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FORECASTING WITH A COMPUTABLE GENERAL EQUILIBRIUM MODEL

by

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ABSTRACT

Computable general equilibrium (hereafter CGE) models represent a rapidly emerging field in applied economic analysis. CGE models have, with few exceptions, been used solely for policy analysis; however there is a growing demand for forecasts from these models. Let a "set of scenarios" (or information set) on the exogenous variables of a CGE model denote not only point estimates, but also measures of their precision (and, where relevant, measures of correlation among these variables). This paper gives an exposition of a method of transforming such an information set into point forecasts of the CGE model's endogenous variables and associated set of confidence intervals. This method will not usually require repeated solutions of the CGE model for use with different information sets on the exogenous variables.

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1. INTRODUCTION

The first CGE model was developed by Johansen (1960). The primary use of his model was to forecast changes in the Norwegian economy. In forecasting applications of the Johansen model, the initial solution was interpreted as the current state of the economy. Forecasts were then made of the expected growth rates in the exogenous variables relying on information from outside the model. Once a complete set of forecasts was made for the exogenous variables, the expected growth rates in the endogenous variables were forecast by the model.

Further development of Johansen's approach has continued in Norway[1] and more recently in Australia. The ORANI CGE model of the Australian economy (developed by Dixon, Parmenter, Sutton, and Vincent (1982)) was initially used primarily for policy analysis; more recently, it has been used for forecasting.[2] To date there have been only two applications of the ORANI model in forecasting mode. The first of these was by Dixon (1986), who used the model to generate forecasts for the Australian economy for the period 1985 to 1990. In this study Dixon first made forecasts (outside of the ORANI model) about rates of protection for Australian industries, world prices, technology, population and employment, the cost of capital, and rates of capacity utilisation. These forecasts were then used as input to the ORANI model, which in turn produced projections of growth rates in key macroeconomic variables, industry outputs, and the demand for labour by occupation. The second application of the ORANI model in forecasting mode was by Dixon and Parmenter (1986). This study was similar to the original one, except for the inclusion of equations to explain the processes of Australia's active and passive accumulation of foreign debt.[3]

The above forecasting applications of the ORANI model, similar to those of the Johansen model, have been limited to forecasting just the expected values for the endogenous variables. This approach is limiting as it ignores any information concerning the variance and covariances of the forecasts of the exogenous variables. This paper gives an exposition of a method for transforming such information into point forecasts of the CGE model's endogenous variables and associated set of confidence intervals.

The remainder of the paper is organized as follows. In section 2 we illustrate how a CGE model can be used for forecasting. To do this we first suppose that the forecasts of the exogenous variables are discrete. Then the case is discussed where the forecasts are continuous. For both the discrete and continuous forecasts we consider situations were the forecasts of the exogenous variables are dependent and independent. Some concluding remarks are offered in section 3.

2. FORECASTING WITH A CGE MODEL

Here we will use a relatively small stylized CGE model for illustrating how a CGE model can be used for forecasting. The stylized CGE model is fully documented in Higgs (1986a).[4] Briefly, the model contains 3 industries representing the export, import-competing, and non-traded sectors of the economy. The model distinguishes 6 commodities, three of which are domestically produced and three are imported. The domestic commodities are assumed to be produced by single-product industries. In addition to requiring inputs of commodities for production, these industries also require capital and labour inputs. There are three sources of final demands modelled: investment, household consumption, and exports. The model has been calibrated to roughly approximate the Australian economy as represented by the 1977-78 input-output tables; see Higgs (1986a) and Australian Bureau of Statistics (1983). Finally, the model is solved in a linearized form (following Johansen (1960)).

For forecasting purposes we require from a CGE model projections of the effects of changes in the exogenous variables (for which forecasts will be made outside of the CGE model) on the endogenous variables of interest. Before projections can be made with a CGE model, however, an economic environment must first be specified (i.e. the variables that are to be exogenous must be chosen such that the number of endogenous variables is equal to the number of equations of the CGE model with the Jacobian of the so configured system having full rank). The economic environment selected here had the following key aspects. The industry capital stocks were set exogenously at zero change. This choice can serve to define the time-period of the model's projections.

For example, setting industry capital stocks exogenously at zero change defines a short-run, the length of which has been estimated for the ORANI model by Cooper (1983) as about 2 years. The second key exogenous variable was the nominal exchange rate. This variable acts as the numeraire. Note that a typical CGE model will have mechanisms which determine changes in the real exchange rate,[5] but will lack mechanisms suitable for partitioning such variation into changes in the domestic inflation rate on the one hand and changes in the nominal exchange rate on the other. With the nominal exchange rate as the numeraire, changes in domestic price indices can be interpreted as changes in domestic relative to world prices. The third key group of exogenous variables were the tariffs or tariff equivalents of quantitative restrictions on imports. By making tariffs exogenous we can compute the effects of exogenously projected changes in the government's protection policy. The fourth key exogenous variable was real absorption (i.e. aggregate consumption plus aggregate investment deflated by the appropriate price indices). In this case the CGE model indicates, among other things, the change in the balance of trade that would be required to maintain a projected target level for real absorption. The final exogenous variable of interest was the real wage rate. Here we allow for the calculation of the effects of exogenously projected movements in real wages.

Next we will assume that forecasts have been made (outside of the CGE model) about developments over the next, say, 2 years in the government's policy on the tariff on the import-competing good, on real absorption, and on the real wage rate. The projections from the CGE model are given in Table 1. The first three endogenous variables namely -- the real exchange rate, the change in the balance of trade as

TABLE 1 : SELECTED ELASTICITIES FROM THE CGE MODEL*

Variable	One per cent increase in:		
	One plus the ad valorem tariff on the import-competing good[a]	Real domestic absorption	The real wage
	t_3	$c_R + i_R$	$f_{(41)}$
<u>Macroeconomic</u>			
Real exchange rate	0.7321	0.8849	2.7207
Change in the balance of trade as a share of base-period GDP	-0.0004	-0.0025	-0.0010
Aggregate employment	-0.1769	0.8012	-1.0954
<u>Industry Activity Levels</u>			
1. Export sector	-0.5005	-0.4945	-1.7687
2. Non-traded sector	-0.0311	0.8286	-0.2639
3. Import-competing sector	0.0914	0.4507	-0.9647

* See Higgs (1986a). All projections, with the exception of the balance of trade, are percentage deviations from what the variable in question would have been in the absence of the shock at the head of the column. The balance of trade projections, while also a deviation from control, are the changes in the balance of trade expressed as a share of the base-period GDP.

a Note that this is equivalent to a 4.3874 per cent increase in the ad valorem rate of protection on good 3.

a share of GDP, and aggregate employment -- describe key aspects of the macroeconomy. The remaining endogenous variables describe industry activity levels.

It can be seen from Table 1 that all three exogenous shocks cause an appreciation of the real exchange rate. An appreciation of the real exchange rate is synonymous with a deterioration in the international competitiveness of the traded sectors. Since all three exogenous shocks cause declines in competitiveness, the balance of trade is projected to decline in each case. An increase in protection for the import-competing sector causes an increase in its output and a contraction in the output of the export sector. In the case of an increase in real absorption, the export sector contracts and there is an expansion in the domestic economy which benefits the import-competing and non-traded sectors. Note that the increase in real absorption is also projected to cause an increase in aggregate employment. Finally, all the sectors are projected to experience contractions in output and aggregate employment is projected to decline if there is an increase in the real wage rate as a cost to employers. These results are qualitatively similar to those obtained by the ORANI model; see, for example, Dixon, Powell, and Parmenter (1979) and Higgs (1986b).

Given the linearized form of the CGE model, the elasticities in Table 1 can be scaled up or down to show the effects of changes other than one per cent increases. For example, if real absorption were forecast to increase by, say, 2 per cent then the effect on aggregate employment would be a 1.6024 per cent increase (i.e. 0.8012 × 2). Note that this approach ignores linearization errors resulting from treating elasticities obtained from the CGE model as constants. However, Dixon, Parmenter, Sutton, and Vincent (1982) have compared the projections produced by the Johansen method, which involves linearizing the CGE model, with those produced by a full non-linear solution. They found, for example, that the projected effect of a 25 per cent across-the-board tariff increase on aggregate employment was a fall of 0.20546 per cent using the Johansen method, while the full non-linear solution produced a fall of 0.20086 per cent.[6] After comparing the projected effects on a large number of endogenous variables, Dixon, Parmenter, Sutton, and Vincent (1982, p. 326) concluded that for "most practical purposes the Johansen method yields solutions of acceptable accuracy."[7]

2.1 DISCRETE FORECASTS

Here we will suppose that the forecasts of the exogenous variables are discrete. First we will assume that the forecasts are independent, then later we will examine the case when they are dependent.

2.1.1 Independent Discrete Forecasts of the Exogenous Variables

In this section we assume that forecasts made about developments over the next 2 years in the government's policy on the tariff of the import-competing good, on real absorption, and on the real wage rate, are independent of each other. For illustrative purposes, we will assume that the tariff on the import-competing good will be reduced by 10 per cent with a probability of 0.3, by 20 per cent with a probability of 0.4, and by 30 per cent with a probability of 0.3. These probabilities indicate that we are not very confident about the exact size of the tariff cut. However it is assumed that we have to be able to deduce from some source (say government announcements) that the tariff cut will be somewhere between 10 and 30 per cent. The next exogenous variable for which forecasts are to be made is real absorption. Here we will assume that real absorption will increase by 0.5 per cent with a probability of 0.1, by 1.0 per cent with a probability of 0.7, and by 1.5 per cent with a probability of 0.2. Note that we are relatively confident about our forecasts for real absorption. The final exogenous variable for which forecasts will be made is the real wage rate. Here we assume that there will be a small reduction in real wages. We expect a 1 per cent cut in the real hourly wage rate with a probability of 0.3, a 2 per cent cut with a probability of 0.5, and a 3 per cent cut with a probability of 0.2. The above forecasts and associated probabilities are listed in Table 2.

