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ORANI-FUEL:

INCORPORATING INTERFUEL SUBSTITUTION INTO THE STANDARD ORANI SYSTEM

by

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Abstract

The currently available standard version of the ORANI model of the Australian economy (Dixon et al., 1982) does not allow for substitution between different materials used as inputs by industries. This makes this version of the model unsuitable for the analysis of price competition among different fuels (oil, gas, electricity, coal). The standard version of the model does include variables, however, which although designed primarily to accommodate different types of technical change, can be used instead to modify the structural form of the model. In the present paper a procedure has been devised for using this facility to modify the ORANI theory to allow price-responsive substitution between the different fuel types by different industries. The method is illustrated by imposing a world oil price shock, equivalent to a 10 per cent drop in the price of imported crude oil, on the modified model, termed ORANI-FUEL. The shock is imposed under the assumption that the price to users of domestic crude follows the world price. This exercise establishes that ORANI-FUEL is a suitable vehicle for the analysis of competition among fuels. Because this study was undertaken primarily as a feasibility trial, more work is required before policy conclusions are drawn.

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1. INTRODUCTION

ORANI (Dixon, et al., 1982, hereafter referred to as DPSV), is a large-scale computable general equilibrium model of the Australian economy. The model is potentially a very useful tool for policy analysis of various aspects of interfuel and interfactor substitution in the economy. At present, the standard version[1] of ORANI makes explicit allowance neither for interfuel nor for interfactor substitution. However, as demonstrated by Truong et al. (1985), interfuel and interfactor substitution can easily be incorporated into the standard ORANI model through the 'technical change' coefficients. In this paper, we illustrate such a procedure with a practical experiment.

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1. By this we mean the model structure as available from Impact Centre, through the GEMPACK I Release 3 - February 1986.

The motivation for our study is as follows. Consider, for example, the issue of "the effects of assessing and levying duty on petroleum products at various points in the production, storage and distribution processes"[2]. Petroleum product excise duties and/or sales taxes will affect the relative prices of petroleum (and other) fuels, as well as the prices of other non-fuel commodities. An increase in the price of a fuel (following the imposition of a tax) will cause the demand for that fuel to decrease. The extent of this reduction in the demand for the fuel (and hence the reduction in revenue collected through the tax) will depend, among other factors, upon the ability of producers and/or consumers to switch from one fuel to another, as well as from fuels to non-fuel commodities. This implies that a study of "the implications [of a change in the petroleum products taxation structure] for Government revenue"[3] could not be complete without a study of interfuel and interfactor substitution.

In this paper, we look only at interfuel substitution. Interfactor substitution will be the topic of a future study which awaits the release of the GEMPACK II software by the Impact Project. The latter will greatly facilitate the implementation of interfactor substitution procedures as set out by Truong et al. (1985).

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2. Industry Assistance Commission (1985), Appendix A.

3. Ibid.

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Table B.1 (continued)

Industries : 88, 89, 90				
k / i	16	58	86	87
16	−.3 (∓.15)	.1 (±.05)	.1 (±.05)	.1 (±.05)
58	.15 (±.1)	−.4 (∓.3)	.1 (±.1)	.15 (±.1)
86	.1 (±.05)	.1 (±.05)	−.3 (∓.15)	.1 (±.05)
87	.1 (±.1)	.2 (±.1)	.2 (±.1)	−.5 (∓.3)

The balance of this paper is structured as follows. In Section 2 the modifications which have to be made to the standard ORANI theory are outlined, and auxiliary variables and equations necessary to implement the new version of ORANI are defined. In Section 3 technical aspects of the simulations reported in Section 4 are discussed. In particular, Section 3 details how an appropriate choice of shocks can be used to circumvent some rather serious limitations which aggregations in the currently available data base would otherwise impose. Besides offering a comparison between standard ORANI and ORANI-FUEL results for a 10 per cent reduction in the foreign currency price of crude oil, Section 4 also contains the results of a sensitivity analysis to variations in the values of interfuel substitution elasticities. Some brief concluding remarks and perspectives for further energy-related research using ORANI-FUEL are offered in Section 5.

2. THEORY

Let us start with a standard ORANI specification, such as that given by equation (12.23) in DPSV:

$$x^{(1)}_{(is)j} = z_j - \sigma^{(1)}_{ij}[p^{(1)}_{(is)j} - \sum_{s=1}^{2} S^{(1)}_{(is)j}\ p^{(1)}_{(is)j}] + a^{(1)}_{ij}; \qquad (1)$$

where:

$x^{(1)}_{(is)j}$ denotes (percentage change or log change in)[4] usage of fuel of type i from source s (s = 1, domestic; s = 2, imported) in industry j used for current production (superscript (1));

z_j is output of industry j;

$\sigma^{(1)}_{ij}$ is the import/domestic substitution parameter (viz., Armington elasticity) for fuel type i in industry j;

$p^{(1)}_{(is)j}$ is the price corresponding to $x^{(1)}_{(is)j}$;

$S^{(1)}_{(is)j}$ is the share of source s in the value of usage of fuel i by industry j for current production (s = 1, 2) -- (thus

$$S^{(1)}_{(i1)j} + S^{(1)}_{(i2)j} = 1);$$

4. Since ORANI variables are defined in terms of percentage or log changes, this will be left implicit throughout the remainder of the paper.

Table B.1 (continued)

	Industries: 64			
i \ k	16	58	86	87
16	-.8 (∓.3)	.1 (±.1)	.5 (±.1)	.2 (±.1)
58	.1 (±.1)	-.5 (∓.3)	.1 (±.1)	.3 (±.1)
86	.2 (±.05)	.1 (±.1)	-.5 (∓.2)	.2 (±.05)
87	.1 (±.1)	.3 (±.1)	.1 (±.1)	-.5 (∓.3)

Table B.1 (continued)

i \ k	58	86	87
	Industry : 63		
58	-.5 (∓.3)	.15 (±.15)	.35 (±.15)
86	.2 (±.1)	-.5 (∓.2)	.2 (±.1)
87	.35 (±.15)	.15 (±.15)	-.5 (∓.3)

$a_{ij}^{(1)}$ is a shift term normally used to simulate technological change, but which is going to be used in this paper to simulate interfuel substitution.

Apart from domestic/import substitution between fuels of the same type, equation (1) does not allow for interfuel substitution. This is because input of fuel type i, source s, into industry j is related only to the activity level z_j and not the relative fuel prices. To incorporate interfuel substitution, let us first replace (1) with:

$$x_{(is)j}^{(1)} = x_{(i.)j}^{(1)} - \sigma_{ij}^{(1)}[p_{(is)j}^{(1)} - \sum_s S_{(is)j}^{(1)} p_{(is)j}^{(1)}] \quad ; \quad (2)$$

$$x_{(i.)j}^{(1)} = \varepsilon_i^j z_j + \sum_k \eta_{i,k}^j p_{(k.)j}^{(1)} \quad ; \quad (3)$$

$$p_{(i.)j}^{(1)} = \sum_s S_{(is)j}^{(1)} p_{(is)j}^{(1)} \quad ; \quad (4)$$

where we have introduced the following terms:

$x_{(i.)j}^{(1)}$ is $x_{(is)j}^{(1)}$ aggregated over sources s, and thus represents 'effective' input of fuel i to industry j for current production;

$p_{(i.)j}^{(1)}$ is the price of $x_{(i.)j}^{(1)}$;

ε_i^j is the output elasticity of demand for fuel i in industry j;

$\eta^{j}_{i,k}$ is the price elasticity of demand by industry j for fuel i (to be used for current production) with respect to the price of fuel k.

Equation (1) can be made equivalent to equations (2) - (4) if we set:[5]

$$a^{(1)}_{ij} = \sum_s \sum_k S^{(1)}_{(ks)j} \; p^{(1)}_{(ks)j} \; \eta^{j}_{i,k} + (\varepsilon^{j}_{i} - 1) z_j \quad . \qquad (5)$$

Before we can use (5), we note that $p^{(1)}_{(ks)j}$ is eliminated from the ORANI 'condensed' system of equations (DPSV, Table 32.1). It can, however, be recovered from standard ORANI results by relating this to the 'basic' price of fuel k, $p^{(o)}_{(kl)}$, using the DPSV equation (18.18)[6]:

$$p^{(1)}_{(is)j} = p^{(o)}_{(is)} \; \zeta_1(is, jl) + g(is, jl) \; \zeta_2(is, jl)$$

$$+ \left\{ \sum_{r=1}^{h} M^{(is)jl}_{(rl)} \; p^{(o)}_{(rl)} \right\} \zeta_3(is,jl) \quad , \qquad (6)$$

where:

$\zeta_1(is,jl)$ is the basic-value share in the purchasers' value of fuel i from source s used as an input by industry j in current production (see DPSV, Table 27.1, p. 162);

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5. Although the theory below accommodates the possibility that $\varepsilon^{j}_{i} \neq 0$, in the implementation reported in Section 4, all ε^{j}_{i} values are set to unity.

