to which of these two standard expectations formation processes is assumed to apply in financial markets.[8] As argued by Pesaran (1987), the adaptive expectations hypothesis (AEH) and the rational expectations hypothesis (REH) represent two extremes, both of which have serious methodological and empirical shortcomings. In the theoretical literature, rational learning models and learning models exhibiting bounded rationality have been advanced as alternative expectation formation processes.

Somewhat related, but in many respects novel is the approach adopted by Gruen and Gizycki (GG) (1993). In it the jumping behaviour of exchange rates can be attenuated substantially (or even wholly) under plausible assumptions which explain the persistence of less than fully rational traders in the foreign exchange rate market in a manner that is consistent with the widely observed (but otherwise puzzling) existence of forward discount bias.

To our knowledge, however, these alternative expectations formation processes have not been implemented in macroeconometric models used for short-run forecasting and policy analysis.

*2.2.1 Advantages of TRYM's current approach*

For macroeconometric modellers the QMC expectations formation process implemented in TRYM is an alternative to the REH and the AEH that has some clear advantages:

- Relative to the AEH, with very little additional computational effort the QMC relaxes the former's extreme assumption that agents form their expectations without using any of the model-generated information that is available about the future.
- Both the QMC and the REH relax the extreme assumption that agents' expectations are totally backward looking; however the QMC approach does this with a tiny fraction of the computational effort that is required by the REH.

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7 In some cases there can be both types of expectations in the one model with agents in some markets, usually the labour and goods markets, assumed to have adaptive expectations while in other markets, typically the financial markets, agents are assumed to have rational expectations. For example, in the Murphy Model, financial agents (but not others) have rational expectations (see Powell and Murphy, 1995).

8 These studies complement the theoretical literature which has its roots in the works of Lucas (1972 and 1976), Sargent and Wallace (1976) and Fischer (1977) by comparing the effectiveness of policy shocks when expectations in financial markets are formed rationally with the case in which they are formed adaptively.

As explained above, under the QMC approach, agents do use information about the steady-state effects of a particular shock in forming their expectations (and in this respect QMC has affinities with GG). It follows that the QMC approach offers a computationally less demanding method for modelling genuine forward-looking behaviour than does the REH.

What criteria can be used as a basis for selection of one expectations mechanism rather than another? Given that the existing statistical evidence does not offer a sound basis for discriminating between the different approaches[9], it seems that the theoretical rigour of the REH must be traded off against the computational advantages of other approaches (and possibly also against the greater plausibility of projections produced by the latter, depending on one's judgement about the issues discussed above in Section *2*.1).

The REH, that agents make optimal use of *all* available information, provides a coherent and transparent mechanism by which they form expectations. It offers a practical approach to addressing the concerns raised by Lucas (1976) and allows for policy analysis when the implications of the policy are understood and affected by agents whose actions reflect a planning horizon of two or more periods. In contrast, agents do not use all available information about the future under the QMC approach and their reasons for not doing so are not made explicit.

In this respect an approach along the lines of GG may be superior in that the reasons for departure from full rationality are laid out and the behavioural parameters required to implement this alternative treatment of expectations are identified, and procedures for their calibration are suggested.[10] Moreover, since non-jumping and Dornbusch exchange rates are nested within GG (as well as combinations of the two), their paradigm offers a very flexible treatment of financial markets, but one for which there exists an explicit and plausible (though somewhat complicated) explanation. The prospects for incorporating GG-style dynamics within a practical macro model are currently being investigated by Peter Marshall, a Ph.D student at Monash University.

Another possible criterion for choosing between the REH and the QMC expectations mechanisms is to ask the question: How much difference would it make to TRYM if the latter were replaced by the former? This has been investigated in detail by two members of the Centre of Policy Studies at Monash University.

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9 While the REH is widely accepted (but not universally, see Pesaran, 1987) in the theoretical literature and increasingly adopted in applied models, empirical support for the hypothesis is scant. To our knowledge there has not been any attempt made to test the statistical validity of the QMC approach.

10 For example, may reflect some optimizing behaviour where the costs and benefits of additional information are traded off by agents.

### *2.3 Investigation of the effect of incorporating full rational expectations into TRYM's financial markets*

Malakellis and Transom (MT) (1996) have analyzed in detail the treatment of financial markets in TRYM — their paper is included here as Appendix A. They find it difficult to reject the treatment of interest rates and forward looking expectations in TRYM on purely statistical grounds. Similarly, because the statistical evidence is inconclusive, it is difficult to discriminate between the treatment of financial markets in TRYM and a more conventional one in which (a) expectations are model consistent; (b) uncovered interest parity holds in all periods; and (c) the relationship between long and short-run interest rates is based on the pure expectations theory of the term structure of interest rates. Because of these difficulties MT's analysis is based on a comparative assessment of the simulation properties of TRYM under alternative specifications of the financial markets. In their paper the shocks are all monetary.

The long run is not in contention. This is because, as noted above, if agents' expectations follow QMC they are able to predict the effects that a particular shock will have on the exchange rate and the long-term inflation rate in the steady state; thus the steady state of TRYM, a neo-classical balanced growth path, is invariant to the choice between QMC and REH.

For financial markets at least, there is persuasive anecdotal evidence that announcement effects are important. Central bank and finance ministry officials are particularly sensitive to the way financial markets react to new information and this is reflected in the cautious nature of their public statements. In Australia, for example, the Commonwealth Treasury always assumes that the nominal exchange rate will remain unchanged in its budget forecasts.

The sensitivity of financial markets to new information can also be observed when official statistics (e.g., employment growth, inflation, budget forecasts, current account position, etc.) are released. There is often much speculation in financial markets about such statistics in the lead up to their release. If the official statistics turn out to be broadly in line with market expectations, then the reaction of financial markets will typically be subdued because any new information contained in these statistics will have been factored into agents' decisions prior to the release. Conversely, the reaction of financial markets can be quite volatile if the information contained in newly released statistics is unexpected. Thus one of the aspects of model behaviour studied by MT is the difference between the performance of TRYM under QMC and REH when a credible policy change is announced in advance of its implementation: does the treatment of expectations substantially affect how the model responds to such announcements?

MT find that the results produced by TRYM under the competing expectations hypotheses are similar when the money shock is permanent and unanticipated. For pre-announced money shocks, however, the different treatment of expectations under the two treatments of expectations causes substantial deviations between the two sets of results. These differences are greatest when the announced money shock is temporary. Under QMC the forward-looking agents in financial markets did not respond prior to the monetary shock actually hitting the economy, even though they had five years advance warning.

The responses to the announced money shocks produced by TRYM under the two treatments of expectations also raise questions about the absence of forward-looking behaviour in the real sectors of the economy. (Note that this backward-looking treatment of expectations in the goods and labour markets applies irrespective of whether QMC or REH is used for expectations in financial markets.) In one simulation experiment, agents had 20 quarters advance notice of the shock, yet the real sectors of the economy did not respond at all until shock was implemented; and when they did so, their response was sluggish.

Notwithstanding any of the above, MT's results suggest that for most practical policy and forecasting purposes, the simulation properties of TRYM to a change in monetary conditions are not greatly affected by the choice between fully rational and quasi-rational expectations in financial markets. As already noted, the exceptional cases all involve announcement effects. Unpublished preliminary work with fiscal shocks tends to support the generality of these conclusions.

