Carbon Dioxide Emissions Reductions in New Zealand: A Minimum Disruption Approach

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Abstract

Reductions in carbon dioxide emissions can come from (among other things) changes to the structure of final demands, changes in the use of fossil fuels by industry, and changes to the structure of inter-industry transactions. This paper examines the nature of the least disruptive changes, that is the minimum changes to these three components which are consistent with specified overall reductions in carbon dioxide in New Zealand. In examining the minimum changes needed, constraints are imposed on the corresponding changes in GDP growth and aggregate employment.

JEL CLASSIFICATION D57 - Input-Output Analysis
Q40 - Energy - General
L70 - Industry Studies: Primary Products and Construction - General

KEYWORDS Carbon Dioxide; Minimum Disruption; Carbon Intensities; New Zealand

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1 Introduction

A reduction in carbon dioxide emissions arising from the production of goods and services can come from three main sources: changes to the structure of final demand; changes to fuel mix and efficiency in production, and changes to the structure of inter-industry trading. The aim of this paper is to examine the nature of the least disruptive changes in the New Zealand economy that are necessary to achieve a target annual rate of reduction in emissions. The paper concentrates on changes in final consumer demands and changes in the quantities and mixture of fossil fuels used by industries. A situation in which emissions reductions are achieved by reducing all final demands would imply an increase in aggregate unemployment and a negative growth rate of GDP. In the case of final demand changes, constraints on GDP and employment growth are imposed: these imply that the final demands of some industries would need to increase, while other industries decline. These changes are examined using constrained minimisation techniques within an input-output framework, following the methods developed by Proops et al (1993).[1]

The constrained minimisation method does not consider a specified means of reducing emissions, such as a carbon tax.[2] It is therefore not directly concerned with determining the economic costs associated with curbing carbon dioxide emissions. Instead the method attempts to find the minimum set of structural changes required in different industries of the economy that would achieve a target level of emissions reduction whilst maintaining predetermined levels of variables like GDP growth and employment. In doing so, the method can determine the severity of the required changes.

Subsection 2.1 presents the input-output approach to modelling carbon dioxide emissions, while subsection 2.2 describes the method of allowing for constrained minimisation of disruptions. The minimum disruption approach is applied to New Zealand in sections 3 and 4. Section 3 describes the sources from which the data were gathered and the processes used to form the expressions derived in section 2, while subsections 4.1 and 4.2 analyse the minimum disruption results for respectively final demands and fuel use. Conclusions are provided in section 5.

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[1] For an application to Australia and comparisons with and references to other applications of the basic approach, see Cornwell and Creedy (1997).

[2] For an analysis of the implications of a carbon tax for household demands and the distribution of welfare changes arising from the price changes resulting from a carbon tax, see Creedy and Sleeman (2004).

2 An Input-Output Approach

This section presents the framework of analysis used to compute minimum disruption changes. Subsection 2.1 derives an expression for total carbon dioxide emissions, using an input-output approach. Subsection 2.2 derives the minimum disruption changes to final demands necessary to achieve a required rate of reduction in total emissions, and subject to growth and employment constraints. Finally, subsection 2.3 examines the changes in the fuel use coefficients required to achieve a target carbon dioxide emissions reduction.

2.1 Total Carbon Dioxide Emissions

Consider increasing the final consumption of a good by $1. The problem is to evaluate how much carbon dioxide this would involve. This increase in the final demand by $1 involves a larger increase in the gross, or total output, of the good - as well as requiring increases in the outputs of other goods. This is because intermediate goods, including the particular good of interest, are needed in the production process. The extent to which there is an increase in carbon dioxide depends also on the intermediate requirements of all goods which are themselves intermediate requirements for the particular good. Indeed, the sequence of intermediate requirements continues until it 'works itself out', that is, the additional amounts needed become negligible. This is in fact a standard multiplier process. It can be set out formally as follows.

An industry's gross output derives from both intermediate output which serves as input to other industries and final demand. Let x_{ij} denote the value of output flowing from industry i to industry j and let y_i denote the value of final demand, by consumers, for the output of industry i. The value of an industry's gross output, x_i, may therefore be expressed as the sum of intermediate and final demands:

$$x_i = \sum_j x_{ij} + y_i \tag{1}$$

The direct requirement co-efficient, a_{ij}, measures the value of output from industry i directly required to produce $1 worth of output in industry j. Hence:

$$a_{ij} = \frac{x_{ij}}{x_i} \tag{2}$$

Using (2) to write $x_{ij} = a_{ij}x_i$ and substituting the resulting expression into equation (1) gives gross output as:

$$x_i = \sum_j a_{ij}x_i + y_i \tag{3}$$

Let x and y denote the n-element vectors of x_i and y_i respectively. Further, let A denote the $(n \times n)$ matrix of the direct requirement coefficients, a_{ij}. These definitions enable the system of n equations described in equation (3) to be expressed in matrix notation as:

$$x = Ax + y \tag{4}$$

Continuous substitution for x on the right-hand side of equation (4) produces the following geometric sequence:

$$x = A[Ax + y] + y$$
$$x = A[A\{Ax + y\} + y] + y$$
$$x = [I + A + A^2 + A^3 + \ldots + A^\infty x]y \quad (5)$$

If the condition $\lim_{n \to \infty} A^n = 0$ is satisfied, the system is productive and the non-negative solution is:[3]

$$x = (1 - A)^{-1} y \quad (6)$$

and $(I - A)^{-1}$ is the matrix multiplier required.

Let F denote the $(n \times k)$ matrix of energy requirements (in PJs) for n industries across k fossil fuel types. Let e denote the k-element vector of CO_2 emissions (tonnes of carbon dioxide) per unit of energy (PJ) associated with each of the k fossil fuels.

Multiplying the transpose of the e vector by the transpose of the F matrix gives the following row vector which contains the carbon dioxide emissions per unit of gross output from each industry:

$$e'F' = [e_1 \ldots\ldots e_k] \begin{bmatrix} f_{11} & \cdots & f_{n1} \\ \vdots & & \vdots \\ f_{1k} & \cdots & f_{nk} \end{bmatrix} \quad (7)$$

Total carbon dioxide emissions, E, can then be obtained by post-multiplying the above row vector by the column vector of gross output, x :

$$E = e'F'x$$
$$E = [e'F'(1 - A)^{-1}]y \quad (8)$$

The term in square brackets gives the row vector, c', of the carbon dioxide intensities:

$$c' = e'F'(I - A)^{-1} \quad (9)$$

Equation (8) is used in determining the necessary structural changes to achieve a specified reduction in emissions. Proops et al (1993, pp.11-12) identified three main areas where a change in economic structure might give rise to reductions in carbon dioxide emissions. First, there are changes to final demands, y. Second, there are changes to the efficiency of fuel use, F. Third, changes to the structure of inter-industry trading, A can be made.

The objective is to minimise the disruption to industries with regard to one of these variables while achieving a specified reduction in emissions. Disruption to any variable, z_i say, in industry i is measured in terms of the proportional change in that variable, $\dot{z}_i$. In specifying an objective function, Proops et al (1993, p.228) adopted a quadratic cost function, but it is useful to consider the more general form given by:

$$D = \frac{1}{\theta} \sum_{i=1}^{n} \dot{z}_i^\theta \quad (10)$$

[3] This is given from the solution to the geometric matrix series $S = I + A + A^2 + \ldots = (I - A)^{-1}$, which must be non-negative given that all elements of A are either zero or positive. For the system to be productive it is not merely sufficient for (4) to have a solution. The convergence requirement is equivalent to the Hawkin-Simons conditions.