As we are dealing with discrete forecasts here, we can write down the scenarios of all possible outcomes for the exogenous variables and compute the probabilities associated with each scenario. The above forecasts give rise to 27 possible scenarios (i.e. 3×3×3); see Table 3. For example, the first scenario is when the low forecast tariff cut occurs with the low real absorption increase and the low real wage decrease, etc. Since the forecasts are assumed to be independent here, the probability of a scenario occuring is simply given by the multiplication of the probabilities for the individual settings of the exogenous variables for that particular scenario.

The next step is to compute the outcomes for the endogenous variables of interest. The projected percentage change for endogenous

TABLE 2 : FORECASTS AND ASSOCIATED PROBABILITIES OF THE EXOGENOUS VARIABLES WHEN THE FORECASTS ARE DISCRETE AND INDEPENDENT

One Plus the Ad Valorem Tariff on Imports of Good 3 t_3		Real Absorption $c_R + i_R$		Real Wage $f_{(41)}$	
Forecast percentage change[a]	Probability	Forecast percentage change	Probability	Forecast percentage change	Probability
-2.2793	0.3	0.5	0.1	-1	0.3
-4.5585	0.4	1.0	0.7	-2	0.5
-6.8378	0.3	1.5	0.2	-3	0.2
	1.0		1.0		1.0

a Note that 10, 20, and 30 per cent reductions in the tariff on imports of good 3 are equivalent to 2.2793, 4.5585, and 6.8378 per cent reductions, respectively, in one plus the ad valorem tariff on imports of good 3.

TABLE 3 : ECONOMIC SCENARIOS AND THEIR ASSOCIATED PROBABILITIES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE INDEPENDENT

Scenario	Forecast percentage change in One Plus the Ad Valorem Tariff on Imports of Good 3[a] t_3	Probability of Tariff change Forecast	Forecast percentage change in Real Absorption $c_R + i_R$	Probability of Real Absorption Forecast	Forecast percentage change in the Real Wage $f(41)$	Probability of the Real Wage Forecast	Probability of the Scenario Occurring
[I]	[II]	[III]	[IV]	[V]	[VI]	[VII]	[III] x [V] x [VII]
L:L:L[b]	-2.2793	0.3	0.5	0.1	-1	0.3	0.009
L:L:M	-2.2793	0.3	0.5	0.1	-2	0.5	0.015
L:L:H	-2.2793	0.3	0.5	0.1	-3	0.2	0.006
L:M:L	-2.2793	0.3	1.0	0.7	-1	0.3	0.063
L:M:M	-2.2793	0.3	1.0	0.7	-2	0.5	0.105
L:M:H	-2.2793	0.3	1.0	0.7	-3	0.2	0.042
L:H:L	-2.2793	0.3	1.5	0.2	-1	0.3	0.018
L:H:M	-2.2793	0.3	1.5	0.2	-2	0.5	0.030
L:H:H	-2.2793	0.3	1.5	0.2	-3	0.2	0.012
M:L:L	-4.5585	0.4	0.5	0.1	-1	0.3	0.012
M:L:M	-4.5585	0.4	0.5	0.1	-2	0.5	0.020
M:L:H	-4.5585	0.4	0.5	0.1	-3	0.2	0.008
M:M:L	-4.5585	0.4	1.0	0.7	-1	0.3	0.084
M:M:M	-4.5585	0.4	1.0	0.7	-2	0.5	0.140
M:M:H	-4.5585	0.4	1.0	0.7	-3	0.2	0.056
M:H:L	-4.5585	0.4	1.5	0.2	-1	0.3	0.024
M:H:M	-4.5585	0.4	1.5	0.2	-2	0.5	0.040
M:H:H	-4.5585	0.4	1.5	0.2	-3	0.2	0.016
H:L:L	-6.8378	0.3	0.5	0.1	-1	0.3	0.009
H:L:M	-6.8378	0.3	0.5	0.1	-2	0.5	0.015
H:L:H	-6.8378	0.3	0.5	0.1	-3	0.2	0.006
H:M:L	-6.8378	0.3	1.0	0.7	-1	0.3	0.063
H:M:M	-6.8378	0.3	1.0	0.7	-2	0.5	0.105
H:M:H	-6.8378	0.3	1.0	0.7	-3	0.2	0.042
H:H:L	-6.8378	0.3	1.5	0.2	-1	0.3	0.018
H:H:M	-6.8378	0.3	1.5	0.2	-2	0.5	0.030
H:H:H	-6.8378	0.3	1.5	0.2	-3	0.2	0.012
							1.000

a Note that 10, 20, and 30 per cent reductions in the tariff on imports of good 3 are equivalent to 2.2793, 4.5585, and 6.8378 per cent reductions, respectively, in one plus the ad valorem tariff on imports of good 3.

b L = Low, M = Medium, H= High.

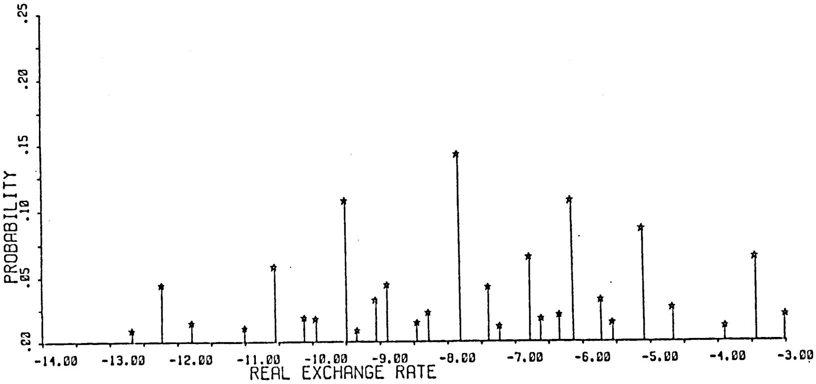
variable α_i in scenario s, α_i^s, is given by:

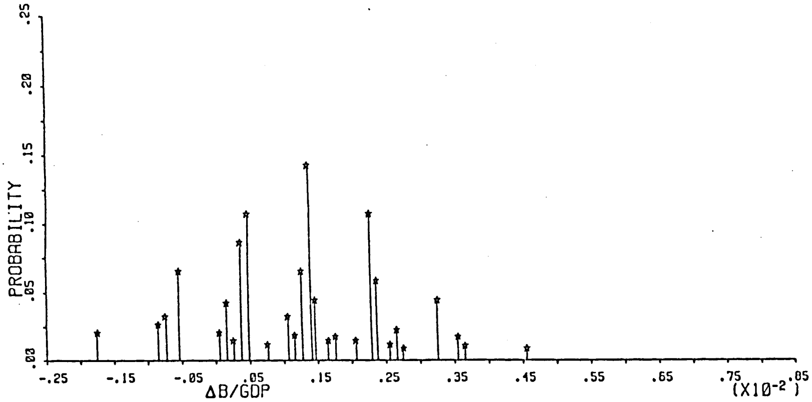
$$\alpha_i^s = \sum_j \eta_{\alpha_i \beta_j} \beta_j^s \quad ; \qquad (1)$$

where $\eta_{\alpha_i \beta_j}$ is the elasticity of endogenous variable α_i with respect to a one per cent increase in exogenous variable β_j; and β_j^s is the forecast percentage change in exogenous variable β_j in scenario s. Recall from above that selected elasticities from the CGE model are given in Table 1. To illustrate equation (1), we will compute the percentage change in the real exchange rate if the first scenario were to occur. A 2.2793 per cent cut in one plus the ad valorem tariff on good 3 (i.e. the tariff change for scenario 1; see Table 3) would cause a depreciation of the real exchange rate of 1.6687 per cent (i.e. 0.7321 × -2.2793). A 0.5 per cent increase in real absorption would cause an appreciation of the real exchange rate of 0.4425 per cent (i.e. 0.8849 × 0.5). Finally, a 1 per cent cut in real wages would cause the real exchange rate to depreciate by 2.7207 per cent (i.e. 2.7207 × -1). Thus the net effect, for the first scenario, is for a 3.9469 per cent depreciation in the real exchange rate (i.e. -1. 6687 + 0.4425 -2.7207). The projected effects on the real exchange rate for the remaining 26 scenarios can be calculated in a similar fashion. These projections, along with those for the other endogenous variables of interest, are depicted in Figure 1.

To assist in the interpretation of Figure 1, some summary statistics are presented in Table 4. For example, the mean forecast for the real exchange rate is for a 7.5775 per cent depreciation, with a standard deviation of 2.3140 percentage points, and a distribution that