## *3. Estimation Issues*

The main issue we have been asked to consider under the above heading is the

> 'possibility of making greater use of joint estimation techniques in the TRYM Model's various sectors and markets'.

We give our remarks on this question in Section 3.1. Section 3.2 contains our other comments relating to estimation. These consist of: (i) a review of the strengths and weaknesses of different estimators that might be used; (ii) a brief canvass of the prospects for estimating TRYM 'in one hit' with a systems estimator; and (iii) an annotated list of miscellaneous points gleaned from the experience of the Centre of policy Studies with TRYM.

### *3.1 Should TRYM make more use of systems (as distinct from single-equation) estimators?*

In the current version of TRYM, most equations are estimated by single-equation methods (usually OLS); the salient exception is the **Private Business Sector** in which business investment, the demand for labour and the price equation for non-'commodity' output are estimated as a simultaneous subsystem.

#### *3.1.1 General nature of the trade-off*

At the dawn of the modern econometric era, the work of the Cowles Foundation established that systems of structural equations need to be estimated via systems methods if *simultaneous equations bias* is to be avoided. Despite general agreement on the validity of this proposition, the use of systems methods in estimating the structural equations of macroeconometric models is the exception rather than the rule. Later we must look for the reasons that macro modellers have so opted.

Simultaneous equations bias aside, deciding to estimate several equations jointly as a subsystem represents a judgement that the systematic parts of some of them, or their stochastic errors, contain useful information that can be brought to bear on the systematic parts of one or more of the other equations, or on their stochastic parts. Thus such a decision in effect is an option to use more, rather than less, prior information.

Quite generally, one can identify a type A and a type B error when using additional *a priori* information in the specification of a behavioural equation or of a subsystem of equations. Type A is the undesirable consequences of incorporating such information when it is inaccurate; type B consists of the unnecessary losses in efficiency of estimation and in interpretive cohesion when sufficiently accurate prior information is available, but is not used in estimation. Type A error will usually result in biased and statistically inconsistent estimates; this, however, does not settle the issue. The bias may be acceptable if it improves the efficiency of estimation.

To see this, suppose that the true value of some parameter of interest is $\beta$, but that an available estimator b has sampling mean B, where $B \neq \beta$. Then the *bias* of the estimator b is $E(b) - \beta = (B - \beta)$. Suppose that mean squared error, MSE, gives a good enough (inverse) criterion for judging 'success' in estimation. Then

$$\begin{aligned} MSE(b) &= E(b - \beta)^2 \\ &= E\{[(b - B) + (B - \beta)]^2\} \\ &= E(b - B)^2 + (B - \beta)^2 \\ &= Var(b) + \textit{bias squared.} \end{aligned} \tag{3.1.1}$$

This shows that to minimize mean squared error some bias introduced by using inaccurate information may be acceptable if it is associated with a sufficiently low sampling variance of the estimator b. Here 'sufficiently low' means low enough for the estimator b to have a smaller MSE than the alternative estimators available.

Apart from the possibility of a tighter sampling distribution, the use of more rather than less prior information may be attractive if it succeeds in binding the system together into an interpretable whole. In the case of a macroeconometric model, however, this judgement can be difficult to make. This is because the interpretability of an estimated subsystem depends on its simulation properties and on the effects it has on the simulation properties of other parts of the model.

*3.1.2 Systems estimators and dynamic parameters*

Considered on an equation-by-equation basis, estimated coefficients may be considered acceptable if they have a plausible order of magnitude and sign, and according to some statistical test differ significantly from a suitable reference value (usually zero or one). But these are essentially static criteria. In a macroeconometric model, plausible dynamic simulation properties are equally important.

We do not yet possess a satisfactory method for specifying the short-run dynamics of a macro model prior to its estimation. The 'general-to-specific' methodology recommended by Hendry and Richard (1982) cannot be implemented in a system of even modest size without ambiguities. Even if the system consists of just one equation, the most general form of lag distribution that is initially considered as the candidate for an adequate representation, as well as its order, are matters of judgement by the modeller. These judgements can, and do, differ widely.

Questions of degrees of freedom and manageability tend to endogenize the behavior of modellers. In a dynamic system of equations most modellers will opt for a diagonal, or nearly diagonal, lag structure, so that the number of lagged endogenous variables appearing on the right of any equation is likely to be small, and often just the equation's 'own' endogenous variable will appear as a lagged right-hand variable (as is commonly the case in TRYM). This is especially likely to be the case when a single-equation, rather than a systems estimator is chosen by the modeller.

The main benefit from doing business this way is that any damage done to the dynamics of the model as a whole by a poorly specified equation is likely to remain somewhat localized. The down side is that important simultaneities may be missed.

The clearest case of logically necessary simultaneities affecting a system's lag structure come not from macroeconomics, but from microeconomics. Consider the structural form of a system of consumer demand equations. In such a system the sum of the right-hand variables at each data point (expenditures on the different consumer commodities) must add to a right-hand variable that is common to all equations (namely, total expenditure). The simplest such system comes from the maximization of a Cobb-Douglas utility function subject to a budget constraint. It has the form:

(3.1.2) $$v_{it} = \beta_i M_t + u_{it} \qquad (i = 1, \ldots, n)$$

where $v_{it}$ is expenditure at time t on item i, the $\beta_i$s are constant positive parameters (which sum over i to unity), $M_t$ is total spending and the $u_{it}$ are stochastic errors that add across i at every t to zero.[11]

Suppose we wanted to endow (3.1.2) with some simple dynamics by adding lag terms to the systematic part of (3.1.2) as follows:

(3.1.3) $$v_{it} = \alpha_i v_{it-1} + \beta_i M_t - \gamma_i M_{t-1} + w_{it} , \qquad (i = 1, \ldots, n)$$

where again the $w_{it}$ are stochastic errors that add across i at every t to zero. The adding-up restriction on the $v_{it}$ then requires that

(3.1.4) $$\Sigma_i \alpha_i v_{it-1} \equiv M_{t-1} \Sigma_i \gamma_i \quad . \qquad \text{(all t)}$$

[11] The adding up constraint on these errors means that their distribution function is degenerate in the sense that the rank of its variance-covariance structure is (n-1) rather than n.

This will not be possible for arbitrary values of the coefficients $\alpha_i$ and $\gamma_i$ (even if they both add individually over i to unity). Indeed, as the problem is set up, to satisfy the adding-up constraint on expenditures at every data point t we need

(3.1.5) $$\alpha_i = \textstyle\sum_j \gamma_j = \lambda \text{ (say)} \quad . \qquad \text{(all } i = 1, \ldots, n)$$

Dynamic stability then requires that the coefficient $\lambda$ is less than one in absolute value. Solving the recursion (3.1.3) for $v_{it}$ with a stationary value of M, and using (3.1.2), we find that the only feasible values of $\gamma$ are $\gamma_i \equiv \lambda\beta_i$ (for all i = 1, …, n), and that the errors of (3.1.2) and (3.1.3) are related by:

(3.1.6) $$u_{it} = \sum_{\tau=0}^{\infty} \lambda^{\tau} w_{it-\tau} \quad . \qquad \text{(all } i = 1, \ldots, n)$$

It then follows that (3.1.3) and (3.1.2) are equivalent; that is, the *ad hoc* imposition of a lag structure on (3.1.2) has no effect and induces no dynamics if it is required that the system continue to reflect utility-maximizing decisions.

