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Further enquiries to:
The Administrator
Chair in Public Finance
Victoria University of Wellington
PO Box 600
Wellington 6041
New Zealand

Phone: +64-4-463-9656
Emil: cpf-info@vuw.ac.nz

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Measuring Revenue Responses to Tax Rate Changes in Multi-Rate Income Tax Systems: Behavioural and Structural Factors

John Creedy and Norman Gemmell*

Abstract

This paper shows how income changes in response to changes in marginal income tax rates (MTRs) translate into tax revenue changes for the familiar multi-step income tax function used in many countries. Previous literature has focused on the relatively straightforward case of a proportional income tax or the top MTR only. The paper examines revenue responses at both the individual and aggregate levels, and it is shown that for individual MTRs within a multi-rate regime, simple expressions for tax revenue responsiveness can be derived that nevertheless capture the various behavioural and structural responses to income tax reforms involving changes to multiple rates and thresholds. Illustrations are provided using changes to the New Zealand income tax structure in the 2010 Budget. This reduced all marginal tax rates while leaving income thresholds unchanged.

Keywords: Income Tax Revenue; Elasticity of taxable income; revenue elasticity.

JEL Codes: H24; H31; H26

*The authors are, respectively, the Truby Williams Professor of Economics at Melbourne University, and Professor of Public Finance, Victoria University of Wellington. The research was supported by the New Zealand Royal Society, through their Cross Departmental Research Pool scheme. We have benefited from very helpful comments on a previous version by two annonymous referees, the editor of this Journal, and by Matt Benge, Steve Cantwell, Raj Chetty, Andrew Coleman and Chris Heady. The work began in an attempt to answer a question raised by Antoine Bozio.

1 Introduction

The concept of the 'elasticity of taxable income', introduced by Feldstein (1995), has become a routine part of the empirical toolkit used by economists to examine behavioural responses to changes in tax rates. This elasticity is defined as the response of taxable income to a change in the marginal net-of-tax rate (one minus the marginal rate). It is a helpful summary measure because it captures the net effect on income of all incentive effects associated with the marginal rate change.[1] As Feldstein (1999) shows, under certain conditions it also plays a convenient role in measuring the deadweight costs of marginal tax changes. However, the literature on the elasticity of taxable income has generally ignored the associated effects on income tax revenues. In part this reflects the tendency for the analysis to be set in the context of a single rate, proportional income tax structure where the revenue effects are analytically trivial – a given percentage change in incomes implies the same percentage change in revenues. To the extent that revenue consequences have been explored analytically, these have been restricted to changes in the top marginal rate affecting those on high incomes; see Saez (2004) and Saez *et al.* (2012).[2]

The aim of this paper is to show how income changes, in response to changes in marginal income tax rates, translate into tax revenue changes for the multi-step income tax function used in many countries. The paper examines revenue responses at both the individual and aggregate levels, and it is shown that for individual marginal rate changes within a multi-rate regime, it is possible to derive simple expressions for tax revenue responsiveness that nevertheless capture the various behavioural and structural

[1] It avoids the considerable complexities of attempting to combine the varied behavioural adjustments into a structural model, as well as providing (under certain assumptions) a convenient method of measuring the marginal excess burden arising from tax changes. However, its use crucially depends on an assumed absence of income effects. The elasticity can be influenced by policy changes concerning, for example, regulations regarding income shifting and the timing of income receipts and tax payments. The seminal paper is Feldstein (1995), with important evidence for the US by Auten and Carroll (1995, 1999) and Auten *et al.* (2008). Giertz (2007) and Saez, Slemrod and Giertz (2009) provide comprehensive reviews of evidence, while Creedy (2010) provides an introduction to the underlying analytics.

[2] Saez *et al.* (2012) examined changes in total tax revenue obtained from the top marginal rate in the course of deriving the aggregate excess burden. Following Saez, the two components were also discussed by, for example, Giertz (2009). The simple proportional income tax case is discussed by Goolsbee (1999) and Hall (1999). Blomquist and Simula (2010) consider the welfare effects of an equal percentage point change in the marginal tax rate at all income levels, and compare results with a linearized budget constraint.

responses to income tax reforms involving changes to multiple rates and thresholds.

These expressions may be applied to generally available data to provide a convenient method for tax policy-makers to translate alternative assumptions or beliefs regarding taxable income elasticities into revenue change forecasts. In addition, the decomposition is useful in contexts where revenue changes form one component of a larger economic model.[3]

The decomposition is shown to involve a number of elements. First, in elasticity terms there is the obvious *ceteris paribus* positive revenue effect of a rate rise which depends (at the individual level) only on the tax structure: this is the *partial* elasticity of revenue with respect to the relevant tax rate. Second there is a negative effect arising from behavioural responses. This latter effect involves two multiplicative components: Feldstein's '*elasticity of taxable income*' (ETI), and the *tax revenue elasticity* – the elasticity of tax revenue with respect to a change in income – sometimes referred to as the 'fiscal drag' parameter. The recognition of two basic effects of a rate rise is not of course new. Reference has long been made to 'tax base' and 'tax rate' effects of rate changes and, for example, behavioural and 'mechanical' effects of an increase in the top marginal tax rate were distinguished by Saez (2004).

