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<tr>
<th><strong>Title</strong></th>
<th>A computable general equilibrium model of the Irish economy : technical appendix</th>
</tr>
</thead>
<tbody>
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CENTRE FOR ECONOMIC RESEARCH

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"A Computable General Equilibrium
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by
Kevin Denny, Aoife Hannan, Kevin O'Rourke

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A Computable General Equilibrium Model of the Irish Economy: Technical Appendix

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January, 1995

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Section 1. Introduction

This working paper provides a technical introduction to a computable general equilibrium (CGE) model of the Irish economy, developed at the UCD Economics Department. The paper is intended as a technical reference point for readers of forthcoming working papers which will apply the model to various policy issues. Section 2 presents the model's theoretical structure. Section 3 outlines how the model was calibrated to 1985 data. Section 4 gives the parameters (elasticities) that are used in the model and explains how these values were chosen.

Section 2. A general equilibrium model of the Irish economy

There are four components of a neoclassical general equilibrium model.\footnote{Production sectors are characterized by a production function; to each sector there corresponds an activity level, which is endogenously determined by the model. Commodities each have a price, which is determined by the model. Consumers are characterized by endowments and a utility function; their income and utility are endogenous. Finally, a model may also incorporate side constraints (e.g. a minimum real wage), to which there correspond 'rationing variables' which move so as to ensure that the constraints are satisfied.} Production sectors are characterized by a production function; to each sector there corresponds an activity level, which is endogenously determined by the model. Commodities each have a price, which is determined by the model. Consumers are characterized by endowments and a utility function; their income and utility are endogenous. Finally, a model may also incorporate side constraints (e.g. a minimum real wage), to which there correspond 'rationing variables' which move so as to ensure that the constraints are satisfied.
adopt this standard framework.² Production and utility functions are specified; the package then calculates cost, factor demand and commodity demand functions for all sectors and commodities. Equilibrium is defined by a set of prices, activity levels and incomes such that (i) no sector earns a positive profit; (ii) supply minus demand for each commodity is nonnegative; (iii) income from factor endowments is fully distributed.³ In addition, in an environment with taxes, all tax income must accrue to some agent (in this case, the government).

2.1. An overview of the model

Apart from its labour and capital market assumptions, the model is a standard neoclassical one, assuming perfect competition and constant returns to scale. All domestic producer goods are produced by sectors using other domestic and imported producer goods, as well as labour and capital, as inputs. Producer goods and imports are transformed into all consumer goods, which are then used to produce an aggregate consumption good. Producer goods can also be exported, or used to produce other aggregate goods (private and public investment, and government consumption).

The single consumer in the model is endowed with labour and capital, and receives transfers from the government and abroad. Consumption and savings trade off in the production

² Although by introducing side constraints appropriately a variety of non-standard features can be introduced into the model.

petrol, durables, transport equipment, other goods, other services, and foreign holidays. Each is produced by an artificial sector also indexed by m. Finally, there are 4 aggregate goods in the model, indexed by n: a public and a private investment good, a government consumption good, and a private consumption aggregate.

There are four primary factors of production: labour, capital, high-tech capital and agricultural capital. Agricultural capital is only used in the agricultural sector, and is in fixed supply: land is considered to form a part of this stock. High-tech capital is only used in the high-tech sector, and is supplied to the economy in a perfectly elastic fashion, at an exogenous (post-tax) rate of return. Capital is perfectly mobile between the other 9 production sectors, and is in fixed supply. Finally, labour is mobile across all 11 sectors.

2.3. Balance for individual commodities

2.3.1. Producer goods

Let \( Q_i \) be the output of producer good \( i \). \( A_{ij} \) is the input of good \( i \) into sector \( j \), \( C_{im} \) is the input of good \( i \) into consumption good \( m \), and \( B_{in} \) is the input of good \( i \) into aggregate good \( n \). \( E_i \) represents exports of good \( i \). For each \( i \), balance requires that

\[ Q_i = \sum_j A_{ij} + \sum_m C_{im} + \sum_n B_{in} + E_i \]  \hspace{1cm} (1)

2.3.2. Imported goods

Let \( M_k \) represent imports of good \( k \). \( A_{kj} \) represents inputs of good \( k \) into sector \( j \), \( C_{km} \) inputs of good \( k \) into consumption good \( m \), and \( B_{kn} \) inputs of good \( k \) into aggregate good \( n \). For each \( k \), balance requires that

\[ M_k = \sum_j A_{kj} + \sum_m C_{km} + \sum_n B_{kn} \]  \hspace{1cm} (2)

2.3.3. Consumer goods

The output of each consumer good is entirely used in the production of the aggregate consumption good.

2.3.4. Aggregate goods

The entire output of the aggregate consumption good is used in the production of the first utility good, \( U_1 \). The entire output of government investment and consumption are consumed by the government.

Balance for the private investment good is trickier, since this aggregate good is used to represent all private savings and investment flows in the economy. Savings represent a demand for the investment good, while borrowing represents a supply of the good.

Let \( I \) be the output of the investment good, \( S_p \) be private savings, \( G_p \) government borrowing, and \( X_1 \) net capital inflows (the negative of the current account). Balance requires that

\[ I + G_p - S_p + X_1 \]  \hspace{1cm} (3)
2.3.5. Factors of production

The entire endowment of agricultural capital is used by the agricultural sector. All high-tech capital is used in the high-tech sector. The balance for non-agricultural, non-high-tech capital is however somewhat complicated, since capital is used to model all flows of interest as well as profits in the economy. Let \( K_j \) be the capital used in sector \( j \), \( H_k \) the household's endowment of capital, \( G_k \) the government's endowment of capital, \( G_t \) interest payments on the national debt, and \( F_k \) net interest and profits paid to foreigners. Balance requires that

\[
G_k + H_k + F_k = \sum_j K_j + G_t \tag{4}
\]

2.3.6. Foreign exchange

An artificial commodity, foreign exchange, is introduced to handle foreign transactions. Let \( F_l \) be the foreign exchange earned from exports from sector \( i \), \( F_k \) be foreign exchange used to import good \( k \), \( F_G \) be net foreign transfers to the government, \( F_H \) net foreign transfers to households, and \( T_S \) the trade surplus. Balance requires that

\[
\sum_i F_l + F_G + F_H = \sum_k F_k + (T_S + F_G + F_H) \tag{5}
\]

where the term in parentheses represents the foreign consumer's demand for foreign exchange.

2.4. Production

In each sector, we assume a nested two-level production structure (see Figure 1). At the upper level, aggregate producer goods (i.e. intermediate goods) combine with a value-added aggregate. At the lower level, capital and labour produce value-added via a CES production function, and imported and domestic producer goods combine to produce aggregate producer goods via CES production functions. There are 10 intermediate goods, associated with each of the production sectors apart from export services. For reasons explained below the entire output of this sector is exported.\(^4\)

Taxes are levied on inputs of capital and labour, as well as on inputs of intermediate goods. Within a sector, all intermediate input taxes are the same. All input taxes vary by sector.