Putting the matter slightly differently, if we want a lag structure to be present in behavioral equations *that are consistent with optimization by agents*, the process generating the lag structure (typically a cost of adjustment, habit persistence, or other behavioral characteristic inducing aversion to change) must be written directly into the original microeconomic problem being solved by the agent, not imposed later[12].

When might we wish to include dynamics of this sort in a macro model? Other than consumer demand, the most obvious candidate is input demand equations (in the above example, substitute ‘production function’ for ‘utility function’, and ‘minimize cost M’ for ‘maximize utility’).

Basically two options are available. The **first** (and easiest) approach is simply to drop the requirement that the economy operates on its production function in the foreground and middle distance of an adjustment period following a shock. This is the *ad hoc* approach adopted in most macroeconometric models (including TRYM and the Murphy Model).

In this case the between-equations restrictions on lag structures need only be respected to the extent needed to preserve convergence to the steady-state growth path. If the individual equations have appropriate error-correction specifications, in practice this means that the between-equation lag coefficient restrictions can be dropped.

The **second** approach is to strengthen the micro underpinnings of the model. In this case aversion to change becomes an explicit part of agents’ optimizing behaviour which then generates time paths in which the dynamics of related variables (e.g., demands for different inputs) are restricted to mutually consistent trajectories.

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12 Under plausible assumptions about adjustment costs and expectations, the solution to such a microeconomic problem results in familiar lag distributions. See McLaren (1979).

For present purposes the main point to emerge from the above discussion is that the desire to preserve dynamic consistency between equations does not seem to be a very strong argument, in the context of typical contemporary macro models, for implementing joint estimation of equation subsystems. This is because macro models usually neither specify nor enforce the microeconomic relations that require such consistency, except in the steady state. What are the other arguments in favour of estimating equations in groups, rather than singly?

*3.1.3 Systems estimators and parameters in common*

The first relates to common parameters that appear in the steady-state forms of two or more equations. Typically this occurs in the first-order conditions for utility maximization by households or for cost minimization by firms. Joint estimation is the cleanest way to implement the commonality of parameters demanded by the theory. Moreover, on the maintained hypothesis that the system is correctly specified, systems estimation is more efficient than single-equation approaches. Such are the motivations for jointly estimating the three key equations (labour demand, investment and product price) of the Private Business Sector in TRYM (Commonwealth Treasury, 1996b).

In the Murphy Model the production structure is somewhat more elaborate than in TRYM (Powell and Murphy, ch. 10). This results in rather more first-order conditions for optimal behaviour of firms, and the natural candidate block for simultaneous estimation contains eight, rather than three equations. If TRYM's production structure is modified, it is likely that the size of the simultaneous block to be estimated for the Private Business Sector will grow.

*3.1.4 Systems estimators and seemingly unrelated regressions*

The second circumstance in which systems estimation may well be attractive in a macro model is where it can be argued that a particular block of equations is best seen as a set of *seemingly unrelated regressions (SUR)*. In TRYM the *relative price block* provides an example. The motivation for using a systems estimator here is that the errors of the different equations are likely to be correlated, and that the *SUR* approach harnesses these correlations to produce a more efficient estimator.

A word of caution may be needed about the practical applicability of *SUR*. The additional efficiency of the estimator is gained via 'knowledge' of the covariance matrix of the n equations' residuals. Of course, these covariances are rarely (if ever) known *a priori*, and they must be found empirically. The number of covariances that must be estimated (either implicitly or explicitly) when using the *SUR* method is $\varpi = \frac{1}{2} n(n-1)$. In the case of the five equations of the relative price block this represents an additional 10 parameters (relative to an equation-by-equation approach). It is not immediately clear that the additional cybernetic load will be met by the available data.

In demand systems work it is often found that methods that require all $\varpi$ correlations to be estimated are extremely unstable in the sense that the addition or deletion of one or a few data points can have large effects on the structural coefficient estimates. The solution normally adopted in this case is to reduce the number of free correlations to be estimated by imposing more structure on the variance-covariance matrix.

There is a more basic objection sometimes raised about methods that use or correct for correlations in the errors of fitted equations. This is that a well specified equation almost by definition should have white noise errors. For this school of thought, correlations in the errors mean that the *systematic* part of one or more equations has been misspecified; or perhaps that the data are deficient. Whilst econometric practice has ignored this view largely as a matter of practical necessity, errors that are strongly correlated between different equations present us with a conundrum: whilst *SUR* is likely to 'work' in the sense that the correlations are strong enough to be estimated, the subsystem is misspecified to the extent that an unknown mechanism is causing the correlations. One then has to decide whether to attempt to trace the source of the correlations (usually a big job, but one that sometimes will identify a previously unnoticed data problem or equation misspecification), or alternatively just to 'harness' the correlations via *SUR* or some other systems estimator.

Irrespective of one's attitude to the 'white noise is bliss' point of view, the size of the subsystem chosen for SUR should be kept fairly small because the dimensionality of the covariance parameter space will otherwise become too large for successful estimation from the relatively short time-series samples that are available. The selection of no more than five equations (as in the relative price block) may be close to optimal.

*3.1.5 Summary of Section 3.1 and recommendations based thereon*

From the discussion above it will be clear that the most attractive candidates for systems estimation are those parts of the model where steady-state behavioural equations involve common parameters. Typically this occurs where equations have been derived from a single micro-economic problem. It follows that more use of systems estimators will be needed if additional behavioural equations outside the Private Business Sector are built on more explicit microeconomic assumptions, or if the Private Business Sector is expanded to include additional behavioral equations. There are arguments in favour of doing the latter anyway.

Apart from blocks of equations containing common parameters, the main other candidates for systems estimation are groups of seemingly unrelated regressions. Here there is very little theoretical guidance to assist in deciding which equation groupings to use. Practical considerations discussed above in sub-section 3.1.4 indicate that the subsets of equations to be estimated should not be too large. Since the arguments for using the *SUR* are entirely statistical, it would not matter if some equation subsets contained strange bedfellows. One method for selecting membership of subsets would be to do a first round estimation using single-equation methods on all of the relevant equations, and tabulate the pair-wise correlations. Assignment to equation subsets for the second round of estimation by *SUR* would then be done on the basis of the strength of the [absolute values of the] pair-wise correlations. Since such a procedure is highly heuristic, only experience would (in time) indicate whether persevering with the *SUR* approach is justified.

If the micro underpinnings of the model are strengthened, another area will become important for systems estimation; namely, subsystems of dynamic equations generated from explicit optimization of problems including an aversion to change. Because these equations will, of necessity, share some dynamic parameters, systems methods will be required for efficient estimation.

### *3.2 Other comments relating to estimation*[13]

Below we give our additional comments in two sub-sections. The first (subsection 3.2.1) considers the choice of an appropriate estimator for the joint estimation of subsystems of the type discussed above in subsection 3.1.3. Under heading 3.1.3(a) some arguments against the use of non-linear least-squares are put forward. Under 3.1.3(b) the prospect for estimating the entire TRYM model as a system is briefly canvassed and the suitability of non-linear three-stage least-squares as an estimator for the model as a whole, or for subsystems of it, is considered. Subsection 3.2.2 contains a miscellany of remarks, mostly from the group (Malakellis, Marshall and Transom) who have considerable hands-on experience with TRYM data and estimation.