6. Assuming no technical change associated with the use of services in facilitating input flows to industries for current production (i.e., $a^{(is)jl}_{(rl)} = 0$ for all i,s,j,r), the fourth term on the right hand side of DPSV equation (18.18) disappears.

Table B.1(continued)

Industry : 58				
i \ k	16	58	86	87
16	-1.0 (∓.3)	.1 (±.1)	.1 (±.1)	.8 (±.1)
58	.2 (±.1)	-1.0 (∓.3)	.2 (±.1)	.6 (±.1)
86	.1 (±.05)	.1 (±.1)	-.5 (∓.2)	.3 (±.05)
87	.8 (±.1)	.1 (±.1)	.1 (±.1)	-1.0 (∓.3)

Table B.1 (continued)

Industry : 50				
i \ k	16	58	86	87
16	-.5 (∓.3)	.15 (±.1)	.15 (±.1)	.20 (±.1)
58	.15 (±.1)	-.5 (∓.3)	.15 (±.1)	.20 (±.1)
86	.15 (±.1)	.15 (±.1)	-.5 (∓.3)	.20 (±.05)
87	.25 (±.1)	.25 (±.1)	.25 (±.1)	-.75 (∓.3)

$\zeta_2(is, j1)$ is the share of commodity taxes in the purchasers' value of fuel i from source s used by industry j for current production (DPSV, loc. cit.);

$g(is, j1)$ is the tax on sales of fuel i from source s to industry j for current production (DPSV, Table 23.2, p. 141);

$\zeta_3(is, j1)$ is the share of total margins (excluding taxes) in user j's purchasers' value of inputs of fuel i from source s for current production (DPSV, Table 27.1, p. 163);

$M_{(r1)}^{(is)j1}$ is the share of inputs of good r in the total cost of margins (excluding taxes) required to transfer flows of fuel i (of source s) from the producer (if s = 1), or from the port of entry (if s = 2), to user j for current production.

Again, g(is, j1) is eliminated from the condensed ORANI system, and hence, it must be recovered, using DPSV equation (18.20):

$$g(is, j1) = h_1(is, j1)\, \xi^{(3)} + h_2(is, j1)[t(is, j1) + p_{(is)}^{(o)}] + h_3(is, j1)\, v(is, j1) \quad ; \quad (7)$$

where:

$\xi^{(3)}$ is the ORANI consumer price index (DPSV, p. 138);

t(is, jl) is the ad valorem sales tax on the basic value of fuel i, source s, when used by industry j for current production;

v(is, jl) is the corresponding specific sales tax;

and

h_1, h_2, h_3 are parameters.

The standard short-run ORANI system normally assumes $h_2 = 0$, and $h_1 = h_3 = 1$. As a result, equation (7) reduces to:

$$g(is, jl) = \xi^{(3)} + v(is, jl) \qquad . \qquad (8)$$

Substituting (8) into (6) we have:

$$P^{(1)}_{(is)j} = P^{(o)}_{(is)} \zeta_1(is, jl) + [\xi^{(3)} + v(is, jl)] \zeta_2(is, jl)$$
$$+ \{\sum_{r=1}^{h} M^{(is)jl}_{(rl)} P^{(o)}_{(rl)}\} \zeta_3(is, jl) \qquad . \qquad (9)$$

Table B.1 (continued)

	Industry : 18			
i \ k	16	58	86	87
16	-1.0 (∓.3)	.2 (±.1)	.3 (±.1)	.5 (±.1)
58	.2 (±.1)	-.5 (∓.3)	.1 (±.1)	.2 (±.1)
86	.05 (±.05)	.2 (±.1)	-.3 (∓.2)	.05 (±.05)
87	.25 (±.1)	.25 (±.1)	.25 (±.1)	-.75 (∓.3)

APPENDIX B

ELASTICITIES OF INTERFUEL SUBSTITUTION

Based on previous work in the area of fuel substitution (Donnelly, 1983; Magnus and Woodland, 1984; Truong, 1985; Turnovsky et al., 1982), some 'typical' fuel substitution elasticities are chosen for the experiment. These figures are chosen for the purpose of illustration only. They are not intended as a basis for rigorous policy analysis. Table B.1 gives the values of these illustrative substitution elasticities and the range chosen for sensitivity analysis. Note that 'crude oil' (commodity 17) is used as input mainly to industry 56 (petroleum and coal products). Other industries (which are chosen for the experiment) do not use crude as a direct input but instead use mainly refined fuels (commodity 58).

Substitution, thus, occurs mainly between commodity 58 and other fuels (rather than between crude oil and other fuels).

Table B.1

SLUTSKY ELASTICITIES OF INTERFUEL SUBSTITUTION

Industries : j = { 2, 12, 18, 50, 58, 63, 64, 88, 89, 90}

Fuels : i,k = {16, 58, 86, 87}

Values given in the Tables are the 'base-case' values for $\eta^{j}_{i,k}$ with the variations indicated within the parentheses.

	Industries : 2, 12	
i \ k	58	86
58	-.2 (+.2)	.2 (±.2)
86	.2 (±.2	-.2 (+.2)

When $x^{(1)}_{(is)j}$ and $p^{(1)}_{(is)j}$ are eliminated from the condensed system, the terms $a^{(1)}_{ij}$ and v(is, j1) are absorbed into the (vector) variable b_8 of equation (32.17) of DPSV, where[7]

$$[b_8]_i \supset \sum_j B^{(1)}_{(i1)j} \{a^{(1)}_{ij} - \sigma^{(1)}_{ij}[v(is, j1)\ \zeta_2(is, j1)$$

$$- \sum_s S^{(1)}_{(is)j}\ v(is, j1)\zeta_2(is, j1)]\} \qquad (10)$$

and where:

$B^{(1)}_{(i1)j}$ is the share of source s = 1 (domestic) in the total sales of fuel i to industry j for usage in current production.

If we are not modelling any specific sales tax on fuels, i.e., if v(is, j1) = 0, and furthermore if $a^{(1)}_{j} = a^{(2)}_{j} = a^{(2)}_{ij} = a^{(2)}_{(is)j} = a^{(3)}_{(is)} = 0$ in DPSV equations (12.23), (13.4) and (14.21) - - i.e., if we are not modelling any other types of technological changes (except for those 'associated' with interfuel substitution) - - then (10) reduces to:

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7. $a^{(1)}_{ij}$ is also absorbed into the vector variable b_9 of equation (32.18) of DPSV. To simplify the analysis we have set $a^{(1)}_{ij} = 0$ for $x^{(1)}_{(i2)j}$. This does not imply, however, that fuel substitution does not occur among imported fuels. The constraint of constant imported/domestic fuel shares imposed in Section 3 (see equation (28)) will ensure that any substitution among domestic fuels will also bring about similar results for imported fuels.

$$[b_8] = \sum_j B^{(1)}_{(i1)j} \, a^{(1)}_{ij} \quad ; \qquad (11)$$

while (9) reduces to:

$$P^{(1)}_{(is)j} = p^{(o)}_{(is)} \, \zeta_1(is, j1) + \xi^{(3)} \zeta_2(is, j1)$$

$$+ \{\sum_{r=1}^{h} M^{(is)j1}_{(r1)} \, P^{(o)}_{r1}\} \, \zeta_3(is, j1) \quad . \qquad (12)$$

Substituting (12) and (5) into (11), we have:

$$[b_8]_i = \sum_j B^{(1)}_{(i1)j} \sum_s \sum_k S^{(1)}_{(ks)j} \, \eta^j_{i,k} \, [\zeta_1(ks, j1) \, P^{(o)}_{(ks)} +$$

$$\zeta_2(ks, j1) \, \xi^{(3)} + \{\sum_{r=1}^{h} M^{(ks)j1}_{(r1)} \, P^{(o)}_{(r1)}\} \, \zeta_3(ks, j1)]$$

$$+ \sum_j B^{(1)}_{(i1)j} \, (\varepsilon^j_i - 1) z_j \quad . \qquad (13)$$

Equation (13) describes the relationship between the endogenous (vector) variables b_8, $P^{(o)}$, $\xi^{(3)}$, and z. Note that if there is no interfuel substitution, then $\eta^j_{i,k} = 0$ for all i, k, j; furthermore, if $\varepsilon^j_i = 1$, for all i, j, then (13) reduces to:

$$[b_8]_i = 0 \text{ for all i.} \qquad (14)$$

10

6. $M^{(is,j1)}_{(r1)}$: i = {16, 17, 58, 86, 87}

s = {1, 2}

j = {2, 12, 18, 50, 58, 63, 64, 88, 89, 90} and {84, 85}

r = {1, ..., 114}

To calculate this share of input of good r in the total cost of margins (excluding taxes) required to transfer flows of fuel 1 from source s from the producer (or port of entry) for use in current production in industry j, note that:

$$M^{(i1,j1)}_{(r1)} = K_{r(i,j)} \, / \sum_{n=1}^{g} K_{n(i,j)} \quad ,$$

and

$$M^{(i2,j1)}_{(r1)} = P_{r(i,j)} \, / \sum_{n=1}^{g} P_{n(i,j)} \quad .$$

7. $H^{(1)}_{(i1)j}$: i = {17}

j = {84, 85}

To calculate this share of the purchasers' value of input of domestic commodity 17 in the total costs of industry j, first sum the ijth elements of matrices A, K_1, ..., K_{g+1} to get $SUM1_{(i,j)}$ and divide this by the total cost of industry j.