Firms in all sectors minimize costs, which generates factor demand and cost functions. It is a standard problem to generate these functions in the Leontief and CES cases. In the Leontief case, where production is given by

\[
Q = \min_i [(X_i/a_i)] \tag{6}
\]

the demand for factor \( i \) equals

\[
X_i = a_i Q \tag{7}
\]

\(^4\) Production functions in the three manufacturing sectors are specified differently, for reasons given in section 4.1.2.
and the cost function is given by

\[ c([w_i], Q) = \sum_i w_i a_i Q \] \hspace{1cm} (8)

where \( w_i \) represents the cost to the firm of input \( i \), inclusive of input taxes.\(^5\)

In the CES case, where production is given by

\[ Q = \left[ \sum_i a_i x_i^{\gamma} \right]^{1/\gamma} \] \hspace{1cm} (9)

where \( \gamma = (\sigma - 1)/\sigma \), and \( \sigma \) is the elasticity of substitution, factor demands are given by

\[ x_i([w_j], Q) = Q((a_i/w_i)\sum_j (a_j w_j^{1-\sigma})^{1/(1-\sigma)})^{1-\sigma}/\sigma \] \hspace{1cm} (10)

and the cost function is

\[ c([w_i], Q) = Q(\sum_i (w_i/a_i)^{1-\sigma})^{1/(1-\sigma)} \] \hspace{1cm} (11)

The 'top level' production function is Leontief. Therefore equation (7) generates the demands for the value added aggregate and for the aggregate producer goods in each sector.\(^6\) In this case the \( w_i \)'s refer to the cost of the value added aggregate and intermediate inputs.

The 'bottom level' production functions are CES.

Equation (10) generates the demands for labour and capital, in the case where \( Q \) represents the value-added aggregate; and it generates the demands for domestic and imported producer goods, in the case where \( Q \) represents aggregate producer goods. In the former case, \( \sigma \) represents the elasticity of substitution between capital and labour within a sector; in the latter case, \( \sigma \) represents the 'Arzintgen' elasticity of substitution between domestic and imported producer goods. Since the cost of input \( i \), \( w_i \), is inclusive of input taxes, these taxes influence firms' choice of techniques.

The model assumes perfect competition and constant returns to scale. Thus, for each sector, price equals cost (where the cost includes taxes levied on inputs). The cost function for each sector is represented by equation (8).

However, the \( w_i \)'s in equation (8) are equal to the average cost of producing the input in question (value-added aggregate or intermediate input). These average cost functions are given by equation (11).

2.5. Consumption

Consumers are endowed with labour, capital and agricultural capital. They also receive transfers (of foreign exchange) from abroad, and transfers (of an artificial "transfer" commodity) from the central government. Some of the government transfers are related to the level of unemployment. Consumers have a 4-level nested utility function, represented here by a series of pseudo-production functions (see Figure 2). At the top level, consumption

\(^5\) For the sake of notational simplicity, we here drop subscripts referring to sectors; with the understanding that there are separate production functions for each sector.

\(^6\) Except in the cases of utilities and building, where the top level production function is CES; in these cases factor demands are generated by (10). See section 4.1.3.
substitutes with savings (modelled as purchases of an aggregate investment good). At the next level, consumption goods substitute in the production of the consumption aggregate. At the next level, aggregate producer goods substitute in the production of consumer goods and the investment good. At the lowest level, domestic and imported producer goods substitute in the production of aggregate producer goods.

Proceeding from the bottom up: consumers consume 11 goods: food, drink, tobacco, clothes and footwear, fuel, petrol, durables, transport equipment, other goods, other services, and foreign tourism services. The last good is imported. Fictional sectors produce the other 10 consumption goods, by combining domestic and imported producer goods. Again, these sectors are characterised by nested production functions. At the top level, aggregate producer goods produce consumption goods via Leontief production functions. At the lower level, aggregate producer goods are produced by CES production functions, with domestic and imported producer goods as inputs. Again, the elasticity of substitution in the lower level functions is the 'Armington' elasticity.

(Similar fictional sectors are used to produce, in precisely the same way, an aggregate investment good, as well as a government investment good, and a government consumption good. It is the aggregate investment good which here concerns us.)

The 11 consumption goods are then combined to produce an aggregate consumption good, via a CES production function. Consumption taxes are modelled as taxes on the inputs of consumption goods in this sector. Next, a pseudo-sector uses a CES production function to produce the 'first utility good', with the consumption and investment goods as inputs. Inputs of the investment good here represent household savings; the elasticity of substitution in this sector represents the consumers willingness to trade off present for future consumption. Finally, a further pseudo-sector transforms the entire output of this 'first utility good' into a 'second utility good', taxing inputs of the first good at the marginal income tax rate: this is how income taxation is introduced into the model. Consumers spend their entire income on this second utility good.

2.6. The government sector

The government receives all tax revenues. In addition it is endowed with capital (representing government trading profits) and the investment good (representing government borrowing). It is also endowed with foreign exchange, representing lump sum transfers from abroad. It makes

7 Inputs into the production of the investment good are uniformly subsidised, reflecting capital subsidies. Inputs into the production of government investment are uniformly taxed, as are inputs into the production of government consumption.

8 The formulation here follows that of the single period submodel in Ballard, Fullerton, Shoven and Whalley (1985).

9 Since in fact not all income is taxed at this marginal rate, the government has to transfer the excess taxation arising from this procedure back to the households. This is an admittedly crude way of incorporating a marginal income tax rate which differs from the average income tax rate.
transfers to consumers, and consumes capital (representing interest payments on the national debt). The government consumes two goods: the government investment and consumption aggregates.

In order to do "equal yield" tax analysis, government expenditures are kept constant. Government expenditures on aggregate goods are treated as negative endowments, which effectively fixes their quantities, as are government interest payments on the national debt. Transfers are modelled by endowing households with the transfer good; the government spends all net income on this transfer good. Auxiliary constraints keep the price of this transfer good equal to the price of the aggregate consumption good, fixing the amount of the transfers in real terms.\(^{10}\)

To summarise, the government statement will be of the following form (E representing endowments, and D demands):

\[
\begin{align*}
E: & \text{capital} \quad \text{(government trading profits)} \\
E: & \text{foreign exchange} \quad \text{(foreign transfers)} \\
E: & \text{investment good} \quad \text{(government borrowing)} \\
E: & -\text{capital} \quad \text{(interest on national debt)} \\
E: & -\text{government consumption} \\
E: & -\text{government investment} \\
E: & -\text{transfers} \quad \text{(related to unemployment)} \\
D: & \text{transfers} \quad \text{(not related to unemployment)}
\end{align*}
\]

2.7. Trade

Pseudo-production functions are used to model trade flows. Export 'sectors' convert domestic producer goods into foreign exchange. Import 'sectors' convert foreign exchange into the import good. In the benchmark equilibrium, Ireland ran a trade surplus. A foreign consumer is introduced, and endowed with enough foreign exchange to allow her to finance this deficit. This (together with the assumption that 'foreign exchange' is the numeraire good) amounts to assuming that the nominal trade surplus is exogenous. This is of course unsatisfactory; but it is no more convincing (and more complicated) to assume, for example, that trade is always balanced, or that the real value of the surplus is exogenous.

As is well known, an intertemporal model would be required to model the current account rigorously; in the context of a static model, some ad hoc assumption is required.

Ireland is assumed to be 'small' in the markets for foreign producer goods; thus their prices are exogenous. This is modelled by allowing imports of these goods to exchange for foreign exchange at a fixed ratio. Let \(I_i\) stand for imports of good \(i\), and let \(F_i\) denote the amount of foreign exchange used as an input into the relevant import sector:

\[
\begin{align*}
\text{Sector} & & \text{Output} & & \text{Input} \\
\text{Imports of good } i & & I_i & = & F_i/p_{if}
\end{align*}
\]

where \(p_{if}\) is the world price of foreign good \(i\). In the benchmark equilibrium all these prices are unity.

The price-cost equations for these sectors tie down the exogenous prices of these goods; it remains to determine the level of imports of the goods.