The term θ is simply a scaling factor which drops out in differentiation. This objective function assumes that there is an equal social cost associated with a 1 percentage point change in a certain variable, irrespective of the industry.[4]

2.2 Disruptions to Final Demands

Consider first the problem of minimising the disruption to final demand. To impose no more than a constraint on the amount of emissions reduction is obviously not a case that should be considered seriously. In particular, the required final demand changes would all be negative. However, this case serves to introduce the basic approach adopted.[5]

Total emissions, when written in algebraic as opposed to matrix form are equal to $E = \sum_{i=1}^{n} c_i y_i$, so that:

$$\frac{dE}{E} = \sum_{i=1}^{n} \left(\frac{c_i y_i}{\sum_{i=1}^{n} c_i y_i} \right) \frac{dy_i}{y} \tag{11}$$

If R is the required proportional change in total carbon dioxide emissions $\left[R = \frac{dE}{E} \right]$, the constraint can be written as:

$$R = \sum_{i=1}^{n} w_i \dot{y}_i \tag{12}$$

where w_i is i's share of emissions, and $\dot{y}_i$ denotes the proportional change in final demand for industry i. The Lagrangean for this problem is given by:

$$L = \frac{1}{\theta} \sum_{i=1}^{n} \dot{y}_i^{\theta} + \lambda \left[R - \sum_{i=1}^{n} w_i \dot{y}_i \right] \tag{13}$$

Differentiation gives the set of first-order conditions:

$$\dot{y}_i = \left(\lambda w_i \right)^{1/(\theta - 1)} \tag{14}$$

Multiplying equation (14) by w_i , adding over all industries, and solving for λ gives:

$$\lambda = \left[\frac{R}{\sum_{i=1}^{n} w_i^{\theta/(\theta-1)}} \right]^{\theta - 1} \tag{15}$$

Substituting this result into the first-order condition gives the solution for the required proportional reduction in output of:

[4] It might be argued that there should be some weighting attached to the different industries, according to each industry's proportional contribution to the total level of an appropriate variable, such as aggregate employment. However, the method imposes constraints on such variables, so that further weighting is not necessary. Indeed, it can be shown that such further weighting is not possible if the weighting mechanism desired uses the same variable as that already accounted for in the constraint.

[5] Allowing for these factors handles the problem of weighting discussed above, as doing so implicitly attaches weights according to each industry's contribution to the total level of the constraint variable in question.

$$\dot{y}_i = R\left[\frac{w_i^{1/(\theta-1)}}{\sum_{i=1}^{n} w_i^{\theta/(\theta-1)}}\right] \tag{16}$$

This result shows that the larger is θ, the smaller is the dispersion in the required rates of change. Therefore, increasing the power ultimately leads toward an equalisation of the proportional changes. Furthermore, when additional constraints are imposed, the first-order conditions cannot be solved explicitly. For this reason, the quadratic form is retained in this study, and the substitution of $\theta = 2$ gives the result, as in Proops et al (1993, p.144), that:

$$\dot{y}_i = R\left[\frac{w_i}{\sum_{i=1}^{n} w_i^2}\right] \tag{17}$$

Carbon Dioxide and GDP Growth Targets

It is appropriate to include a constraint on GDP growth in addition to the constraint on the level of carbon dioxide emissions reduction. This constraint can be written as:

$$G = \sum_{i=1}^{n} w_i^Y \dot{y}_i \tag{18}$$

where G represents the desired rate of growth, expressed as a weighted sum of the changes in final demands once again, with each weight being the proportion of that industry's contribution to total GDP, that is $w_i^Y = y_i / \sum_{i=1}^{n} y_i$. The Lagrangean for this problem is:

$$L = \frac{1}{2}\sum_{i=1}^{n} \dot{y}_i^2 + \lambda\left[R - \sum_{i=1}^{n} w_i \dot{y}_i\right] + \mu\left[G - \sum_{i=1}^{n} w_i^Y \dot{y}_i\right] \tag{19}$$

Differentiating with respect to each of the $\dot{y}_i$ gives rise to the first-order conditions:

$$\frac{\partial L}{\partial \dot{y}_i} = \dot{y}_i - \lambda w_i - \mu w_i^Y = 0 \tag{20}$$

along with the two constraints relating to R and G. Using $\dot{y}_i = \lambda w_i + \mu w_i^Y$ from the first-order conditions and substituting into the constraints gives the resulting two simultaneous equations:

$$\begin{bmatrix} R \\ G \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{n} w_i^2 & \sum_{i=1}^{n} w_i w_i^Y \\ \sum_{i=1}^{n} w_i w_i^Y & \sum_{i=1}^{n} \left(w_i^Y\right)^2 \end{bmatrix} \begin{bmatrix} \lambda \\ \mu \end{bmatrix} \tag{21}$$

If the determinant of this matrix is written as Δ, the solutions for the Lagrange multipliers are:

$$\begin{bmatrix} \lambda \\ \mu \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} R\sum_{i=1}^{n} \left(w_i^Y\right)^2 - G\sum_{i=1}^{n} w_i w_i^Y \\ -R\sum_{i=1}^{n} w_i w_i^Y + G\sum_{i=1}^{n} w_i^2 \end{bmatrix} \tag{22}$$

The resulting multipliers can be substituted into the first-order conditions to solve for the $\dot{y}_i$ s; see also Proops et al (1993, pp.234-235).[6]

Carbon Dioxide, GDP and Employment Targets

An additional constraint concerns the rate of growth in employment, M. This is expressed as:

$$M = \sum_{i=1}^{n} w_i^m \dot{y}_i \tag{23}$$

where the weights w_i^m are the levels of employment in each industry as a proportion of total employment. Minimising the disruption to final demands subject to all three constraints simultaneously, involves the Lagrangean:

$$L = \frac{1}{2}\sum_{i=1}^{n} \dot{y}_i^2 + \lambda\left[R - \sum_{i=1}^{n} w_i \dot{y}_i\right] + \mu\left[G - \sum_{i=1}^{n} w_i^Y \dot{y}_i\right] + \gamma\left[M - \sum_{i=1}^{n} w_i^m \dot{y}_i\right] \tag{24}$$

In this case there are three Lagrangean multipliers, so that a set of three linear equations can be solved using matrix methods. The procedure is a simple extension of that described above; see also Proops et al (1993, pp.238-9).

2.3 Disruptions to Fuel-use Coefficients

As an alternative to minimising changes to the vector of final demands, consider minimising the change in fuel-use coefficients subject to a carbon dioxide emissions-reduction target. The direct fuel-use coefficients are embodied in the matrix, F. The objective is to minimise:

$$D = \frac{1}{2}\sum_{i=1}^{n} \sum_{j=1}^{K} \dot{f}_{ij}^2 \tag{25}$$

where $f_{i,j}$ represents the proportional change in the production fuel requirement per unit of total demand of fuel j in industry i. The change is minimised subject to the constraint that a target proportional reduction, R_F, in carbon dioxide emissions, attributable to changes in the production fuel-use coefficients, is achieved. Given that total emissions are $E = \sum_{i=1}^{n} \sum_{j=1}^{K} f_{ij} e_j x_i$, differentiation gives:

$$\frac{dE}{E} = \sum_{i=1}^{n} \sum_{j=1}^{K} \frac{f_{ij} e_j x_i}{E} \frac{df_{ij}}{f_{ij}} \tag{26}$$

[6] If weights equal to the proportional contribution of each industry to total GDP are attached to $\dot{y}_i^2$, the Lagrangean multipliers are not identified. That is, the constraints on the carbon dioxide emission target and the rate of growth of GDP, R and G, become equal to the sums of the Lagrangean multipliers, thus illustrating how additional weighting is not appropriate.

This can be rewritten as:

$$R_F = \sum_{i=1}^{n} \sum_{j=1}^{K} w_{ij} \dot{f}_{ij} \tag{27}$$

Hence R_C is a weighted row and column sum of the production fuel-use-coefficients, with each weight given by $w_{ij} = f_{ij} e_j x_i / E$, that is the proportional contribution to emissions of fuel j in industry i. The Lagrangean is therefore:

$$L = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{K} \dot{f}_{ij}^{2} + \lambda \left[R_F - \sum_{i=1}^{n} \sum_{j=1}^{K} w_{ij} \dot{f}_{ij} \right] \tag{28}$$

Following Proops et al (1993, pp.241, 144), solving this yields:

$$\dot{f}_{ij} = \left[\frac{w_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{K} w_{ij}^{2}} \right] R_F \tag{29}$$

3 Fuel Use and Carbon Content in New Zealand

This section outlines the data and approach used to evaluate the expressions, derived in the previous section, for New Zealand.

The "Inter Industry Study of 1996" from New Zealand's System of National Accounts provided inter-industry flows in value terms for a 49 industry group classification (IGC).[7] These flows were divided by each industry's gross output to produce the direct requirement coefficients which were then collected to form the (49×49) A matrix.

By subtracting each industry's intermediate output from their gross output, the Accounts were also used to compile the 49-element y vector of final demands.

The F matrix was constructed from New Zealand's Energy Flow Accounts which provided the energy use arising from the fossil fuels, expressed in physical terms (PJs), for the year ended March 1996 based on the Energy Account Industry Classification (EAIC). The translation between the Energy Account Industry Classification (EAIC) and the 49 industry group classification (IGC) which was used for the analysis is provided in Table A1. Only those fuels for which at least one industry recorded a positive expenditure were incorporated, which provided nine fossil fuels for analysis. Table A2 provides information about the demands for these fuels which are expressed in physical terms and based on the 49 industry group classification (IGC). Dividing these figures by each industry's gross output provided the required elements of the (49×9) F matrix.