The tax revenue elasticity is the central concept in the literature on 'fiscal drag' and is concerned only with the nature of the income tax structure itself and, when considering aggregation over individuals, the form of the income distribution.[4] But the two, largely separate, literatures on fiscal drag and the elasticity of taxable income have failed to draw out the direct connections between the two elasticity concepts. It is shown below how the revenue elasticity has a clear role at the individual level in influencing the change in tax revenue resulting from a marginal rate change. In considering aggregate revenue over all individuals, changes can be expressed in terms of the revenue elasticities at arithmetic mean income levels within each tax bracket in a multi-rate income tax structure. These elasticities are readily calculated from tax

[3] Blundell (2011) argues that hours and employment responses are unlikely to be the most prevalent reactions to *top* income tax rate changes; hence taxable income response estimates are potentially more relevant. An alternative approach is to use behavioural microsimulation models that incorporate an elasticity of taxable income; see, for example, Elmendorf *et al.* (2008) for an application. However, such models are rarely available to individual researchers and the approach in this paper offers a simple analytical and practical method to decompose revenue responses to tax rate changes.

[4] See the survey in Creedy and Gemmell (2002). The revenue elasticity is also used in discussions of local measures of tax progressivity.

schedule and taxpayer income data. It is also shown that the restriction of previous analyses to the *top* marginal rate involves a substantial simplification. The present paper extends the treatment to deal with changes resulting from any tax rate, and thereby also deals with simultaneous changes in all tax rates. At the aggregate level, unlike the Saez *et al.* (2012) top rate case, no specific income distribution assumption is required.[5]

Section 2 explores the precise relationships among the various elasticities, extending the analysis of a single rate tax function to the ubiquitous multi-step tax case. Section 3 looks at aggregation over individuals when a single marginal rate changes within a multi-rate tax structure. The analysis focuses on the effects on income tax revenue, and it is worth recognising that, to the extent that the elasticity of taxable income captures some shifting towards sources which attract lower marginal rates, there are additional consequences for tax revenue. However, as is shown below following Saez *et al.* (2012), income-switching effects can be included with a suitable redefinition of the marginal tax rate.

To illustrate the orders of magnitude involved, section 4 applies the aggregate analysis to the New Zealand income tax system. This provides a convenient example since the New Zealand government's 2010 Budget involved changes to all marginal income tax rates whilst holding all thresholds constant. Brief conclusions are in Section 5.

2 Relationships Among Elasticities

This section demonstrates, at the individual level, how the revenue elasticity and the elasticity of taxable income combine to generate the elasticity of tax with respect to the marginal rate. For convenience, the distinction between gross income and taxable income is ignored, though this distinction is likely to be important for countries with extensive income tax deductions.[6] If there are endogenous, income-related deductions,

[5]Following Feldstein (1999), Saez *et al.* (2012), Brewer *et al.* (2010) and Blundell (2011) also use the elasticity of taxable income (ETI) concept to derive and discuss simple analytical results, in terms of the ETI, for the deadweight losses associated with top marginal tax rates. Creedy (2010) provides a comparable analysis for the multi-step income tax considered here.

[6]For discussion of the empirical importance of income-related deductions in personal income tax regimes in OECD countries, see Caminada and Goudswaard (1996) and Wagstaff and van Doorslaer (2001). For the US, Feldstein (1999, p. 675) estimated that total income tax deductions in 1993 amounted to about 60 per cent of estimated taxable income.

the following analysis must be in terms of income after deductions have been made.

The literature on the tax revenue elasticity concentrates on the effects of changes in taxation resulting from exogenous changes in taxable income, with tax rates and thresholds held constant.[7] Furthermore, it is usual to assume that the exogenous change in income does not cause the individual to move into a higher tax bracket. Such a movement, where the tax function involves discrete changes in marginal rates, gives rise to a large jump in the elasticity, and this can – when carrying out appropriately tax-share weighted aggregation – distort aggregate elasticity values. To help clarify the main features, subsection 2.1 concentrates on the simple case of a single marginal rate applied to income measured in excess of a tax-free threshold. The extension to a multi-rate function is in subsection 2.2. The effect of income shifting to an alternative source facing a lower tax rate is examined in subsection 2.3.

2.1 A Single Rate Above a Tax-free Threshold

Let the tax paid by an individual with income of $y > a$ be denoted $T(y) = \tau(y-a)$, and $T(y) = 0$ for $y \leqslant a$. The individual revenue elasticity, $\eta_{T,y}$, is defined as:

$$\eta_{T,y} = \frac{dT}{dy}\frac{y}{T} \tag{1}$$

and is given by the ratio of the marginal tax rate to the average tax rate faced by the individual. The following uses the general notation, $\eta_{b,a} = \frac{a}{b}\frac{db}{da}$, to denote a 'total' elasticity, and $\eta'_{b,a} = \frac{a}{b}\frac{\partial b}{\partial a}$, to denote a partial elasticity. The revenue elasticity thus has the property that $\eta_{T,y} = \eta'_{T,y}$. For this structure:

$$\eta_{T,y} = \frac{y}{y-a} \tag{2}$$

and the individual elasticity must exceed unity so long as $a > 0$.