8. $H^{(1)}_{g+2,j}$: j = {84, 85}

This share of 'other costs' in the total costs of industry j is given by the jth element of the vector X divided by the total costs in industry j.

4. $\zeta_2(is,j1)$: $i = \{16, 17, 58, 86, 87\}$

$s = \{1, 2\}$

$j = \{2, 12, 18, 50, 58, 63, 64, 88, 89, 90\}$

To calculate this share of commodity taxes in the purchasers' value of inputs of fuel i from source s for use in current production in industry j, use the $SUM_{(i,j)}$ as calculated above, while noting that:

$$\zeta_2(i1,j1) = K_{g+1(i,j)}/SUM_{(i,j)},$$

and

$$\zeta_2(i2,j1) = P_{g+1(i,j)}/SUM_{(i,j)}.$$

5. $\zeta_3(is,j1)$ = $i = \{16, 17, 58, 86, 87\}$

$s = \{1, 2\}$

$j = \{2, 12, 18, 50, 58, 63, 64, 88, 89, 90\}$

To calculate this share of total margins (excluding taxes) in the purchasers' value of inputs of fuel i from source s for use in current production in industry j, use the $SUM_{(i,j)}$ as calculated above, while noting that:

$$\zeta_3(i1,j1) = \sum_{n=1}^{g} K_{n(i,j)} / SUM_{(i,j)} ,$$

and

$$\zeta_3(i2,j1) = \sum_{n=1}^{g} P_{n(i,j)} / SUM_{(i,j)} .$$

With fuel substitution (and/or non-unitary production elasticity of fuel demand) b_8 is normally non-zero. Thus, to model interfuel substitution in ORANI, we initially treat b_8 as an 'exogenous' variable and then run standard ORANI with b_8 subjected to a uniform shock. The standard ORANI results should give:

$$z_j = E_j^{(1)} . x + E_j^{(2)} . b_8 \quad ; \qquad (15a)$$

$$p_{(is)}^{(o)} = E_{(is)}^{(3)} . x + E_{(is)}^{(4)} . b_8 \quad ; \qquad (15b)$$

$$\xi^{(3)} = E^{(5)} . x + E^{(6)} . b_8 \quad ; \qquad (15c)$$

where E's stand for the standard ORANI elasticity matrices -- i.e.,

$E_j^{(n)}$ is the jth row of $E^{(n)}$ (n = 1,2),

$E_{(is)}^{(n)}$ is the (is)th row of $E^{(n)}$ (n = 3,4)

$E^{(n)}$ is a single-row vector (n = 5,6,)) --

and x is the usual exogenous shock vector (excluding b_8). Substituting (15) into (13) should enable us to express b_8 in terms of x alone:

$$b_8 = F . x \quad ; \qquad (16)$$

where:

$$F = (I - F2 - F4 - F6)^{-1} . (F1 + F3 + F5) \quad ; \qquad (17)$$

in which:

F1 is the matrix whose ith row is

$$\sum_j B^{(1)}_{(i1)j} \; (\epsilon^j_i - 1) \; E^{(1)}_j \quad ; \qquad (18)$$

F2 is the matrix whose ith row is

$$\sum_j B^{(1)}_{(i1)j} \; (\epsilon^j_i - 1) E^{(2)}_j \quad ; \qquad (19)$$

F3 is the matrix whose ith row is

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} \; S^{(1)}_{(ks)j} \; \eta^j_{i,k} \; \zeta_1(ks, j1) E^{(3)}_{(ks)} \; +$$

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} \; S^{(1)}_{(ks)j} \; \eta^j_{i,k} \; \zeta_1(ks, j1) \sum_{r=1}^{h} M^{(ks)j1}_{(r1)} \; \zeta_3(ks, j1) E^{(3)}_{(rs)}; \qquad (20)$$

Next, sum all entries in K_i, P_i, L_i, Q_i, M_i, R_i, N_i, O_i, T_i (total margin type i on sale of all domestic and imported commodities). Denote this as $MARGIN_{(i)}$. Since none of the fuels are used as margins, $MARGIN_{(i)} = 0$. Thus, we have simply:

$$B^{(1)}_{(i1)j} = A_{(i,j)} / (TDU_{(i)} + MARGIN_{(i)})$$

$$= A_{(i,j)} / TDU_{(i)}$$

3. $\zeta_1(is,j1)$: $i = \{16, 17, 58, 86, 87\}$

$s = \{1, 2\}$

$j = \{2, 12, 18, 50, 58, 63, 64, 88, 89, 90\}$

To calculate this basic-value share in the purchasers' value of fuel i from source s for use in current production in industry j, first sum the i jth elements of matrices A, K_1, ..., K_{g+1}. Denote this as $SUM1_{(i,j)}$. Next do the same for matrices B, L_1, ..., L_{g+1}. Denote this as $SUM2_{(i,j)}$. Repeat for matrices F, P_1, ..., P_{g+1} ($SUM3_{(i,j)}$) and matrices G, Q_1, ..., Q_{g+1} ($SUM4_{(i,j)}$). Add SUM1 to SUM4 to get SUM, i.e. $SUM_{(i,j)}$ is the sum of the i jth elements of matrices A, B, F, G, K's, L's, P's, Q's.

$$\zeta_1(i1,j1) = A_{(i,j)} / SUM_{(i,j)}$$

$$\zeta_1(i2,j1) = F_{(i,j)} / SUM_{(i,j)}$$

APPENDIX A

SHARES CALCULATIONS

1. $S^{(1)}_{(is)j}$: $i = \{16, 17, 58, 86, 87\}$

$s = \{1, 2\}$

$j = \{2, 12, 18, 50, 58, 63, 64, 88, 89, 90\}$

To calculate this share of the purchasers' value of fuel i from source s in industry j's total purchases of fuel i for use in current production, first sum the ijth elements of matrices A, K_1, K_2,..., K_{g+1} of the input-output table (see DPSV p. 151). Denote this as $SUM1_{(i,j)}$. Next, do the same with matrices F, P_1, P_2, ... P_{g+1} (i.e. the import matrices). Denote this as $SUM2_{(i,j)}$.

$$S^{(1)}_{(i1)j} = SUM1_{(i,j)}/(SUM1_{(i,j)} + SUM2_{(i,j)}).$$

$$S^{(1)}_{(i2)j} = SUM2_{(i,j)}/(SUM1_{(i,j)} + SUM2_{(i,j)}).$$

$$= 1 - S^{(1)}_{(i1)j}$$

2. $B^{(1)}_{(i1)j}$: $i = \{16, 17, 58, 86, 87\}$

$j = \{2, 12, 18, 50, 58, 63, 64, 88, 89, 90\}$

To calculate this share of the total sales of domestic fuel i which is absorbed by industry j as a direct input into production, let $A_{(i,j)}$ denote the i jth element of matrix A (in DPSV, p. 151). Next, sum over the ith row of matrices A, B, C, D, E (total direct usage of domestic energy commodity i). Denote this as $TDU_{(i)}$.

F4 is the matrix whose ith row is

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} S^{(1)}_{(ks)j} \eta^j_{i,k} \zeta_1(ks, j1)E^{(4)}_{(ks)} +$$

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} S^{(1)}_{(ks)j} \eta^j_{i,k} \zeta_1(ks, j1) \sum_{r=1}^{h} M^{(ks)j1}_{(r1)} \zeta_3(ks, j1)E^{(4)}_{(rs)}; \qquad (21)$$

F5 is the matrix whose ith row is:

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} S^{(1)}_{(ks)j} \eta^j_{i,k} \zeta_2(ks, j1)E^{(5)} \qquad (22)$$

and

F6 is the matrix whose ith row is

$$\sum_j \sum_k \sum_s B^{(1)}_{(i1)j} S^{(1)}_{(ks)j} \eta^j_{i,k} \zeta_2(ks, j1) E^{(6)} . \qquad (23)$$

Substituting (16) back into (15a) gives:

$$z = \{E^{(1)} + E^{(2)} . F\} . x \quad . \qquad (24)$$

Without fuel substitution, the effect of the exogenous shock x on z would have been given by $E^{(1)}$. The effect of fuel substitution is thus given by the term $[E^{(2)} . F]$. Clearly, from (18) – (23), if $\varepsilon^j_i = 1$ and $\eta^j_{i,k} = 0$ for all i, j then F = 0, and (24) reverts back to standard ORANI result. Note that equation (24) applies to all industries irrespective of whether there is significant fuel substitution within that industry or not. Let j* denote an industry within which there is significant fuel substitution and/or non-unitary output elasticity of fuel demand. The jth scalar equation from (24) is:

$$z_j = \{E_j^{(1)} + \sum_i E_{ji}^{(2)} F_i\} x; \quad \text{all } j\text{'s} \quad . \qquad (25)$$