#### *3.2.1 Possible subsystems estimators*

There are several potential estimators that could be suitable for sub-sets of TRYM equations. Here just two are examined — a subsystem nonlinear generalized least-squares[14] (NLSQ) estimator and the three-stage nonlinear least-squares (NL3SLS) estimator of Jorgenson and Laffont (1974). Write the $i^{th}$ equation of the model as

(3.2.1) $$f_i\left(Y,\bar{Y}_i,X;\theta_i\right)=U_i;\quad \bar{Y}_i=g_i\left(Y,X;\delta_i\in\theta_i\right)\qquad (i=1,\ldots,n)$$

where $f_i(\,)$ and $g_i(\,)$ are nonlinear functions;

Y is an $n\times T$ matrix of endogenous variables;

$\bar{Y}_i$ is the vector of equilibrium values for $Y_i$ based on a long-run relationship $g_i(\,)$ between $Y_i$ and other variables in the model;

X is a matrix of predetermined variables;

$\theta_i$ is a $k_i\times 1$ vector of parameters to be estimated;

$\delta_i$ is a subvector of $\theta_i$ , and its elements are parameters required to characterize the equilibrium relationship $g_i(\,)$;

$U_i$ is a $T\times 1$ vector of disturbances;

$n$ is the number of equations;

$k_i$ is the number of parameters in the in $i^{th}$ equation; and

T is the number of observations on the endogenous variables.

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13 Some tension between sections 3.1 and 3.2 will be detected by the reader who may suspect, correctly, that different primary authors were responsible for the drafts of these sections.

14 The Ordinary least-squares (OLS) approach can be discarded *a priori*: under conditions likely to prevail in many of TRYM's equations, OLS yields biased and inconsistent estimates.

*3.2.1(a) Subsystems approaches: arguments against using non-linear least squares*

Estimation has previously been undertaken by nonlinear generalized least squares (NLSQ) on subsystems of the model (Treasury (1996a) §2.10). NLSQ involves minimizing a criterion function formed from the residuals of the equation/s under consideration, finding $\underset{\theta_s \in \theta}{\mathbf{argmin}}\, \mathbf{U}_s'\mathbf{S}_s^{-1}\mathbf{U}_s$ where the subscript s is used to indicate a subsystem of the entire model, and $S_s$ is a weighting matrix (the current estimate of the residual covariance matrix is used).

The simultaneity problem (the presence of endogenous regressors in a subsystem of the model) could in principle be overcome by a nonlinear two-stage least squares (N2LS) approach in estimating a single equation. The N2LS estimator $\tilde{\theta}_i$ of Amemiya (1974) chooses $\theta_i$ to minimize

$$S_{N2LS}\left(\theta_i \middle| W_i\right) = \mathbf{U}_i' W_i (W_i' W_i)^{-1} W_i' U_i \qquad (i = 1,\ldots, n) \tag{3.2.2}$$

where $W_i$ is a matrix of instruments used to form least-squares estimates of the endogenous regressors. Amemiya (1985) shows that the N2LS estimator $\tilde{\theta}_i$ is consistent and asymptotically normally distributed, and that violation of the normality assumption for the estimation residuals does not undermine the asymptotic properties of the estimator. The only requirement of the residual vector for each equation is that its elements be independently and identically distributed with zero mean and a constant covariance structure over time,

$$U_i = \{[u_{it}]' \ , \ t=1, \ldots, T: \ \ u_{it} \sim \text{iid}(0,\sigma_i^2)\}. \tag{3.2.3}$$

In a single equation, $\tilde{\theta}_i$ will be a consistent estimator of $\theta_i$, and asymptotically normally distributed. These two properties are absent from the NLSQ estimator in the presence of endogenous regressors; consequently N2LS should be employed whenever one or more regressors is endogenous. Furthermore, N2LS estimates are more efficient asymptotically than NLSQ estimates. Both N2LS and NLSQ estimators are dominated by systems estimators insofar as asymptotic statistical properties are concerned. But as we have seen above in Section 3.1, there are major practical difficulties associated with increasing the size of the unit that must be estimated as a single system. Even so, below we briefly explore the prospect for estimating TRYM as a whole using a systems estimator.

*3.2.1(b) Could the whole model, or a large part of it, be estimated as a single system?— the suitability of the non-linear three-stage least squares estimator*

Greene (1993) points out that systems estimators must dominate subsystem and single-equation estimators asymptotically. He also indicates non-trivial caveats, which may be paraphrased as:

> the computing requirement for full systems estimation may be excessive;

problems which arise from misspecification of a single equation in the model need to be prevented from propagating throughout the system; and

although the asymptotic properties of systems estimators are superior to single equation or subsystem estimators, their small sample properties may be poor.

Greene also notes that the first of these is no longer as serious a constraint as it was in the past. With contemporary computing power, system-wide estimation of models of the size of TRYM probably could be carried out on a desktop PC (though not without some difficulty).[15]

The most pressing of the above three problems is that if any of the equations of the system are misspecified, the misspecification feeds through into other equations under a system-wide estimation method. Subject to our being able to identify (through simulation trials or otherwise) the source of such a problem, the remainder of the equation system can be 'quarantined' from the misspecified equation if its estimation is undertaken on a single-equation/subsystem basis. Specification tests can be performed on the model as a whole at the estimation stage to assess the degree to which this is a problem, and corrective action taken.

For the application of a systems estimator to TRYM as a whole, the only viable candidate is a nonlinear three-stage least-squares (NL3SLS) approach. Nonlinear full information maximum likelihood (NLFIML) is not viewed as a practical systems estimation methodology at this juncture. While FIML is consistent for a linear simultaneous equations model even if the assumed and true distributions of the residual are different, this is not true in the nonlinear case. To guarantee consistency, NLFIML requires a more restrictive set of assumptions on the residual components than other systems estimation techniques; indeed, NLFIML is consistent if and only if the actual and assumed distributions for the residuals coincide (Amemiya, 1977).[16]

In the least-squares family of estimators, three-stage nonlinear least squares (NL3SLS) delivers consistency and asymptotic normality with minimal assumptions for the residual vector in any given period. So long as $U_t = \{[u_{it}]', i = 1, \ldots, n\text{: } U_i \sim \text{iid}(0, \Sigma)\}$, consistency and asymptotic normality of the NL3SLS is assured (Gallant, 1977). The robustness of the asymptotic properties of this estimator is an additional recommendation for NL3SLS over non-systems approaches to estimation.

Estimation can be undertaken using the NL3SLS estimator of Jorgenson and Laffont (1974), rather than that of Amemiya (1977), although the latter is more flexible than the former in that it permits different sets of instruments for each

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15 Indeed, the 1993 Conference version of TRYM has been estimated as a single system by non-linear three-stage least squares — see subsection 3.2.2 below.