Consider a change in the individual's tax liability resulting from an exogenous increase in τ, with the threshold, a, unchanged. From the total differential, $dT = \frac{\partial T}{\partial \tau}d\tau + \frac{\partial T}{\partial y}dy$, dividing by $d\tau$ and writing in elasticity form gives:

$$\eta_{T,\tau} = \eta'_{T,\tau} + \eta_{T,y}\eta_{y,\tau} \tag{3}$$

[7] The restriction to exogenous income changes is easily handled when considering individual elasticity values, but of course the nature of the overall distribution of income, which is needed to obtain aggregate values, may well be influenced by the incentive effects of the consequent tax changes.

The first term may be said to reflect a pure 'tax rate' effect of a rate change, with unchanged incomes, while the second term reflects the combined 'tax base' effect, resulting from the incentive effects on taxable income, and the revenue consequences of that income change. The first term is given by:

$$\eta'_{T,\tau} = \frac{\tau\,(y-a)}{T\,(y)} = 1 \tag{4}$$

Hence, for a single rate tax, the 'tax rate' effect in (3) equals one for all taxpayers where $y > a$. When discussing the effect on total revenue of a change in the top income tax rate, Saez *et al.* (2009) refer to the tax rate effect as 'mechanical' and the second term as the 'behavioural' effect respectively. Thus, their 'behavioural effect' combines the revenue elasticity and elasticity of taxable income effects.[8]

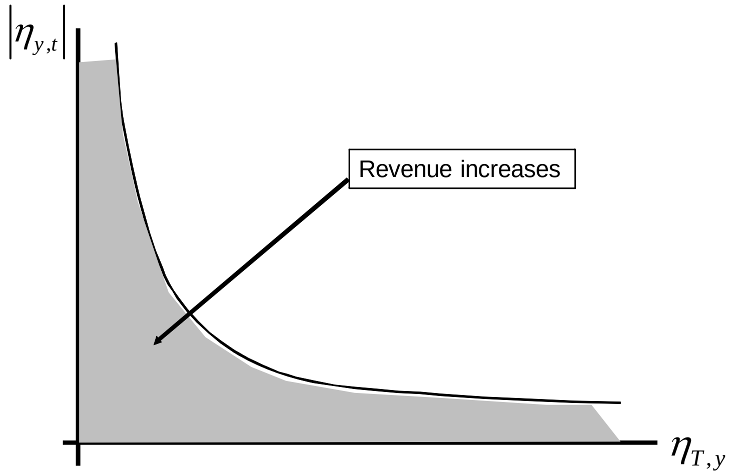

Figure 1: Revenue-Increasing Elasticity Combinations

From (3), tax paid by the individual increases, when the marginal rate increases, only if:

$$\left(\eta_{T,y}\right)\left|\eta_{y,\tau}\right| < \eta'_{T,\tau} \tag{5}$$

The condition in equation (5) can be illustrated with the aid of Figure 1, where the terms on the left-hand side, $\eta_{T,y}$ and $\left|\eta_{y,\tau}\right|$, are respectively on the horizontal and

[8]Saez *et al.* (2009, p. 5) do not discuss the separate role of the revenue elasticity in this context. Discussion of the rate and base effects is often discussed in the context of a simple proportional tax structure, with constant average and marginal rate, t, where the revenue elasticity is everywhere unity. Thus if $\bar{y}$ is arithmetic mean income, $\frac{dT}{dt} = \bar{y} + \frac{td\bar{y}}{dt}$ and in terms of elasticities, $\eta_{T,t} = 1 + \eta_{\bar{y},t}$.

vertical axes.[9] This shows that, for the individual's tax liability to increase when τ increases, the combination of (absolute) elasticities must lie to the south west of a rectangular hyperbola shown in the Figure. The position of the hyperbola is determined by the 'mechanical' elasticity, $\eta'_{T,\tau}$, which in this case is 1.

Equation (3) contains $\eta_{y,\tau}$, while the Feldstein elasticity of taxable income, $\eta_{y,1-\tau}$, measures behavioural responses with respect to a change in a marginal net-of-tax rate, $1-\tau$, facing the individual. However, the two elasticities are related by $\eta_{y,1-\tau} = -\left(\frac{1-\tau}{\tau}\right)\eta_{y,\tau}$. Hence the elasticity of revenue with respect to the marginal rate faced by an individual can be obtained by substituting (2) and (4) in (3) to get:

$$\eta_{T,\tau} = 1 - \left(\frac{y}{y-a}\right)\left(\frac{\tau}{1-\tau}\right)\eta_{y,1-\tau} \tag{6}$$

The term after the minus sign captures the behavioural response and combines the reduction in the tax base (via the individual elasticity of taxable income) with the structural effect (via the individual revenue elasticity). The next subsection shows that similar elasticity expressions can be obtained for any multi-step income tax function.

2.2 The Multi-rate Tax Function

The multi-step tax function is described by a set of income thresholds, $a_k, ..., a_K$, and a corresponding set of marginal tax rates $\tau_k, ..., \tau_K$. It can be written as:[10]

$$\begin{aligned} T(y) &= \tau_1 (y - a_1) & & a_1 < y \leq a_2 \\ &= \tau_1 (a_2 - a_1) + \tau_2 (y - a_2) & & a_2 < y \leq a_3 \end{aligned} \tag{7}$$

and so on. If y falls into the kth tax bracket, so that $a_k < y \leq a_{k+1}$, $T(y)$ can be expressed for $k \geq 2$ as:

$$T(y) = \tau_k (y - a_k) + \sum_{j=1}^{k-1} \tau_j (a_{j+1} - a_j) \tag{8}$$

[9] The constant revenue line in Figure 1 is similar to that obtained by Fullerton (1982, p. 9), concentrating on labour supply responses to tax increases. Fullerton drew a downward sloping convex curve with the labour supply elasticity on the vertical axis and the tax rate on the horizontal axis. For tax revenue to increase when the tax rate increases, the supply elasticity must be sufficiently small; that is, the combination of tax rate and elasticity must lie to the south west of his curve. In simulations, Fullerton (1982, p. 13) held the revenue elasticity, $\eta_{T,y}$, constant as the tax rate was varied (by increasing average and marginal rates by the same percentage).