FIGURE 1 : PROBABILITY DISTRIBUTIONS FOR SELECTED ENDOGENOUS VARIABLES GENERATED BY INDEPENDENT EXOGENOUS FORECASTS*





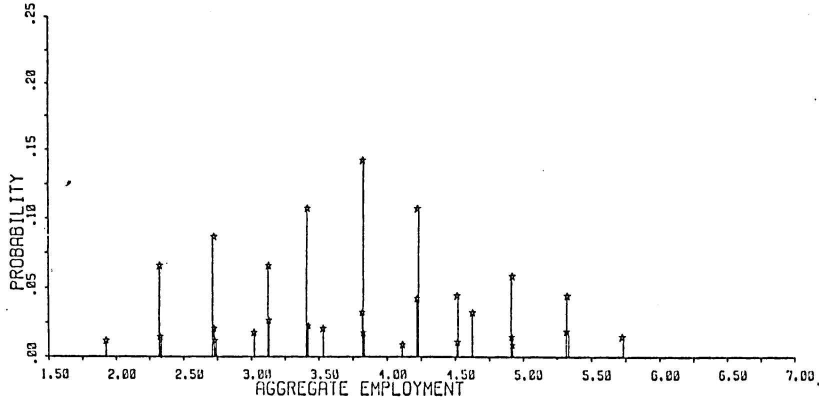
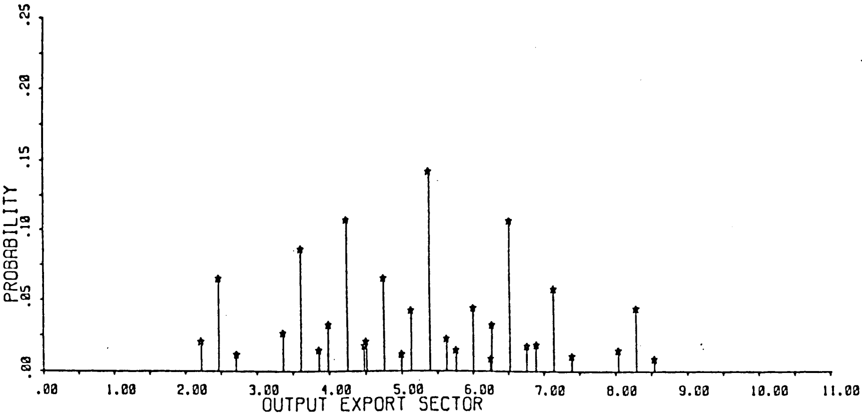
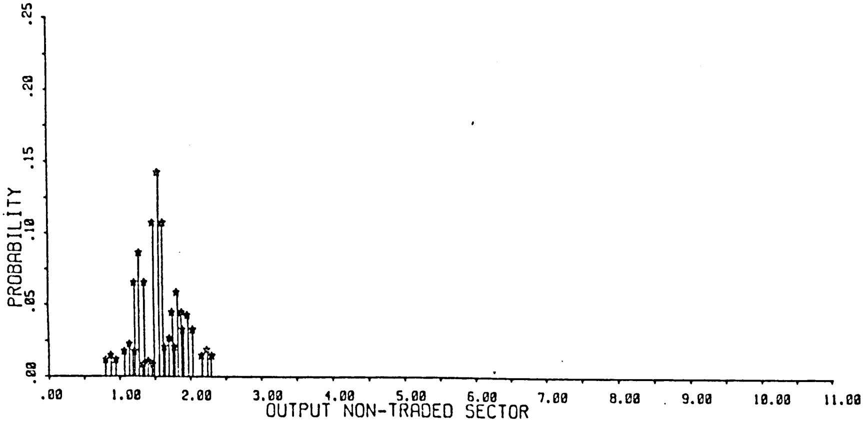
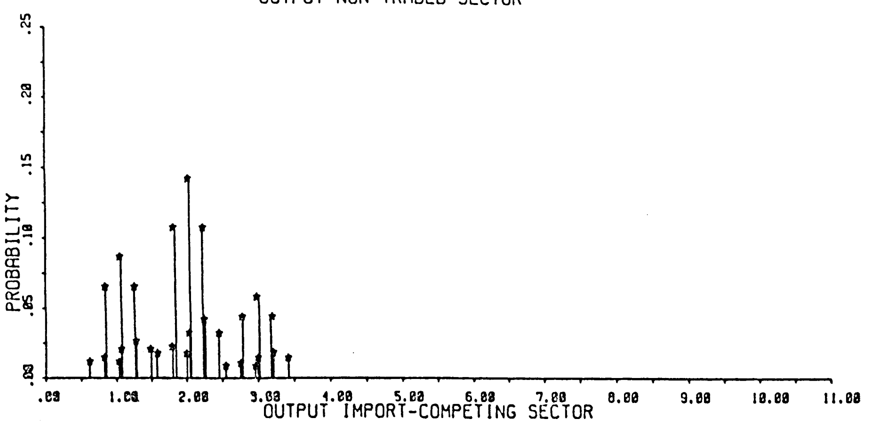


FIGURE 1 Continued







* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

TABLE 4 : FORECASTS OF SELECTED ENDOGENOUS VARIABLES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE DISCRETE AND INDEPENDENT*

Variable	Mean	Variance	Standard Deviation	Skew[a]
Macroeconomic				
Real exchange rate	-7.5775	5.3545	2.3140	-0.9657
Change in the balance of trade as a share of base-period GDP	0.0011	0.0000	0.0012	0.0000
Aggregate employment	3.7289	0.7320	0.8556	0.0639
Industry Activity Levels				
1. Export sector	5.1228	2.3314	1.5269	0.2654
2. Non-traded sector	1.5132	0.0869	0.2948	0.0017
3. Import-competing sector	1.8895	0.4968	0.7048	0.0432

* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

a The measure of skewness is calculated by taking the expectation of the cube of the difference between each forecast and its mean. If the distribution is symmetric the measure will be equal to zero. If the distribution is skewed to the left (i.e. its left tail is elongated) the measure will be negative, and if the distribution is skewed to the right the measure will be positive. For more details, see, for example, Kmenta (1971, p.62).

is slightly skewed to the left. The projected depreciation in the real exchange rate is due to the tariff and real wage cuts dominating the inflationary effects of the expansion in real absorption. As the lower panels of Figure 1 show, both the export and import-competing sectors are expected to experience increases in output. The balance of trade is therefore expected to improve, which it does (row 2 of Table 4). The non-traded sector is also projected to experience an increase in output. This is largely due to the forecast increase in real absorption. Finally, the mean forecast for aggregate employment is an expansion of 3.7289 per cent.

Note that the projections for the export sector have the highest variance, with the import-competing sector's projections having the next largest variance, and finally the non-traded sector's projections having the smallest variance. It will be shown below that the variance of an endogenous variable is a function of the elasticities of the endogenous variable with respect to the exogenous variables and the variance-covariance matrix of the exogenous variables. Briefly the sector with the highest variance will be the one whose elasticities with respect to those exogenous variables with the highest variances are relatively large. The tariff cut forecast has the highest variance, followed by the real wage forecast, and finally by the real absorption forecast. The export sector is the most volatile as it is very sensitive to tariff and real wage cuts; see Table 1. On the other hand, the non-traded sector is not sensitive to the high variance shocks.

The final statistics we will compute here are confidence intervals for the forecasts of the endogenous variables. To do this we first calculated the cumulative probability distributions. These are depicted in Figure 2. Any confidence intervals of interest can be read from Figure 2. If, for example, we wish to estimate the 90 per cent confidence interval for the aggregate employment projections, we read from Figure 2 the aggregate employment projections associated with cumulative probabilities of 0.05 and 0.95. Note that a problem of indeterminancy arises if there are no discrete projections with cumulative probabilities of exactly 0.05 and 0.95. To overcome this indeterminancy, we elected to initially look for the first ordered discrete projections with cumulative probabilities that were less than 0.05 and greater than 0.95. If by chance there were no projections that fell in the ranges of 0.00 to 0.05 and 0.95 to 1.00, then we adopted the first projections that were greater than 0.05 and less than 0.95 for our 90 per cent confidence interval. Using this method we generally obtained conservative estimates of the confidence intervals. Table 5 contains estimates of the 90 per cent and 70 per cent confidence intervals.

2.1.2 Dependent Discrete Forecasts of the Exogenous Variables

In this section we will illustrate the implications of dependency among the discrete forecasts of the exogenous variables. Figure 3 depicts some hypothetical correlated real wage and real absorption forecasts, and a fitted regression. The points on the regression line are the conditional means of the real wage forecast given the value of the real absorption forecast. The positive slope of the regression line reflects a situation where if something good happens -- for example, a favourable change in the simulated economy's terms of trade -- the benefits are realized both as higher real wages and as a higher level of real domestic absorption.

FIGURE 2 : CUMULATIVE PROBABILITY DISTRIBUTIONS FOR SELECTED ENDOGENOUS VARIABLES GENERATED BY INDEPENDENT EXOGENOUS FORECASTS*