16 When the residuals are assumed to be normal and this is indeed the case, however, NLFIML is efficient relative to all estimators (Amemiya, 1977).

estimated equation. The NL3SLS method of Jorgenson and Laffont (1974) chooses $\theta$ to minimize

$$(3.2.4) \qquad S_{N3LS}(\theta|W) = \mathbf{U}'\left[\hat{\Sigma}^{-1} \otimes W(W'W)^{-1}W'\right]U$$

where W is a matrix of instruments used to form least-squares estimates of the endogenous regressors; $U = [U_1' \, U_2' \ldots U_n']'$, an $nT\times1$ vector of residuals; and $\hat{\Sigma}$ is a consistent estimator of $\Sigma$ (an N2LS estimator is used).

In implementation, NL3SLS employs a (sub)set of the matrix of exogenous variables W as instruments for endogenous variables which appear as regressors. In econometrics software packages such as TSP, one set of instruments is provided by the user. This instrument set is used in all equations.

To use NL3SLS on TRYM as a whole, probably it would first be necessary and desirable to attempt to reduce the number of distinct covariances that must be estimated. Obtaining a reliable method for doing this requires further research. In any event, the desirable features of NL3SLS make it a leading candidate as an estimator for sub-systems.

*3.2.2 Miscellaneous remarks about estimation — an annotated list*

At CoPS/Impact we have investigated some of the estimation issues canvassed above, using an implementation of the 1993 Conference version of the TRYM equation system (Taplin *et al.*, 1993). Some or all of these remarks may relate to features that have been improved upon in the current version of TRYM.

The model has been estimated by both NLSQ and NL3SLS methods, both on subsystems and on the model as a whole. We do not report results here, as this estimation was carried out prior to the discovery of errors in the ABS database which are yet to be fixed.

Several points arise as a result of our investigations:

1 The absence of a useful set of statistics to discriminate between estimates obtained by each of the methods (particularly a summary 'goodness of fit' measure for the entire system) leads us to investigate the simulation properties of the model under the parameter estimates obtained via each method. The simulation properties of the model were found to change little across estimation techniques; however there was an unexplained discrepancy between these simulation results and the those obtained using the Treasury's parameter estimates then current. This is still being investigated as part of an ARC funded historical review of the forecasting ability of Australia's leading macro models.

2 Most of the observed differences in the simulation properties of the model were traced to just three key parameters; the Harrod-neutral rate of technical change (CLAM), the factor elasticity of substitution (CSIG) and the coefficient on the

NAIRU/RNU gap[17] in the wage equation (C5WT). It follows that the pay-off to research on the empirical provenance of these three parameters should be high. More generally, the adoption of a systematic procedure for identifying key parameters is desirable.

3 Estimated parameters can be very sensitive to additional data. Although the model's parameters usually satisfy parameter stability (e.g., Chow) tests for a given database, they do not appear to be stable across databases. Keeping the estimation method fixed, changing the database from D95S to D95D substantially alters several parameters as well as the simulation properties of the model. This is of significance in the light of (2) above, since C5WT changes across methods and databases (including changes in sign) such that the model's dynamic properties are altered. According to a standard t test, however, C5WT is never statistically significant.

4 Each edition of the database contains revisions to recent data, i.e., data for the last six to ten periods. It appears that these revisions are the cause of apparent parameter instability when new databases are used. This leads to the suggestion that only that part of the database which can be considered 'reliable', be used for estimation.

We believe our current work on historical validation will progressively offer further insights into estimation difficulties of the type outlined above.

## *4. The Treatment of Taxes in TRYM*

Because the availability of tax instruments in TRYM inevitably is tied to the aggregation level of the model, the discussion in this section will to some extent overlap that in the next (which deals explicitly with the aggregation issue).

Tax reform has re-emerged as a key policy issue. TRYM is not well suited to dealing with many aspects of taxation reform mainly because, as a *macro* model, it necessarily lacks much of the micro-economic detail needed for the policy debate. However, keeping the detail in TRYM more or less at the current level, it seems to us that that the operation of taxes can be made more transparent by re-basing some aspects of the existing commodity disaggregation upon firmer microeconomic foundations.

Our suggestions concerning the commodity disaggregation are put forward in subsection 4.2. But first in subsection 4.1 we briefly introduce some detail concerning the tax instruments available in TRYM. The final subsection, 4.2, offers some remarks on TRYM's treatment of income taxes and the prospects for modelling a trade-off between direct and indirect taxes.

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[17] RNU is the unemployment rate.

### *4.1 Availability of tax instruments in TRYM*

The three levels of government in Australia have many thousands of tax instruments at their disposal; however only a few of these raise large amounts of revenue. Local governments raise a substantial share of their revenue by taxes on fixed real estate assets (‘rates’); state governments by a variety of fees and imposts of an indirect (i.e., not income-based) kind, including a tax on the employment of labour (payroll tax) and numerous charges on financial transactions; and the central government by direct taxes on income, a sales tax (collected on wholesale transactions), excises on alcohol, tobacco and petroleum products, and taxes on trade (principally tariffs). What is the treatment of taxes in TRYM?

In a macroeconometric model, the level of aggregation precludes explicit recognition of even a subset of the categories outlined above. In TRYM, average tax rates over broad classes of domestic expenditure, factor incomes and production are defined. These average rates have to proxy for the detailed schedules over the many items that they replace. Of the twelve distinct tax variables (see Table 4.1), only the rate of tax on labour income is modelled explicitly; ten of the remaining eleven are exogenous (the capital income tax rate is the exception — it is linked to the tax rate on labour income). The tax rate on labour income is modelled via a reaction function which makes adjustments to labour income tax rates (and, indirectly, capital income tax rates) such that the government achieves its target debt-to-GDP ratio in the long run.

TRYM’s aggregation level does not allow recognition of differential rates of taxation of intermediate and final demand for goods and services, although (as seen in Table 4.1) differential rates of taxation across broad expenditure categories are defined. Tax collections from intermediate demand account for around 40 per cent of indirect tax collections, and are an important source of ‘wedges’ between producer’s and purchaser’s prices, and hence have the potential to affect profitability and output, and the composition of supply and hence of final demand.

### *4.2 Commodity disaggregation in TRYM*

Relating tax and other wedges to TRYM’s behaviour is not straightforward, because of the (in our view, barely tenable) attempt to preserve the fiction that TRYM is a one-commodity model. By this we mean that aggregate supply is seen as the supply of a single commodity the total size of which is obtained by adding up individual components, including imports. For this to be valid, from the output side, the elasticities of transformation between all pairs of the different end-use destined

Table 4.1

*Tax Instruments Available in TRYM*

**Direct taxes:**

1. labour income taxes
2. income taxes on capital

**Indirect taxes:**

**(a) on inputs to production**

3. taxes on private employment (payroll and FBT)
4. taxes on government employment (payroll and FBT)

**(b) on final demand**

**— consumption**

5. taxes on consumption other than dwelling services
6. taxes on dwelling services consumption

**— investment**

7. taxes on non-dwelling investment
8. taxes on dwelling investment

**— international trade**

9. taxes on non-commodity exports
10. taxes on commodity exports
11. taxes on imports

**— government market demand**

12. taxes on government market demand

outputs must be (minus) infinity. Then the law of one price applies, and there is only one price of output, whatever end use it is destined for. Moreover, since imports are then added to domestically sourced output, forming the total to be distributed over the domestic final demand categories, the assumption on the demand side must be that imports and domestically produced output are perfect substitutes — an assumption which directly contradicts both the existence of separate prices for imports and domestically produced output, as well as TRYM's import demand function.