[10] The revenue elasticity properties of this function are examined in more detail in Creedy and Gemmell (2002).

Hence:

$$T(y) = \tau_k (y - a_k^*) \tag{9}$$

where a_k^* is given by:

$$a_k^* = \frac{1}{\tau_k} \sum_{j=1}^{k} a_j (\tau_j - \tau_{j-1}) \tag{10}$$

and $\tau_0 = 0$. Thus the tax function facing any individual taxpayer in the kth bracket is equivalent to a tax function with a single marginal tax rate, τ_k, applied to income measured in excess of a single 'effective' threshold, a_k^*. Unlike a_j, a_k^* differs across individuals depending on the marginal income tax bracket into which they fall. Hence the results obtained in the previous subsection can easily be adapted for the multi-rate system. For example, the revenue elasticity for those in the kth bracket is:

$$\eta_{T,y} = \frac{y}{y - a_k^*} \tag{11}$$

Within each tax bracket the elasticity declines as income increases. As an individual crosses an income threshold, the revenue elasticity takes a discrete upward jump, before gradually declining again. The resulting saw-tooth pattern is illustrated in Figure 2, which is based on the New Zealand income tax system with four (non-zero) marginal tax rates and thresholds, examined further in section 4.

The mechanical effect – the partial individual elasticity, η'_{T,τ_k}– is readily obtained from (8) and is given by:[11]

$$\eta'_{T,\tau_k} = \frac{\tau_k (y - a_k)}{T(y)} = \frac{T_k(y)}{T(y)} \tag{12}$$

where $T_k(y)$ is the tax paid at the rate, τ_k, and $T(y)$ is total tax paid by the individual. Hence, for the multi-rate case, (6) becomes:

$$\eta_{T,\tau_k} = \frac{T_k(y)}{T(y)} - \left(\frac{y}{y - a_k^*}\right)\left(\frac{\tau_k}{1 - \tau_k}\right)\eta_{y,1-\tau_k} \tag{13}$$

for a change in the kth marginal rate. Unlike the single rate case, the mechanical effect associated with changes in each τ_k in (13), η'_{T,τ_k}, is less than 1, and can be measured by the individual's tax revenue share, $T_k(y)/T(y)$.

[11] The partial individual elasticity, η'_{T,τ_j}, for $j < k$ (that is, for changes in marginal tax rates below the tax bracket in which the individual falls) is also obtained as $\eta'_{T,\tau_j} = \frac{\tau_j(a_{j+1} - a_j)}{T(y)} = \frac{T_j(y)}{T(y)}$, where $T_j(y)$ is tax paid at the rate, τ_j, and $T(y)$ is total tax paid by the individual. Across all tax brackets $\sum_{j=1}^{k} \eta'_{T,\tau_j} = 1$.

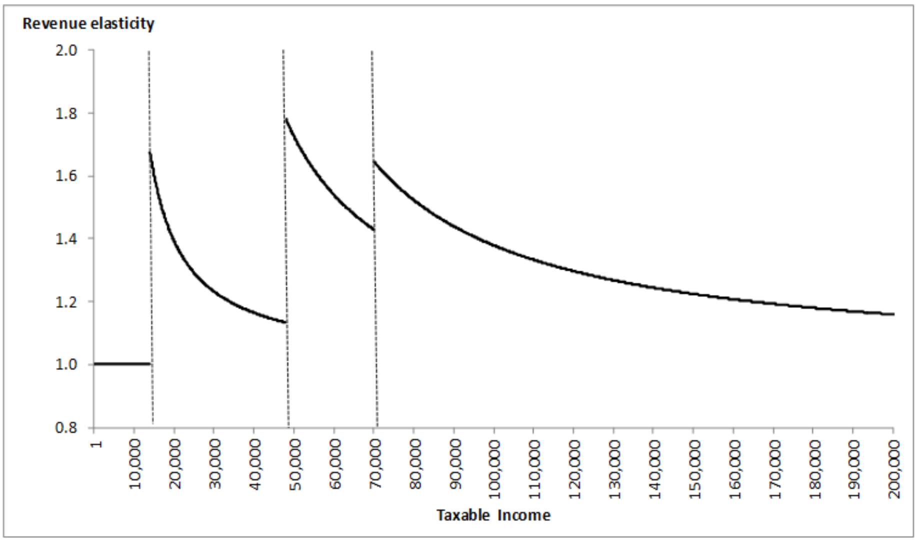

Figure 2: The Income Tax Revenue Elasticity

2.3 Allowing for Income Shifting

The behavioural responses captured in equation (13) assume that taxable income reductions in response to an increase in τ_k are untaxed. However, income shifted to avoid income tax is likely to be taxed at a lower rate via alternative taxes such as corporate income tax (for example, when individuals incorporate) or indirect taxation, when the avoided income tax is spent. Saez *et al.* (2009) address this for the case of the top income tax rate, where a fraction of taxable income, $s < 1$, is shifted out of the income tax regime in response to a top marginal rate rise, and is taxed at the lower rate, t.

