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"Harmonizing Irish Tax Rates: A Computable General Equilibrium Approach"

by
Kevin Denny, Aoife Hannan, Kevin O'Rourke

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Harmonising Irish tax rates:  
a computable general equilibrium approach

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January, 1995

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Section 1. Introduction

The impact of fiscal policy on economic performance in Ireland is one of the most important issues facing economists and policy makers today. The ability to use discretionary macroeconomic policy is very limited, especially in the context of the Maastricht Treaty. Moreover, there is a widespread belief among observers that both the overall levels of tax and the structure of the tax system are currently far from optimal.

Such observations are not new and there have been several reports on the future of tax policy. Aside from the reports of the Commission on Taxation there are a number of studies on the taxation of savings, corporate tax and so on. One key feature of these is that they consider particular sectors or taxes. However, decisions made in one sector will generally have knock-on effects in other sectors. For example, an increase in payroll taxes in an industry producing intermediate inputs will have effects on employment in that industry, and on wages throughout the economy. There will be an impact on industries using those intermediate inputs (and indeed labour). The tax will affect the consumption decisions of workers and hence their decisions about savings. In the long run since investment depends on savings the growth of the economy may be affected.

These complex interactions remind us that a proper evaluation of economic policy, and fiscal policy in particular, requires a general equilibrium approach. Simple analyses of a particular market may give misleading results.
For general equilibrium models where the number of agents, factors and goods is small (one or two) it is possible to work out analytical solutions, using local approximation techniques if necessary. This is how the pioneering work of Arnold Harberger on the incidence of the corporate tax proceeded. However, the more realistic, higher dimensional models which economists typically use today can only be solved using numerical methods: we require a computable general equilibrium (CGE) model. This is the approach taken by Shoven, Whalley and many others.

This paper will present what is to our knowledge the first attempt to construct a CGE model of the entire Irish economy. Using national accounts data, input-output tables and other data sources we calibrate the model so that the equations fit reality in a benchmark year (1985). We can then carry out comparative static analyses of various policy reforms, real or imagined. In this paper, we examine the impacts of the non-uniform nature of the tax structure--that is, the fact that different sectors pay different input taxes, and that consumption taxes vary by consumption good. We do this by examining what the effects would be of moving to a more uniform tax structure. Unemployment is naturally a key feature of the model; we are chiefly interested in whether moving to a more uniform tax structure would increase or reduce the level of unemployment.

Section 2 presents the model, and section 3 introduces the data used to calibrate it. Section 4 describes the comparative static experiments performed, and Section 5 presents and interprets the results.

section 2. A general equilibrium model of the Irish economy

There are four components of a neoclassical general equilibrium model.\(^1\) 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 constraint is fulfilled (e.g. emigration or unemployment).

The software which we use, MPS\textregistered GE, forces the modeller to 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

\(^1\) Shoven and Whalley (1992) provide a good introduction.

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

\(^3\) See Rutherford (1988, 1994).
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. 11 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 11 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 of a first utility good, U1. U1 is then entirely used in the production of a second utility good, U2. Inputs of U1 into this sector are taxed at the marginal rate of income tax, which is how income tax is introduced into the model. The consumer spends its entire income on U2.

The government levies taxes on consumption, on inputs into production, and on exports (the latter taxes being for the most part negative). It also receives transfers from abroad, and borrows to finance its deficit. It is endowed with some capital, but pays interest on the national debt. It makes transfers to households, and consumes the public investment and government consumption aggregates.

A foreign consumer has capital invested in the high-tech sector, receives income on these investments, transfers money to domestic agents, and buys up the Irish trade surplus.

2.2. Commodities and sectors

There are 11 producer goods in the model, indexed by i: agriculture, traditional manufacturing, food processing, high-tech manufacturing, utilities, building, distribution, transport and communications, other market services, non-market services, and exported services. To each of these goods there corresponds a production sector, indexed by j. Imported goods are indexed by k. There are 7 such goods: imports of agricultural output, traditional manufactures, processed foods, high-tech manufactures, utilities, foreign tourism, and invisibles. There are 11 consumer goods, indexed by m: food, drink, tobacco, clothes and footwear, fuel, 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

$$Q_i = \sum_j A_{ij} + \sum_m C_{im} + \sum_n B_{in} + E_i \quad (1)$$

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

$$M_k = \sum_j A_{kj} + \sum_m C_{km} + \sum_n B_{kn} \quad (2)$$

2.3.3 Consumer goods

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

2.1.4 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, $G_b$ government borrowing, and $K_i$ net capital inflows (the negative of the current account). Balance requires that

$$I + G_b = S_p + K_i \quad (3)$$

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, $G_c$ the government's endowment of capital, $G_i$ interest payments on the national debt, and $F_i$ net interest and profits paid to foreigners. Balance requires that
\[ G_t + H_t + F_t = \sum_i x_i + G_t \]  \hspace{1cm} (4)

2.3.6. Foreign exchange

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

\[ \sum_i F_i + F_k + F_a = \sum_i x_i + (TS + F_k + F_h) \]  \hspace{1cm} (5)

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

2.4. Production

In non-manufacturing sectors, 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 given in Denny et al. (1985) the entire output of this sector is exported.