The second term in the bracket represents the effects of the exogenous shocks on input of fuel i in all industries. Relative to the standard ORANI result, these effects can be considered to be equivalent to some form of 'technological change' in the sense that the activity level in industry j can be increased or reduced via interfuel substitution. Important in determining the sign of the net interfuel substitution term will be the intensities with which the different fuels are used by j, and the change induced by the exogenous shock in their relative prices. These considerations apply to all industries, not just those with significant fuel substitution. Moreover, equation (24) applies to all other endogenous variables, not just industry activity levels. Thus let:

$$y = E^x . x + E^b b_8 \quad , \qquad (26)$$

where E^x, E^b are standard ORANI industry matrices of the endogenous variables y with respect to the x- and b_8- shocks respectively. Using (16), we can in general write:

$$y = \{E^x + E^b F\}x = G.x \quad . \qquad (27)$$

In calculating the E elasticity matrices, we need to set the exogenous shocks x and b_8 initially to 1.0. The actual size of the x-shocks can then be applied to the final equation (27) to calculate the total effect on y.

on the GEMPACK II computing package, as well as the recent refinement of ORANI long-run closures (Horridge, 1985), should help fill these needs.

Finally, there is the issue of an up-to-date and more comprehensive energy data base. With large fluctuations in energy prices and in growth rates of energy demands during the last decade, there is a continuing urgent need for up-to-date data for use in current policy simulations. So far as ORANI is concerned, the data base should be detailed enough to allow the 'oil, gas, and brown coal' industry to be disaggregated into oil, gas and brown coal separately.

This paper has demonstrated the feasibility of using an extended version of the ORANI model, ORANI-FUEL, to analyse energy policy issues. A number of areas for further development and improvement have been identified above. While policy analysis with ORANI-FUEL should be cautious pending the implementation of these enhancements, it should not be postponed until they are all completed. The relevant question to ask is: 'does the existing framework capture important elements of the energy market which at present cannot be modelled by alternative means?' This paper was written in the belief that the answer quite clearly is 'yes'.

to a sales tax on petroleum products to recover the crude oil excise revenue loss would be greater if the scope for interfuel substitution were less extensive. In general, one cannot calculate accurately the effects on tax revenue, or on social welfare, arising from changes to the structure of energy taxation, without a detailed knowledge of the different magnitudes of demand elasticities for different fuels by different users. In principle (Ramsey, 1927) it is clear that an optimal energy tax structure needs to take precisely these magnitudes into consideration. ORANI-FUEL, thus, is a useful vehicle for taking that principle on board, provided more research is devoted towards:

a) refining estimates of the elasticities of interfuel substitution,

and

b) further extending the model to allow more industries (not just those listed in Table 1) to engage in interfuel substitution.

The overall magnitude of the demand for fuels as a whole is conditional on the degree of substitutability or complementarity between energy and non-energy inputs. So, while the results fron interfuel substitution studies are important, one should not forget the still outstanding issue of interfactor (energy/labour/capital/non-energy materials) substitution. The theoretical framework for incorporating interfactor substitution into the standard ORANI system has been developed in Truong et al. (1985). What is still required is powerful yet simple-to-use computing software to implement this structure. Also, more thought needs to be given to the appropriate (long-run) environment within which interfactor substitution should be modelled. Work currently in progress at the Impact Centre

3. THE EXPERIMENT

The c.i.f. foreign currency import price of crude oil[8] $p^{m}_{(i2)}$ (where i = 17, see DPSV Table 23.2, p. 137) is shocked by -10%. The export price (f.o.b.) of crude oil $p^{e}_{(i1)}$ is also shocked by the same percentage (using the shift term $f^{e}_{(i1)}$, i = 17, in DPSV equation (15.2) to preserve import-export pricing parity. We want to impose the assumption that imported crude does not increase its share in the domestic market.[9] This can be achieved firstly by setting the domestic-import elasticity of substitution for crude to a high value of $\sigma^{(1)}_{ij} = 50$ (for i = 17, all j's).[10] Secondly, we need also to set:

$$p^{(o)}_{(i1)} = p^{(o)}_{(i2)}, \qquad \text{for } i = 17 \quad . \qquad (28)$$

From (27), we can write:

$$p^{(o)}_{(i1)} = G^{x'}_{1} . x' + G^{15}_{1} f_{15} \quad ; \qquad (29a)$$

and

$$p^{(o)}_{(i2)} = G^{x'}_{2} . x' + G^{15}_{2} . f_{15} \quad ; \qquad (29b)$$

where x' is the usual exogenous shock vector, but excludes f_{15}, a shock to the 'other costs' ticket price variable in industry 15 through the shift term $f^{(1)}_{g+2,\,15}$.

8. By 'crude oil' we really mean 'oil, gas and brown coal' with the existing ORANI 77-78 (typicalized agriculture) data base (see Blampied, 1985)

9. See footnote 7. Also, this implies the existing crude allocation scheme (Department of Resources and Energy, 1984) is preserved.

10. This is standard in the 1977-78 ORANI parameter file (see Blampied, 1985).

Combining (28) and (29), we have:

$$\cdot f_{15} = (G_1^{15} - G_2^{15})^{-1} (G_2^{x'} - G_1^{x'}).\ x' \qquad (30)$$

Because commodity 17 stands for 'crude oil + gas + brown coal', a shock to the price of commodity 17 affects not only the basic price of crude oil but also those of gas and brown coal. To prevent this from happening, a long-term solution is to disaggregate industry 15 (commodity 17) into crude oil, gas, and brown coal, separately. A short-term solution, which is adopted here, is to shock the 'other costs' ticket variables in those industries which use gas and brown coal as inputs, to 'compensate' for the unintended effect of the rise in the price of the (composite) commodity 17.

Let $H^{(1)}_{(11)j}$ be the share of the purchasers' value of input of domestic commodity 17 in the total costs of industry j (which uses gas and brown coal but not crude oil as an input)[11] and let $H^{(1)}_{g+2,j}$ be the share of 'other costs' tickets in the total cost of industry j. To compensate for the (unintended) shock to the basic price of commodity 17 in industry j, equations (18.2) and (22.7) of DPSV say that we must have:

$$p^{(1)}_{(17,1)j} \quad H^{(1)}_{(17,1)j} = - f^{(1)}_{g+2,j} \quad H^{(1)}_{g+2,j} \qquad (31)$$

for j = {84, 85}, the two main industries which are 'inadvertently' affected by the 'crude oil' price shock.

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11. These industries include: electricity generation (j=84), which uses 13.5 per cent of total commodity 17 input; gas production and distribution (j=85), which uses 7.4 per cent of commodity 17 input, and others (including industry 15 itself), which use 8.4 per cent of commodity 17 input. The rest (68.7 per cent of commodity 17 input) is used in industry 56 (petroleum refining). This last industry is assumed to use mainly crude oil as an input.

5. CONCLUDING REMARKS AND PERSPECTIVE FOR FURTHER WORK

As Borges and Goulder (1984, p. 319) remarked: "The nature of the energy problems strongly invites methodologies based on a general equilibrium approach. The interactions between supply and demand, both within the energy markets as well as between the energy sector and the economy as a whole, are far too important to be neglected." In this paper we have focused attention on one specific aspect of the overall web of interactions, namely, the issue of interfuel substitution.

Interfuel substitution affects the demand for individual fuels. Thus, following a fall in the price of petroleum fuels induced by a 10 per cent drop in the world price of crude oil, demand for petroleum products increased by 0.87 per cent, of which 0.13 percentage points is due to interfuel substitution alone (see Table 2). Under the assumption of import-parity pricing of domestic crude oil, the demand for domestic and imported crude each increases proportionately with the increase in the demand for petroleum products; that is, by 0.87 per cent, of which 0.19 percentage points is due to interfuel substitution. Magnitudes of this order could have important implications for policy issues.

Consider, for example, the issue of energy taxation. Suppose (as above) that a reduction in the world price of crude oil also implied a reduction in domestic crude oil excise (import-parity pricing). The reduction in taxation revenue (due to the world price drop) would have been greater had the demand for domestic crude not risen due to increased interfuel substitution. On the other hand, the effectiveness of a switch

2 and 3 that for certain variables (e.g. the aggregate import of crude oil, the activity levels of fuel producing industries), the ORANI-FUEL substitution effects are quite significant. In most other cases, however, the income effect is the predominant one, and hence, standard ORANI results would have been quite sufficient to represent the total effects.