\(^{10}\) This statement is not entirely accurate: as will be seen, some transfers are allowed to vary (proportionally) with the rate of unemployment. This implies that when doing tax reform analysis we are keeping constant (in real terms) all non-transfer expenditures, all real transfers not related to unemployment, and the real unemployment-related transfer per unemployed person.
Ireland is assumed to be 'big' in world markets for its producer goods: the more of a good Ireland exports, the lower will be its price. Thus, the production functions converting exports into foreign exchange will exhibit decreasing rather than constant returns to scale. This is done by modelling the export sectors in a Cobb-Douglas fashion:

$$F_i = A_i E_i^\alpha Z_i^{1-\alpha}$$  \hspace{1cm} (12)

where $A_i$ is a constant and $Z_i$ is a fictitious factor of production (one for each export sector). This factor is in fixed supply, which is what generates the decreasing returns to scale:

$$Z_i = n_i$$  \hspace{1cm} (13)

By 'minimizing costs' in this sector, a foreign demand function for the Irish producer good is generated, which exhibits a constant elasticity of demand:

$$E_i = C_i p_i^{\beta_i}$$  \hspace{1cm} (14)

where $C_i$ is a constant, $\beta_i$ is the elasticity of demand and $p_i$ is the price of the good.  \hspace{1cm} (12)

11 Outputs from 5 sectors are exported: agriculture, traditional manufacturing, food processing, high-tech manufacturing, and exported services.

12 Ownership of the fictitious fixed factors generates income which corresponds to nothing in the real world; so a fictitious consumer is introduced, endowed with the fixed factors, who spends all his income on foreign exchange.

2.8. Employment, unemployment and migration

The labour market in our model differs from most conventional CGE models in two key respects. First, we allow for a semi-rigid real wage which is sufficiently high in the benchmark to generate the benchmark unemployment rate. Since the latter (in 1985) was 18.2% it seems implausible to assume that the economy is at the NAIRU. Unemployment is taken to be classical in this model. The real wage is semi-rigid in the sense that it responds negatively to the level of unemployment. The second key difference is that we allow for migration of labour into and out of the economy. We take our estimates of the key parameters from the literature as explained in section 4.3.

The wage equation is of the form:

$$\log(W/P) = \alpha - \alpha(U - U_b)$$  \hspace{1cm} (15)

where "$\alpha$" is the semi-elasticity of the real wage w.r.t. the rate of unemployment, and $U$ and $U_b$ are the unemployment rate and the benchmark unemployment rate respectively. For convenience we write the model such that in the benchmark the real wage is unity ($\alpha = 0$). In the CGE model the real wage is the nominal wage divided by the price of the second utility good which is essentially the true-cost-of-living index. (The price of this good incorporates income taxes as well as taxes on consumption.)

Labour supply is equal to the labour force plus net migration, which is a function of the unemployment rate and
the levels of real wages and unemployment benefits. Note that we exclude conventional labour supply responses by the existing, indigenous, labour force. The labour supply equation is

\[ L^* = LF + MIG = ((W/P)\cdot(1-U) + (B/P)\cdot U)^\theta \]  

(16)

where \( L^* \) is the labour supply, \( LF \) is the labour force in the benchmark, \( MIG \) is net migration, and \( B \) is unemployment benefit. \( W, P \) and \( U \) are as defined before. \( \theta \) is the relevant elasticity. Note that this differs from conventional migration equations in that the level of the labour force, rather than the change in the labour force (i.e. the rate of migration), depends on the level of wages, unemployment, etc.

2.9. Equilibrium

Equilibrium is defined by the following conditions: for every sector, price equals cost; for every commodity, demand equals supply; the consumer's income equals the value of endowments; and all taxes are fully distributed. If there are \( n \) sectors, \( m \) commodities, and \( p \) consumers, this implies \( n + m + p \) equations (and, owing to Walras' Law, \( n + m + p - 1 \) independent equations), to solve for \( n + m + p \) unknowns (\( n \) activity levels, \( m \) prices and \( p \) consumers' incomes). Sectors here include sectors which transform goods into foreign exchange or vice versa, sectors which transform producer goods into consumer goods, and the sectors producing the various consumption, investment and utility aggregates.

Section 3. Calibrating the model

The model was calibrated to 1985, the last year for which detailed input-output tables were available to us. A social accounting matrix was constructed detailing all intersectoral and inter-agent commodity, factor input, transfer and tax flows for that year. This involved reconciling input-output data with the national income accounts, the balance of payments, and the government accounts.

The three main sources of data were the input-output tables for 1985 (IO 1985), National Income and Expenditure 1989 (NIE 1989), and Curtis and Fitzgerald (1993) (CF). Curtis and Fitzgerald kindly made available to us spreadsheet files containing a more detailed breakdown of the 1985 IO tables, and on occasion it was necessary to turn to these rather than the published version of the tables to get the data we wanted. Table 1 briefly outlines the data sources for the social accounting matrix. The rows of the matrix represent commodities while the columns represent the sources and uses of those commodities (sectors and agents).

3.1. Sectoral aggregation

There are 41 industry sectors in the 1985 input-output table, complying with the NACE-CLIO (R44) classification of the Statistical Office of the European Communities. These sectors are set out in Appendix 1 of this paper. The aggregation of these sectors used here is that of CF (see

\[ \text{13 The consumer goods disaggregation is entirely due to Curtis and Fitzgerald.} \]
Having calculated total SECTOR input and output, the procedure outlined above, the transport and communications sector was treated differently. The large export content of some of its subsectors and the small import content of others.

In the case of transport and communications, we returned to the NACE-CLIO code and considered inputs into each of the subsectors separately, otherwise following exactly the procedure outlined above. The transport and communications sector was treated differently due to the large export content of some of its subsectors and the small import content of others.

For example, the multilateral transport sector (65) exported £1.3 m of its £4.1 m output, or 32%, while communications services (67) exported £1.6 m, or 29%.

Table 2.1.
In addition, the model incorporates an eleventh sector, the exported services (IS). Sector (All). Several service sectors at our level of aggregation exported a non-trivial amount of output. If these sectors were to be treated as non-traded in the model, they were empirically necessary to have their own output table. The result was a new, larger sector input-output table. Tables 3 and 4 present the basic input-output data for these 11 sectors.
Production taxes
1. Employers' PRSI: treated as a tax on labour inputs
2. Corporate taxes: treated as a tax on capital inputs
3. Taxes/subsidies on intermediate inputs: uniform on all inputs in a given sector

Intermediate input taxes: aggregate goods
Levied uniformly on all inputs of producer goods into the production of government consumption, government investment and private investment. Differ by aggregate good.

Export taxes/subsidies
By sector.

Consumption taxes
Household consumer taxes levied on inputs of consumption goods into the production of the consumption aggregate. Differ by consumer good.

Income taxes
Levied on input of the consumption/savings aggregate into the production of household utility. Average tax is 1985 marginal rate (60%); lump sum transfers to household compensate for excessive taxation of intra-marginal income.

2.3.1. Production Taxes

Labour Taxes
The labour tax rate is the employers' PRSI contribution as a percentage of wages and salaries bill in each sector.16 For example the labour tax rate for the agriculture sector was calculated as the employers' PRSI contribution of £14.68 m.