Compiling the 9-element e vector of carbon dioxide emissions entailed obtaining data from multiple sources. Table 1 outlines the carbon dioxide emission factors for each of the nine fossil fuels analysed, along with their sources.

[7] This is the most recent year for which the data are available.

Table 1 – Carbon Dioxide Emission Factors: Tonnes / PJ

Fuel	CO_2 Emissions	Source
Coal	90,010	Statistics NZ (1993, Table 4.5, p21)
Lignite	95,200	Statistics NZ (1993, Table 4.5, p21)
Crude Petroleum	65,100	Taylor et al (1993, Table 6.6, p35)
Natural Gas	52,600	MED (2003, Table A.1.1, p114)
LPG	60,400	Baines (1993, Table 5.7, p30)
Petrol	66,600	Baines (1993, Table 6.6, p35)
Diesel	68,700	Baines (1993, Table 6.6, p35)
Fuel Oil	73,700	Baines (1993, Table 6.6, p35)
Aviation Fuels & Kerosene	68,700	Baines (1993, Table 6.6, p35)

The resulting values of e, F and A were used to calculate the 49-element c vector of carbon dioxide intensities, using the expression $c' = e'F'(I - A)^{-1}$ derived in subsection 2.1. The results of this calculation are provided in Table A3.

It is not surprising that petroleum and industrial chemical manufacturing (industry no. 18), which demands the greatest quantity of fuel across all industries, recorded by far the highest carbon content of 3.64 tonnes of carbon dioxide per dollar of gross output. Rubber, plastic and other chemical product manufacturing (industry no. 19) and basic metal manufacturing (industry no. 21) which respectively demand the largest quantities of natural gas and coal record similarly high carbon contents of 1.83 and 1.40 tonnes of carbon dioxide per dollar of gross output. The only other industry to record a carbon content in excess of 1, was electricity generation and supply (industry no. 26) with 1.21.

4 Minimum Disruption Calculations

This section applies to New Zealand the minimum disruption approach described in section 2.

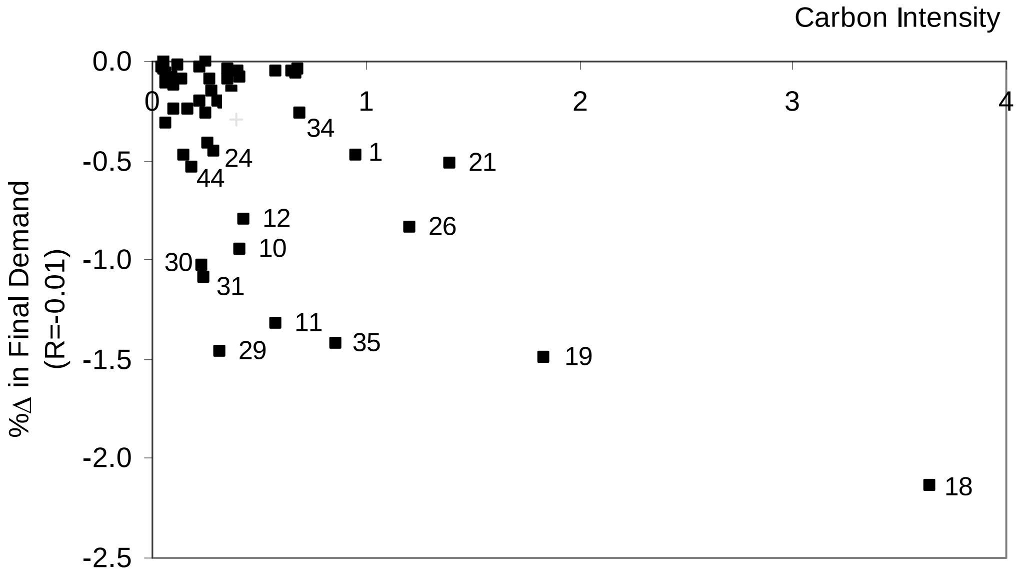
4.1 Final Demands

Table 2 provides the annual changes to the elements of the final demand vector, y, which minimise disruptions to final demand while satisfying the constraints described. All values are expressed in percentage terms. Additionally, Table 2 gives the final demand, carbon intensity and employment weight of each industry.

Column 4 of Table 2, labeled R only, represents the results of the minimum disruption approach where the only constraint is a 1 percent reduction in carbon dioxide emissions. Accordingly, all industries are required to reduce their final demand. The largest annual rate of reduction in final demand is for petroleum and industrial chemical manufacturing (industry no. 18) at -2.141 percent, followed by rubber, plastic and other chemical product manufacturing (industry no. 19) at -1.491 percent and construction (industry no. 29) at -1.462 percent.

The annual reductions in final demand are proportional to the carbon dioxide intensities of each industry, as seen from equation (17). Therefore, those industries whose products are most carbon intensive are required to achieve the greatest reductions in final demand, as shown by Figure 1. In addition, the changes in final demand required to achieve a 2 percent reduction in carbon dioxide emissions are simply double those for the 1 percent case. For this reason, they are not displayed in Table 2.

Figure 1 – Carbon Intensity and Changes in Final Demands with Carbon Dioxide Reductions Only



As mentioned in section 2, these reductions should not be viewed as realistic values to be pursued, but instead benchmarks against which later results may be compared.

Demand Changes with a GDP Growth Constraint

Column 5 reports the changes to final demand when 2 percent growth in GDP is imposed in addition to the 1 percent reduction in carbon dioxide emissions. The two constraints exert opposing influences on final demand. The GDP growth constraint prompts increases in final demand, while the carbon dioxide constraint necessitates reductions.

The objective function requires minimising the sum of the square of the proportionate changes in final demand of each industry. To achieve the GDP growth constraint, increasing the final demands of industries which have relatively larger final demands, gives smaller proportionate changes, thereby minimising the objective function. Figure 2 clearly shows the positive correlation between the final demand of an industry and its associated required change in final demand. Similarly, in achieving the carbon constraint, industries whose outputs have higher carbon contents achieve greater reductions in emissions for given reductions in final demand. The negative correlation between carbon content per dollar of output and the required change in final demand is shown in Figure 3.

An industry's required change in final demand is therefore determined by balancing the carbon intensity of output against the level of final demand. Accordingly, ownership of owner-occupied dwellings (industry no. 41) which has the largest final demand coupled with one of the smallest carbon contents is required to achieve the largest increase in final demand of 8.4695 percent. Similarly, health and community services (industry no. 47), wholesale trade (industry no. 30), retail trade (industry no. 31) and education (industry no. 46) are all required to achieve substantial increases in final demand. All four of these industries may be classified as service industries which produce low carbon dioxide emissions, yet have high levels of final demand. Regarding industries required to reduce their final demand, petroleum and industrial chemical manufacturing (industry no. 18) and rubber, plastic and other chemical product manufacturing (industry no. 19), which have the two highest carbon intensities require the greatest reductions in final demand of respectively -9.5474 and -5.8031 percent.