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

\[ Q = \min_i \{ (X_i/a_i) \} \]  \hspace{1cm} (6)

the demand for factor \( i \) equals

\[ x_i = a_i Q \]  \hspace{1cm} (7)

and the cost function is given by

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

where \( w_i \) represents the cost to the firm of input \( i \), inclusive of input taxes.\(^4\)

In the CES case, where production is given by

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

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

\(^4\) 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.
\[ X_i(\{w_j\}, Q) = Q(\{a_i/w_i\} \sum_j a_j^{\alpha_j} w_j^{1-\alpha_j})^{1/(1-\sigma_j)} \]  
(10)

and the cost function is

\[ C(\{w_j\}, Q) = QX_i(\{w_j/a_i\}^{\alpha_j} w_j^{1-\alpha_j}) \]  
(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.\(^5\) In this case the \(w_j\)’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 'Armington' 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 \(w_j\)'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).

In manufacturing sectors, we assume a different nesting structure (Figure 2). At the lower level, labour and intermediate inputs are combined in fixed proportions, while the resulting bundle of inputs is combined with capital in a CES fashion.\(^6\)

Table 1 gives an overview of the elasticities of substitution embodied in the model.

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 3). At the top level, consumption 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

\(^5\) 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 Denny et al. (1985).

\(^6\) See Denny et al. (1995) for a justification of this procedure.
investment goods. 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 Cobb-Douglas 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 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

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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.
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.

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:

\[
I_i = \frac{F_i}{P_i}
\]

where $P_i$ 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.

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:

\[
F_i = A_i E_i Z_i^{1-s}
\]

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:

\[
Z_i = Z_i
\]

By ‘minimizing costs’ in this sector, a foreign demand

\[10\] Outputs from 6 sectors are exported: agriculture, traditional manufacturing, food processing, high-tech manufacturing, and exported services.
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.\(^{11}\)

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. One consequence of modelling migration is that fluctuations in unemployment are dampened: emigration reduces unemployment in a slump, while immigration increases unemployment in a boom.

The wage equation is of the form:

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

where "a" 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 (\(a = 0\)). 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

$$L^* = LF + MIG = (W/P) \cdot (1 - U) + (B/P) \cdot U$$  \hspace{1cm} (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. \(B\) 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.\(^{12}\)

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\(^{11}\) 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.

\(^{12}\) Denny et al. (1995) describe how the labour market equations were parametrised.
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).\textsuperscript{13} 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 2 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). Table 3 gives the benchmark tax rates. A full description of the data used to calibrate the model may be found in Denny et al. (1995).

Section 4. Some comparative static experiments

The model is fairly simple, yet it incorporates enough taxes that a wide variety of experiments can be performed. In this paper we examine four distinct tax reforms:

1. A move to uniform labour taxes across sectors \textsuperscript{(TL)}
2. A move to uniform capital taxes across sectors \textsuperscript{(TK)}
3. A move to a uniform value added tax across sectors and factors \textsuperscript{(TVA)}
4. A move to uniform consumption taxes across consumption goods \textsuperscript{(TC)}

In each case, we run two different experiments. In the first, we set the uniform tax at a level which yields the same revenues \textit{ex ante} as before; that is, the uniform tax yields the same revenue as before, when applied to the benchmark quantities. For example, the uniform labour tax chosen would

\textsuperscript{13} The consumer goods disaggregation is entirely due to Curtis and FitzGerald.
yield the same PRSI revenue as the old system of taxes, if employment levels in the various sectors remained constant. The justification for this experiment is that civil servants, when considering policy reform, may well use this type of ex ante reasoning.

Ex post, of course, a tax reform will change the equilibrium configuration of the economy, which implies that the total tax take will also change. We keep government borrowing constant in our experiments, and therefore need to let some other tax, or some element of government expenditure, vary in an off-setting way. For these runs, we change the real value of government transfers to the private sector; in other words, lump sum transfers do the adjusting.

The second set of experiments chooses the uniform tax in such a way that an ex post equal yield is ensured; that is, it ensures that the sum of all government expenditures is held fixed in real terms, without changing the level of government borrowing. 14 The one exception to this rule is that unemployment-related transfers are allowed to vary with the level of unemployment: we are in fact keeping constant (in real terms) all non-transfer expenditures, all transfers not related to unemployment, and the unemployment-related transfer per unemployed person (i.e. the level of unemployment.