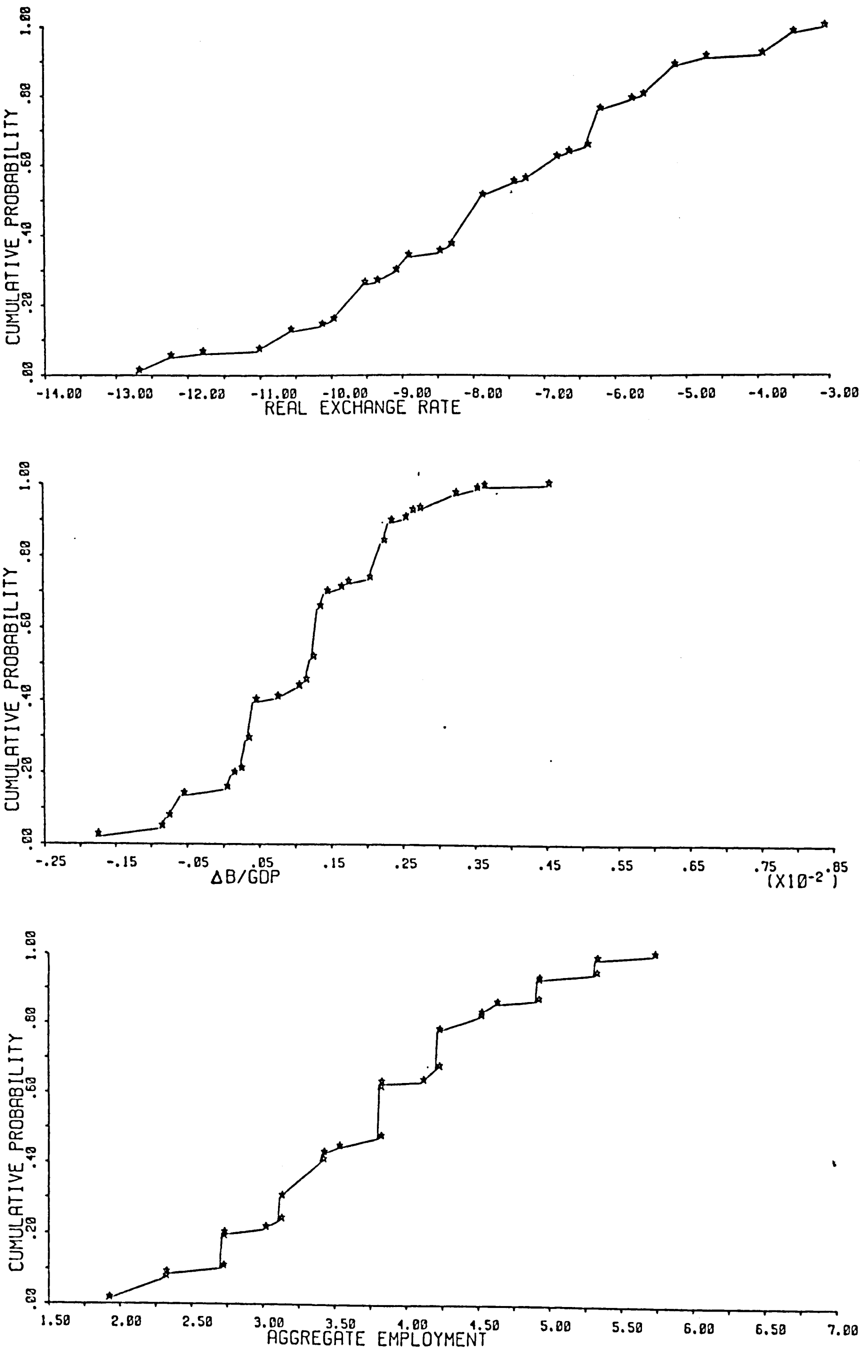
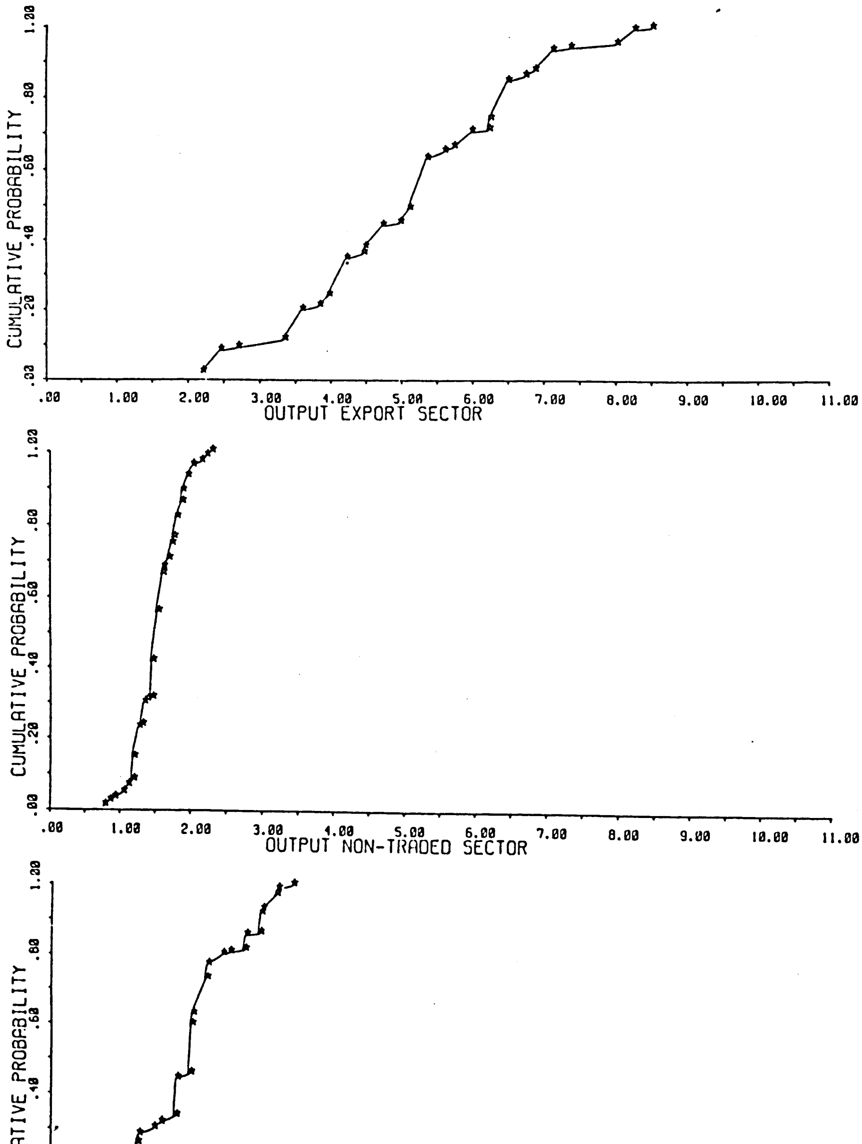


FIGURE 2 Continued



* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

TABLE 5 : CONFIDENCE INTERVALS OF THE FORECASTS OF SELECTED ENDOGENOUS VARIABLES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE DISCRETE AND INDEPENDENT

Variable	Mean	90 per cent Confidence Interval low	90 per cent Confidence Interval high	70 per cent Confidence Interval low	70 per cent Confidence Interval high
Macroeconomic					
Real exchange rate	-7.5775	-12.2832 (-11.3840)[a]	-3.5045 (-3.7709)	-10.1720 -(10.7365)	-5.1731 (-4.4184)
Change in the balance of trade as a share of base-period GDP	0.0011	-0.0009 (-0.0009)	0.0032 (0.0031)	-0.0006 (-0.0005)	0.0023 (0.0027)
Aggregate employment	3.7289	1.8992 (2.3214)	5.2970 (5.1364)	2.7004 (2.5608)	4.6022 (4.8970)
Industry Activity Levels					
1. Export sector	5.1228	2.1677 (2.6110)	7.9867 (7.6346)	3.3085 (3.0383)	6.7125 (7.2073)
2. Non-traded sector	1.5132	1.0130 (1.0283)	1.9834 (1.9981)	1.1634 (1.1107)	1.8330 (1.9157)
3. Import-competing sector	1.8895	0.7734 (0.7301)	3.1365 (3.0489)	0.9817 (0.9273)	2.7198 (2.8517)

a For comparative purposes, the confidence intervals calculated assuming a continuous normal distribution with the same mean and standard derivation as the discrete distribution are given in parentheses.

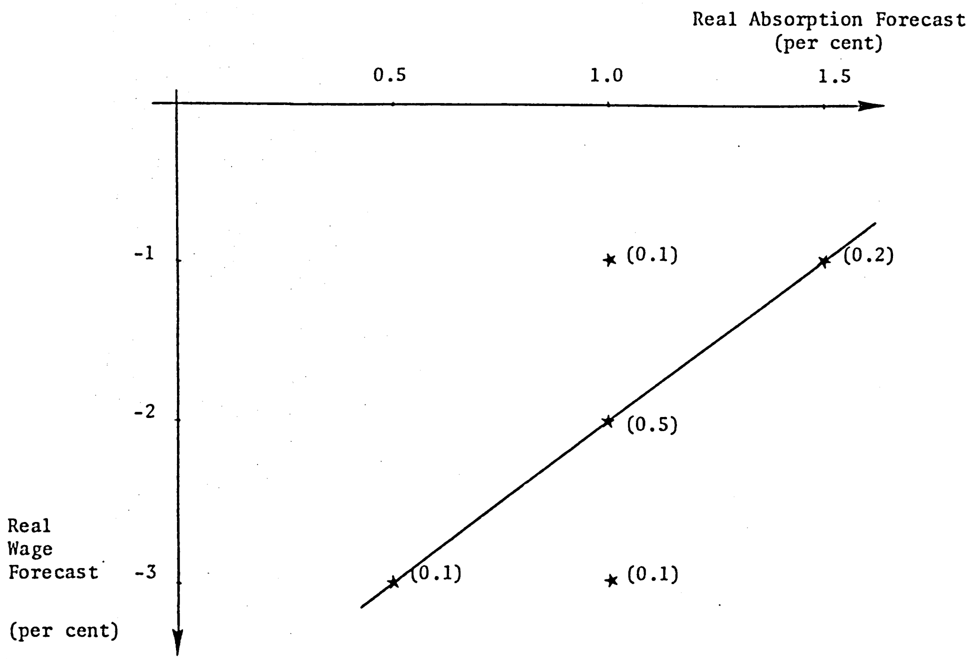


FIGURE 3 : REGRESSION OF THE REAL WAGE FORECAST ON THE REAL ABSORPTION FORECAST*

* The points on the regression line show the conditional means of the real wage forecast given the value of the real absorption forecast. The numbers in parentheses give the joint probabilities.

The joint probabilities for the real absorption and real wage forecasts are given in Table 6. Note that we continue to make the assumption that the real absorption and real wage forecasts are independent of the tariff change forecast. Note also that the unconditional probabilities for the real wage and real absorption forecasts have been chosen to equal those in section 2.1. Similarly, it is assumed that the tariff change forecasts and associated probabilities are the same as those in section 2.1. These assumptions have been made to highlight the effect of the joint probabilities between the real wage and real absorption forecasts.

The above forecasts again give rise to 27 possible scenarios; see Table 7. Since the forecasts of the real wage and real absorption are assumed to be dependent, the probability of a scenario occurring is given by multiplying the respective joint probability by the probability of a tariff cut of the size relevant to that particular scenario.

The frequency distributions for the endogenous variables of interest are depicted in Figure 4. To assist in the interpretation of Figure 4, some summary statistics are presented in Table 8. Note that as the unconditional probabilities have been chosen to be the same as above in section 2.1, the mean forecasts in Table 8 are the same as those listed in Table 5; see equation (1). However the variances of the forecasts given in Table 8 differ from those in Table 5. Recall from Figure 3 that the slope of the regression line of the real absorption forecasts on the real wage forecasts is positive. Thus if the elasticities of an endogenous variable with respect to real absorption and the real wage have the same sign, then the variance of the projections for that endogenous variable will be larger when the real

TABLE 6 : JOINT PROBABILITIES FOR THE REAL ABSORPTION AND REAL WAGE FORECASTS*

		Real Absorption Forecast			Unconditional Probability of Real Wage Forecast
		0.5	1.0	1.5	
Real Wage Forecast	-1	0	0.1	0.2	0.3
	-2	0	0.5	0	0.5
	-3	0.1	0.1	0	0.2
Unconditional Probability of Real Absorption Forecast		0.1	0.7	0.2	

* Note that it is assumed that the real absorption and real wage forecasts are independent of the tariff change forecasts.