In the present context, suppose that, for a given marginal tax rate, τ_k, a fraction $1 - s$ of an individual's tax-liable income, $y - a_k^*$, is declared for tax under the income tax, while a fraction s is shifted but is taxed at an *average* tax rate $t \geq 0$ under an alternative tax. Equation (9) can thus be rewritten as:

$$\begin{aligned} T(y) &= \tau_k(1-s)(y-a_k^*) + ts(y-a_k^*) \\ &= [\tau_k - s(\tau_k - t)](y-a_k^*) \\ &= \tau_k^*(y-a_k^*) \end{aligned} \tag{14}$$

where $T(y)$ is now total revenue raised via both taxes and $\tau_k^* = [\tau_k - s(\tau_k - t)]$. Substituting τ_k^* for τ_k in (9), it follows that the revenue elasticity in (11) is unaffected except that a_k^* in (10) is now defined in terms of τ_k^* rather than τ_k. The revenue elasticity remains equal to $y/(y-a_k^*)$ because the marginal tax rate terms in both the numerator and denominator cancel. The combined revenue effect of a change in the tax rate, τ_k^*, is thus obtained from (13), simply by replacing τ_k with τ_k^*.[12]

3 Aggregate Revenue

For tax policy purposes attention is often devoted to aggregate revenue and its variation as component tax rates are changed. This section therefore examines aggregation over individuals. The key aspect of interest is the effect on total income tax revenue of a change in a single tax rate, and the effect of a simultaneous similar change in all rates. As above, attention is focussed on the case of the multi-rate tax function.[13] First, components of total revenue are examined in subsection 3.1. Aggregate elasticities are then derived in subsection 3.2.

3.1 Components of Total Revenue

In the multi-rate form, if y is in the kth tax bracket a distinction can be made between the total tax paid by the individual and the tax paid at the marginal rate, τ_k, only, thereby ignoring tax paid on income falling within lower thresholds. Let R represent aggregate revenue over all individuals, while R_k refers to the aggregate revenue obtained from all individuals whose incomes fall in the kth tax bracket. Hence, R_k is the aggregate over individuals in the kth bracket of $\tau_k(y-a_k^*)$ values. Let $R_{(k)}$ denote the aggregate amount raised only at the rate k from individuals who fall into the kth bracket. Thus $R_{(k)}$ is the sum over individuals in the kth bracket of $\tau_k(y-a_k)$ values. Furthermore, $R_{(k)}^+$ refers to the aggregate revenue obtained at the kth rate from individuals whose incomes fall into *higher* tax brackets. Hence, $R_{(k)}^+$ is the number of all individuals in higher tax brackets multiplied by $\tau_k(a_{k+1}-a_k)$.

Formally, in the multi-step tax function with K brackets, suppose P_k people are in each bracket, for $k=1,...,K$, and the arithmetic mean income in each bracket is $\bar{y}_k$,

[12] This analysis assume that both s and t do not change in response to changes in τ_k.

[13] It is assumed that all individuals face the same income thresholds, so that endogenous allowances are not considered here.

then:

$$R_k = \tau_k P_k \left(\bar{y}_k - a_k^*\right) \tag{15}$$

$$R_{(k)} = \tau_k P_k \left(\bar{y}_k - a_k\right) \tag{16}$$

$$R_{(k)}^+ = \tau_k P_k^+ \left(a_{k+1} - a_k\right) \tag{17}$$

where $P_k^+ \equiv \sum_{j=k+1}^{K} P_j$ denotes the number of people *above* the kth tax bracket. For the top marginal rate, where $k = K$, clearly $P_K^+ = 0$.

The components of aggregate revenue, $\sum_{k=1}^{K} R_k$, are represented in tabular form in Table 1, where $k = 1, ..., 4$ is used for illustration. The term $R_{(k)}$ in the second column shows revenue raised from taxpayers in each tax bracket at their marginal rates; columns 3-5 show revenue raised intramarginally at each lower rate, $R_{(k)}^+$. Total revenue raised at each marginal rate, R_k, is also shown in each row and can also be expressed in terms of the effective thresholds, a_k^*; with total revenue raised at all marginal rates given by: $R = \sum_{k=1}^{4} R_k = \sum_{k=1}^{4} \tau_k \left(\bar{y}_k - a_k^*\right) P_k$.