Figure 2 – Final Demand and Changes in Final Demands with Growth of 2 Percent

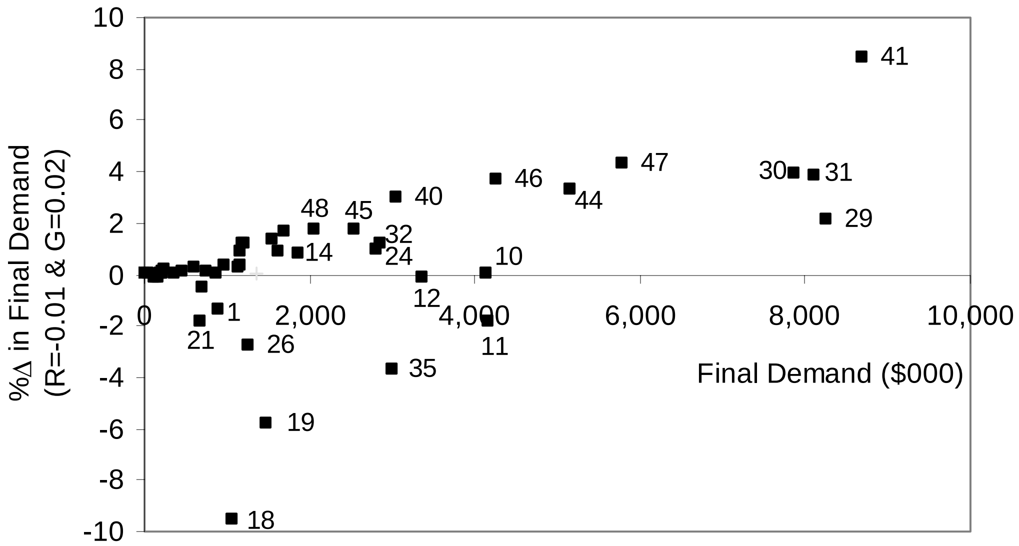
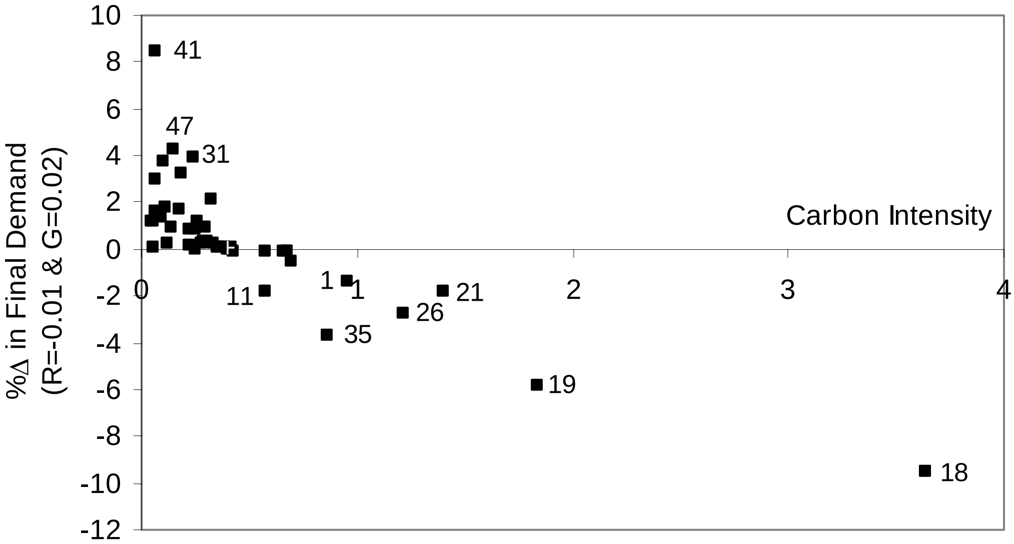
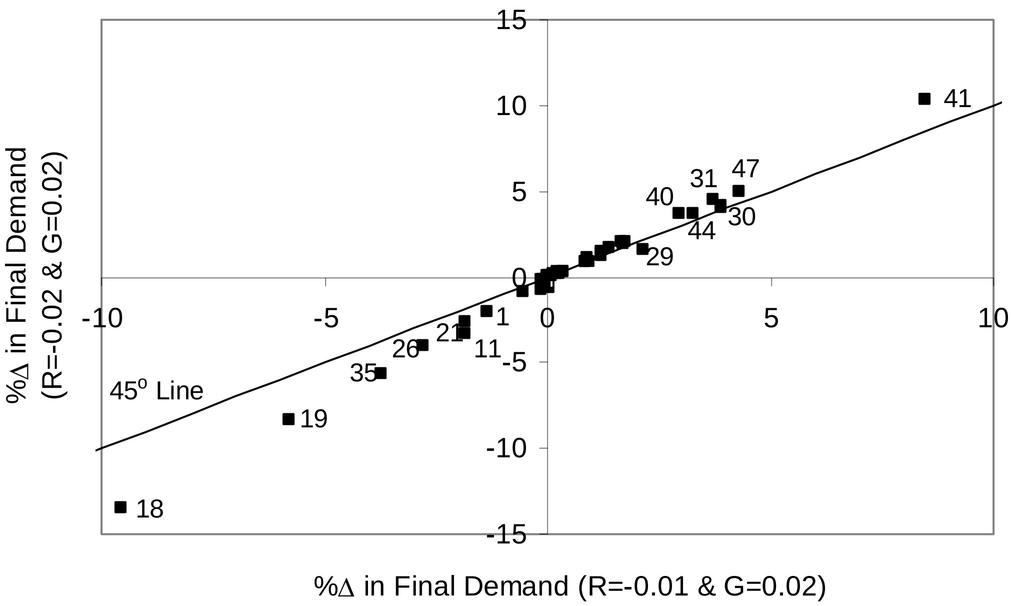


Figure 3 – Carbon Intensity and Changes in Final Demands with Growth of 2 Percent



Column 7 of Table 2 shows the required changes to final demand when the carbon dioxide constraint is raised from 1 to 2 percent, while holding the GDP growth constraint constant. Variations in the changes to final demand which arise from raising the carbon constraint are displayed in Figure 4. If the points were all to lie on the 45 degree line, the higher carbon constraint would have no effect. However, as Figure 4 clearly shows, the higher constraint requires greater reductions to be achieved in final demand. Consequently, increases in final demand must also be accentuated so as to achieve the growth constraint. These two effects combine to increase the spread of the distribution, thereby increasing the costs of disruption. However, the relative positions of the industries are seen to change only slightly.

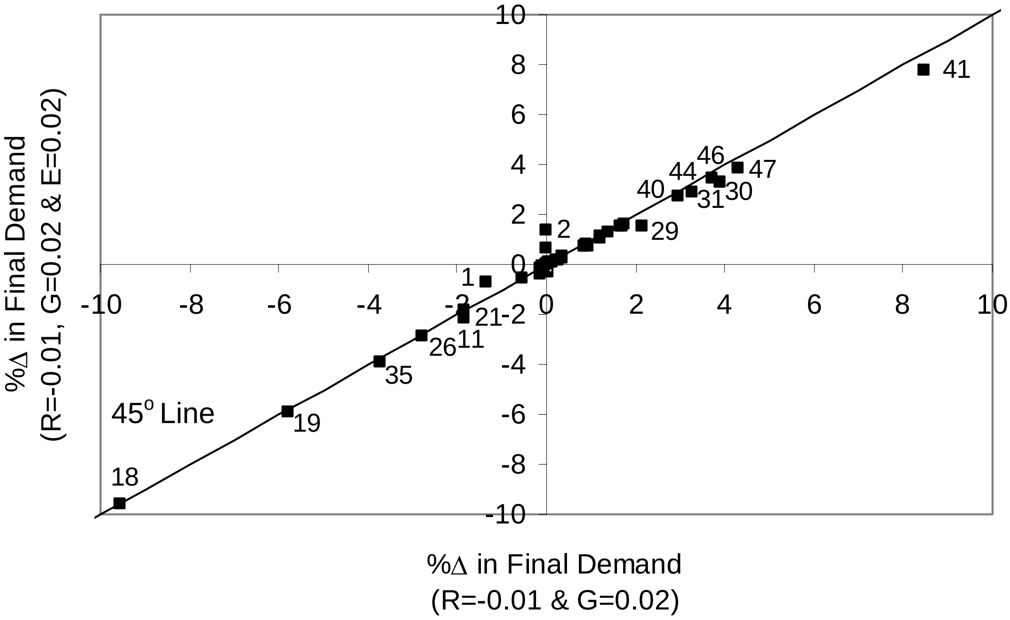
Figure 4 – Changes in Final Demands and Raising the CO_2 Reduction Target



Demand Changes with GDP and Employment Growth Constraints

Proops et al (1993, p.252) imposed a 2 percent growth constraint on both GDP and employment, 'so that the growing productivity of labour [could] be taken into account, without needing the labour coefficients to be altered'. Both constraints, in addition to the 1 percent reduction in carbon dioxide emissions, were used to generate the results shown in column 6 of Table 2. In similar fashion to Figure 4, Figure 5 analyses the impact on the required changes to final demand caused by the employment constraint.