TRYM recognizes that the law of one price is not viable on the demand side. The *relative price block* is designed to take account of two facets of the model's specification:

(1) The five principal final uses of output have different input structures which lead to divergences in their prices. An important aspect of this is their differing import intensities which is stressed in the documentation of the relative price block (Commonwealth Treasury 1996a, pp. 4.1-4.7).

(2) Prices enter into the demand side as determinants of the sizes of the five principal sub-aggregates of GNE (other than dwelling rental services[18]): non-rental consumption, private business investment, dwelling investment, real estate transfers and government market demand. In the case of the two investment categories, this dependence is via their respective Tobin's (average) q ratios; in the case of the consumption function in which real wealth appears as an argument, the dependence is via the consumption price deflator which is used to deflate nominal private wealth.

Thus good reasons for distinguishing between the different major components of GNE are established; but the treatment in TRYM leads to five separate prices which apply to just one commodity which is conceptually the same in all five instances.

To obtain a microeconomically interpretable treatment, the production processes dual to the five relative price equations must be made explicit. In principle there are two alternatives:

(a) To treat the five end-use specific components of output as imperfect transformates and to model them as joint products using a CET, CRETH or other suitable product transformation frontier. This does not seem an attractive option in this case as the existing TRYM documentation emphasizes that the relative input intensities of the five end-use specific outputs vary considerably; if true, this is in serious tension with the input-output separability postulate underlying the use of a single product transformation surface.

(b) To specify five separate production functions. If the relative price block is taken as guide, each of these would have at least raw output and imports as inputs. This seems to accord well with the intent of TRYM's current structure.

Then the long-run (error-correction) parts of the equations of the relative price block would be replaced with the dual unit cost functions of these production functions, and full microeconomic consistency would be restored. Formally, up to ten types of commodity would be recognized in the model:

- the five final demand categories discussed above: non-rental consumption, private business investment, dwelling investment, real estate transfers and government market demand;
- the services of the housing stock;
- raw domestic output (possibly modelled in the way that the domestic component of final supply is currently modelled);

[18] In the short run, the demand for housing rental services is given by the stock, and the rental price adjusts.

- imports;
- ‘commodity’ exports;
- non-‘commodity’ exports.

Some thought would need to be given to the last two categories. The non-‘commodity’ exportable might be made conceptually the same commodity as raw output (reducing the number of distinct commodities on the above list to nine). A CET production frontier between the ‘commodity’ exportable and the remainder of raw output would fit the revenue maximizing description of export supply given in the TRYM documentation (Commonwealth Treasury 1996a, p. 4.11), and have the advantage of microeconomic transparency.

The greater level of explicit commodity disaggregation recommended above is modest, fits well with the intent of implicit mechanisms already in place, but replaces them with explicit microeconomically valid constructs; moreover, relatively few additional variables and equations are introduced. These enhancements would facilitate tracing the impacts of tax changes through the system because the relationship of wedges to unit costs for the nine or ten explicitly recognized commodities would be clear. But we must consider also taxes affecting primary factor inputs.

### *4.3 Income taxes in TRYM and the possibility of a trade-off*

The ‘macro’ focus of TRYM precludes modelling the labour market to a level of disaggregation which could capture the effects of changes in the labour income tax schedules. For example, the effect of changing the top marginal tax rate while keeping the aggregate implicit tax rate constant will have effects on aggregate labour supply, expenditure and saving which will not be captured. As a result of both of these limitations, it is not clear that simulations involving substituting a single-rate, broad-based indirect tax for income taxes will provide anything more than ‘first pass’ estimates of the economic implications[19], including the implications for how the income tax rates must be restructured. This is probably a case where cooperative work between the proprietors of TRYM and those of a more highly disaggregated model would be appropriate.

The above remarks apply to the long-run or steady-state relationships affected by tax changes. The dynamics present more of a conundrum. Basically, the nature of the Australian labour market is changing rather rapidly (at least by Australian standards), and it is difficult to know (a) what trade-offs involving direct and indirect taxes would be seen as acceptable to those workers having sufficient power to affect the bargained outcome; (b) what is the size and strength of the group having such power. Even if we had rough quantitative measures in answer to these questions, the lack of historical precedent would make it very difficult (or perhaps impossible) to predict the dynamic

[19] For example, setting all indirect tax rates to the broad-based tax rate, and endogenizing the income tax rate, may miss important compositional aspects of tax reform; however to extend TRYM to capture these effects may compromise its efficacy as a structural *macro* model.

path of the response. It does not seem that historically based time-series models have much to offer for our journey into these uncharted waters.

## *5. Possible Advantages of Further Disaggregation in TRYM*

The reasons for disaggregating a macro model include at least the following:

(a) To provide information about components of aggregates because these are of interest in their own right. Distributional issues immediately spring to mind.

(b) To improve the stability and estimability of the model. When the composition of an aggregate changes violently (as happened during the oil price shocks of the 1970s), it is likely that the equation modelling that aggregate will fail.

We deal with each of these in turn in Sections 5.1 and 5.2.

### *5.1 Distributional issues*

For macro policy-making the main advantages of disaggregated models is that they provide information about distributional issues. For example, monetary and fiscal policies have disparate effects across industries, occupations, households and regions (see, e.g., Dixon, Malakellis and Meagher (1996) and Dixon, Malakellis, McDonald and Meagher (1996)). Some of these microeconomic implications of macro policies are subtle but may be of crucial policy importance. If the government is looking to use fiscal policy to stimulate employment in the short run, an industry model like MONASH will show that a $1 increase in government spending will be more effective than a tax cut which stimulates consumption spending by an equivalent amount. This is because the government's market purchases are typically more labour-intensive than the private household's consumption basket.

Probably it is not realistic to attempt to build a model 'that is good at everything'. The limited resource bases from which they are built require that models be focused. The lesson to be learned from overly ambitious attempts during the 'seventies to disaggregate existing macro models to cover sectoral activity levels at a fine level of detail is that it is not feasible to create a good multisectoral model as an input-output driven extension of macroeconomics. Feasible methods for obtaining quality models that span both the macroeconomy and sectoral detail include (a) the *Impact paradigm* (Cooper, McLaren and Powell, 1985) and (b) the full integration of macro- and micro-elements within a single model (Murphy in Powell and Murphy, forthcoming 1997).

The *Impact paradigm* 'renders unto Walras the things that are Walras', and unto Keynes the things that are Keynes' (Breece *et al.*, 1994). In it a macrodynamic model is used to determine the big aggregates in the economy, as well as the absolute price level, nominal exchange rate, and real wage. An applied (or computable) general equilibrium (hereafter, CGE) model then provides the sectoral detail on output, employment, international trade, and many other variables. A procedure along these lines was implemented using a version of TRYM in the context of a *dynamic* CGE model (namely, MONASH) by Malakellis and Dixon (1994) and by Dixon *et al.* (1996).