Capital/Corporate Taxes
NIE gives corporate tax revenue received by the government as £217.52 m. To this figure fees under the Petroleum and Minerals Development Act (£8.001 m.) are added, giving a corporate tax level of £225.521 m. Because of the discrimination between manufacturing (the traditional, high-tech and food processing sectors, which faced a 10% tax rate) and non-manufacturing sectors (utilities, distribution, buildings, transport and communications, other marketed services and non marketed services, which faced a 50% rate) there are two tax rates calculated. These tax rates are calculated by assuming that the non-manufacturing rate is five times the manufacturing rate, ('t'), and adjusting 't' so as to produce the actual tax yield:

\[ \frac{tK_m}{(1+t)} + \frac{5tK_n}{(1+5t)} = £225.521 \text{ m.} \]  

where $K_m$ = manufacturing profits, and $K_n$ = non-manufacturing profits. It is assumed that the agricultural sector does not pay corporate tax, since the majority of agricultural profits consists of income accruing to the self-employed. There are a limited number of agricultural firms, such as stud farms.

---

16 Net of PRSI, of course.
which would pay corporate tax but as these figure are (a) not available and (b) probably very small they are ignored here.

The corporate tax rates that were calculated are: 0.014652 for manufacturing sectors and 0.074262 for non-manufacturing sectors.

Note that this ratio reflects only the difference in legal tax rates and not differences in effective tax rates which might arise from differences in tax allowances across sectors or assets. The methods used to deal with this problem are well known\(^{18}\) but it was not possible to implement them in the current model.

**Input Taxes**

Input taxes are calculated as the sum of indirect taxes, less subsidies, divided by total output. This calculation is carried out for each of the eleven sectors, as well as for private and public investment, and government consumption. Table 9 gives details.

**3.3.2. Export Taxes**

IO gives indirect taxes and subsidies for both merchandise and invisible exports, and within the merchandise category, for agricultural and manufactured exports. IO and CF break down exports from each sector into their invisible, agricultural, and industrial components. (See Table 10.) It is assumed that export taxes (or subsidies) vary across these three types of exports, but are otherwise constant across sectors. To calculate the average export tax rate for sector i, we proceed as follows. Let \( E_{i,j} \) represent exports from sector i of category j (where \( j = \) invisible, agricultural, or industrial). Let \( T_j \) be total export taxes on exports of category j. The average tax on exports of category j, \( t_j \), is then given by

\[
 t_j = \frac{T_j}{\Sigma_i E_{i,j}} \quad (18)
\]

For example, the export tax on invisible exports is \((77.91/1078.92) = 7.2\%\). The export tax for sector i, \( r_i \), is then given by

\[
 r_i = \frac{T_i}{\Sigma_j E_{i,j}} \quad (19)
\]

**3.3.3. Consumption taxes**

The consumption tax rate is calculated for each of the consumer goods, based on data given in CF (see Table 11).\(^{19}\)

**Section 3.4. Reconciliation with the national accounts**

**Section 3.4.1. Household income and expenditure**

Households are endowed with labour and capital, and receive transfers from the government and from abroad. They pay taxes on their labour and capital income, consume consumer goods, and save the remainder. Households are here taken to be the entire Irish private sector; so undistributed company profits are part of household income.

\(^{18}\) See King and Fullerton (1984).

\(^{19}\) The tax on foreign holidays is taken to be zero.
All labour is owned by households. The labour endowment of the economy is listed as £9504.60 m. (IO, p. 5). Table 12 of NIE lists total labour income as £9518.0 m.; however, of this, £13.4 m. is labour income received abroad. This will be treated as a foreign transfer; the residual accords with the IO figure.

Of the total labour payments of £9504.6 m., £642.8 m. are employers' PRSI contributions (IO, p. 29). This money obviously does not accrue to households; households are thus endowed with £8861.8 m. (=£9504.6-£642.8) in labour income.

Table 2 of NIE lists the following sources of 'capital' income accruing to households:

- Income of independent traders, etc.: £2212.4 m.
- Profits/rents/interest accruing to non-profit sector: £965.1 m.
- Undistributed company profits: £657.1 m.

This implies a total household capital income of £3840.6 m. However, corporate taxes amounted to £225.5 m. (NIE, p. 21). This money does not accrue as income to the private sector either (it is here treated as representing a tax on the use of capital by firms). Capital income received by households thus amounted to £3615.1 m.

In addition, households receive transfers of £3129.3 + £13.4 = £3142.7 m. Where do these transfers come from?

NIE, Table 30a, lists transfers from abroad of £1319.3 m.

and transfers made to foreigners of £345.5 m., implying that the Irish economy received net transfers from abroad of £973.8 m. To this the £13.4 m. in wages received overseas is added, yielding a total net transfer from abroad of £987.2 m.

NIE Table 21 lists total government transfers of £3002.9 m. Tables 19 and 20 reveal that of this total, £45.0 m. consisted of transfer payments to the rest of the world (ROW), with the residual, £2957.9 m., accruing to households.

Households are therefore taken to receive £2957.9 m. in transfer payments from the government. Subtracting this total from £3142.7 m., we find that transfers to households from ROW amounted to £184.8 m. (including the £13.4 m. figure referred to earlier). Finally, subtracting £184.8 m. from £987.2 m. implies that the government receives transfers of £802.4 m.

Note that this figure includes EC subsidies (net of EC taxes) which are treated as government expenditure here, but not in NIE.

The model distinguishes between government transfers to households that vary with the level of unemployment, and those that do not. The following transfers are taken to vary with the level of unemployment: unemployment assistance, redundancy payments, unemployment benefit, retirement pensions, pay-related benefit, the social employment scheme, the enterprise allowance scheme, and FÁS allowances. Disability benefit and invalidity pensions are a grey area: we assume that half of these transfers in 1985 were by nature linked to unemployment.

From Table 24 in NIE, we arrive at a total for these transfers of £990.2 m. This implies that a residual of £1967.7 m.
represented transfers not linked with unemployment.

To summarise, households receive labour income of £8861.8 m., capital income of £3615.1 m., unemployment-related transfers from the government of £990.2 m., other transfers from the government of £1967.7 m. and transfers from the ROW of £184.8 m. This implies a total household income of £15619.6 m. The total given in NIE Table 12 is £16487.9 m. However, this includes the corporate taxes of £225.5 m., and the employers' PRSI contributions of £642.8 m. Subtracting these taxes from the total given in NIE, we arrive again at £15619.6 m.

NIE Table 22 gives details of taxation. The table lists taxes on income and wealth of £3557.5 m., and taxes on capital of £30.5 m. Taxes on capital are here aggregated with taxes on income and wealth, yielding a tax total of £3588 m. However, of this £3588 m., £64.5 m. consists of motor vehicle duties paid by households. These are here treated as taxes on expenditure. They are therefore subtracted from £3588 m., yielding a total for taxes on income and wealth of £3523.5 m. Furthermore, this figure includes the corporate taxes of £225.5 m.; and the total for social insurance includes the employers' contributions to PRSI of £642.8 m. Subtracting these figures, we arrive at a total for taxes on household income and wealth of £2655.2 m.

Taxes on expenditure equal 3032.5 + 237.2 (taxes on expenditure plus EC taxes) = £3269.7 m. To this, £2.5 m. has to be added (see IO, p. vii) to yield a total of £3272.2 m., which accords with the entry in IO (p. 5). To this total, however, the motor vehicle duties of £64.5 m. referred to earlier must be added, yielding a total expenditure tax of £3336.7 m.

Household income is £15619.6 m. Taxes on income and wealth equal £2655.2 m. Consumption expenditure by households (including sales taxes) is given as £10493.1 m. in IO (p. 5). This is equal to the entry in NIE Table 7 (£10490.6 m.) plus £2.5 m. To this figure, the extra £64.5 m. in motor vehicle duties must be added, yielding a total consumption expenditure of £10557.6 m. Subtracting taxes on income and wealth, and consumption, from household income, we arrive at a figure for household saving of £2406.8 m.