Table 1: The Decomposition of Aggregate Revenue

R_k	$R_{(k)}$	$R_{(1)}^+$	$R_{(2)}^+$	$R_{(3)}^+$
$R_1 =$	$\tau_1 \left(\bar{y}_1 - a_1\right) P_1$	0	0	0
$R_2 =$	$\tau_2 \left(\bar{y}_2 - a_2\right) P_2$	$+ \tau_1 \left(a_2 - a_1\right) P_2$	0	0
$R_3 =$	$\tau_3 \left(\bar{y}_3 - a_3\right) P_3$	$+ \tau_1 \left(a_2 - a_1\right) P_3$	$+ \tau_2 \left(a_3 - a_2\right) P_3$	0
$R_4 =$	$\tau_4 \left(\bar{y}_4 - a_4\right) P_4$	$+ \tau_1 \left(a_2 - a_1\right) P_4$	$+ \tau_2 \left(a_3 - a_2\right) P_4$	$+ \tau_3 \left(a_4 - a_3\right) P_4$

Within each kth bracket, $R_k \neq R_{(k)} + R_{(k)}^+$. This is because R_k includes revenue raised from kth bracket taxpayers including on their income taxed at *lower* tax rates. For example, from row 3, column 2 of the table, $R_{(2)} = \tau_2 \left(\bar{y}_2 - a_2\right) P_2$ while, from column 4, $R_{(2)}^+ = \tau_2 \left(a_3 - a_2\right) \sum_{k=3}^{4} P_k$. However, from row 3:

$$R_2 = \tau_2 \left(\bar{y}_2 - a_2\right) P_2 + \tau_1 \left(a_2 - a_1\right) P_2 \tag{18}$$

That is, R_2 involves the term $\tau_1 \left(a_2 - a_1\right)$ for P_2 individuals, not included in $R_{(2)}$ or $R_{(2)}^+$. As shown in (15), R_2 can be expressed more simply in terms of the *effective* threshold, a_2^*, which captures all marginal and intramarginal effects on R_2.

The aggregate revenue decomposition is illustrated in Figure 3. This shows, on the horizontal axis, the percentage of total taxpayers, P, ranked by income. The vertical axis shows the amount of total tax revenue paid by each taxpayer (truncated

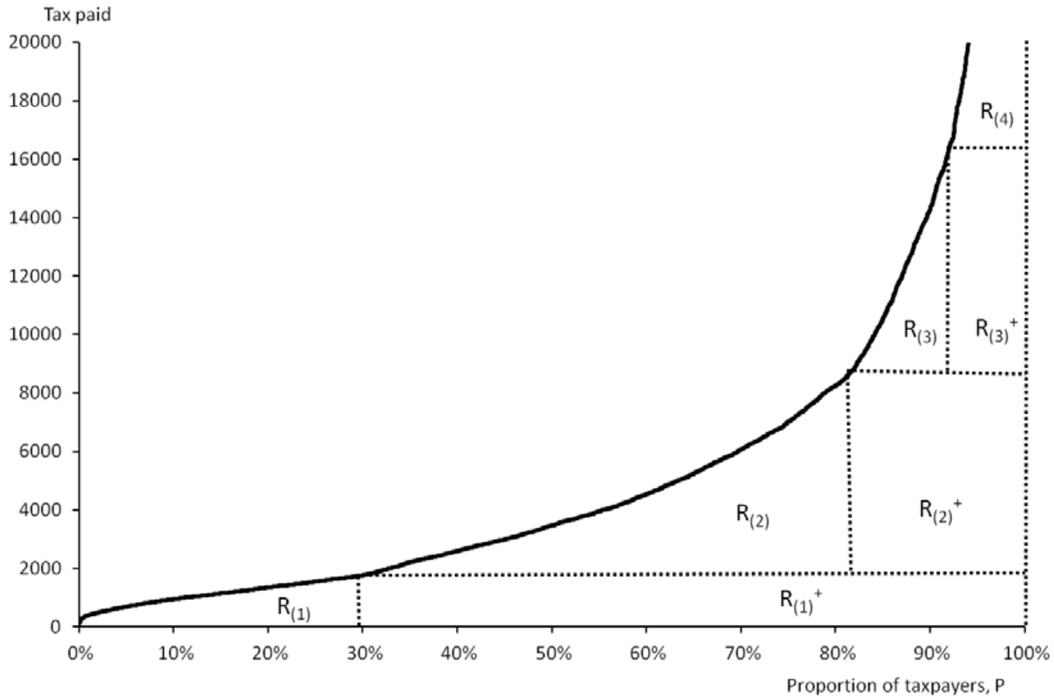

Figure 3: Aggregate Revenue Decomposition

at \$20,000 for ease of illustration). As in Figure 2, this is illustrated for the New Zealand income tax system with four non-zero marginal tax rates and thresholds. A population of 5000 individuals has been simulated whose incomes are assumed to follow a lognormal distribution, with mean and variance of logs of 10 and 0.7 respectively, yielding an arithmetic mean income of approximately \$31,000 and a mean tax payment of approximately \$5300.

The resulting relationship between the numbers of taxpayers and total tax paid is given by the line AB in Figure 3. The shape of the line reflects the combined effects of the moments of the taxable income distribution and the structure of the income tax function. The area under the curve AB indicates, for any subset of taxpayers, P_i, total tax revenue from those i taxpayers, $R_i = \tau_i \left(\bar{y}_i - a_i^*\right) P_i$. The figure shows revenue for the four tax brackets and subsets of taxpayers, P_1 to P_4.