The fully integrated macro-CGE model recently pioneered by Murphy (hereafter MM2), on the other hand, endows each of its sectors with its own individual dynamics. The model's macrodynamics is then the result of adding up variables like investment across sectors. The advantage of Murphy's method is that macro and CGE models do not have to be interfaced; thus consistency between the macro and GE elements of the modelling exercise can be maximized. The down side is that the data base will support estimation of separate dynamic structures for less than twenty sectors. More detail than this will require resort to ancillary models or assumptions about dynamic behaviour that is common across finely disaggregated sectors.

The relatively successful experience at Monash using a version of TRYM (MonTRYM) in conjunction with the CGE MONASH model suggests that distributional and sectoral issues can be handled quite well using TRYM to provide the macroeconomics, and an applied general equilibrium model to provide compositional detail. The alternative would be the development of a new version of TRYM along MM2 lines. This does not seem to be a sensible division of labour.

*5.2 Disaggregating to improve the macro performance of the estimated model*

What can go wrong when working with an aggregate relationship can be illustrated by a simple, highly stylized example. In what follows, for simplicity, all variables are scalars.

Assume that there are two stable micro relationships as follows:

(5.2.1) $$y_1 = x\beta_1 + u_1 ,$$

(5.2.2) $$y_2 = z\beta_2 + u_2 ;$$

in which x and z are exogenous, stochastic, regressors, and $u_1$and $u_2$ are uncorrelated, zero-mean, well behaved error terms. 'Stability' of these relationships implies that the coefficients $\beta_1$ and $\beta_2$ do not change; nor do the variances of $u_1$ and $u_2$.

Now assume that 'Nature' presents us with exogenous variables x and z that are generated by the process

(5.2.3) $$x = z\alpha + v ,$$

where v has zero mean, is uncorrelated with each of z, $u_1$ and $u_2$ and is otherwise well behaved (at least in the initial regime in which we are working).

Suppose that our macro theory deals with the aggregate y, where

(5.2.4) $$y \equiv y_1 + y_2 ,$$

which (for simplicity) is related (in the macro theory) to just one of the exogenous determinants of its components (in the micro theory):

(5.2.5) $$y = z\gamma + w ,$$

where w is an error term. Then by construction,

(5.2.6) $$\gamma = \alpha\beta_1 + \beta_2 ,$$

and

(5.2.7) $$w = u_1 + u_2 + v\beta_1 .$$

Let the ratio of the variance of the error in the relationship (5.2.3) between the two regressors to the variance of the regressor appearing in the macro relation be

(5.2.8) $$\mathrm{Var}(v)/\mathrm{Var}(z) = \lambda .$$

Then it is easily shown that the correlation between the two regressors is:

(5.2.9) $$\mathrm{Correl}\,(x,z) = \alpha/\{\alpha^2 + \lambda\}^{1/2} .$$

When the variance of v is low relative to that of z, this correlation is high, and approaches unity in absolute value as $\lambda \to 0$.

For our example suppose that in the initial regime in which the macrorelation (5.2.5) is estimated, $\lambda = 0$, so that x and z are perfectly correlated, and Var(v) = 0. If $\alpha > 0$, then the correlation between x and z is +1. An OLS estimate of $\gamma$ will consistently estimate $\{\alpha\beta_1 + \beta_2\}$ and the macrorelation will be stable. The variance of the error term in the macrorelation will be $\{\mathrm{Var}(u_1) + \mathrm{Var}(u_2)\}$.

Underlying regime shifts in the part of the world that we don't model within this framework appear as changes in $\alpha$ and/or $\lambda$. Suppose that the variance of v jumps from zero to $3\alpha^2$. Then the correlation between x and z falls to ½. An OLS estimate of $\gamma$ will still be consistent for $\{\alpha\beta_1 + \beta_2\}$, but since the variance of the error term in the macrorelation (5.2.5) has now increased to $\{\mathrm{Var}(u_1) + \mathrm{Var}(u_2) + \beta_1^2\mathrm{Var}(v)\}$, this estimate will be less precise. From the viewpoint of diagnostics on the fitted macrorelation, the effect of such regime shifts would appear as heteroskedasticity.

So far, the change in regime has not affected the value of the macro parameter; namely, $\gamma = \{\alpha\beta_1 + \beta_2\}$. But suppose now that the correlation between the regressors x and z breaks down completely (rather than just becomes weaker, as above). A 'complete breakdown' of the previously existing correlation would occur if the sign of $\alpha$ was reversed (i.e., $\alpha$ in (5.2.3) is replaced by $-\alpha$). Now the correlation between x and z changes sign, becoming:

(5.2.10) $$\mathrm{Correl}\,(x,z) = -\alpha/\{\alpha^2 + \lambda\}^{1/2} ,$$

and the macroparameter has changed from $\gamma^{old} = \{\alpha\beta_1 + \beta_2\}$ to $\gamma^{new} = \{\beta_2 - \alpha\beta_1\}$. Whilst the underlying micro-relations have remained stable, the macrorelation has not: $\gamma$ cannot be estimated because it is no longer a parameter. In the diagnostics on the fitted macrorelation, the effect of such regime shifts would appear as a structural break that hopefully would be revealed by a Chow test.

To apply the lessons from this example to TRYM, we need to look for aggregates whose components are likely to driven by different exogenous variables. If the correlations between such exogeneities have not been stable in the sample, and/or are expected to break down in the future, then disaggregation is essential to preserve the integrity of the macro model.

The use of standard specification tests (such as the Chow test) will diagnose problems that have already become serious, but is of little prophylactic value against new dislocations in the correlation structure of the model's exogenous variables. So it may be worthwhile as a routine measure when reviewing TRYM's equations to explicitly identify the major sub-components of each of the main components of aggregate demand as well as the associated driving variables. Evaluations concerning likely disruptions to established sample patterns of correlations among the driving variables should not focus so much on statistical testing as on intuition about likely future changes. After all, there is some larger framework in the stylized example sketched above, in which both of the exogenous regressors x and z may be considered co-determined.

## Bibliography

Amemiya, T (1974) "The Nonlinear Two-Stage Least Squares Estimator," *Journal of Econometrics,* **2**, pp. 105-110.

Amemiya, T (1977) "The Maximum Likelihood and the Nonlinear Three Stage Least Squares Estimator in the General Nonlinear Simultaneous Equations Model," *Econometrica*, **4**, pp. 955-968.

Amemiya, T (1985) *Advanced Econometrics*, Cambridge, Mass.:Harvard University Press:

Breece, J.H., K.R. McLaren, C.W. Murphy and A.A. Powell (1994) "Using the Murphy Model to Provide Short-run Macroeconomic Closure for ORANI", *Economic Record*, **70**, No. 210 (September), pp. 265-287.

Campbell J.Y. and N.G. Mankiw (1989) “Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence”, *NBER Macroeconomics Annual* **4**, pp. 185-216.

Commonwealth Treasury (1981) *The NIF-10 Model of the Australian Economy*, Canberra: AGPS.

Commonwealth Treasury (1996a) *Documentation of the Treasury Macroeconomic (TRYM) Model of the Australian Economy*, Canberra: AGPS.

Commonwealth Treasury (1996b) *The Macroeconomics of the TRYM Model of the Australian Economy*, Canberra: AGPS.

Commonwealth Treasury (1996c) *The Macroeconomics of the TRYM Model of the Australian Economy*, Canberra: AGPS.