TABLE 7 : ECONOMIC SCENARIOS AND THEIR ASSOCIATED PROBABILITIES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE DEPENDENT

Scenario	Forecast percentage change in One Plus the Ad Valorem Tariff on Imports of Good 3[a] t_3	Probability of Tariff change Forecast	Forecast percentage change in Real Absorption $c_R + i_R$	Forecast percentage change in the Real Wage $f(41)$	Joint Probability of Real Absorption and Real Wage Forecasts	Probability of the Scenario Occurring
[I]	[II]	[III]	[IV]	[V]	[VI]	[III] × [VI]
L:L:L[b]	-2.2793	0.3	0.5	-1	0.0	0
L:L:M	-2.2793	0.3	0.5	-2	0.0	0
L:L:H	-2.2793	0.3	0.5	-3	0.1	0.03
L:M:L	-2.2793	0.3	1.0	-1	0.1	0.03
L:M:M	-2.2793	0.3	1.0	-2	0.5	0.15
L:M:H	-2.2793	0.3	1.0	-3	0.1	0.03
L:H:L	-2.2793	0.3	1.5	-1	0.2	0.06
L:H:M	-2.2793	0.3	1.5	-2	0.0	0
L:H:H	-2.2793	0.3	1.5	-3	0.0	0
M:L:L	-4.5585	0.4	0.5	-1	0.0	0
M:L:M	-4.5585	0.4	0.5	-2	0.0	0
M:L:H	-4.5585	0.4	0.5	-3	0.1	0.04
M:M:L	-4.5585	0.4	1.0	-1	0.1	0.04
M:M:M	-4.5585	0.4	1.0	-2	0.5	0.20
M:M:H	-4.5585	0.4	1.0	-3	0.1	0.04
M:H:L	-4.5585	0.4	1.5	-1	0.2	0.08
M:H:M	-4.5585	0.4	1.5	-2	0.0	0
M:H:H	-4.5585	0.4	1.5	-3	0.0	0
H:L:L	-6.8378	0.3	0.5	-1	0.0	0
H:L:M	-6.8378	0.3	0.5	-2	0.0	0
H:L:H	-6.8378	0.3	0.5	-3	0.1	0.03
H:M:L	-6.8378	0.3	1.0	-1	0.1	0.03
H:M:M	-6.8378	0.3	1.0	-2	0.5	0.15
H:M:H	-6.8378	0.3	1.0	-3	0.1	0.03
H:H:L	-6.8378	0.3	1.5	-1	0.2	0.06
H:H:M	-6.8378	0.3	1.5	-2	0.0	0
H:H:H	-6.8378	0.3	1.5	-3	0.0	0
						1.00

a Note that 10, 20, and 30 per cent reductions in the tariff on imports of good 3 are equivalent to 2.2793, 4.5585, and 6.8378 per cent reductions, respectively, in one plus the ad valorem tariff on imports of good 3.

b L = Low, M = Medium, H = High.

FIGURE 4 : PROBABILITY DISTRIBUTIONS FOR SELECTED ENDOGENOUS VARIABLES GENERATED BY DEPENDENT EXOGENOUS FORECASTS*

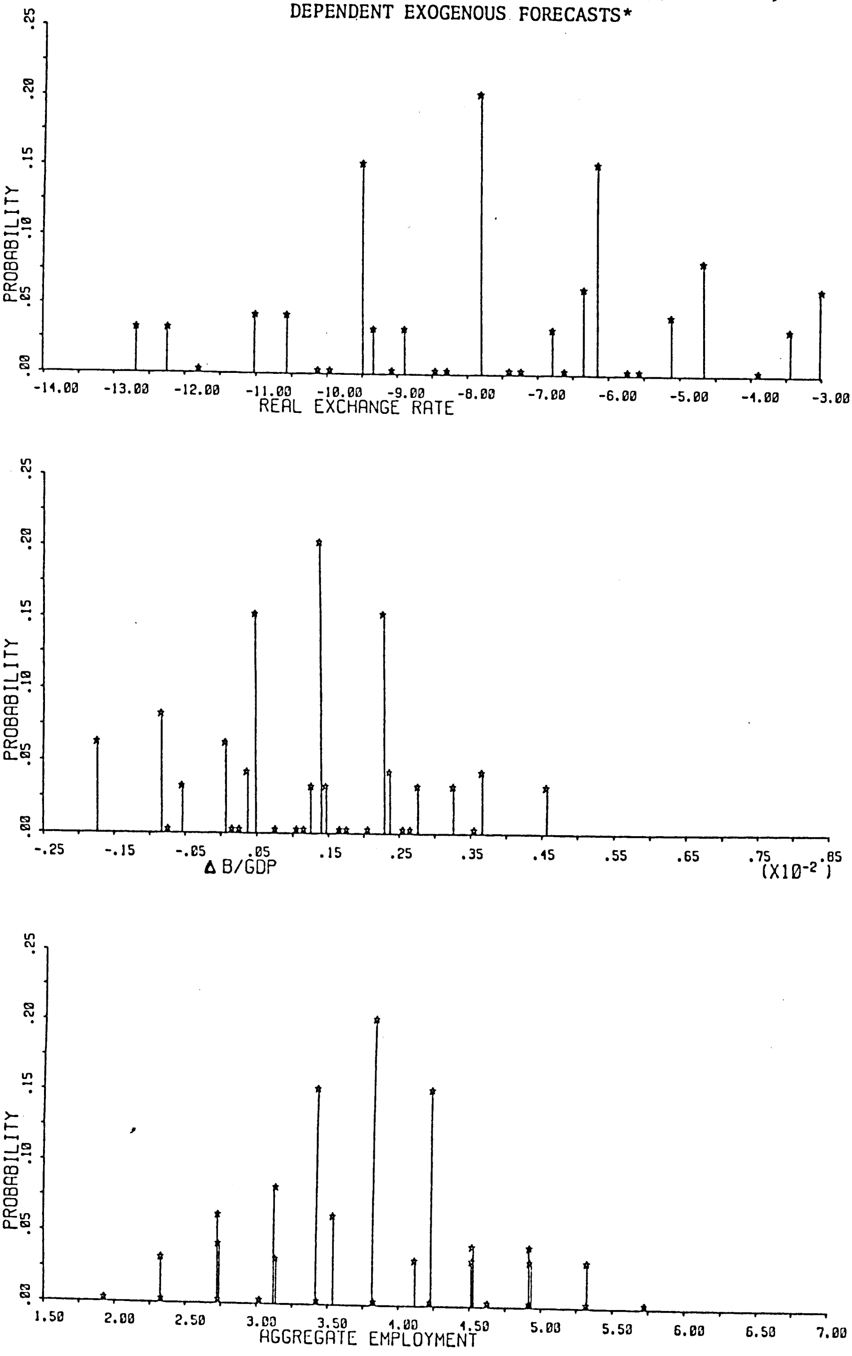
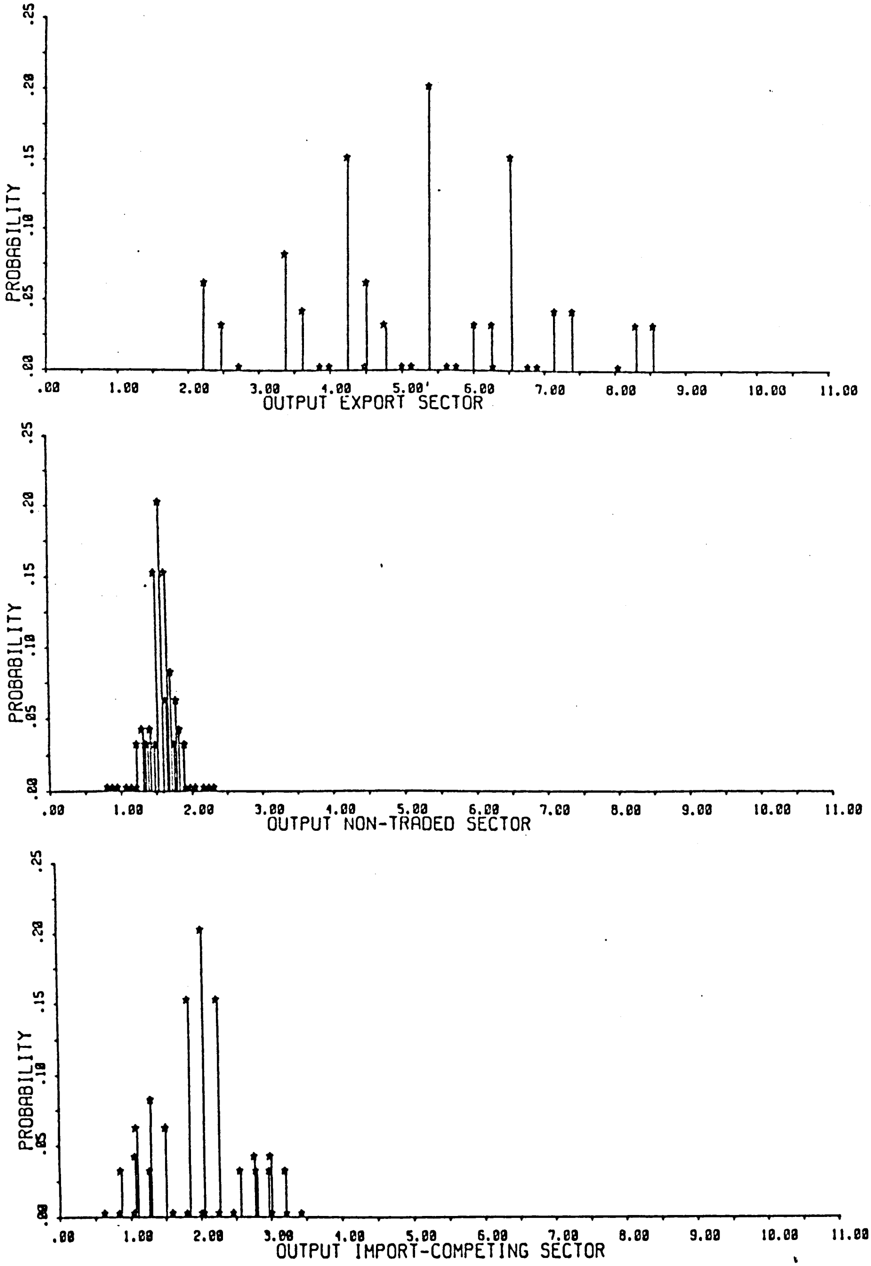