Some uncertainty about the appropriate values of the price elasticities reflecting interfuel substitution is inevitable. High, low and mid-range estimates are offered in Appendix B. A comparison of ORANI-FUEL results for the high, low and mid-range cases (Table 5) shows that, within the fuels sector, ORANI-FUEL results are quite sensitive to the substitution paramenters $\eta^{j}_{i,k}$ chosen.[13] This implies that one should exercise some care when choosing the values of $\eta^{j}_{i,k}$, especially for simulations which focus primarily on interfuel substitution issues. The values of $\eta^{j}_{i,k}$, however, should not have too great an effect on the rest of the ORANI results, where the 'income effects' of the energy price changes dominate.

Finally, we note that with large energy price changes, ORANI-FUEL results obtained (as here) by a one-step Johansen computation would tend to be an underestimate of the 'true' substitution results. This is because with large price changes, fuel shares will also move with the substitution direction. In a multi-step Johansen computation (or other full non-linear solution of the model), larger interfuel substitution effects could be expected.

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13. We have not investigated the sensitivity of ORANI-FUEL results with respect to output elasticity of fuel demand ε^{j}_{i}, as this is not the main focus of our analysis. See footnote 5.

Using (12), we can rewrite (31):

$$f^{(1)}_{g+2,j} = F7 \cdot p^{(o)}_{(17,1)} + F8 \cdot \xi^{(3)} + F9 \{\sum_{r} M^{(17,1)j1}_{(r1)} \, p^{(o)}_{(r1)}\}; \quad (32)$$

where:

$$F7_{j} = - \{H^{(1)}_{(i1)j} \;/\; H^{(1)}_{g+2,j}\} \cdot \zeta_{1} \,(i1, j1), \quad i=17 \;;$$

$$F8_{j} = - \{H^{(1)}_{(i1)j} \;/\; H^{(1)}_{g+2,j}\} \cdot \zeta_{2} \,(i1, j1), \quad i=17 \;;$$

and

$$F9_{j} = - \{H^{(1)}_{(i1)j} \;/\; H^{(1)}_{g+2,j}\} \cdot \zeta_{3} \,(i1, j1), \quad i=17.$$

Also, using (15b, c), we can write[12]

$$p^{(o)}_{(i1)} = E^{(3)x''}_{(i1)} \cdot x'' + \sum_{j} E^{(3)f_j}_{(i1)} \cdot f_{j} \;; \quad (33)$$

$$\xi^{(3)} = E^{(5)x''} . x'' + \sum_{j} E^{(5)f_j} \cdot f_{j} \;; \quad (34)$$

where the exogenous vector x in (15b, c) is now split into two components: x'' and f_j, with f_j denoting the shocks to $f^{(1)}_{g+2,j}$, j=84, 85.

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12. Since we are not 'compensating' industries j = {84, 85} for the fuel-substitution effect, we ignore the term b_8 in (15b, c). This is in contrast to the situation in equations (29) and (30), where we want to maintain the existing crude oil allocation scheme, even after taking into account the interfuel substitution effect.

Substituting (33) and (34) into (32), we have:

$$f_j = H_j x'' \quad , \tag{35}$$

where:

$$H_j = (I - H1)^{-1} . H2_j \quad ; \tag{36}$$

and where:

$$H1_{jj'} = F7_j E^{(3)f}_{(i1)j'} + F8_j E^{(5)f}{}_{j'}$$

$$+ F9_j \{\Sigma_r M^{(i1)j1}_{(r1)} E^{(3)f}_{(r1)j'}\} , \quad i=17; \tag{37}$$

and

$$H2_j = F7_j E^{(3)x''}_{(i1)} + F8_j E^{(5)x''}$$

$$+ F9 \{\Sigma_r M^{(i1)j1}_{(r1)} E^{(3)x''}_{(r1)}\} , \quad i=17. \tag{38}$$

Equations (30) and (35) should be solved simultaneously. This is because x' in equation (30) contains $f^{(1)}_{g+2,84}$, $f^{(1)}_{g+2,85}$, while x" in equation (35) contains $f^{(1)}_{g+2,15}$.

Let $f = \{f_1, f_2, f_3\}$ now stand for the shocks to $f^{(1)}_{g+2,j}$ in industries $j = \{15, 84, 85\}$. Equations (30) and (35) can be combined into:

$$\alpha f = \beta \quad ; \tag{39}$$

Table 5 (continued)

Industry	ORANI-FUEL RESULT AS A PERCENTAGE OF STANDARD ORANI RESULT		
	Low[a]	Mid-range[b]	High[a]
73 ELECTRONIC EQUIPMENT	0.33%	0.56%	0.77%
74 HOUSEHOLD APPLIANCES	0.57%	0.63%	0.67%
75 OTHER ELECTRICAL GOODS	0.01%	-0.03%	-0.06%
76 AGRICULTURAL MACHINERY	0.31%	0.48%	0.64%
77 CONSTRUCTION MACHINERY	0.09%	0.17%	0.23%
78 OTH. MACHINERY & PLANT	1.28%	3.93%	6.49%
79 LEATHER PRODUCTS	0.33%	0.60%	0.85%
80 RUBBER PRODUCTS	0.35%	0.67%	0.97%
81 PLASTIC PRODUCTS, ETC.	0.34%	0.65%	0.94%
82 SIGNS; WRITING GEAR	0.33%	0.64%	0.95%
83 OTHER MANUFACTURING	0.32%	0.57%	0.80%
84 ELECTRICITY	-16.55%	-36.16%	-54.86%
85 GAS	0.05%	1.51%	2.77%
86 WATER; SEWERS & DRAINS	0.42%	1.04%	1.63%
87 RESIDENTIAL BUILDING	0.00%	0.00%	0.00%
88 OTHER CONSTRUCTION	0.64%	1.95%	3.04%
89 WHOLESALE TRADE	0.38%	0.99%	1.58%
90 RETAIL TRADE	0.99%	2.03%	2.99%
91 MECHANICAL REPAIRS	0.52%	1.16%	1.78%
92 OTHER REPAIRS	0.32%	0.70%	1.07%
93 ROAD TRANSPORT	0.38%	0.82%	1.25%
94 RAIL & OTHER TRANSPORT	0.49%	0.97%	1.44%
95 WATER TRANSPORT	0.61%	1.60%	2.57%
96 AIR TRANSPORT	0.03%	-0.01%	-0.06%
97 COMMUNICATION	0.26%	0.62%	0.96%
98 BANKING	0.36%	1.11%	1.84%
99 NON BANK FINANCE	-0.38%	-0.71%	-1.01%
100 INVESTMENT & SERVICES	0.38%	1.08%	1.75%
101 INSURANCE & SERVICES	0.36%	0.81%	1.23%
102 OTH. BUSINESS SERVICES	0.32%	0.71%	1.09%
103 OWNERSHIP OF DWELLINGS	0.00%	0.00%	0.00%
104 PUBLIC ADMINISTRATION	0.41%	0.96%	1.49%
105 DEFENCE	0.00%	0.00%	0.00%
106 HEALTH	-0.45%	-1.01%	-1.55%
107 EDUCATION, LIBRARIES	0.54%	0.94%	1.32%
108 WELFARE AND RELIGIOUS	0.29%	0.71%	1.11%
109 ENTERTAINMENT, LEISURE	0.27%	0.83%	1.37%
110 RESTAURANTS, HOTELS	2.12%	4.71%	7.12%
111 PERSONAL SERVICES	2.55%	5.57%	8.39%
112 NON-COMPETING IMPORTS	0.34%	0.63%	0.89%

(a) For a definition of these cases, see Appendix B.

(b) See Table 2, last column.

Table 5 (continued)