Cooper, R.J., K.R. McLaren and A.A. Powell (1985) "An Approach to the Short Run Macroeconomic Closure of General Equilibrium Models", in J. Piggott and J. Whalley (eds), *New Developments in Applied General Equilibrium*, New York: Cambridge University Press, pp. 411-40.

Dixon, P. B., M. Malakellis, D. McDonald and G. A. Meagher (1996) "Cuts in Public Expenditure: Some Implications for the Australian Economy in 1996-97 and 1997-98", *Australian Bulletin of Labour,* **22**, No. 2 (June), pp. 83-108.

Dixon, P.B., M. Malakellis and G.A. Meagher (1996) “The Sectoral and Distributional Impacts of Tighter Monetary Policy” Paper Presented at the *EMBA Model Comparison Conference on Monetary Policy* held in Canberra, 23 May 1996.

Dornbusch, R. (1976) “Expectations and Exchange Rate Dynamics,” *Journal of Political Economy*, **84**, No. 6, pp. 1161-1176.

Ericsson, N.R. and J.S. Irons (1995) "The Lucas Critique in Practice: Theory without Measurement", Board of Governors of the Federal Reserve System, *International Finance Discussion Papers*, No. 506 (March).

Fair, R.C. (1979) "An Analysis of A Macroeconometric Model with Rational Expectations in the Bond and Stock Markets," *American Economic Review*, **69**, pp. 539-552.

Fair, R.C. (1984) *Specification, Estimation and Analysis of Macroeconometric Models*, Cambridge, Mass.: Harvard University Press.

Fisher, P.G., D.S. Turner and K.F. Wallis (1992) "Forward Unit Root Exchange-Rate Dynamics and the Properties of Large-Scale Macroeconometric Models," in C. Hargreaves (ed.), *Macroeconomic Modelling of the Long Run*, Brookfield, Vermont: Edward Elgar Press.

Gallant, A.R. (1977) "Three Stage Least Squares Estimation for a System of Simultaneous, Nonlinear, Implicit Equations," *Journal of Econometrics* **5** pp. 71-88.

Greene, W.H. (1993) *Econometric Analysis*, 2nd edn, Macmillan.

Gruen, D.W.R. and M.C. Gizycki (1993) "Explaining Forward Discount Bias: Is it Anchoring?", Research Department, Reserve Bank of Australia, *Research Discussion Paper* No. 9307.

Hamilton, J.D. (1994) *Time Series Analysis*, Princeton, N.J.: Princeton University Press.

Hendry, D. F. and J. F. Richard (1982) "On the Formulation of Empirical Models in Dynamic Econometrics", *Journal of Econometrics*, **20**, pp. 3-33.

Higgins C.I., and V.W. FitzGerald (1973) "An Econometric Model of the Australian Economy," *Journal of Econometrics*, **1**, pp. 229-265.

Horridge, M. (1992) "ESP: Equation Solving Package", mimeo, Centre of Policy Studies, Monash University.

Jorgenson, D. and Laffont (1974) "Efficient Estimation of Nonlinear Simultaneous Equations with Additive Disturbances," *Annals of Economic and Social Measurement*, **3** pp. 615-640.

Layard, R., S. Nickell and R. Jackman (1991) *Unemployment—Macroeconomic Performance and the Labor Market*, New York: Oxford University Press.

Layard, R., S. Nickell and R. Jackman (1994) *The Unemployment Crisis*, New York: Oxford University Press.

Lucas, R.E., (1976) "Econometric Policy Evaluation: A Critique," *Journal of Monetary Economics*, Supplementary Series 1976, **1**, pp. 19-46.

Lucas, R.E., (1972) "Expectations and the Neutrality of Money," *Journal of Economic Theory*, **4** (April), pp. 103-124.

Malakellis, M. and P.B. Dixon (1994) "The Economic Implications of an Improvement in Labour Productivity: Comparative Dynamic Results from the Monash Model", in Colin Hagreaves (ed.), *A Comparison of Economy-wide Models of Australia*, Economic Planning Advisory Commission, *Commission Paper* No. 2, Canberra: Australian Government Publishing Service (October), pp. 159-190.

Malakellis, M. and G.J. Transom (1996) “Simulation Properties of TRYM under Alternative Specifications of the Financial Sector”, in M. McAleer, P.M. Miller and K. Leong (eds), Volume 3 of *Econometric Society Australasian Meeting 1996 Proceedings*, Perth: University of Western Australia, pp. 91-118.

Mankiw, N.G. (1990) “A Quick Refresher Course in Macroeconomics,” *Journal of Economic Literature*, **XXVIII** (December), pp. 1645-1660.

McLaren, K.R.(1979) “The Optimality of Rational Distributed Lags,” *International Economic Review*, **20**, No. 1 (February), pp. 183-192.

Murphy, C.W. (1988) “Rational Expectations in Financial Markets and the Murphy Model,” *Australian Economic Papers*, **27**, Supplementary Conference Volume (July), pp. 7-26

Murphy, C.W. (1992a) *Access Economics Murphy Model Manual Version 2.1 - The Model in Detail*, Canberra: Access Economics Pty Ltd.

Murphy, C.W. (1992b) “The Steady State Properties of a Macroeconometric Model”, Ch. 7 in C. Hargreaves (ed.), *Macroeconomic Modelling of the Long Run*, Brookfield, Vermont: Edward Elgar Press.

Pesaran, H. (1987) *The Limits to Rational Expectations*, New York: Basil Blackwell.

Powell, A.A. and C.W. Murphy (1995) *Inside a Modern Macroeconometric Model: A Guide to the Murphy Model*, Lecture notes in Economic and Mathematical Systems, No. 428, Berlin, Heidelberg and New York: Springer-Verlag.

Powell, A.A. and C.W. Murphy (forthcoming 1997) *Inside a Modern Macroeconometric Model: A Guide to the Murphy Model*, second revised and enlarged edition, Berlin, Heidelberg and New York: Springer-Verlag.

Sargent, T.J. and N. Wallace (1976) "Rational Expectations and the Theory of Economic Policy", *Journal of Monetary Economics*, Vol. 2, pp. 168-84.

Simes R.M., P.M. Horn, and M. Kouparitsas (1988) “Equation Listing for the NIF88 Model,” Background Paper No. 2 for Conference, *The Australian Macroeconomy and the NIF88 Model*, 14-15 March 1988, Centre for Economic Policy Research, ANU.

Taplin, B., P. Jilek, L. Antioch, A. Johnson, P. Parameswaran and C. Louis (1993) “Documentation of the Treasury Macroeconomic (TRYM) Model of the Australian Economy”, *TRYM Paper* No. 2, Canberra: Commonwealth Treasury.

Turnovsky, S.J. (1989) “The Intertemporal Optimizing Approach to International Macroeconomics: An Overview,” Handout for Presentation to Australian Meeting of the Econometric Society July 13-15, University of New England.

Wallis, K.F. (1988) “Some Recent Developments in Macroeconometric Modelling in the U.K.,” *Australian Economic Papers*, **27** (July) Supplementary Conference Volume, pp. 7-26

Wallis, K.F. (1993) “On Macroeconomic Policy and Macroeconometric Models,” *The Economic Record*, **69**, (June), pp. 113-130.