Section 5. The results

Table 4 gives the main results of moving to uniform taxes, assuming ex ante equal yields. In general, moving to more uniform tax structures would increase employment, indicating that the current biases in the system work against the employment of labour. The one exception is capital taxes: equalising capital taxes across sectors would increase the unemployment rate, although not by much (it would rise to 18.6%, from 18.2% in the benchmark). This is a surprising result, given the perception that services, which are currently discriminated against, tend to be relatively labour-

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14 As mentioned, government expenditures on aggregate goods are treated as negative endowments, which fixes their quantity; the way we keep the real value of transfers constant is to keep the price of the transfer good equal to that of the aggregate consumption good (households are endowed with given quantities of the transfer good).

15 One way of thinking about the ex ante/ex post distinction is that the ex ante experiments assume that policy makers are myopic, in that they foresee no behavioural consequences of their actions; the ex post experiments assume perfect foresight, in that policy makers understand exactly what the consequences of their actions will be. Obviously reality lies in between these two extreme cases.
intensive. In fact, as Table 5 shows, traditional manufacturing is very labour-intensive, as is food-processing; services only appear very labour-intensive compared to high-tech manufacturing. What appears to be chiefly driving this result, however, is the fact that the model assumes that high-tech capital is perfectly mobile between Ireland and the rest of the world. Increasing taxes on high-tech capital drives it out of the economy, leading to a contraction of 7% in the high-tech sector. The net impact is a fall in employment. This indicates that reforms equalising profit taxes across sectors should take account of the impact on direct foreign investment; in particular, profits taxes should be equalised downwards, rather than upwards.

Equalising labour taxes across sectors reduces unemployment, to 16.9%. The labour-intensive traditional manufacturing sector paid relatively high labour taxes in 1985; a move to uniform taxes boosts output in that sector by 4.7%. Even though the high-tech sector is not very labour-intensive, it experiences the second-highest increase in output—this is due to the positive effects of lower labour costs on inward direct foreign investment. Moving to equal treatment of labour and capital further reduces unemployment, to 16.2%, as firms substitute towards more labour-intensive techniques, and relatively labour-intensive sectors expand (taxes on labour tend to fall, and taxes on capital to rise). The big loser under such a regime would be the capital-intensive high-tech sector, which contracts by 8.3%, as capital flees the country as a result of higher capital taxes.

One would expect unemployment to fall by a lot more if taxes on foreign capital were not significantly increased, as they are in this experiment.

Surprisingly, the most dramatic impact on unemployment comes from harmonising consumption taxes across goods: unemployment would fall to 13.8% if this were done. Goods facing the highest consumption taxes in 1985 were drink, tobacco and transport equipment; inputs into drink consisted of traditional manufactures and distribution (Table 6), both labour-intensive activities. Harmonising consumption taxes leads to traditional manufacturing expanding by 18.5%, and the distribution sector expanding by 11.5%.

The results are far more dramatic when we move from an ex ante to an ex post version of equal yield analysis. As mentioned before, there are cumulative processes at work in these simulations: a shock which boosts employment raises tax revenues, lowering the endogenous tax, which further boosts employment, and so on. The striking feature of our results is that these cumulative processes actually imply multiple equilibria: that is, we find that there are two distinct outcomes, which according to the model are equally likely to occur.

This is not the case for the capital tax experiment; all that happens in this case is that unemployment increases a little more, as capital taxes are increased further and more high-tech capital leaves the country (Table 7). However, equalising all other taxes does lead to multiple equilibria; which equilibrium you find depends merely on where you start.
looking from. To identify equilibria in CGE models, the computer typically takes an initial starting set of prices, taxes, activity levels and so on; checks if these constitute an equilibrium; and if they do not, converges to the real equilibrium in a manner reminiscent of the classic tâtonnement process.

In our simulations, we found that starting from a very low initial level of the endogenous tax (say zero) the programme converged to a 'good' equilibrium, with low taxes (in fact, endogenous taxes are zero) and low unemployment; starting from a high initial tax (say 60%), the programme converged to a 'bad' equilibrium, featuring high endogenous taxes and high unemployment.

Why did we find multiple equilibria for the labour, value added and consumption tax experiments, but not the capital tax experiment? The answer appears to be that the feedback loops mentioned above are not strong enough in the case of capital taxes (higher capital taxes, less foreign investment, less employment, higher capital taxes) to produce multiple equilibria; but if the endogenous tax involved is a tax on labour, the feedback loops become very powerful indeed. Consumption taxes are indirectly a tax on labour, due to the way we specify wage formation (equation (13)). We assume (realistically) that increases in goods prices are passed on in the form of higher wages; thus high consumption taxes imply high wages and low employment, while low consumption taxes imply low wages and high employment.