NIE Table 21 gives personal saving at £2608.2 m., and corporate saving at £313.6 m., implying a total saving of £2539.8 m. However, this figure includes the £30.5 m. in capital taxes, which we have here included with taxation rather than saving. Subtracting 30.5 from 2439.8 yields £2409.3 m. Moreover, the NIE figures do not take into account the extra £2.5 m. in expenditure taxes included in the IO figures. This £2.5 m. should be added to the NIE consumption figures, and hence subtracted from the NIE savings figures, yielding a new total of £2406.8 m., which is the figure we have already arrived at.

Section 1.4.2. The Government sector

The government levies taxes on income and expenditure. It receives transfers from abroad, and is endowed with capital. It purchases current goods and services, as well as
the investment good; it subsidises expenditure, as well as private sector purchases of the investment good; it pays interest on the national debt; it pays transfers to households; and it borrows the excess of expenditure over revenue.

We have already covered some items of government income. Total tax receipts on household income and wealth amounted to £2655.2 m. Total expenditure taxes amounted to £3336.7 m. Corporate taxes were £225.5 m., and employers' PRSI contributions were £642.8 m. Total tax receipts therefore equalled £6860.2 m. The government received net transfers from abroad of £802.4 m. Government capital income was £551.1 m. (NIE, Table 10).

Government transfers to households amounted to £2957.9 m. (see above). Government current expenditures on goods and services amounted to £3301.0 m. (IO, p. 5). This accords with the figure given in Table 10 of NIE. Table 21 lists current expenditures of £3590.9 m., and miscellaneous current receipts of £419.7 m. A note on p. 54 states that the figure in Table 10 equals £3590.9 - 419.7, plus estimated public authorities' depreciation (excluding the depreciation of local authority dwellings). One may therefore infer that this depreciation amounted to £129.8 m.

Government gross physical capital formation amounted to £711.0 m. (NIE, Table 21). In addition, capital grants to the private sector amounted to £155.1 + 95.8 = £250.9 m. (ibid.). Moreover, EC capital grants amounted to £50.4 m. (NIE Table 11). Total capital subsidies therefore amounted to £301.3 m.

Expenditure subsidies amounted to £1452.7 m. (IO, p. 5). This equals the sum of Irish government subsidies (£588.5 m.) and EC subsidies (£864.2 m.) given in NIE Table 23. Interest payments on the national debt totalled £1824.7 m. (NIE Table 21).

Total expenditures therefore equalled £10548.6 m. Total income equalled £8213.7 m. The government therefore borrowed £2334.9 m.

Given the way in which Tables 10 and 21 in the NIE are presented (they are presented in incompatible formats), it is difficult to reconcile this figure with the data in Table 21. It is however possible to reconcile the figure with the figure for net public current saving in Table 10 (-£1406.1 m.).

This figure does not take into account taxes on capital (£30.5 m.). If these are included with taxes on income, as we have done, then the figure should be reduced by £30.5 m., yielding £1375.6 m. Second, the NIE figures do not take into account the extra consumption tax receipts of £2.5 m.; these should also be subtracted from the figure to give £1373.1 m. Third, we are here including 2 types of expenditure classified in the NIE as being 'capital' in nature: government purchases of the investment good (£711.0 m.) and government capital subsidies (£301.3 m.). These expenditures should be added to the figure, giving £2385.4 m. Finally, £50.4 m. of the capital subsidies were as we saw EC subsidies; this figure was not included in the government receipts in Table 10. 50.4 should therefore be subtracted from 2385.4, yielding a final result of £2335 m., only £0.1 m. greater than our figure for
government borrowing.

Section 3.4.2. The savings-investment balance

Household saving is £2406.8 m. Net capital inflows (the negative of the current account balance) amounted to £650.1 m. (NIE, Table 30a). In addition, additions to the pool of available savings have to be made to take account of stock appreciation (£99.4 m.; NIE Table 11) and depreciation (£1723.8 m.; IO, p. 5). Government borrowing amounted to £2334.9 m. The net amount available for investment expenditure was thus £2545.2 m.

Gross fixed capital formation (including changes in stocks of £168.9 m.) amounted to £3557.6 m. (IO, p. 5). This is also the amount given in NIE, Table 11. However, this includes capital expenditures by the government (£711 m.), as well as government capital subsidies (£301.3 m.). Subtracting these from the total yields a figure of £25453.3 m. This differs from the pool of available savings by £0.1 m., since in NIE (Table 11), the value of depreciation is given as £1723.9 m., not £1723.8 m. as in IO.

The stock appreciation adjustment, as well as the value of depreciation, are both elements of gross income not allocated to any consumer. An artificial consumer could be introduced, endowed with capital to the extent of £1823.4 m., the sum of these two amounts. In an earlier version of the model this is what was done; in this iteration of the model, however, the representative consumer is endowed with this extra capital, and her consumption of the investment good is correspondingly increased.

Section 3.4.4. The foreign consumer

The foreign consumer is endowed with capital. It makes transfers to the Irish government and Irish households, and makes available savings to the Irish economy. Its residual income is spent on the surplus foreign exchange earnings generated in the model; i.e. the balance of trade surplus.

Irish residents earned £793.8 m. on investments abroad in 1985; foreigners earned £2772.9 m. on investments in Ireland. There was thus a net deficit on trading and investment income of £1979.1 m. (NIE, Table 30a). The foreigner is thus endowed with capital of £1979.1 m. Net transfers to Ireland from abroad amounted to £987.2 m. £184.8 m. of these went to households, and £802.4 m. went to the government. In addition, the foreign agent made available £650.1 m. in savings to the Irish economy in 1985. Finally, total exports in 1985 came to £10822.9 m. (IO, p. 5), and total imports to £10481.1 m. The trade surplus was thus £341.8 m.

Section 4. Benchmark elasticities and other parameters

Section 4.1. Elasticities of Substitution

In most cases we relied on a literature search to provide estimates of production function substitution elasticities. In the cases of building, utilities and non-market services we estimated CES production functions to calculate substitution elasticities as there were none readily available. In cases where we lacked evidence on the elasticity of substitution
between value added and materials, we assumed that the elasticity was zero. Table 12 gives an overview of the elasticities we chose and the sources used.

Section 4.1.1. Agriculture

McKillop and Glass (1991) (MG) use a two-output multiple-input cost function to analyse empirically (1961-1985) the production structure of Irish agriculture. The two outputs are "livestock and livestock products" and "crops", while the four inputs are capital, feedstuffs and seed, fertilizers, and labour. MG use a translog cost function which assumes Hicks-neutral technical change; using the iterative Zellner procedure they give estimates of the elasticities of substitution between capital and labour for a number of years including 1985 (0.59), the mean value being 0.41. We used an average figure of 0.5.

Section 4.1.2. Manufacturing

A literature search for elasticities of substitution for the individual manufacturing sectors found none that were suitable. Moreover, an attempt to calculate elasticities using the same structural specification as with building and utilities (see section 4.1.3) proved unsuccessful.

We therefore used the elasticities, for manufacturing as a whole, calculated by Hannan (1993). The estimation procedure used is similar to that of MG: a three input translog cost function was used, the inputs being capital, labour and materials, and the Allen partial elasticities of substitution calculated. The share equations were estimated using an iterative Zellner estimator. The Allen partial elasticity of substitution between capital and labour was estimated as 0.968577; that between capital and materials was 0.904403; and that between labour and materials was -0.015156.

We therefore adopted an alternative nesting system for the manufacturing sectors (see Figure 3): labour and materials were assumed to be used in fixed proportions, with the resulting bundle of inputs substituting with capital (the elasticity being 0.936). In the context of section 2.4., this implies that equation (10) generates the demands for capital and the labour/materials bundle, while at the lower level of the production function equation (7) generates the demands for labour and aggregate producer goods.