FIGURE 4 Continued



* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

TABLE 8 : FORECASTS OF SELECTED ENDOGENOUS VARIABLES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE DISCRETE AND DEPENDENT*

Variable	Mean	Variance	Standard Deviation	Skew[a]
Macroeconomic				
Real exchange rate	-7.5775	6.0527	2.4602	-1.0251
Change in the balance of trade as a share of base-period GDP	0.0011	0.0000	0.0015	0.0000
Aggregate employment	3.7289	0.4775	0.6910	0.0460
Industry Activity Levels				
1. Export sector	5.1228	2.5850	1.6078	0.2801
2. Non-traded sector	1.5132	0.0235	0.1533	-0.0006
3. Import-competing sector	1.8895	0.3707	0.6088	0.0364

* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

a The measure of skewness is calculated by taking the expectation of the cube of the difference between each forecast and its mean. If the distribution is symmetric the measure will be equal to zero. If the distribution is skewed to the left (i.e. its left tail is elongated) the measure will be negative, and if the distribution is skewed to the right the measure will be positive. For more details, see, for example, Kmenta (1971, p.62).

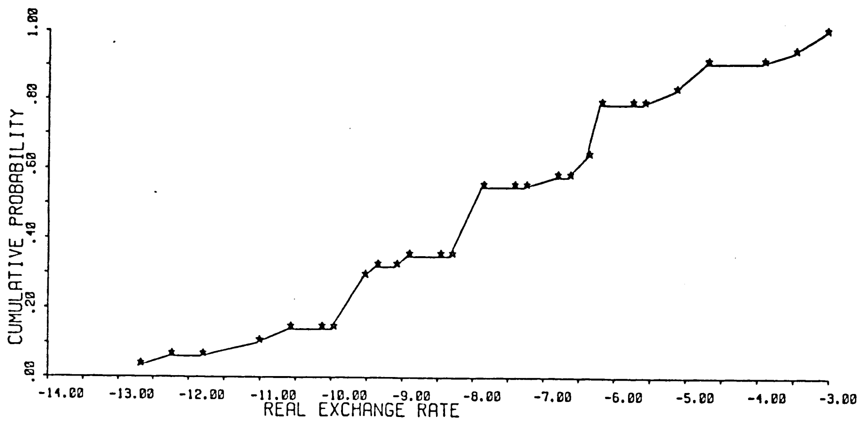
absorption and real wage forecasts are positively correlated as opposed to when they are independent. For example, the elasticities of the real exchange rate with respect to real absorption and the real wage are both positive; see Table 1. The variance of the real exchange rate projections when the real absorption and real wage forecasts are dependent is 6.0527 (see Table 8) which is greater than the corresponding variance of 5.3545 (see Table 4) given independent forecasts. Note that the opposite is the case for the aggregate employment projections.

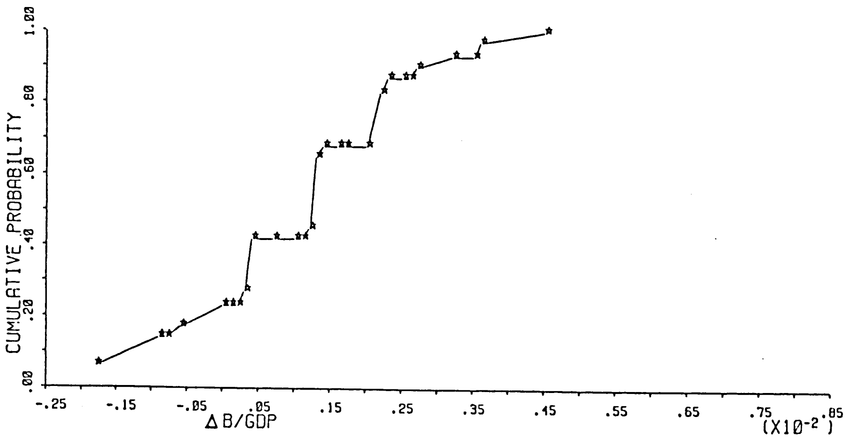
The cumulative probability distributions for the endogenous variables are depicted in Figure 5. As discussed in section 2.1.1, any confidence intervals of interest can be estimated from Figure 5. Here we have again elected to calculate the 90 per cent and 70 per cent confidence intervals; see Table 9. Note that the differences between the confidence intervals given in Table 9 with those in Table 5 can be explained using a similar argument to that used above with respect to the variances.

2.2 CONTINUOUS FORECASTS

Here we will suppose that the forecasts of the exogenous variables are continuous. For example, we might assume a continuous distribution for the exogenous variables each with its own mean and variance. In the first case we will assume that these continuous forecasts are independent, then later we will examine the case when they are correlated.

FIGURE 5 : CUMULATIVE PROBABILITY DISTRIBUTIONS FOR SELECTED ENDOGENOUS VARIABLES GENERATED BY DEPENDENT EXOGENOUS FORECASTS*





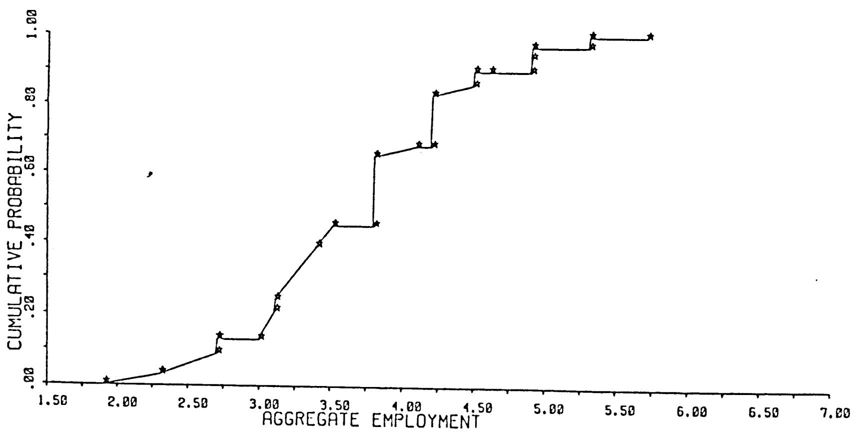
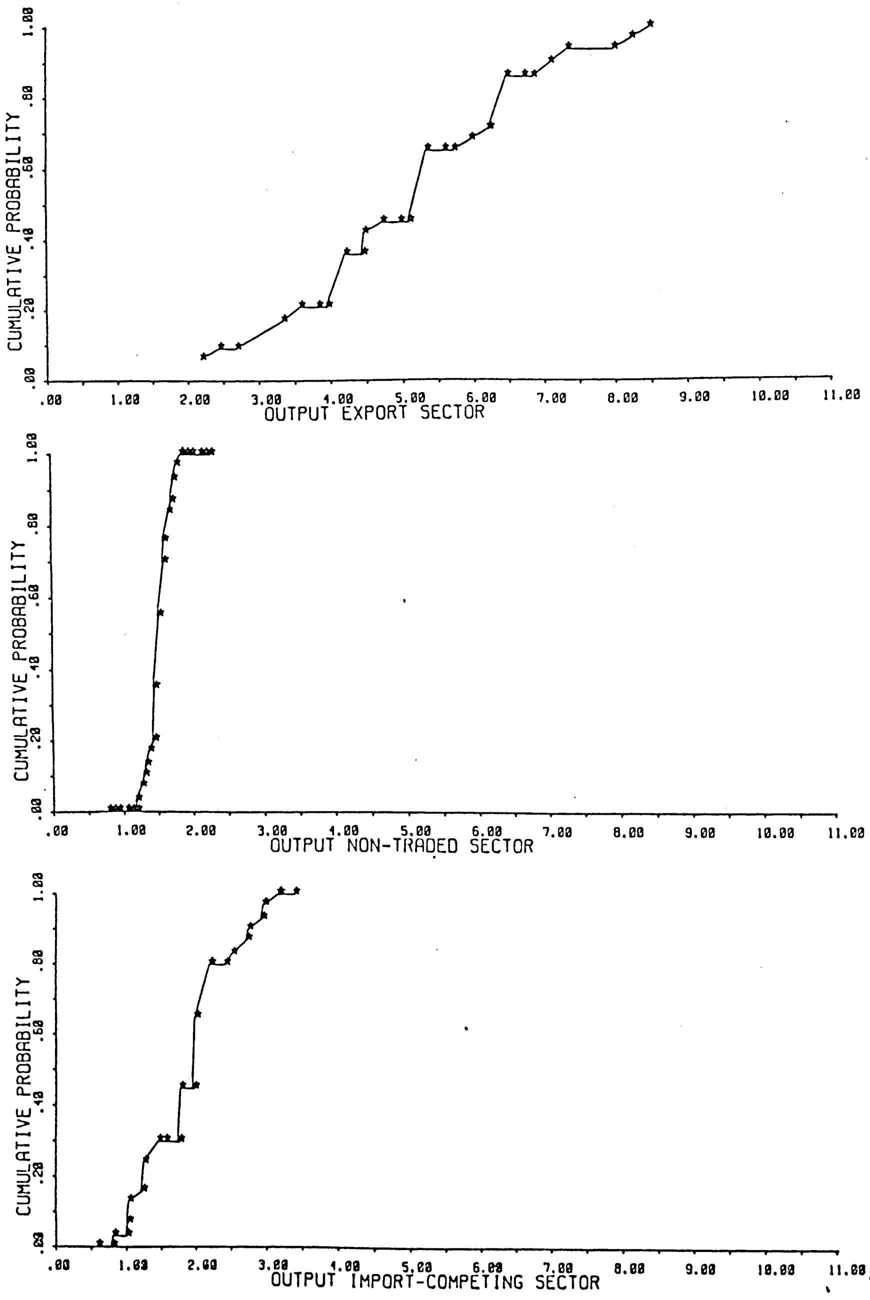


FIGURE 5 Continued



* These projections, with the exception of the balance of trade, are growth rates over the next 2-year period. The balance of trade projection is the projected 2-year change in the balance of trade as a share of the base-period GDP.