Industry	Low[a]	Mid-range[b]	High[a]
	ORANI-FUEL RESULT AS A PERCENTAGE OF STANDARD ORANI RESULT		
33 WORSTED & WOOLLEN YARN	0.35%	0.64%	0.91%
34 TEXTILE FINISHING	0.33%	0.61%	0.86%
35 TEXTILE FLOOR OVERLAYS	0.53%	1.14%	1.74%
36 OTHER TEXTILE PRODUCTS	0.38%	0.76%	1.13%
37 KNITTING MILLS	0.34%	0.61%	0.85%
38 CLOTHING	0.33%	0.57%	0.80%
39 FOOTWEAR	0.33%	0.59%	0.83%
40 SAWMILL PRODUCTS	0.31%	0.56%	0.79%
41 VENEERS AND BOARDS	0.35%	0.71%	1.06%
42 JOINERY & WOOD NEC	0.15%	0.09%	0.02%
43 FURNITURE & MATRESSES	0.40%	0.84%	1.24%
44 PULP PAPER PAPERBOARD	0.39%	0.81%	1.21%
45 BAGS, FIBREBOARD BOXES	0.35%	0.72%	1.08%
46 PAPER PRODUCTS NEC	0.27%	0.50%	0.72%
47 NEWSPAPERS AND BOOKS	0.33%	0.64%	0.94%
48 COMMERCIAL PRINTING	0.32%	0.73%	1.12%
49 CHEMICAL FERTILISERS	0.30%	0.54%	0.76%
50 OTHER BASIC CHEMICALS	0.30%	0.58%	0.84%
51 PAINTS, VARNISHES	0.37%	0.70%	1.01%
52 PHARMACEUTICAL GOODS	0.32%	0.58%	0.81%
53 SOAP AND DETERGENTS	0.31%	0.57%	0.82%
54 COSMETICS & TOILETRIES	0.33%	0.59%	0.83%
55 OTHER CHEMICAL GOODS	0.52%	1.35%	2.15%
56 PETROL & COAL PRODUCTS	4.71%	16.89%	28.92%
57 GLASS & GLASS PRODUCTS	0.33%	0.62%	0.90%
58 CLAY PRODS; REFRACT'S	0.28%	0.49%	0.69%
59 CEMENT	-0.17%	-1.43%	-2.92%
60 READY MIXED CONCRETE	0.69%	2.07%	3.22%
61 CONCRETE PRODUCTS	0.76%	2.25%	3.47%
62 NON-METALLIC ORE GOODS	0.24%	0.32%	0.39%
63 BASIC IRON AND STEEL	0.36%	0.71%	1.04%
64 OTHER BASIC METALS	0.33%	0.61%	0.88%
65 STRUCTURAL METAL GOODS	0.28%	0.21%	0.12%
66 SHEET METAL PRODUCTS	0.67%	1.81%	2.96%
67 OTHER METAL PRODUCTS	0.37%	0.70%	1.01%
68 MOTOR VEHICLES & PARTS	0.39%	0.70%	0.99%
69 SHIPS AND BOATS	-0.33%	-1.44%	-2.51%
70 LOCOMOTIVES	0.41%	0.81%	1.18%
71 AIRCRAFT	-0.19%	-0.55%	-0.90%
72 SCIENTIFIC EQUIPMENT	0.45%	0.85%	1.23%

(a) For a definition of these cases, see Appendix B.

(b) See Table 2, last column.

where:

$$\alpha_{11} = \alpha_{22} = \alpha_{33} = 1 \tag{40a}$$

and from equation (30):

$$\alpha_{12} = (G_1^{15} - G_2^{15})^{-1} (G_1^{84} - G_2^{84}) \quad ; \tag{40b}$$

$$\alpha_{13} = (G_1^{15} - G_2^{15})^{-1} (G_1^{85} - G_2^{85}) \quad ; \tag{40c}$$

with G_s^j denoting the elasticity of $P_{(is)}^{(o)}$, i=17, with respect to $F_{g+2,j}^{(1)}$ (taking into account the fuel substitution effect - - see equation (29)).

Also, from equation (35):

$$\alpha_{21} = - H_{84}^{15} \quad ; \quad \alpha_{23} = - H_{84}^{85} \quad ; \tag{40d}$$

and

$$\alpha_{31} = - H_{25}^{15} \quad ; \quad \alpha_{32} = - H_{85}^{84} \quad ; \tag{40e}$$

where $H_j^{j'}$ stands for the elasticity (defined by equation (35)) of $F_{g+2,j}^{(1)}$ with respect to $F_{g+2,j'}^{(1)}$.

Finally, equations (30) and (35) also give:

$$\beta_1 = (G_1^{15} - G_2^{15})^{-1} (G_2^x - G_1^x) \, . \, x \quad ; \tag{40f}$$

$$\beta_2 = H^x_{84} \cdot x \quad ; \qquad (40g)$$

and

$$\beta_3 = H^x_{85} \cdot x \quad ; \qquad (40h)$$

where x now stands for the usual exogenous shock vector excluding f.

The solution to (39) is then simply:

$$f = \alpha^{-1} \beta \quad . \qquad (41)$$

We want to investigate the extent of substitution between the following fuels: i = {16, 17, 58, 86, 87} standing for {black coal, 'crude oil', refined fuels, electricity and gas} which arise from changes in relative fuel prices $p^{(1)}_{(is)j}$ following an exogenous drop in the world price of crude oil (reflected in the model by a drop in the price of imported crude). The industries under focus in the experiment are j = {2, 12, 18, 50, 58, 63, 64, 88, 89, 90}. The extent of fuel usage in these industries is given in Table 1. The interfuel substitution parameters for these industries are given in Appendix B. As in standard ORANI, the interfuel substitution parameters for other industries are set to zero.

Table 5 SENSITIVITY OF ORANI-FUEL RESULTS TO CHANGES IN PRICE ELASTICITIES OF INTERFUEL SUBSTITUTION

Industry	ORANI-FUEL RESULT AS A PERCENTAGE OF STANDARD ORANI RESULT		
	Low[a]	Mid-range[b]	High[a]
1 PASTORAL ZONE	0.32%	0.56%	0.79%
2 WHEAT-SHEEP ZONE	0.28%	0.48%	0.67%
3 HIGH RAINFALL ZONE	0.31%	0.55%	0.77%
4 NORTHERN BEEF	0.33%	0.58%	0.82%
5 MILK CATTLE AND PIGS	0.33%	0.59%	0.83%
6 O.FARM(SUGAR,FRUIT&NUT)	0.30%	0.52%	0.73%
7 O.FARM(VEG,COT,SEEDS,ETC)	0.30%	0.53%	0.74%
8 POULTRY	0.32%	0.58%	0.81%
9 AGRICULTURAL SERVICES	0.30%	0.52%	0.73%
10 FORESTRY AND LOGGING	0.66%	1.46%	2.16%
11 FISHING AND HUNTING	0.27%	0.46%	0.64%
12 FERROUS METAL ORES	0.37%	0.68%	0.97%
13 NON-FERROUS METAL ORES	0.35%	0.64%	0.92%
14 BLACK COAL	0.25%	0.45%	0.64%
15 OIL, GAS & BROWN COAL	0.05%	0.12%	0.18%
16 OTHER MINERALS	0.52%	1.35%	2.16%
17 SERVICES TO MINING	0.06%	0.12%	0.17%
18 MEAT PRODUCTS	0.32%	0.58%	0.81%
19 MILK PRODUCTS	0.32%	0.61%	0.89%
20 FRUIT AND VEGETABLES	0.22%	0.40%	0.58%
21 MARGARINE, OILS & FATS	0.33%	0.63%	0.91%
22 FLOUR & CEREAL PRODS.	0.33%	0.61%	0.87%
23 BREAD CAKES & BISCUITS	0.28%	0.58%	0.85%
24 CONFECTIONERY & COCOA	0.35%	0.62%	0.87%
25 OTHER FOOD PRODUCTS	0.30%	0.52%	0.73%
26 SOFT DRINKS & CORDIALS	0.34%	0.86%	1.37%
27 BEER AND MALT	-1.55%	-3.32%	-5.03%
28 OTHER ALCOHOLIC DRINKS	0.31%	0.54%	0.76%
29 TOBACCO PRODUCTS	0.25%	0.45%	0.63%
30 COTTON GINNING ETC.	0.31%	0.53%	0.75%
31 MAN-MADE FIBRES, YARNS	0.35%	0.63%	0.90%
32 COTTON YARNS & FABRICS	0.37%	0.68%	0.97%

(a) For a definition of these cases, see Appendix B.

(b) See Table 2, last column.

Table 4 ADDITIONAL CHANGES IN THE DEMANDS BY SELECTED INDUSTRIES FOR DIFFERENT FUELS INDUCED BY THE FALL IN THE PRICE OF IMPORTED CRUDE OIL

Mid-range Elasticities (a)				
2 WHEAT-SHEEP ZONE	0.00	0.19	-0.19	0.00
12 FERROUS METAL ORES	0.00	0.43	-0.43	0.00
18 MEAT PRODUCTS	-1.00	0.75	-0.34	0.17
50 OTHER BASIC CHEMICALS	-0.57	0.81	-0.34	0.13
58 CLAY PRODS; REFRACT'S	-1.01	1.09	-0.30	0.78
63 BASIC IRON AND STEEL	0.00	0.53	-0.50	-0.21
64 OTHER BASIC METALS	-0.52	0.38	-0.17	0.04
88 OTHER CONSTRUCTION	-0.45	1.10	-0.32	-0.22
89 WHOLESALE TRADE	-0.39	0.84	-0.25	-0.09
90 RETAIL TRADE	-0.39	0.85	-0.25	-0.09
Low Elasticities (a)				
2 WHEAT-SHEEP ZONE	0.00	0.00	0.00	0.00
12 FERROUS METAL ORES	0.00	0.00	0.00	0.00
18 MEAT PRODUCTS	-0.67	0.29	-0.16	0.11
50 OTHER BASIC CHEMICALS	-0.22	0.31	-0.14	0.08
58 CLAY PRODS; REFRACT'S	-0.70	0.70	-0.19	0.70
63 BASIC IRON AND STEEL	0.00	0.18	-0.29	-0.18
64 OTHER BASIC METALS	-0.23	0.08	-0.05	-0.08
88 OTHER CONSTRUCTION	-0.22	0.27	-0.16	-0.16
89 WHOLESALE TRADE	-0.19	0.21	-0.13	-0.09
90 RETAIL TRADE	-0.20	0.21	-0.13	-0.09
High Elasticities (a)				
2 WHEAT-SHEEP ZONE	0.00	0.37	-0.37	0.00
12 FERROUS METAL ORES	0.00	0.84	-0.84	0.00
18 MEAT PRODUCTS	-1.34	1.19	-0.50	0.23
50 OTHER BASIC CHEMICALS	-0.93	1.30	-0.53	0.18
58 CLAY PRODS; REFRACT'S	-1.32	1.48	-0.44	0.87
63 BASIC IRON AND STEEL	0.00	0.89	-0.70	-0.25
64 OTHER BASIC METALS	-0.81	0.66	-0.27	0.15
88 OTHER CONSTRUCTION	-0.68	1.93	-0.47	-0.29
89 WHOLESALE TRADE	-0.59	1.47	-0.37	-0.09
90 RETAIL TRADE	-0.59	1.49	-0.37	-0.09

* The figures shown in this Table are the values of $a_{ij}^{(1)}$ for fuel i, industry j (see text, equation (5)). These values show the additional percentage increase ($a_{ij}^{(1)}>0$), or decrease ($a_{ij}^{(1)}<0$) in the demand for fuel i, as induced by interfuel substitution following the 10 per cent fall in the price of imported crude oil.