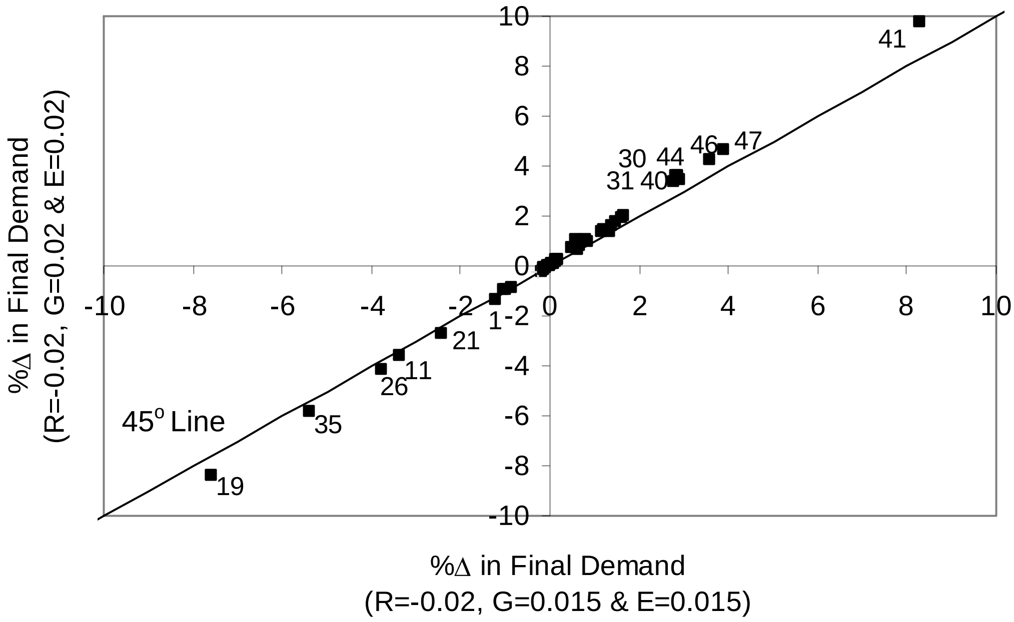
Figure 5 – Changes in Final Demands and the Introduction of an Employment Constraint



The additional constraint is seen to cause very little variation to the required changes in final demand. This should not be surprising as those industries which have the largest final demands and consequently employ the greatest proportion of workers also require the largest increases in final demands to achieve 2 percent growth in GDP. Furthermore, in achieving this growth, a certain level of growth in employment is essential. Consequently, making the employment constraint explicit makes very little difference to the required changes in final demand.

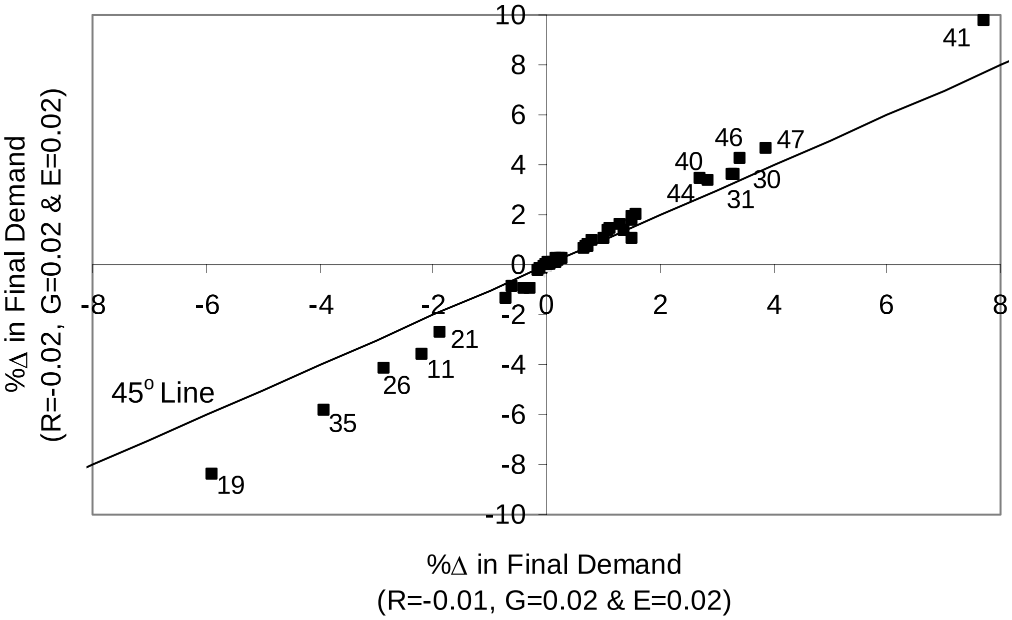
Shown in the final two columns of Table 2 and contrasted in Figure 6 are the minimum disruption changes to final demand which arise from respectively 1.5 and 2 percent growth rates in GDP and employment, holding constant a 2 percent reduction in carbon dioxide emissions. The higher growth rate of 2 percent necessitates greater increases in final demand, which are sought from those industries which already required the largest increases in the case of the 1.5 percent growth rate. The resulting rise in carbon dioxide emissions is countered almost solely by one industry, rubber, plastic and other chemical product manufacturing (industry no. 19), which is required to reduce its final demand by a further 0.8 percent. These changes at the extremes of the distribution again increase the spread which leads to further increases in the cost of adjustment.

Figure 6 – Changes in Final Demand and an Increase in the Growth Rates



This result is magnified when the minimum disruptions of columns 6 and 9 are contrasted. Figure 7 shows the required changes to final demand in the case of 1 and 2 percent reductions in carbon dioxide emissions, holding constant 2 percent growth rates in GDP and employment. Achieving the 1 percentage point increase in the carbon constraint clearly requires relatively greater changes in final demand than that which was required to achieve the 0.5 percentage point increase in both growth rates.

Figure 7 – Changing the CO_2 Reduction Requirement, with Growth and Employment Constraints



4.2 Changes in Fuel Mix

This subsection examines the annual minimum disruption changes to fuel efficiency and use necessary to reduce carbon dioxide emissions by 1 percent.

The elements of the F matrix, which describe the quantity of fuel required per unit of gross output, vary subject only to the carbon reduction constraint being achieved. Consequently, the changes given in Table 3 are all non-positive values, which are again expressed in percentage terms.

The largest annual rate of change required is in the use of crude petroleum by petroleum and industrial chemical manufacturing (industry no. 18). The only other required change over one percent is in the use of natural gas by rubber, plastic and other chemical product manufacturing (industry no. 19). All other changes are either zero or negligible, suggesting that achieving a 1 percent reduction in carbon dioxide emissions purely through fuel substitution is feasible.

The required changes to the fuel-use coefficients are again proportional to the carbon dioxide intensity of each fuel for each industry. Consequently, the changes required for a 2 percent reduction in carbon dioxide emissions are simply double those shown in Table 3 and for this reason are not reported.