The four brackets, $k = 1, ..., 4$, account for approximately 30, 52, 10 and 8 per cent of taxpayers respectively. Revenue contributed by taxpayers in the lowest tax brackets, at marginal rate τ_1, is shown by the shaded segment $R_{(1)}$, while the blue shaded rectangle $R^+_{(1)}$ measures revenue raised at rate τ_1 from higher marginal rate (τ_2, τ_3, τ_4) taxpayers. Similarly for higher tax brackets, $k = 2, ..., 4$, the respective $R_{(k)}$ and $R^+_{(k)}$ areas under the curve are shown in Figure 3, with $R^+_{(4)} = 0$. Hence summing the revenue 'blocks' for each tax rate in Figure 3 *horizontally* represents $R_{(k)} + R^+_{(k)}$, while summing the revenue 'blocks' for each tax bracket *vertically* represents R_k.

As stressed above, although $R_k \neq R_{(k)} + R^+_{(k)}$, summing across all $k = 1, ..., K$ tax brackets (the sum of all shaded areas in Figure 3), it is nevertheless true that $R = \sum_{k=1}^{K} R_k = \sum_{k=1}^{K} R_{(k)} + \sum_{k=1}^{K} R^+_{(k)}$, (with $R^+_{(K)} = 0$). Thus aggregate revenue can be written as:

$$
\begin{aligned}
R &= \sum_{k=1}^{K} \tau_k \left(\bar{y}_k - a^*_k\right) P_k \\
&= \sum_{k=1}^{K} \tau_k \left(\bar{y}_k - a_k\right) P_k + \sum_{k=1}^{K-1} \tau_k \left(a_{k+1} - a_k\right) P^+_k \qquad (19) \\
&= \sum_{k=1}^{K} \left(R_{(k)} + R^+_{(k)}\right) \qquad (20)
\end{aligned}
$$

The expression in (19) provides the basis, in the next subsection, for an examination of changes in aggregate revenue in response to changes in individual marginal tax rates.

3.2 Changes in Aggregate Revenue

Consider a change in the kth marginal tax rate. The change in aggregate revenue can be obtained by differentiation of (19) and expressed in elasticity form: η_{R,τ_k}. Assume first that there are no behavioural responses, and letting $\eta_{R,\tau_k} \equiv \frac{\tau_k}{R} \frac{\partial R}{\partial \tau_k}$:

$$\eta_{R,\tau_k} = \frac{R_{(k)} + R^+_{(k)}}{R} \qquad (21)$$

That is, the responsiveness of aggregate revenue to a change in any tax rate, τ_k, is obtained simply as the ratio of revenue raised at rate τ_k (from all taxpayers in the kth tax bracket *and above*) to total revenue. For this 'no behavioural response' case, these elasticities sum to unity across all $k = 1, ..., K$, so that the elasticity of total revenue with respect to an equal proportional change in all rates is unity. Any behavioural response clearly reduces the elasticity below 1, as shown below.

In the case where there are behavioural effects of marginal rate changes, it is convenient to assume that all those in a given bracket have the same behavioural elasticity; that is $\eta_{y,\tau_k} = \eta_{\bar{y}_k,\tau_k}$. In this case, $\bar{y}_k$ in (19) can be suitably adjusted to $\bar{y}_k\left(1+\eta_{y,\tau_k}\right)$ and (21) becomes:

$$\eta_{R,\tau_k} = \frac{R_{(k)} + R^{+}_{(k)}}{R} + \frac{\tau_k P_k \bar{y}_k \eta_{y,\tau_k}}{R} \qquad (22)$$

where the additional term, $\tau_k P_k \bar{y}_k \eta_{y,\tau_k}/R$, captures the behavioural effect in revenue terms. This can be simplified, and expressed in terms of the Feldstein elasticity by noting from (15) that $\tau_k P_k = R_k/\left(\bar{y}_k - a^*_k\right)$, and using $\eta_{y,\tau_k} = -\left(\frac{\tau_k}{1-\tau_k}\right)\eta_{y,1-\tau_k}$. Equation (22) then becomes:

$$\eta_{R,\tau_k} = \frac{R_{(k)} + R^{+}_{(k)}}{R} - \frac{R_k}{R}\left(\frac{\bar{y}_k}{\bar{y}_k - a^*_k}\right)\left(\frac{\tau_k}{1-\tau_k}\right)\eta_{y,1-\tau_k} \qquad (23)$$

Equation (23) allows the separate components influencing η_{R,τ_k} to be identified in a more transparent way. Firstly, the mechanical effect is given by $\left(R_{(k)} + R^{+}_{(k)}\right)/R$, while the behavioural effect is captured by the terms after the minus sign. This is composed of the Feldstein elasticity of taxable income of those in the kth tax bracket, $\eta_{y,1-\tau_k}$, the revenue elasticity at $\bar{y}_k$, equal to $\bar{y}_k/\left(\bar{y}_k - a^*_k\right)$, and the tax rate term $\tau_k/(1-\tau_k)$. The revenue share term, R_k/R, translates these effects into a total revenue response, as distinct from total revenue from kth bracket taxpayers, R_k.