Section 4.1.3. Building and utilities

For building and utilities nested CES production functions were estimated. At the lower level, net output (Z) is a function of labour (L) and capital (K) (equation 20), while at the upper level gross output (Y) is a function of net output and materials (M) (equation 21):

\[
Z = \left[ aL^{\theta} + (1-a)K^{\theta} \right]^{-1/\theta} \quad (20)
\]

\[
Y = \left[ 4Z^{\theta} + (1-6)M^{\theta} \right]^{-1/\theta} \quad (21)
\]

21 The data used was provided by the CSO and the data range is from 1960 to 1989. The cost of capital estimates are those of Francis (1990).

22 The share equation for materials was dropped.
The marginal product of labour (partial derivative of gross output with respect to labour) is calculated (equation 22) and set equal to the wage (W). We then log the equation in order to linearise it (equation 23):

\[
\frac{\delta Y}{\delta L} = \gamma^{(1+\rho)}(\theta - \rho)L^{-\theta(1+\rho)}
\]

\[
\ln L = a_0 + a_1 \ln Y + a_2 \ln Z + a_3 \ln W
\]

(22)

(23)

where \(a_0\) is a constant, \(a_1 = (1+\rho)/(1+\theta)\), \(a_2 = (\theta - \rho)/(1+\theta)\), and \(a_3 = -1/(1+\theta)\).

The elasticity of substitution between labour and capital is given by the negative of the coefficient on the log wage:

\[
\sigma_{KL} = 1/(1+\theta)
\]

(24)

while the elasticity of substitution between net output and materials is given by

\[
\sigma_{LM} = 1/(1+\rho)
\]

(25)

These elasticities can also be estimated in the context of a regression taking the log wage as the dependent variable:

\[
\ln W = b_0 + b_1 \ln Y + b_2 \ln Z + b_3 \ln L
\]

(26)

where \(b_1 = 1+\rho\), \(b_2 = (\theta - \rho)\), \(b_3 = -(1+\theta)\). This specification has the advantage that the restriction to be placed on the coefficients takes a simple, linear form:

\[
b_1 + b_2 + b_3 = 0
\]

(27)

The ESRI/Department of Finance Databank (28th May 1993) was used in the estimation. Gross output, net output, the wage bill, and numbers employed over the period 1970 to 1990 (Buildings) and 1961 to 1990 (Utilities) are the series used. Estimates including a lagged dependent variable and a time trend were considered and the best estimates are outlined below for the individual sectors.

**Buildings**

Separate estimates for the buildings sector were calculated using employment and wages as dependent variables. In both cases a lag and a time trend was added. The time trend is added to allow for bias in technical progress between factors. The most robust results emerged when labour was the dependent variable with both a lag and time trend included in the model.

The elasticity of substitution between capital and labour is 0.8685913, while the elasticity of substitution between value added and materials is 1.4461948. (See Table 13).

**Utilities**

When employment is endogenous and a lag and time trend are included, the coefficient on the wage bill term turns out to be positive, invalidating the regression. An average estimate was calculated based on two regressions: (1) employment regressed on gross and net output and the wage
rate, and (ii) the wage rate regressed on gross and net output and employment (see Table 14).

The elasticity of substitution between labour and capital for (i) is 0.1007011 and for (ii) is 0.28738. An average estimate, 0.1940434, is used. Similarly an average elasticity of substitution between value added and materials was calculated as 0.2662776.

4.1.4. Non-market services

Data was taken from the ESRI/Department of Finance Databank. The available data (1961-1990) consisted of value added, the wage bill, and total numbers employed. It was thus only possible to estimate a production function using two inputs (K and L) to produce value added:

\[ V = (\delta L^p + (1-\delta)K^p)^{1-\delta} \quad (28) \]

Converting this to a linear demand system implies:

\[ \ln V = a_0 + a_1 \ln L + a_2 \ln W \quad (29) \]

where \( W \) is the wage, as before, and where \( a_1 = -1/(1-p) \), \( a_2 = p/(1+p) \).

Two regressions were estimated, where (i) labour and (ii) the wage rate were the dependent variable; a lagged dependent variable was included in the regression. Results are given in Table 15.

The elasticity of substitution between labour and capital was calculated as 0.1226729 under (i), and 0.1645285 under (ii). The average (0.1436007) is used.

4.1.5. Marketed services

Bradley, Fitzgerald and Kearney (1991) (BFK) note the lack of empirical research on marketed services and build a model for the marketed services subsectors. Due to data constraints they could only model the supply side within a value-added framework using two factors, capital and labour. BFK use a translog cost function, with the underlying assumption that output is market determined; using Shephard's Lemma the factor demand equations are calculated assuming cost minimisation.

BFK also include a capacity utilisation variable, defined as actual output divided by trend output. This adds a dynamic element to the model, allowing short-run changes in utilisation rates to influence the share of value-added which accrues to capital. The authors use the ESRI/Department of Finance data bank and the data range is from 1970 to 1987 unless otherwise stated.

Distribution

A value of 0.86 is calculated for the elasticity of substitution between capital and labour. A CES production function yielded a higher but quite similar value of 0.94. We used an average value of 0.9.
Other marketed services

Data was only available from 1974 to 1987 for this sector. The elasticity of substitution between labour and capital was calculated as 1.2. Using a CES production function the estimate dropped slightly, to 1.07. We took an average value of 1.135.

Transport and Communication

BFK had difficulties in modelling this sector as it is dominated by a large number of state owned firms, operating in a market that is clearly not freely competitive. The translog production function produced poor results for the sector. The authors then used the Morrison version of the Generalised Leontief model, treating capital stock as a quasi-fixed factor, and estimated the system using the iterative Zellner procedure. They do not give a numerical estimate for the elasticity of substitution between capital and labour but state that all of the relevant determining coefficients are significant and that the estimated substitution possibilities were low. We assumed a value of 0.3.

4.1.6. Exported services

Since this sector is an artificial construct, we are obliged to impose an elasticity of substitution arbitrarily on the model: we chose 0.59, the average for utilities, distribution, other market services and non-market services.

Section 4.2. Trade-related elasticities

4.2.1. Armitage elasticities

Armitage elasticities measure the substitution between domestic and imported goods. In our model there are five import-competing sectors: agriculture, traditional manufacturing, food processing, high-tech, and utilities. Armitage elasticities for these sectors are calculated as a weighted average of those used by Keuschnigg and Kohler (1993) (KK). KK review available Armitage elasticities for 31 sectors, using the following sources: Harrison et al. (1991), Shills, Deardoff and Stern (1986), Deardoff and Stern (1986), Lächer (1985) and Harris (1986). They choose either the most representative value, or else take an unweighted average of different estimates given by the various sources. The values used in our model are given in Table 16.

4.2.2. Export demand elasticities

It was not possible to estimate export demand elasticities for individual commodities. Our estimate of the world's price elasticity of demand for Irish exports is taken from Browne (1982). Browne uses a log-linear model of demand and supply, incorporating a simple partial adjustment specification.

The equation which Browne estimates is

$$\ln X^d_t = a_0 + a_1 \ln (P/XW)_t + a_2 YW_t$$

where $X^d_t$ is the demand for Irish exports, $P/XW$ is the price
of Irish exports relative to the price of competing goods on world markets, and \( YW \) is world income. The parameter of interest is \( a_1 \); this is estimated as \(-16.1\), implying that Irish exporters have virtually no market power.