Table 2 – Minimum Disruption Changes to Final Demand

						R = -0.01				
IGC Code	IGC Description	Final Demand	Carbon Intensity	Employment Weight	R Only	G = 0.02	G = 0.02 E = 0.02	G = 0.02	G = 0.015 E = 0.015	G = 0.02 E = 0.02
1	Horticulture and fruit growing	896,214	0.96	0.017	-0.472	-1.3425	-0.7122	-2.0309	-1.2052	-1.3886
2	Livestock and cropping farming	213,229	0.40	0.034	-0.047	0.0077	1.3626	-0.0260	1.3268	1.3320
3	Dairy cattle farming	213,893	0.40	0.017	-0.047	0.0096	0.6760	-0.0235	0.6405	0.6460
4	Other farming	161,922	0.58	0.001	-0.051	-0.0715	-0.0837	-0.1278	-0.1302	-0.1377
5	Services to agriculture, hunting and trapping	111,614	0.68	0.007	-0.042	-0.0811	-0.0852	-0.1326	-0.1254	-0.1354
6	Forestry and logging	1,127,374	0.34	0.005	-0.208	0.2545	0.1646	0.1615	0.0286	0.0880
7	Fishing	173,891	0.68	0.002	-0.065	-0.1255	-0.1379	-0.2053	-0.1999	-0.2153
8	Mining and quarrying	367,660	0.41	0.003	-0.083	0.0057	-0.0225	-0.0553	-0.0862	-0.0783
9	Oil & gas exploration & extraction	229,624	0.23	0.000	-0.029	0.1206	0.1014	0.1291	0.0909	0.1133
10	Meat and meat product manufacturing	4,150,526	0.41	0.015	-0.945	0.0335	-0.2953	-0.6680	-1.0210	-0.9370
11	Dairy product manufacturing	4,174,399	0.58	0.006	-1.324	-1.8512	-2.1799	-3.3065	-3.3793	-3.5762
12	Other food manufacturing	3,370,380	0.43	0.015	-0.795	-0.1136	-0.3781	-0.7392	-1.0026	-0.9553
13	Beverage, malt and tobacco manufacturing	1,171,464	0.31	0.003	-0.198	0.3569	0.2619	0.2971	0.1437	0.2193
14	Textile and apparel manufacturing	1,854,639	0.25	0.016	-0.258	0.8435	0.6995	0.8596	0.5814	0.7427
15	Wood product manufacturing	877,534	0.39	0.010	-0.188	0.0667	0.0015	-0.0580	-0.1373	-0.1106
16	Paper & paper product manufacturing	1,357,094	0.40	0.006	-0.297	0.0728	-0.0344	-0.1320	-0.2563	-0.2196
17	Printing, publishing & recorded media	594,218	0.28	0.015	-0.090	0.2337	0.1944	0.2244	0.1471	0.1934
18	Petroleum and industrial chemical manufacturing	1,069,290	3.64	0.003	-2.141	-9.5474	-9.5919	-13.5292	-12.1604	-13.5655
19	Rubber, plastic and other chemical product manufacturing	1,478,374	1.83	0.011	-1.491	-5.8031	-5.8915	-8.3660	-7.5995	-8.4377
20	Non-metallic mineral product manufacturing	144,620	0.66	0.004	-0.052	-0.0958	-0.1042	-0.1588	-0.1538	-0.1654
21	Basic metal manufacturing	671,546	1.40	0.005	-0.516	-1.8257	-1.8692	-2.6676	-2.4431	-2.7028
22	Structural, sheet and fabricated metal product manufacturing	761,224	0.37	0.017	-0.155	0.0981	0.0473	0.0061	-0.0634	-0.0341
23	Transport equipment manufacturing	1,629,210	0.23	0.006	-0.202	0.8661	0.7338	0.9300	0.6615	0.8218
24	Machinery & equipment manufacturing	2,805,651	0.29	0.019	-0.452	0.9610	0.7407	0.8601	0.4837	0.6806
25	Furniture and other manufacturing	977,413	0.29	0.011	-0.153	0.3566	0.2828	0.3301	0.1985	0.2704
26	Electricity generation and supply	1,256,515	1.21	0.005	-0.837	-2.7632	-2.8508	-4.0787	-3.7616	-4.1503

IGC Code	IGC Description	Final Demand	Carbon Intensity	Employment Weight	R Only	R = -0.01 G = 0.02	G = 0.02 E = 0.02	G = 0.02	G = 0.015 E = 0.015	G = 0.02 E = 0.02
27	Gas supply	188,335	0.36	0.001	-0.037	0.0307	0.0157	0.0105	-0.0099	-0.0017
28	Water supply	720	0.26	0.001	0.000	0.0003	0.0008	0.0003	0.0007	0.0008
29	Construction	8,246,331	0.32	0.066	-1.462	2.1587	1.5212	1.5971	0.5994	1.0789
30	Wholesale trade	7,874,809	0.24	0.049	-1.031	3.8996	3.2738	4.0945	2.8520	3.5844
31	Retail trade	8,105,204	0.24	0.130	-1.086	3.8902	3.3003	4.0416	2.8326	3.5684
32	Accommodation, restaurants and bars	2,859,420	0.26	0.044	-0.412	1.2253	1.0166	1.2202	0.8150	1.0526
33	Road transport	456,138	0.35	0.017	-0.088	0.0819	0.0557	0.0359	-0.0051	0.0159
34	Water and rail transport	693,698	0.70	0.005	-0.266	-0.5385	-0.5891	-0.8722	-0.8462	-0.9133
35	Air transport, services to transport and storage	3,001,753	0.86	0.019	-1.424	-3.7048	-3.9212	-5.6955	-5.3757	-5.8716
36	Communication services	1,706,165	0.07	0.018	-0.063	1.6531	1.5192	2.0168	1.6290	1.9084
37	Finance	1,181,042	0.05	0.022	-0.032	1.2017	1.1154	1.4764	1.2054	1.4074
38	Insurance	1,205,743	0.06	0.004	-0.039	1.1942	1.0936	1.4615	1.1779	1.3792
39	Services to finance and insurance	50,149	0.06	0.008	-0.002	0.0497	0.0507	0.0608	0.0540	0.0624
40	Real estate	3,053,166	0.06	0.012	-0.109	2.9764	2.7226	3.6345	2.9243	3.4269
41	Ownership of owner-occupied dwellings	8,693,724	0.07	0.000	-0.311	8.4695	7.7241	10.3411	8.2982	9.7282
42	Equipment hire and investors in other property	249,195	0.12	0.000	-0.016	0.2059	0.1847	0.2448	0.1919	0.2274
43	Business services	1,561,393	0.10	0.090	-0.082	1.3895	1.3170	1.6733	1.3841	1.6218
44	Central government administration, defence, public order and safety services	5,158,249	0.19	0.044	-0.533	3.2718	2.8666	3.6848	2.7687	3.3556
45	Local Government Administration Services and Civil Defence	2,537,488	0.17	0.014	-0.241	1.7173	1.5127	1.9634	1.4917	1.7965
46	Education	4,272,040	0.10	0.076	-0.239	3.7313	3.4180	4.4797	3.5902	4.2290
47	Health and community services	5,793,658	0.15	0.072	-0.474	4.3032	3.8607	5.0170	3.9066	4.6597
48	Cultural and recreational services	2,047,472	0.11	0.022	-0.121	1.7534	1.5937	2.0983	1.6680	1.9689
49	Personal and other community services	1,158,033	0.14	0.031	-0.087	0.9006	0.8229	1.0593	0.8416	0.9982

Table 3 – Minimum Disruption Changes to Fuel-Use: R = -0.010

IGC Code	IGC Description	Percentage Changes in the F Matrix								
		Coal	Lignite	Crude Petroleum	Natural Gas	LPG	Petrol	Diesel	Fuel Oil	Aviation Fuels & Kerosene
1	Horticulture and fruit growing	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0870	-0.1610	0.0000	-0.0010
2	Livestock and cropping farming	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0210	-0.0380	0.0000	0.0000
3	Dairy cattle farming	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0210	-0.0380	0.0000	0.0000
4	Other farming	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0160	-0.0290	0.0000	0.0000
5	Services to agriculture, hunting and trapping	0.0000	0.0000	0.0000	-0.0060	0.0000	-0.0110	-0.0720	-0.0070	0.0000
6	Forestry and logging	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0110	-0.0280	0.0000	0.0000
7	Fishing	0.0000	0.0000	0.0000	-0.0100	0.0000	0.0000	-0.0810	-0.0110	0.0000
8	Mining and quarrying	-0.0110	0.0000	0.0000	0.0000	0.0000	-0.0030	-0.0240	-0.0030	0.0000
9	Oil & gas exploration & extraction	-0.0070	0.0000	0.0000	0.0000	0.0000	-0.0020	-0.0150	-0.0020	0.0000
10	Meat and meat product manufacturing	-0.0530	-0.0080	0.0000	-0.0160	-0.0060	-0.0070	-0.0020	-0.0030	0.0000
11	Dairy product manufacturing	-0.1350	-0.0200	0.0000	-0.0610	-0.0010	0.0000	-0.0270	-0.0090	0.0000
12	Other food manufacturing	-0.0130	-0.0020	0.0000	-0.0360	-0.0080	-0.0250	-0.0160	-0.0140	0.0000
13	Beverage, malt and tobacco manufacturing	-0.0040	-0.0010	0.0000	-0.0120	-0.0030	-0.0090	-0.0060	-0.0050	0.0000
14	Textile and apparel manufacturing	-0.0130	-0.0020	0.0000	-0.0130	-0.0010	-0.0020	-0.0090	-0.0070	0.0000
15	Wood product manufacturing	-0.0070	-0.0010	0.0000	-0.0130	-0.0010	0.0000	-0.0030	-0.0130	0.0000
16	Paper & paper product manufacturing	-0.0130	-0.0020	0.0000	-0.0360	-0.0020	0.0000	-0.0010	-0.0250	0.0000
17	Printing, publishing & recorded media	-0.0060	-0.0010	0.0000	-0.0160	-0.0010	0.0000	-0.0010	-0.0110	0.0000
18	Petroleum and industrial chemical manufacturing	0.0000	0.0000	-2.5730	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19	Rubber, plastic and other chemical product manufacturing	-0.0070	-0.0010	0.0000	-1.1790	-0.0030	-0.0020	-0.0440	-0.0110	0.0000
20	Non-metallic mineral product manufacturing	-0.1000	-0.0150	0.0000	-0.0150	-0.0100	0.0000	-0.0060	-0.0020	0.0000
21	Basic metal manufacturing	-0.3240	0.0000	0.0000	-0.1090	-0.0060	0.0000	-0.0030	-0.0420	0.0000
22	Structural, sheet and fabricated metal product manufacturing	0.0000	0.0000	0.0000	-0.0020	-0.0010	-0.0010	-0.0080	-0.0010	0.0000
23	Transport equipment manufacturing	-0.0010	0.0000	0.0000	-0.0040	-0.0030	-0.0020	-0.0170	-0.0020	0.0000
24	Machinery & equipment manufacturing	-0.0010	0.0000	0.0000	-0.0070	-0.0050	-0.0030	-0.0300	-0.0030	0.0000
25	Furniture and other manufacturing	-0.0020	0.0000	0.0000	-0.0020	0.0000	-0.0020	0.0000	0.0000	0.0000