(a) These refer to settings of the interfuel substitution parameters -- see Appendix B.

Table 1

ENERGY USAGE BY MAJOR ENERGY-USING INDUSTRIES

INDUSTRY DESCRIPTION	ENERGY USAGE ($M) (i=16) BLACK COAL	(i=17) CRUDE OIL	(i=58) REFINED FUELS	(i=86) ELEC	(i=87) GAS
2 Wheat-Sheep	0.0	0.0	44.1	10.7	0.0
12 Iron Ores	0.0	0.0	10.5	24.8	0.0
18 Meat Products	3.0	0.1	22.1	44.4	2.2
50 Other Basic Chem. Products	1.2	0.4	36.3	21.4	4.4
58 Clay Products	2.5	1.6	11.6	12.5	2.5
63 Basic Iron & Steel	164.7	0.2	31.4	71.6	3.2
64 Other Basic Metals	15.0	10.5	25.5	51.6	2.9
88 Non-Residential Buildings	0.2	0.2	98.0	15.8	3.2
89 Wholesale Trade	1.9	0.2	67.7	30.3	7.3
80 Retail Trade	2.7	0.5	43.6	53.4	10.8
TOTAL ($M)	191.2	13.7	390.8	336.5	36.6
TOTAL (%)	36.8	2.0	25.3	15.3	22.6

SOURCE: ORANI 77-78 data base (Blampied, 1985)

4. THE RESULTS

Firstly we want to check that we have correctly implemented the theory contained in the previous two sections.

We start by verifying that the relative market shares of imported and domestic crude oil have not changed. Imported crude increases its volume by 0.87 per cent (see Table 3). Since all imported crude (99.9 per cent) goes into petroleum refining, the activity level of this industry ought to show an increase of 0.87 per cent: it does so (see Table 2). To check that domestic crude also increased by this amount, let S_j be the share of the output of industry 15 (crude oil + gas + brown coal) which goes into industry j. Then we must have:

percentage change in activity in industry 15 =

$$z_{15} = \sum_j S_j z_j \quad . \qquad (42)$$

If domestic crude input into industry 56 were to have increased by z_{56} = 0.87 per cent and domestic 'gas + brown coal' inputs into industries 84, 85 were to have increased by z_{84} = 0.06 per cent and z_{85} = 0.23 per cent respectively (see Table 2), then, using the values of S_j given in footnote 11 for j = 56, 84 and 85, but ignoring the remainder, equation (42) gives:

$$z_{15} \doteq 0.687 \times 0.87 + 0.135 \times 0.06 + 0.074 \times 0.23 = 0.623 \quad .$$

This is indeed very close to the value of z_{15} given in Table 2 (namely, 0.6238).

Table 3 PERCENTAGE CHANGES IN SELECTED ORANI VARIABLES CAUSED BY A 10 PER CENT REDUCTION IN THE PRICE OF IMPORTED CRUDE OIL - INTERFUEL SUBSTITUTION PARAMETERS SET TO THEIR MID-RANGE VALUES

Variable	Total Effects	=	Standard ORANI (a)	+	ORANI-FUEL (b)	(b) ÷ (a) x 100
basic prices of domestic fuel commodities:						
16 BLACK COAL	0.0884		0.0893		-0.0009	-1.01%
17 OIL, GAS & BROWN COAL	-10.0000		-10.0049		0.0049	-0.05%
58 PETROL & COAL PRODUCTS	-6.0565		-6.0679		0.0114	-0.19%
86 ELECTRICITY	-0.3728		-0.3313		-0.0415	12.51%
87 GAS	-1.0289		-1.0304		0.0015	-0.15%
basic prices of imported fuel commodities:						
16 BLACK COAL	0.0000		0.0000		0.0000	0.00%
17 OIL, GAS & BROWN COAL	-10.0000		-10.0000		0.0000	0.00%
58 PETROL & COAL PRODUCTS	0.0000		0.0000		0.0000	0.00%
86 ELECTRICITY	0.0000		0.0000		0.0000	0.00%
87 GAS	0.0000		0.0000		0.0000	0.00%
ORANI index of consumer prices	-0.4797		-0.4767		-0.0030	0.62%
Aggregate import of crude	0.8691		0.6797		0.1893	27.86%

Next, we want to estimate the effect of interfuel substitution. This is indicated by the term $a_{ij}^{(1)}$ in equation (5). If $a_{ij}^{(1)} > 0$ (< 0), then the given shock (namely, a fall in the price of imported crude oil) will additionally (i.e. relative to standard ORANI) increase (reduce) industry j's demand for fuel i by $|a_{ij}^{(1)}|$ per cent. Due to cheaper oil prices, industries switch away from black coal and electricity (and to some extent also natural gas) into petroleum fuels. Relative to standard ORANI, this effect appears as if it were due to 'technical progress' with respect to the use of black coal and electricity, and 'technical progress' with respect to the use of petroleum fuels. The first and third columns of Table 4, thus, are all negative, while the second column is all positive. The fourth column shows a mixture of positive and negative $a_{ij}^{(1)}$'s. This is because a substitution away from gas into petroleum fuel in some cases is counter-balanced by a substitution into gas from black coal and/or electricity.

'Technical progress' (or regress) as induced by interfuel substitution is not 'Hicks-neutral' across all industries as indicated by the different magnitudes of $a_{ij}^{(1)}$ across industries j's (Table 4). This is explained by the fact that interfuel substitution elasticities $\eta_{i,k}^{j}$, fuel shares $S_{(is)j}^{(1)}$, and fuel price changes $p_{(is)j}^{(1)}$, vary across industries. (Note, however, that the imposed assumption of constant fuel shares across the domestic/imported sources has implied that the interfuel substitution effect is Hicks-neutral across the sources, i.e. $a_{(is)j}^{(1)} = 0$).

If we regard standard ORANI results as representing the 'income effect' of the crude oil price change, and ORANI-FUEL results as representing the 'substitution effect', then it is clear from Tables

Table 2 PERCENTAGE CHANGES IN INDUSTRY OUTPUT LEVELS CAUSED BY A 10 PER CENT REDUCTION IN THE PRICE OF IMPORTED CRUDE OIL - INTERFUEL SUBSTITUTION PARAMETERS SET TO THEIR MID-RANGE VALUES

	Industry	Total Effects	=	Standard ORANI (a)	+	ORANI-FUEL (b)	Relativity (b) ÷ (a) x 100
1	PASTORAL ZONE	0.3553		0.3533		0.0020	0.56%
2	WHEAT-SHEEP ZONE	0.3311		0.3296		0.0016	0.48%
3	HIGH RAINFALL ZONE	0.4538		0.4513		0.0025	0.55%
4	NORTHERN BEEF	0.6997		0.6957		0.0041	0.58%
5	MILK CATTLE AND PIGS	0.2394		0.2380		0.0014	0.59%
6	O.FARM(SUGAR,FRUIT&NUT)	0.7063		0.7026		0.0037	0.52%
7	O.FARM(VEG,COT,SEEDS,ETC)	0.2367		0.2355		0.0012	0.53%
8	POULTRY	0.3531		0.3510		0.0020	0.58%
9	AGRICULTURAL SERVICES	0.3241		0.3224		0.0017	0.52%
10	FORESTRY AND LOGGING	-0.1250		-0.1232		-0.0018	1.46%
11	FISHING AND HUNTING	0.1565		0.1557		0.0007	0.46%
12	FERROUS METAL ORES	0.3878		0.3852		0.0026	0.68%
13	NON-FERROUS METAL ORES	0.5962		0.5924		0.0038	0.64%
14	BLACK COAL	0.7616		0.7582		0.0034	0.45%
15	OIL, GAS & BROWN COAL	0.6238		0.6231		0.0007	0.12%
16	OTHER MINERALS	0.1573		0.1552		0.0021	1.35%
17	SERVICES TO MINING	1.3141		1.3125		0.0016	0.12%
18	MEAT PRODUCTS	0.6655		0.6617		0.0038	0.58%
19	MILK PRODUCTS	0.0179		0.0177		0.0001	0.61%
20	FRUIT AND VEGETABLES	0.0267		0.0265		0.0001	0.40%
21	MARGARINE, OILS & FATS	0.1500		0.1491		0.0009	0.63%
22	FLOUR & CEREAL PRODS.	0.1116		0.1109		0.0007	0.61%
23	BREAD CAKES & BISCUITS	0.0154		0.0153		0.0001	0.58%
24	CONFECTIONERY & COCOA	0.0405		0.0402		0.0002	0.62%
25	OTHER FOOD PRODUCTS	1.2255		1.2191		0.0064	0.52%
26	SOFT DRINKS & CORDIALS	0.0315		0.0312		0.0003	0.86%
27	BEER AND MALT	-0.0033		-0.0034		0.0001	-3.32%
28	OTHER ALCOHOLIC DRINKS	0.1256		0.1249		0.0007	0.54%
29	TOBACCO PRODUCTS	0.0292		0.0291		0.0001	0.45%
30	COTTON GINNING ETC.	0.6208		0.6175		0.0033	0.53%
31	MAN-MADE FIBRES, YARNS	0.7887		0.7838		0.0049	0.63%
32	COTTON YARNS & FABRICS	0.5614		0.5576		0.0038	0.68%