4.3. Labour market parameters

4.3.1. The wage equation

To parametrise the wage equation (equation (13) in section 2.8 above) we use estimates taken from the ESRI Hermes model (Bradley et al. (1989), Barry and Bradley (1991)). While their modelling framework does not correspond exactly to ours, we attempted to model wage-setting in a manner as similar as possible to Hermes, partly to facilitate the comparison of results. Hermes specifies a wage equation of the form

\[
\ln(W/P) = a_1 + a_2 \ln(TW) + a_3 (U+U_{-1})/2 + a_4 \ln(LP)/(1-a_4) \ln(W/P)
\]  

(31)

where \( W \) is the wage rate in industry, \( P \) is the output deflator, \( U \) is the unemployment rate, \( LP \) is labour productivity, and \( TW \) is a tax wedge variable (being a function of firms' real labour costs divided by the real wage received by suppliers of labour).

In this model the long run semi-elasticity of the real wage with respect to the unemployment rate is \( a_3/a_4 \). Using the Hermes point estimates gives a value of \(-0.035\).

4.3.2. Labour supply

In our model the labour force is a (constant elasticity) function of the expected real wage, where this is an unemployment-weighted average of wages and unemployment benefits. Our estimate of the relevant elasticity (\( \theta \)) is based on Keil and Newell (1992). They estimate an equation of the form

\[
\text{Migration/Population} = \theta \cdot \lambda (W_I - W_R) + X
\]

(32)

where \( X \) includes terms in the level of wages and unemployment, \( \lambda \) represents a proportionate change, and I and UK stand for Ireland and the United Kingdom respectively. We interpret the estimate of \(-\theta\) as a measure of the long run elasticity of population/labour force w.r.t. the expected wage.\(^{23}\) Keil and Newell find a value for this of 0.11, with a t-ratio of 3.9.

\(^{23}\) We emphasize that this is our interpretation, which may not be shared by the authors of the paper cited.
References


Table 1. Outline of data sources for CGE model

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Notes:

- P-Goods: producer goods
- C-Goods: consumer goods
- Agg-Goods: aggregate goods
- Factors: factors of production
- Tax-P: taxes on factors of production
- Tax-In: taxes on intermediate inputs
- Tax-Cons: taxes on consumer goods
- Tax-Y: income tax
- A1: Table A1 of the 1985 Input-Output Tables
- A4: Table A4 of the 1985 Input-Output Tables
- B2: Table B2 of the 1985 Input-Output Tables
- NIE: National Income and Expenditure 1989
- C&F: Curtis and Fitzgerald (1993)

Unless otherwise stated sources for the following tables are given above.
## Table 3. Domestic inter-industry flows

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**Notes:**

TS: traded services  
All figures in millions of Irish pounds. The same is true of subsequent tables.

## Table 4. Foreign and other inputs into domestic production

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</table>

**Notes:**

-F: imported input (e.g. AG-F: imported agricultural goods)  
INV-F: invisible imports  
LAB: labour costs  
CAP: capital inputs - all sectors except AG and HT  
CAP+AG: agricultural capital  
CAPHT: high-technology inputs  
TX: tax on intermediate inputs  
TL: labour tax  
TR: capital tax
### Table 5. Domestic goods: end uses

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<th>Total Output</th>
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**Notes:**
- TII: total inter-industry flows
- Personal: personal consumption
- GOV: government consumption
- INV: investment

### Table 6. Imported goods: end uses

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**Notes:**
- TOUR-F: foreign holidays
### Table 7. Consumption of domestic goods

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**Notes:**
- FO: FOOD
- DR: DRINK
- TB: TOBACCO
- CF: CLOTHING AND FOOTWEAR
- FU: FUEL
- PL: PETROL
- DU: DURABLES
- TE: TRANSPORT EQUIPMENT
- OG: OTHER GOODS
- OS: OTHER SERVICES

### Table 8. Consumption of imported goods

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**Notes:**
- FO: FOOD
- DR: DRINK
- TB: TOBACCO
- CF: CLOTHING AND FOOTWEAR
- FU: FUEL
- PL: PETROL
- DU: DURABLES
- TE: TRANSPORT EQUIPMENT
- OG: OTHER GOODS
- OS: OTHER SERVICES
### Table 9. Labour and intermediate input taxes

#### (a) Producer goods

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#### (b) Aggregate goods

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**Notes:**
- L TAX: employers' PRSI
- WAGES: wage bill minus employers' PRSI
- I TAX: L TAX/WAGES
- I TAX: tax on purchases of intermediate inputs
- INPUTS: domestic and imported intermediate inputs
- % I TAX: I TAX/INPUTS

PI: private investment
GI: government investment
GC: government consumption

### Table 10. Export taxes

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<td>1431.49</td>
<td>38.6818</td>
<td>2.7</td>
</tr>
<tr>
<td>ALL EX</td>
<td>1078.92</td>
<td>7249.35</td>
<td>2338.14</td>
<td>520.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E TAX</td>
<td>77.91</td>
<td>111.77</td>
<td>620.92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% E TAX</td>
<td>7.2</td>
<td>1.5</td>
<td>26.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- INVEX: invisible exports
- MANEX: manufacturing exports
- AGRX: agricultural exports
- ALL EX: total exports
- E TAX: export taxes
- % E TAX: E TAX/ALL EX

**Source:**
- Curtis and Fitzgerald's disaggregation of I095.
Table 12. Production elasticities of substitution: overview

<table>
<thead>
<tr>
<th>Sector</th>
<th>Source</th>
<th>Elast-KL</th>
<th>Elast-VN</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>MG</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>U</td>
<td>DHO</td>
<td>0.194</td>
<td>0.266</td>
</tr>
<tr>
<td>B</td>
<td>DHO</td>
<td>0.569</td>
<td>1.446</td>
</tr>
<tr>
<td>DI</td>
<td>BFK</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>TC</td>
<td>BFK</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>CMS</td>
<td>BFK</td>
<td>1.135</td>
<td>0</td>
</tr>
<tr>
<td>NMS</td>
<td>DHO</td>
<td>0.1436</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sector</th>
<th>Source</th>
<th>Elast-KLM</th>
<th>Elast-LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing TR, HT, FP</td>
<td>Hannan (1993)</td>
<td>0.936</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:

MG: McKillop and Glass (1991)
Est.: Estimated in this paper

Elast-KL: elasticity of substitution between capital and labour
Elast-VN: elasticity of substitution between value added and materials
Elast-KLM: elasticity of substitution between capital and labour/materials
Elast-LM: elasticity of substitution between labour and materials
Table 13. Calculating the elasticity of substitution: building

<table>
<thead>
<tr>
<th>Dependent variable: L</th>
<th>Coefficient</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_0$ (constant)</td>
<td>-3.503905</td>
<td>1.059636*</td>
</tr>
<tr>
<td>$a_1$ (gross output)</td>
<td>0.1970134</td>
<td>0.1202003</td>
</tr>
<tr>
<td>$a_2$ (net output)</td>
<td>0.6039421</td>
<td>0.1967556*</td>
</tr>
<tr>
<td>$a_3$ (wage rate)</td>
<td>-0.2849197</td>
<td>0.1063404*</td>
</tr>
<tr>
<td>$a_4$ (labour)</td>
<td>0.4992547</td>
<td>0.1728217*</td>
</tr>
<tr>
<td>$a_5$ (time)</td>
<td>0.0278782</td>
<td>0.01546336</td>
</tr>
</tbody>
</table>

Note: * implies that the t-test is significant at the 95% level. All variables in natural logarithms except time.