IGC Code	IGC Description	Percentage Changes in the F Matrix								
		Coal	Lignite	Crude Petroleum	Natural Gas	LPG	Petrol	Diesel	Fuel Oil	Aviation Fuels & Kerosene
26	Electricity generation and supply	-0.1240	0.0000	0.0000	-0.6980	0.0000	-0.0010	-0.0020	0.0000	0.0000
27	Gas supply	-0.0050	0.0000	0.0000	0.0000	0.0000	-0.0020	-0.0120	-0.0020	0.0000
28	Water supply	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0010	0.0000	0.0000
29	Construction	0.0000	0.0000	0.0000	-0.0020	-0.0090	-0.0340	-0.1280	0.0000	-0.0030
30	Wholesale trade	-0.0180	-0.0010	0.0000	-0.0050	-0.0050	-0.1690	-0.0140	-0.0010	0.0000
31	Retail trade	-0.0220	-0.0010	0.0000	-0.0140	-0.0060	-0.1940	-0.0140	-0.0010	0.0000
32	Accommodation, restaurants and bars	-0.0010	0.0000	0.0000	-0.0130	-0.0060	-0.0120	-0.0030	-0.0100	0.0000
33	Road transport	0.0000	0.0000	0.0000	-0.0030	0.0000	-0.0190	-0.0390	-0.0060	-0.0640
34	Water and rail transport	0.0000	0.0000	0.0000	-0.0040	0.0000	-0.0280	-0.0600	-0.0090	-0.0970
35	Air transport, services to transport and storage	-0.0010	0.0000	0.0000	-0.0170	0.0000	-0.1230	-0.2580	-0.0400	-0.4200
36	Communication services	0.0000	0.0000	0.0000	-0.0010	0.0000	-0.0140	-0.0100	0.0000	0.0000
37	Finance	0.0000	0.0000	0.0000	-0.0010	0.0000	-0.0030	0.0000	-0.0010	0.0000
38	Insurance	0.0000	0.0000	0.0000	-0.0010	0.0000	-0.0030	0.0000	-0.0010	0.0000
39	Services to finance and insurance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40	Real estate	0.0000	0.0000	0.0000	-0.0020	0.0000	-0.0070	0.0000	-0.0020	0.0000
41	Ownership of owner-occupied dwellings	-0.0010	0.0000	0.0000	-0.0060	0.0000	-0.0190	0.0000	-0.0060	0.0000
42	Equipment hire and investors in other property	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0010	0.0000	0.0000	0.0000
43	Business services	0.0000	0.0000	0.0000	-0.0010	0.0000	-0.0030	0.0000	-0.0010	0.0000
44	Central government administration, defence, public order and safety services	-0.0120	-0.0010	0.0000	-0.0040	0.0000	-0.0110	-0.0340	-0.0420	-0.0340
45	Local Government Administration Services and Civil Defence	-0.0010	0.0000	0.0000	-0.0050	0.0000	-0.0160	-0.0080	0.0000	0.0000
46	Education	-0.0290	-0.0020	0.0000	-0.0070	0.0000	0.0000	0.0000	-0.0030	0.0000
47	Health and community services	-0.0740	-0.0040	0.0000	-0.0130	0.0000	-0.0140	0.0000	0.0000	0.0000
48	Cultural and recreational services	-0.0010	0.0000	0.0000	0.0000	0.0000	-0.0110	0.0000	-0.0010	0.0000
49	Personal and other community services	-0.0010	0.0000	0.0000	0.0000	0.0000	-0.0060	0.0000	-0.0010	0.0000

5 Conclusions

This paper examined the nature of the least disruptive changes in the New Zealand economy that are necessary to achieve a target annual rate of reduction in emissions, using a cost function that depends on the sum of the squares of the proportionate changes in final demands. The paper followed the methods first developed by Proops et al (1993), and concentrates on changes in final consumer demands and changes in the quantities and mixture of fossil fuels used by industries. A situation in which emissions are achieved by reducing all final demands would imply an increase in aggregate unemployment and a negative growth rate of GDP. To overcome this problem, constraints on GDP and employment growth were imposed, implying that the final demands of some industries need to increase while other industries decline.

The magnitude of an industry's required change in final demand was found to be determined by the relative efficiency by which they could achieve the stated constraints. The carbon intensity of an industry's output was balanced against its employment weight and value of final demand. The small orders of magnitude which resulted from these calculations suggest that reducing carbon dioxide emissions is economically feasible. That is, reductions can be achieved while maintaining acceptable levels of key macroeconomic variables if structural change can be encouraged in the areas indicated by this study. Further employment was found to be essential in achieving the growth constraint. Consequently, the addition of an employment constraint was found to make a negligible difference to the changes in final demand. Raising the magnitudes of the constraints was found to increase the spread of the distribution, thereby increasing the costs of adjustment. An increase in the carbon constraint of one percentage point was found to increase this cost more than increasing each of the growth constraints by 0.5 percentage points.

The required changes in the fuel use coefficients were also small, with only two industries required to reduce specific fuel demands by more than 1 percent to achieve a 1 percent reduction in carbon dioxide emissions. Again, this supports the conclusion that such reductions in carbon dioxide emissions are feasible.

Appendix

Appendix Table 1 – Translation Between the Energy Account Industry Classification (EAIC) and the 49 Industry Group Classification (IGC)

EAIC Code	EAIC Description	IGC Code	IGC Description
A01	Agriculture	1	Horticulture and fruit growing
		2	Livestock and cropping farming
		3	Dairy cattle farming
		4	Other farming
		5	Services to agriculture, hunting and trapping
A02	Fishing and Hunting	5	Services to agriculture, hunting and trapping
		7	Fishing
A03	Forestry and Logging	6	Forestry and logging
A04	Extraction, Mining, Quarrying and Exploration - including gas distribution and supply	8	Mining and quarrying
		9	Oil and gas exploration and extraction
		27	Gas Supply
B01	Petroleum Product Refining, Distribution and Supply	18	Petroleum and industrial chemical manufacturing
B02	Electricity Generation, Distribution and Supply	26	Electricity generation and supply
C01	Slaughtering and Meat Processing	10	Meat and meat product manufacturing
C02	Dairy Products	11	Dairy product manufacturing
C03	Beverages, Tobacco, confectionery and sugar, and other food	12	Other food manufacturing
		13	Beverage, malt and tobacco manufacturing
C04	Textile, Apparel and Leather goods	14	Textile and apparel manufacturing
C05	Wood Processing and Wood Products	15	Wood product manufacturing
C06	Paper and Paper Products, Printing and Publishing	16	Paper and paper product manufacturing
		17	Printing, publishing and recorded media
C07	Chemicals, Related Products and Plastics	19	Rubber, plastic and other chemical product manufacturing
C08	Concrete, Clay, Glass and Related Minerals Manufacture	20	Non-metallic mineral product manufacturing
C09	Basic Metal Industries	21	Basic metal manufacturing
C10	Fabricated Metal Products, Machinery and Equipment	22	Structural, sheet and fabricated metal product manufacturing
		23	Transport equipment manufacturing
		24	Machinery and equipment manufacturing
C11	Other Manufacturing Industries	25	Furniture and other manufacturing
C12	Construction	29	Construction
D01	Water Works and Supply	28	Water supply
D02	Wholesale and Retail Trade - Non Food	30	Wholesale trade
		31	Retail trade
D03	Wholesale Trade - Food	30	Wholesale trade
D04	Retail Trade - Food	31	Retail trade
D05	Motels, Hotels, Guest Houses	32	Accommodation, restaurants and bars