TABLE 9 : CONFIDENCE INTERVALS OF THE FORECASTS OF SELECTED ENDOGENOUS VARIABLES WHEN THE FORECASTS OF THE EXOGENOUS VARIABLES ARE DISCRETE AND DEPENDENT

Variable	Mean	90 per cent Confidence Interval		70 per cent Confidence Interval	
		low	high	low	high
Macroeconomic					
Real exchange rate	-7.5775	-12.7256 (-11.6245)[a]	-3.0620 (-3.5304)	-10.0049 (-10.9361)	-4.7306 (-4.2188)
Change in the balance of trade as a share of base-period GDP	0.0011	-0.0018 (-0.0014)	0.0036 (0.0036)	-0.0008 (-0.0009)	0.0023 (0.0031)
Aggregate employment	3.7289	2.3024 (2.5922)	5.6976 (4.8656)	2.9946 (2.7855)	4.8964 (4.6723)
Industry Activity Levels					
1. Export sector	5.1228	2.1677 (2.4780)	8.2339 (7.7676)	2.6622 (2.9278)	6.4652 (7.3178)
2. Non-traded sector	1.5132	1.1634 (1.2610)	1.7621 (1.7654)	1.3052 (1.3039)	1.6912 (1.7225)
3. Import-competing sector	1.8895	0.9817 (0.8880)	2.9282 (2.8910)	1.0158 (1.0584)	2.7028 (2.7206)

a For comparative purposes, the confidence intervals calculated assuming a continuous normal distribution with the same mean and standard derivation as the discrete distribution are given in parentheses.

2.2.1 Independent Continuous Forecasts of the Exogenous Variables

In this section we will assume that the forecasts of the exogenous variables are continuous and have means and variances consistent with those implied by the discrete forecasts and associated probabilities presented in Table 2.

Given the means and variance-covariance matrix of the exogenous variables and the elasticities of the endogenous variables with respect to the exogenous variables we can calculate the means and variances of the endogenous variables. This can be shown as follows. First we take the expectation of both sides of equation (1):

$$E(\alpha_i) = E\left(\sum_j \eta_{\alpha_i \beta_j} \beta_j\right) . \qquad (2)$$

Next we note that the expected value of a linear combination of random variables is equal to the linear combination of their expected values:[8]

$$E(\alpha_i) = \sum_j \eta_{\alpha_i \beta_j} E(\beta_j) . \qquad (3)$$

Thus according to equation (3) the expected outcome for an endogenous variable α_i can be calculated given the expected outcomes for each of the exogenous variables and the elasticities of α_i with respect to each of the exogenous variables, i.e. the $\eta_{\alpha_i \beta_j}$'s. For example, the expected outcome for the real exchange rage, $E(\varphi_R)$, can be calculated as follows:

$$E(\varphi_R) = \eta_{\varphi_R\, t_3} E(t_3) + \eta_{\varphi_R\, c_R+i_R} E(c_R+i_R) + \eta_{\varphi_R\, f_{(41)}} E(f_{(41)}) \quad . \qquad (4)$$

From Table 2 we can compute the expected outcomes for each of the exogenous variables: the expected cut in one plus the ad valorem tariff on imports of good 3 is -4.5585 per cent; the expected increase in real absorption is 1.05 per cent; and the expected cut in real wages is -1.9 per cent. If we substitute these expectations together with the appropriate elasticities listed in Table 1 into equation (4) we find that:

$$E(\varphi_R) = 0.7321 \times -4.5585 + 0.8849 \times 1.05 + 2.7207 \times -1.9 = -7.5775 \quad .$$

Note that this agrees with our mean estimate for the real exchange rate presented in Table 4, which was calculated by weighting the real exchange rate projections in each scenario by the probability of the scenario occurring. The mean estimates for the other endogenous variables can also be calculated using equation (3).

Similarly the variances of the endogenous variables can be computed directly from the variance-covariance matrix for the exogenous variables and the elasticities of the endogenous variables with respect to the exogenous variables. If we take the variance of both sides of equation (1) we get:

$$\mathrm{Var}\ (\alpha_i) = \mathrm{Var}\ \left(\sum_j \eta_{\alpha_i \beta_j} \beta_j\right) \quad . \tag{5}$$

Next we note that if the β_j's are random variables and the $\eta_{\alpha_i \beta_j}$'s are constants then the variance of a linear combination of random variables can be expressed as:[9]

$$\mathrm{Var}\ (\alpha_i) = \sum_j \sum_k \eta_{\alpha_i \beta_j} \eta_{\alpha_i \beta_k} \mathrm{Cov}\ \left(\beta_j, \beta_k\right) \quad . \tag{6}$$

Equation (6) can also be expressed in matrix notation:

$$\mathrm{Var}\ (\alpha_i) = \eta_i^T \ \mathrm{Cov}(\beta)\ \eta_i \quad ; \tag{7}$$

where η_i is a (nx1) vector of the elasticities of the endogenous variable α_i with respect to each of the (n) exogenous variables; $\mathrm{Cov}(\beta)$ is a (nxn) variance-covariance matrix of the exogenous variables; and η_i^T is the transpose of η_i. Note that since we are assuming that the forecasts of the exogenous variables are independent of each other, then the covariance elements of the variance-covariance matrix are zero. Given the above assumption of independence, the variance-covariance matrix can be written:

$$\mathrm{Cov}(\beta) = \begin{bmatrix} 3.1170 & 0 & 0 \\ 0 & 0.0725 & 0 \\ 0 & 0 & 0.4900 \end{bmatrix} \quad ;$$

where 3.1170, 0.0725, and 0.4900 are assumed values of the variances of the tariff, real absorption, and real wage forecasts, respectively.

Notice that these parameter values are consistent with the variances calculated from our discrete example in Table 2.

To illustrate equation (7) we will calculate the variance of the CPI projections. The vector of elasticities of the real exchange rate with respect to the exogenous variables can be read from Table 1:

$$\eta_{\phi_R} = \begin{bmatrix} 0.7321 \\ 0.8849 \\ 2.7207 \end{bmatrix} .$$

If we substitute the above elasticities and the variance-covariance matrix into equation (7) we can calculate the variance of the real exchange rate projections:

$$\text{Var}\ (\phi_R) = [0.7321,\ 0.8849,\ 2.7207] \begin{bmatrix} 3.1170 & 0 & 0 \\ 0 & 0.0725 & 0 \\ 0 & 0 & 0.4900 \end{bmatrix} \begin{bmatrix} 0.7321 \\ 0.8849 \\ 2.7207 \end{bmatrix} .$$

Thus:

$$\text{Var}\ (\phi_R) = 5.3545 \quad .$$

Note that this agrees with our calculation for the variance of the real exchange rate projections presented in Table 4. The variances for the other endogenous variables can also be calculated using equation (7).

In the previous sections, where we were dealing with discrete forecasts, the confidence intervals for the forecasts of the endogenous variables could be estimated, subject to the indeterminancy associated with discrete forecasts, from the resulting cumulative frequency distributions. If confidence intervals are required in the case of continuous forecasts then they can be estimated by one of the following:

(1) numerically approximating the continuous exogenous forecasts with discrete points and then generating a cumulative frequency distribution as above;

(2) assuming that, for a sufficiently large number of exogenous variables, the resultant distribution of the endogenous forecasts approximates a normal distribution (that is, invoke a central limit theorem, or else assume that the exogenous forecasts themselves are normally distributed[10]);

or

(3) using a measure to calculate the confidence interval which is independent of the distribution or density of the endogenous forecasts (that is, a non-parametric method), such as the Chebyshev inequality.

The problem with method (1), which numerically approximates the continuous forecasts with discrete points, is that it is very computer intensive and may be infeasible if there are a large number of exogenous variables for which forecasts are to be made.

The assumption that the resultant distribution of the endogenous forecasts approaches a normal distribution, i.e. method (2), may be a reasonable assumption to make, even if the available information on the exogenous variables comes in the form of discrete distributions like those discussed above. This can be seen by comparing the confidence intervals given in parentheses in Table 5, which have been calculated for each of the endogenous variables assuming that their distributions were normal,[11] with the confidence intervals calculated from the discrete cumulative probability distributions.

Finally, a method for calculating confidence intervals which is independent of the distribution or density of the endogenous forecasts, i.e. method (3), not surprisingly produces confidence intervals that are relatively large. The Chebyshev inequality says that if α is a random variable with a mean μ and a finite variance σ^2 then:[12]

$$P\{\mu - k\sigma < \alpha < \mu + k\sigma\} \geq 1 - 1/k^2 \quad ; \qquad (8)$$

where k is a constant. For k equals 2, equation (8) says that for any random variable α having a finite variance, at least three-fourths (i.e. $1-1/2^2 = 3/4$) of the mass of α falls within 2 standard deviations of its mean. Thus a 90 per cent confidence interval, for example, can be calculated by setting k equal to 3.1623 (i.e. $k = (1/(1-0.9))^{1/2}$). If this value for k is substituted together with the mean and standard deviation for the real exchange rate projections (i.e. $\mu = -7.5775$ and $\sigma = 2.3140$) into equation (8) we obtain:

$$P\{-14.8951 < \phi_R < -0.2599\} \geq 0.90 \quad ;$$

where ϕ_R is the forecast percentage change in the real exchange rate. Note that this confidence interval is much wider than that obtained when a normal distribution was assumed, where the lower bound was -11.3840 and the upper bound was -3.7709; see Table 5.