Table 2 (continued)

Industry	Total Effects	= Standard ORANI (a)	+ ORANI-FUEL (b)	Relativity (b) ÷ (a) x 100
33 WORSTED & WOOLLEN YARN	0.1413	0.1404	0.0009	0.64%
34 TEXTILE FINISHING	0.1164	0.1157	0.0007	0.61%
35 TEXTILE FLOOR OVERLAYS	0.0493	0.0487	0.0006	1.14%
36 OTHER TEXTILE PRODUCTS	0.1683	0.1670	0.0013	0.76%
37 KNITTING MILLS	0.1147	0.1140	0.0007	0.61%
38 CLOTHING	0.1054	0.1048	0.0006	0.57%
39 FOOTWEAR	0.4873	0.4845	0.0029	0.59%
40 SAWMILL PRODUCTS	0.2124	0.2112	0.0012	0.56%
41 VENEERS AND BOARDS	0.0658	0.0653	0.0005	0.71%
42 JOINERY & WOOD NEC	0.0149	0.0149	0.0000	0.09%
43 FURNITURE & MATRESSES	-0.0306	-0.0303	-0.0003	0.84%
44 PULP PAPER PAPERBOARD	0.3273	0.3247	0.0026	0.81%
45 BAGS, FIBREBOARD BOXES	0.2013	0.1998	0.0014	0.72%
46 PAPER PRODUCTS NEC	0.1475	0.1468	0.0007	0.50%
47 NEWSPAPERS AND BOOKS	0.1579	0.1569	0.0010	0.64%
48 COMMERCIAL PRINTING	0.1109	0.1101	0.0008	0.73%
49 CHEMICAL FERTILISERS	0.3981	0.3960	0.0021	0.54%
50 OTHER BASIC CHEMICALS	0.4979	0.4950	0.0029	0.58%
51 PAINTS, VARNISHES	0.1445	0.1435	0.0010	0.70%
52 PHARMACEUTICAL GOODS	0.1496	0.1487	0.0009	0.58%
53 SOAP AND DETERGENTS	0.0596	0.0592	0.0003	0.57%
54 COSMETICS & TOILETRIES	0.0249	0.0248	0.0001	0.59%
55 OTHER CHEMICAL GOODS	0.2917	0.2879	0.0039	1.35%
56 PETROL & COAL PRODUCTS	0.8689	0.7434	0.1255	16.89%
57 GLASS & GLASS PRODUCTS	0.1646	0.1636	0.0010	0.62%
58 CLAY PRODS; REFRACT'S	0.1613	0.1605	0.0008	0.49%
59 CEMENT	0.0118	0.0120	-0.0002	-1.43%
60 READY MIXED CONCRETE	-0.0155	-0.0152	-0.0003	2.07%
61 CONCRETE PRODUCTS	-0.0150	-0.0147	-0.0003	2.25%
62 NON-METALLIC ORE GOODS	0.0492	0.0491	0.0002	0.32%
63 BASIC IRON AND STEEL	0.1741	0.1728	0.0012	0.71%
64 OTHER BASIC METALS	0.7986	0.7937	0.0049	0.61%
65 STRUCTURAL METAL GOODS	0.0355	0.0354	0.0001	0.21%
66 SHEET METAL PRODUCTS	0.0693	0.0681	0.0012	1.81%
67 OTHER METAL PRODUCTS	0.1916	0.1903	0.0013	0.70%
68 MOTOR VEHICLES & PARTS	0.4171	0.4142	0.0029	0.70%
69 SHIPS AND BOATS	-0.1113	-0.1130	0.0016	-1.44%
70 LOCOMOTIVES	0.1958	0.1942	0.0016	0.81%
71 AIRCRAFT	0.1817	0.1827	-0.0010	-0.55%
72 SCIENTIFIC EQUIPMENT	0.0183	0.0182	0.0002	0.85%

Table 2 (continued)

Industry	Total Effects	= Standard ORANI (a)	+ ORANI-FUEL (b)	Relativity (b) ÷ (a) x 100
73 ELECTRONIC EQUIPMENT	0.1296	0.1289	0.0007	0.56%
74 HOUSEHOLD APPLIANCES	0.0337	0.0335	0.0002	0.63%
75 OTHER ELECTRICAL GOODS	0.0618	0.0618	0.0000	-0.03%
76 AGRICULTURAL MACHINERY	1.9652	1.9558	0.0094	0.48%
77 CONSTRUCTION MACHINERY	0.2630	0.2625	0.0004	0.17%
78 OTH. MACHINERY & PLANT	0.0759	0.0730	0.0029	3.93%
79 LEATHER PRODUCTS	0.3155	0.3136	0.0019	0.60%
80 RUBBER PRODUCTS	0.2628	0.2611	0.0018	0.67%
81 PLASTIC PRODUCTS, ETC.	0.2624	0.2607	0.0017	0.65%
82 SIGNS; WRITING GEAR	0.1837	0.1825	0.0012	0.64%
83 OTHER MANUFACTURING	0.1666	0.1657	0.0009	0.57%
84 ELECTRICITY	0.0624	0.0978	-0.0354	-36.16%
85 GAS	0.2285	0.2251	0.0034	1.51%
86 WATER; SEWERS & DRAINS	0.0739	0.0731	0.0008	1.04%
87 RESIDENTIAL BUILDING	0.0000	0.0000	0.0000	0.00%
88 OTHER CONSTRUCTION	-0.0259	-0.0254	-0.0005	1.95%
89 WHOLESALE TRADE	0.2114	0.2093	0.0021	0.99%
90 RETAIL TRADE	-0.0171	-0.0167	-0.0003	2.03%
91 MECHANICAL REPAIRS	0.0371	0.0367	0.0004	1.16%
92 OTHER REPAIRS	0.0569	0.0565	0.0004	0.70%
93 ROAD TRANSPORT	0.1969	0.1953	0.0016	0.82%
94 RAIL & OTHER TRANSPORT	0.2548	0.2524	0.0024	0.97%
95 WATER TRANSPORT	0.2287	0.2251	0.0036	1.60%
96 AIR TRANSPORT	0.3657	0.3658	0.0000	-0.01%
97 COMMUNICATION	0.0621	0.0617	0.0004	0.62%
98 BANKING	0.0556	0.0550	0.0006	1.11%
99 NON BANK FINANCE	0.0741	0.0746	-0.0005	-0.71%
100 INVESTMENT & SERVICES	0.0215	0.0212	0.0002	1.08%
101 INSURANCE & SERVICES	0.0680	0.0674	0.0005	0.81%
102 OTH. BUSINESS SERVICES	0.0942	0.0936	0.0007	0.71%
103 OWNERSHIP OF DWELLINGS	0.0000	0.0000	0.0000	0.00%
104 PUBLIC ADMINISTRATION	0.0182	0.0181	0.0002	0.96%
105 DEFENCE	0.0000	0.0000	0.0000	0.00%
106 HEALTH	-0.0094	-0.0095	0.0001	-1.01%
107 EDUCATION, LIBRARIES	-0.0007	-0.0007	0.0000	0.94%
108 WELFARE AND RELIGIOUS	0.0218	0.0216	0.0002	0.71%
109 ENTERTAINMENT, LEISURE	0.0144	0.0143	0.0001	0.83%
110 RESTAURANTS, HOTELS	0.0121	0.0116	0.0005	4.71%
111 PERSONAL SERVICES	0.0067	0.0063	0.0004	5.57%
112 NON-COMPETING IMPORTS	-0.0005	-0.0005	0.0000	0.63%