EAIC Code	EAIC Description	IGC Code	IGC Description
D06	Communication	36	Communication services
D07	Finance, Insurance, Real Estate and Business Services	37	Finance
		38	Insurance
		39	Services to finance and insurance
		40	Real estate
		41	Ownership of owner-occupied dwellings
		42	Equipment hire and investors in other property
		43	Business services
D08	Central Government Administration	44	Central government administration, defence, public order and safety services
D09	Central Government Defence Services	44	Central government administration, defence, public order and safety services
D10	Local Government Administration	45	Local government administration services and civil defence
D11	Education Services: Pre-School, Primary and Secondary	46	Education
D12	Education Services: Tertiary Education	46	Education
D13	Health and Welfare Services	47	Health and community services
D14	Other Social and Related Community Services	48	Cultural and recreational services
		49	Personal and other community services
D15	Sanitary and Cleaning Services	45	Local government administration services and civil defence
E01	Domestic Transport and Storage	33	Road transport
		34	Water and rail transport
		35	Air transport, services to transport and storage

Statistics New Zealand provided fuel demands based on the EAIC. The above translation was used to convert the fuel demands to the 49 industry group classification. Where an industry from the EAIC incorporated multiple IGC industries, final demand was used as a weight to distribute the fuel demand of the EAIC industry to each of the IGC industries.

Appendix Table 2 – Fuel Demands by Industry Group Classification (IGC) for the Year Ended March 1996 (Gross PJ)

IGC Code	Coal	Lignite	Crude Petroleum	Natural Gas	LPG	Petrol	Diesel	Fuel Oil	Aviation Fuels & Kerosene
1	0.000	0.000	0.000	0.017	0.000	5.029	9.032	0.014	0.070
2	0.000	0.000	0.000	0.004	0.000	1.197	2.149	0.003	0.017
3	0.000	0.000	0.000	0.004	0.000	1.200	2.156	0.003	0.017
4	0.000	0.000	0.000	0.003	0.000	0.909	1.632	0.003	0.013
5	0.000	0.000	0.000	0.466	0.000	0.631	4.029	0.374	0.009
6	0.000	0.000	0.000	0.000	0.000	0.635	1.564	0.000	0.000
7	0.000	0.000	0.000	0.723	0.000	0.008	4.525	0.580	0.000
8	0.454	0.000	0.000	0.012	0.000	0.171	1.333	0.179	0.000
9	0.284	0.000	0.000	0.007	0.000	0.107	0.832	0.112	0.000
10	2.273	0.318	0.000	1.184	0.412	0.403	0.099	0.138	0.000
11	5.784	0.808	0.000	4.455	0.045	0.001	1.524	0.457	0.000
12	0.537	0.075	0.000	2.602	0.504	1.434	0.925	0.715	0.000
13	0.187	0.026	0.000	0.905	0.175	0.498	0.321	0.248	0.000
14	0.557	0.078	0.000	0.962	0.047	0.140	0.504	0.383	0.000
15	0.310	0.043	0.000	0.936	0.043	0.008	0.149	0.677	0.000
16	0.572	0.080	0.000	2.649	0.150	0.006	0.083	1.310	0.000
17	0.251	0.035	0.000	1.160	0.066	0.002	0.036	0.573	0.000
18	0.000	0.000	152.267	0.000	0.000	0.000	0.000	0.000	0.000
19	0.279	0.039	0.000	86.372	0.193	0.116	2.467	0.566	0.000
20	4.272	0.597	0.000	1.134	0.645	0.000	0.346	0.094	0.000
21	13.862	0.000	0.000	7.955	0.392	0.007	0.160	2.191	0.000
22	0.017	0.002	0.000	0.136	0.078	0.048	0.454	0.044	0.000
23	0.036	0.005	0.000	0.292	0.168	0.103	0.972	0.094	0.000
24	0.061	0.009	0.000	0.503	0.289	0.177	1.674	0.163	0.000
25	0.092	0.013	0.000	0.167	0.012	0.104	0.016	0.002	0.000
26	5.290	0.000	0.000	51.118	0.000	0.068	0.134	0.000	0.000
27	0.233	0.000	0.000	0.006	0.000	0.088	0.683	0.092	0.000
28	0.000	0.000	0.000	0.000	0.000	0.023	0.051	0.000	0.000
29	0.000	0.000	0.000	0.111	0.594	1.946	7.201	0.000	0.192
30	0.789	0.043	0.000	0.374	0.331	9.764	0.779	0.028	0.000
31	0.923	0.050	0.000	1.043	0.366	11.228	0.810	0.030	0.000
32	0.033	0.002	0.000	0.934	0.355	0.704	0.159	0.541	0.000
33	0.009	0.000	0.000	0.194	0.000	1.083	2.199	0.318	3.579
34	0.013	0.000	0.000	0.295	0.000	1.647	3.345	0.484	5.443
35	0.056	0.000	0.000	1.274	0.000	7.126	14.473	2.092	23.551
36	0.000	0.000	0.000	0.038	0.018	0.827	0.562	0.000	0.000
37	0.008	0.000	0.000	0.056	0.000	0.150	0.000	0.045	0.000
38	0.008	0.000	0.000	0.058	0.000	0.153	0.000	0.046	0.000
39	0.000	0.000	0.000	0.002	0.000	0.006	0.000	0.002	0.000
40	0.020	0.001	0.000	0.146	0.000	0.388	0.000	0.117	0.000
41	0.056	0.003	0.000	0.415	0.000	1.104	0.000	0.333	0.000
42	0.002	0.000	0.000	0.012	0.000	0.032	0.000	0.010	0.000
43	0.010	0.001	0.000	0.074	0.000	0.198	0.000	0.060	0.000
44	0.530	0.029	0.000	0.299	0.000	0.643	1.902	2.194	1.918
45	0.034	0.002	0.000	0.332	0.000	0.921	0.425	0.014	0.000
46	1.240	0.067	0.000	0.518	0.000	0.000	0.000	0.144	0.000
47	3.156	0.170	0.000	0.976	0.000	0.835	0.000	0.000	0.000
48	0.051	0.003	0.000	0.036	0.000	0.636	0.000	0.056	0.000
49	0.029	0.002	0.000	0.020	0.000	0.359	0.000	0.032	0.000

Appendix Table 3 – Carbon Dioxide Intensities by Industry Group Classification (IGC) for the Year Ended March 1996

IGC No.	IGC Description	Carbon Content per Dollar of Output	IGC No.	IGC Description	Carbon Content per Dollar of Output
1	Horticulture and fruit growing	0.96	26	Electricity generation and supply	1.21
2	Livestock and cropping farming	0.40	27	Gas supply	0.36
3	Dairy cattle farming	0.40	28	Water supply	0.26
4	Other farming	0.58	29	Construction	0.32
5	Services to agriculture, hunting and trapping	0.68	30	Wholesale trade	0.24
6	Forestry and logging	0.34	31	Retail trade	0.24
7	Fishing	0.68	32	Accommodation, restaurants and bars	0.26
8	Mining and quarrying	0.41	33	Road transport	0.35
9	Oil & gas exploration & extraction	0.23	34	Water and rail transport	0.70
10	Meat and meat product manufacturing	0.41	35	Air transport, services to transport and storage	0.86
11	Dairy product manufacturing	0.58	36	Communication services	0.07
12	Other food manufacturing	0.43	37	Finance	0.05
13	Beverage, malt and tobacco manufacturing	0.31	38	Insurance	0.06
14	Textile and apparel manufacturing	0.25	39	Services to finance and insurance	0.06
15	Wood product manufacturing	0.39	40	Real estate	0.06
16	Paper & paper product manufacturing	0.40	41	Ownership of owner-occupied dwellings	0.07
17	Printing, publishing & recorded media	0.28	42	Equipment hire and investors in other property	0.12
18	Petroleum and industrial chemical manufacturing	3.64	43	Business services	0.10
19	Rubber, plastic and other chemical product manufacturing	1.83	44	Central government administration, defence, public order and safety services	0.19
20	Non-metallic mineral product manufacturing	0.66	45	Local Government Administration Services and Civil Defence	0.17
21	Basic metal manufacturing	1.40	46	Education	0.10
22	Structural, sheet and fabricated metal product manufacturing	0.37	47	Health and community services	0.15
23	Transport equipment manufacturing	0.23	48	Cultural and recreational services	0.11
24	Machinery & equipment manufacturing	0.29	49	Personal and other community services	0.14
25	Furniture and other manufacturing	0.29			

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