2.2.2 Dependent Continuous Forecasts of the Exogenous Variables

In this section we will assume that the forecasts of the exogenous variables are continuous and have means, variances, and covariances consistent with the discrete forecasts and associated probabilities presented in Tables 2 and 6.

The expected outcome for an endogenous variable can again be calculated using equation (3). As the elasticities and the expected outcomes for each of the exogenous variables are assumed to be the same for the dependent forecasts as for the independent forecasts, then it follows from equation (3) that the expected outcomes for the endogenous variables here will also be the same as those calculated above.

The variances of the projections of the endogenous variables can be estimated using equation (7). Equation (7) requires the vector of the elasticities of the endogenous variable of interest with respect to each of the exogenous variables and the variance-covariance matrix for the exogenous variables. The vectors of elasticities are as listed above in Table 1. The variance-covariance matrix can be calculated from the exogenous forecasts presented in Tables 2 and 6:

$$\text{Cov}(\beta) = \begin{bmatrix} 3.1170 & 0 & 0 \\ 0 & 0.0725 & 0.1450 \\ 0 & 0.1450 & 0.4900 \end{bmatrix} ;$$

where 3.1170, 0.0725, and 0.4900 are the variances of the tariff, real absorption, and real wage forecasts, as above; and 0.1450 is the covariance between the real absorption and real wage forecasts. Note that the covariance is positive as there is a positive correlation assumed between the real absorption and real wage forecasts; see Figure 3.

To illustrate equation (7) for the case of dependent continuous exogenous forecasts we will calculate the variance of the real exchange rate projections. If we substitute the appropriate elasticities vector and the above variance-covariance matrix into equation (7) we obtain:

$$\mathrm{Var}\,(\varphi_R) = [0.7321 \quad 0.8849 \quad 2.7207] \begin{bmatrix} 3.1170 & 0 & 0 \\ 0 & 0.0725 & 0.1450 \\ 0 & 0.1450 & 0.4900 \end{bmatrix} \begin{bmatrix} 0.7321 \\ 0.8849 \\ 2.7207 \end{bmatrix} .$$

Thus:

$$\mathrm{Var}\,(\varphi_R) = 6.0527 \quad .$$

Note that this agrees with our calculation for the variance of the real exchange rate projections presented in Table 8.

The final statistics to be presented are the 90 per cent and 70 per cent confidence intervals calculated assuming a normal distribution for the forecasts of the endogenous variables. These are presented in parentheses in Table 9. By comparing these confidence intervals with those calculated in the discrete case it can be seen that, at least for our illustrative example, the assumption that the resultant distribution of the endogenous forecasts approaches a normal distribution could again be a reasonable assumption to make.

3. CONCLUDING REMARKS

This paper, which is expository in nature, has outlined procedures for transforming statements about the reliability of forecasted exogenous variables into statements about the precision of endogenous forecasts made with a CGE model. In future work the procedures illustrated here will be applied to the forecasts made by Dixon and Parmenter (1986) with the ORANI CGE model of the Australian economy. These procedures could also be extended to incorporate uncertainty in the parameters of the CGE model. Preliminary work along these lines has been completed by Pagan and Shannon (1985), Harrison, Jones, Kimbell, and Wigle (1985), and Adams and Higgs (1986). These studies test the robustness of CGE projections to the assumptions employed in calibrating the models.

NOTES

* The author is indebted to George Codsi, Peter Dixon, Brian Parmenter, Ken Pearson, and Alan Powell for comments and assistance.

1. For a recent summary of this work see Føorsund, Hoel, and Longva (1985).

2. See Dixon, Parmenter, and Horridge (1986) for a discussion of forecasting versus policy analysis.

3. See also Dixon and McDonald (1986).

4. Note that the model is very similar to the miniature ORANI model developed by Dixon, Parmenter, Sutton, and Vincent (1982).

5. The real exchange rate, Φ_R, is equal to the nominal wage, W, say \$A/labour hour, divided by the nominal exchange rate, Φ, say \$A/\$US. Thus Φ_R is equal to (\$A/labour hour)/(\$A/\$US), which in turn equals \$US/labour hour. That is, the real exchange rate is the number of American dollars that can be purchased with one hour of Australian labour. (Note that for our illustrative example we have not taken into account changes in the US purchasing power of the American dollar.) Furthermore, the percentage change in the real exchange rate, ϕ_R, can be written:

$$\phi_R = w - \varphi \quad ; \tag{1}$$

where w is the percentage change in the nominal wage rate; and φ is the percentage change in the nominal exchange rate. Next we note that since we assume full indexation of nominal wages, the percentage change in the nominal wage rate is given by:

$$w = \xi^{(3)} + f_{(41)} \quad ; \tag{2}$$

where $\xi^{(3)}$ is the percentage change in the consumer price index; and $f_{(41)}$ is a real-wage shift term. If we substitute (2) into (1) and note that the nominal exchange rate is the numeraire (i.e. $\phi = 0$), then the percentage change in the real exchange rate can be written:

$$\phi_R = \xi^{(3)} + f_{(41)} \quad . \tag{3}$$

Thus for the tariff cut and real absorption shocks, the percentage change in the real exchange rate is equivalent to the percentage change in the CGE model's consumer price index; however for the real wage shock it is equal to the percentage change in the consumer price index plus the change in the real-wage shift term.

6. See Dixon, Parmenter, Sutton, and Vincent (1982, p. 327).

7. If this assumption is unacceptable then the alternative is always to use discrete exogenous forecasts and to solve the CGE model for each individual scenario, as discussed in section 2.1. This alternative approach would be extremely computer intensive and may be infeasible if there are a large number of exogenous variables for which forecasts are made.

8. See, for example, Kmenta (1971, p.63).

9. See, for example, Mood, Graybill, and Boes (1974, p.179).

10. Note that the linear combination of normally and independently disributed random variables is also normally distributed. See, for example, Anderson and Bancroft (1952, pp. 63-64).

11. See, for example, Kmenta (1971, pp. 83-90).

12. See, for example, Mood, Graybill, and Boes (1974, pp. 71-2).

REFERENCES

Adams, P.D. and P.J. Higgs (1986) "Calibration of Computable General Equilibrium Models from Synthetic Benchmark Equilibrium Data Sets", IMPACT Preliminary Working Paper No. OP-57, mimeo, 37 pp. Available from Industries Assistance Commission, Canberra.

Anderson, R.L. and T.A. Bancroft (1952) Statistical Theory in Research, McGraw-Hill Book Company, New York.

Australian Bureau of Statistics (1983) Australian National Accounts, Input-Output Tables 1977-78, Australian Government Publishing Service, Canberra.

Cooper, R.J. (1983) "A Tariff Experiment on the Interfaced ORANI-MACRO System", IMPACT Preliminary Working Paper No. IP-17, mimeo, 29 pp. Available from Industries Assistance Commission, Canberra.

Dixon, P.B. (1986) "Prospects for Australian Industries and Occupations, 1985 to 1990", Australian Economic Review, 1st Quarter, pp. 3-28.

Dixon P.B. and D. McDonald (1986) "Australia's Foreign Debt: 1975 to 1985", Australian Economic Review, 2nd Quarter, pp. 22-37.

Dixon, P.B. and B.R. Parmenter (1986) "Medium-Run Forecasts for the Australian Economy Using the ORANI Model", mimeo, pp. 33. Paper presented to the Third Meeting of the Task Force on Applied General Equilibrium Modelling sponsored by the International Institute of Applied Systems Analysis, Laxenburg, Austria, 25th-29th, August, 1986. Paper available from the Institute of Applied Economic and Social Research, University of Melbourne.

Dixon, P.B., B.R. Parmenter, and M. Horridge (1986) "Forecasting Versus Policy Analysis with the ORANI Model", IAESR Working Paper No. 4/1986, mimeo, pp. 27. Available from the Institute of Applied Economic and Social Research, University of Melbourne.

Dixon, P.B., B.R. Parmenter, J. Sutton, and D.P. Vincent (1982) ORANI: A Multisectoral Model of the Australian Economy, North-Holland, Amsterdam.

Dixon, P.B., Powell, A.A., and Parmenter, B.R. (1979) Structural Adaptation in an Ailing Macroeconomy, Melbourne University Press, Melbourne.

Førsund, F.R., M. Hoel, and S. Longva (eds) (1985) Production, Multi-Sectoral Growth and Planning: Essays in Memory of Leif Johansen, North-Holland, Amsterdam.

Harrisoń, G.W., R.Jones, L.J. Kimbell, and R. Wigle (1985) "How Robust is Applied General Equilibrium Analysis? Working Paper No. 8501, Centre for the Study of International Economic Relations, University of Western Ontario.

Higgs, Peter J. (1986a) "A Stylized Computable General Equilibrium Model of the Australian Economy", mimeo, pp. 90. Available from the IMPACT Project, University of Melbourne.

Higgs, Peter J. (1986b) Adaptation and Survival in Australian Agriculture, Oxford University Press, Melbourne.

Johansen, L.F. (1960) A Multi-Sectoral Study of Economic Growth, North-Holland, Amsterdam (2nd edition 1974).

Kmenta, J. (1971) Elements of Econometrics, Macmillan, New York.

Mood, A.M., F.A. Graybill, and D.C. Boes (1974) Introduction to the Theory of Statistics, 3rd edition, McGraw-Hill Book Company, New York.

Pagan, A.R. and J.H. Shannon (1985) "How Reliable are ORANI Conclusions?", Australian National University, Centre for Economic Policy Research, Discussion Paper No.130, mimeo, 50 pp.