Source: see text

Table 14. Calculating the elasticity of substitution: utilities

<table>
<thead>
<tr>
<th>Dependent variable: L</th>
<th>Coefficient</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_0$ (constant)</td>
<td>-0.3305474</td>
<td>0.817911</td>
</tr>
<tr>
<td>$a_1$ (gross output)</td>
<td>0.4421035</td>
<td>0.1322209*</td>
</tr>
<tr>
<td>$a_2$ (net output)</td>
<td>0.0145973</td>
<td>0.0274596</td>
</tr>
<tr>
<td>$a_3$ (wage rate)</td>
<td>-0.1007011</td>
<td>0.364193*</td>
</tr>
<tr>
<td>$a_4$ (labour)</td>
<td>-12.84661</td>
<td>1.840883*</td>
</tr>
<tr>
<td>$a_5$ (time)</td>
<td>3.281078</td>
<td>0.5100624*</td>
</tr>
<tr>
<td>$a_6$ (labour)</td>
<td>0.198569</td>
<td>0.1407831</td>
</tr>
<tr>
<td>$a_7$ (time)</td>
<td>-3.479646</td>
<td>0.3884997*</td>
</tr>
</tbody>
</table>

Note: * implies that the t-test is significant at the 95% level. All variables in natural logarithms except time.

Source: see text
Table 15. Calculating the elasticity of substitution: non-market services

<table>
<thead>
<tr>
<th>Dependent variable: L</th>
<th>Coefficient</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>a₀ (constant)</td>
<td>-3.759258</td>
<td>0.3419146*</td>
</tr>
<tr>
<td>a₁ (value added)</td>
<td>0.9434181</td>
<td>0.0983426*</td>
</tr>
<tr>
<td>a₂ (wage rate)</td>
<td>-0.0816293</td>
<td>0.009092*</td>
</tr>
<tr>
<td>a₃ (labour₁)</td>
<td>0.3345776</td>
<td>0.0974401*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: wage rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>a₀ (constant)</td>
</tr>
<tr>
<td>a₁ (value added)</td>
</tr>
<tr>
<td>a₂ (labour)</td>
</tr>
<tr>
<td>a₃ (wage rate₁)</td>
</tr>
</tbody>
</table>

Note: * implies that the t-test is significant at the 95% level. All variables in natural logarithms except time.

Source: see text

Table 16. Armington elasticities

<table>
<thead>
<tr>
<th>Sector</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1.413</td>
</tr>
<tr>
<td>Traditional</td>
<td>1.539</td>
</tr>
<tr>
<td>Food Processing</td>
<td>0.797</td>
</tr>
<tr>
<td>High-Tech</td>
<td>1.205</td>
</tr>
<tr>
<td>Utilities</td>
<td>1.046</td>
</tr>
</tbody>
</table>

Source: Keuschnigg and Kohler (1993)
### Appendix 1: Sector Classification (41 sectors) and Aggregation (10 sectors)

<table>
<thead>
<tr>
<th>NCC</th>
<th>DESCRIPTION</th>
<th>No.</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>859</td>
<td>Lodging/Catering Services</td>
<td>A7</td>
<td>DI</td>
</tr>
<tr>
<td>661</td>
<td>Inland Transport</td>
<td>A8</td>
<td>TC</td>
</tr>
<tr>
<td>663</td>
<td>Maritime/Air Transport</td>
<td>A8</td>
<td>TC</td>
</tr>
<tr>
<td>665</td>
<td>Auxiliary Transport</td>
<td>A8</td>
<td>TC</td>
</tr>
<tr>
<td>667</td>
<td>Communication Services</td>
<td>A8</td>
<td>TC</td>
</tr>
<tr>
<td>669</td>
<td>Credit and Insurance</td>
<td>A9</td>
<td>OMS</td>
</tr>
<tr>
<td>671</td>
<td>Business Services</td>
<td>A9</td>
<td>OMS</td>
</tr>
<tr>
<td>673</td>
<td>Renting of Immovable Goods</td>
<td>A9</td>
<td>OMS</td>
</tr>
<tr>
<td>679</td>
<td>Other Marketing Services</td>
<td>A9</td>
<td>OMS</td>
</tr>
<tr>
<td>681</td>
<td>General Public Services</td>
<td>A10</td>
<td>NMS</td>
</tr>
<tr>
<td>889</td>
<td>Non Market Health Services</td>
<td>A10</td>
<td>NMS</td>
</tr>
<tr>
<td>893</td>
<td>Other Non Market Services</td>
<td>A10</td>
<td>NMS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NCC</th>
<th>DESCRIPTION</th>
<th>No.</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>801</td>
<td>Agric./Forestry/Fishing</td>
<td>A1</td>
<td>AG</td>
</tr>
<tr>
<td>803</td>
<td>Coal/Lignite/Briquettes</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>805</td>
<td>Products of Coking</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>807</td>
<td>Petrol Prod./Natural Gas</td>
<td>A5</td>
<td>U</td>
</tr>
<tr>
<td>809</td>
<td>Electricity/Gas/Water</td>
<td>A5</td>
<td>U</td>
</tr>
<tr>
<td>811</td>
<td>Radioactive Material &amp; Ores</td>
<td>A5</td>
<td>U</td>
</tr>
<tr>
<td>813</td>
<td>Metals and Ores</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>815</td>
<td>Non Metallic Min Products</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>817</td>
<td>Chemical Products</td>
<td>A4</td>
<td>MT</td>
</tr>
<tr>
<td>819</td>
<td>Metal Prod. (excl. mach.)</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>821</td>
<td>Agric./Industrial Machinery</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>823</td>
<td>Office Machines</td>
<td>A3</td>
<td>FP</td>
</tr>
<tr>
<td>825</td>
<td>Electrical Goods</td>
<td>A4</td>
<td>MT</td>
</tr>
<tr>
<td>827</td>
<td>Motor Vehicles</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>829</td>
<td>Other Transport Equipment</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>831</td>
<td>Meat/Meat Products</td>
<td>A3</td>
<td>FP</td>
</tr>
<tr>
<td>833</td>
<td>Milk &amp; Dairy Products</td>
<td>A3</td>
<td>FP</td>
</tr>
<tr>
<td>835</td>
<td>Other Food Products</td>
<td>A3</td>
<td>FP</td>
</tr>
<tr>
<td>837</td>
<td>Beverages</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>839</td>
<td>Tobacco Products</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>841</td>
<td>Textiles/Clothing</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>843</td>
<td>Leather/Footwear</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>845</td>
<td>Wooden Products/Furniture</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>847</td>
<td>Paper/Printing Products</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>849</td>
<td>Rubber/Plastic Products</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>851</td>
<td>Other Manuf Products</td>
<td>A2</td>
<td>TR</td>
</tr>
<tr>
<td>853</td>
<td>Building &amp; Construction</td>
<td>A6</td>
<td>B</td>
</tr>
<tr>
<td>855</td>
<td>Repair/Recovery Services</td>
<td>A7</td>
<td>DI</td>
</tr>
<tr>
<td>857</td>
<td>Wholesale/Retail Trade</td>
<td>A7</td>
<td>DI</td>
</tr>
</tbody>
</table>
**Figure 1. Production**

VA: value added  
L: labour  
K: capital  
I_1: intermediate goods (aggregate producer goods)  
D_1: domestic producer goods  
F_1: imported producer goods

**Figure 2. Consumption**

C: aggregate consumption good  
S: savings (aggregate investment good)  
I_1: intermediate goods (aggregate producer goods)  
D_1: domestic producer goods  
F_1: imported producer goods  
H: foreign holidays
Figure 3. Production: manufacturing

L: labour  
K: capital  
I: intermediate goods (aggregate producer goods)  
D: domestic producer goods  
F: imported producer goods