The 'good' equilibria look very similar in the cases of uniform labour and value added taxes—not surprisingly, since the crucial element in both experiments is the level of the endogenous labour tax, which is zero in equilibrium. In both cases, unemployment collapses to less than 9%. The key difference between the two scenarios is that when labour taxes alone are unified, high tech expands by less than when labour and capital taxes are unified (in the latter case, capital taxes are also abolished, and high-tech expands much more dramatically). The 'good' consumption tax equilibrium looks even better—unemployment disappears, as the strong employment effects of tax harmonization (Table 4) are combined with virtuous cycle effects.

However, in the 'bad' equilibria unemployment is higher than in the benchmark—in the case of the labour tax experiment, only marginally, but in the two other cases, significantly. Unemployment is 24.6% in the 'bad' value added tax equilibrium, 26.2% in the 'bad' consumption tax equilibrium.

The fact that in some cases our model has generated multiple equilibria is both of academic and policy interest. It is of academic interest, since the conventional wisdom has been that multiple equilibria do not in practice arise in numerical general equilibrium models. In their 1984 survey paper, Shoven and Whalley write that "the current working hypothesis adopted by most modellers seems to be that uniqueness can be presumed for all of the models discussed here [i.e. in their paper] until a clear case of nonuniqueness
is found". Strikingly, our model incorporates none of the features—increasing returns to scale, for example—which theorists recognize may lead to multiple equilibria. Rather, it is the interaction of endogenous tax rates and unemployment which generates the feedback loops necessary for the phenomenon to occur.

Our results are of policy interest, in that they indicate that tax policy can have very significant macroeconomic effects in Ireland. Tax reform in principle play a crucial role in reducing Ireland's crippling unemployment rates; what is needed now is further research into exactly what form such reforms should take.

References


Table 1. Production elasticities of substitution

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<th>Elast-VM</th>
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Notes:
MG: McKillop and Glass (1991)
DHO: Denny, Hannan and O'Rourke (1995)
BFK: Bradley, FitzGerald and Kearney (1991)

Elast-KL: elasticity of substitution between capital and labour
Elast-VM: 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 2. 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-F: 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
- CIF: Curtis and Fitzgerald (1993)

### Table 3. Benchmark tax rates

(a) Input and export taxes by sector

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<th>U</th>
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**Categories:**
- AG: AGRICULTURE
- TR: TRADITIONAL MANUFACTURING
- FF: FOOD PROCESSING
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- WMS: NON-MARKET SERVICES
- TS: EXPORTED SERVICES

(b) Consumption taxes

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<td>OS</td>
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**Consumption goods:**
- 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

**Source:** Denny et al. (1995).
Table 4. The impact of harmonizing taxes: ex ante equal yields

(Percent changes)

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UE (*) 18.6 16.9 16.2 13.8
TAX (*) 3.7 7.3 5.8 21.1

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TC: TRANSPORT & COMMUNICATIONS
OMS: OTHER MARKET SERVICES
NMS: NON-MARKET SERVICES
TS: EXPORTED SERVICES
LF: labour force
UE: unemployment
TAX: level of endogenous tax
KTAX: impact of harmonizing capital taxes
LTAX: impact of harmonizing labour taxes
KLTAX: impact of harmonizing capital and labour taxes
CTAX: impact of harmonizing consumption taxes

Table 5. Labour intensity by sector

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Source:
Calculated from data in Denny et al. (1995).
### Table 6. Domestic inputs into consumption

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- TS: EXPORTED SERVICES
- PO: FOOD
- DR: DRINK
- TB: TABACCO
- CF: CLOTHING AND FOOTWEAR
- PL: FUEL
- DU: PETROL
- DU: DURABLES
- TE: TRANSPORT EQUIPMENT
- OG: OTHER GOODS
- OS: OTHER SERVICES

### Table 7. The impact of harmonizing taxes: ex post equal yields (percent changes)

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- AG: AGRICULTURE
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- NMS: NON-MARKET SERVICES
- TS: EXPORTED SERVICES
- LF: labour force
- (*) : level in percent
- UE: unemployment
- TAX: level of endogenous tax

- KTA: impact of harmonizing capital taxes
- LTA: impact of harmonizing labour taxes
- KLTAX: impact of harmonizing capital and labour taxes
- CTAX: impact of harmonizing consumption taxes
Figure 1. Production: non-manufacturing

VA: value added
L: labour
K: capital
I_i: intermediate goods (aggregate producer goods)
D_i: domestic producer goods
F_i: imported producer goods

Figure 2. Production: manufacturing

L: labour
L: capital
I_i: intermediate goods (aggregate producer goods)
D_i: domestic producer goods
F_i: imported producer goods
Figure 3. Consumption

C: aggregate consumption good
S: savings (aggregate investment good)
I_i: intermediate goods (aggregate producer goods)
D_i: domestic producer goods
F_i: imported producer goods
H: foreign holidays