Equation (23) can alternatively be expressed in terms of actual thresholds, a_k, rather than effective thresholds, a^*_k, by noting that $\frac{R_k}{R} = \frac{R_k}{R_{(k)}}\frac{R_{(k)}}{R}$ and, from (15) and (16), that $\left(R_k/R_{(k)}\right) = \left(\bar{y}_k - a^*_k\right)/\left(\bar{y}_k - a_k\right)$. Substitution into (23) then yields:

$$\eta_{R,\tau_k} = \frac{R^{+}_{(k)}}{R} + \frac{R_{(k)}}{R}\left[1 - \left(\frac{\bar{y}_k}{\bar{y}_k - a_k}\right)\left(\frac{\tau_k}{1-\tau_k}\right)\eta_{y,1-\tau_k}\right] \qquad (24)$$

The decomposition in (24) is useful in subsection 3.4 when comparing with previous results for the top tax rate where effective thresholds have not been considered. Though η_{R,τ_k} in (23) and (24) look cumbersome, they can generally be calculated from information that is readily available for most income tax systems; namely the commonly estimated 'fiscal drag' elasticity, $\bar{y}_k/\left(\bar{y}_k - a^*_k\right)$, the Feldstein elasticity, $\eta_{y,1-\tau_k}$, and various revenue ratios associated with total revenue decompositions by tax bracket or tax rate.

3.3 Revenue-Reducing Tax Rate Increases

The question of when a tax rate increase might reduce, rather than increase, revenue is a frequent concern of tax policy reformers. Using the previous analysis, the aggregate revenue maximum (the top of the 'Laffer curve') can also be obtained from equation (23) by setting $\eta_{R,\tau_k} = 0$, to give:

$$\eta_{y,1-\tau_k} = \left(\frac{R_{(k)} + R^{+}_{(k)}}{R_k}\right)\left(\frac{1-\tau_k}{\tau_k}\right)\left(\frac{\bar{y}_k - a^{*}_k}{\bar{y}_k}\right) \tag{25}$$

For the top bracket only (the focus of previous literature), where $R^{+}_{(K)} = 0$, the relevant condition is $\eta_{R,\tau_K} = 0$, and (25) becomes:

$$\eta_{y,1-\tau_K} = \frac{R_{(K)}}{R_K}\left(\frac{1-\tau_K}{\tau_K}\right)\left(\frac{\bar{y}_K - a^{*}_K}{\bar{y}_K}\right) \tag{26}$$

Hence, an actual elasticity of taxable income greater than that given in (25) or (26) implies a revenue-reducing response to marginal tax rate changes. Considering the right-hand-side of (26), although $\left(\frac{1-\tau_K}{\tau_K}\right)$ exceeds 1 as long as the tax rate, τ_K, is less than 0.5, the ratio of revenue shares $R_{(K)}/R_K < 1$, and the inverse of the revenue elasticity $\left(\frac{\bar{y}_K - a^{*}_K}{\bar{y}_K}\right) < 1$. Hence the critical revenue-maximising value of $\eta_{y,1-\tau_k}$ could be well below 1 in some cases, such that the required elasticity of taxable income for a tax rate increase to generate an *increase* aggregate revenue can also be relatively low. Section 4 provides some illustrative orders of magnitude.

3.4 Comparisons with Earlier Results

The above results for any tax rate in a multi-rate structure may be compared with that given by Saez *et al.* (2012, equation 4) specifically for the top marginal rate, τ_K. They consider changes in aggregate income tax paid at the top rate only and their result refers to the elasticity of income tax paid *at the rate* τ_K, which may be defined here as $\eta_{R_{(K)},\tau_K}$. When converted to the present notation and written in elasticity form, Saez *et al.* (2012, equation 4) can be written as:

$$\eta_{R_{(K)},\tau_K} = \left[1 - \left(\frac{\bar{y}_K}{\bar{y}_K - a_K}\right)\left(\frac{\tau_K}{1-\tau_K}\right)\eta_{y,1-\tau_K}\right] \tag{27}$$

This can be seen to be the top rate equivalent of equation (24) above where in this case, $R^{+}_{(K)} = 0$, and where the 'total' revenue in question is now $R_{(K)}$ rather than R.

Hence comparing equations (24) and (27) it can be seen that the Seaz *et al.* version gives the same revenue responsiveness for the top tax rate as the approach above, in terms of the percentage change in revenue from the top tax rate *only* - captured by the terms in square brackets. Of course this exceeds a measure of the percentage change in *total* income tax revenue (from all tax rates) when the top rate changes, as shown by the full expression in (24) and where $k = K$. That is:

$$\eta_{R,\tau_K} = \frac{R_{(K)}}{R}\left[1 - \left(\frac{\bar{y}_K}{\bar{y}_K - a_K}\right)\left(\frac{\tau_K}{1-\tau_K}\right)\eta_{y,1-\tau_K}\right] \tag{28}$$

where $R_{(K)}/R < 1$, and $R^{+}_{(K)}/R$ does not appear in (28) since $R^{+}_{(K)} = 0$.

Saez *et al.* (2012) discuss the term $\bar{y}_K / (\bar{y}_K - a_K)$, which is constant if the income distribution above the top threshold follows the Pareto form.[14] The Saez *et al.* expression therefore does not highlight the role for the revenue elasticity at $\bar{y}_K$, given by $\bar{y}_K / (\bar{y}_K - a^*_K)$, but which is captured in general form in (23) and is a commonly measured property of income tax systems. Furthermore, their 'behavioural response' combines both the behavioural *income* response and the revenue elasticity effect, where the latter depends on the full tax structure, not just the top rate and threshold, as well as average income above the top threshold. Hence, the Saez *et al.* elasticity result is a special case of the more general result derived in (23) above.

The policy significance of the results derived above is that a given behavioural response to a change in a marginal tax rate could have quite different impacts on tax revenue depending on the nature of the tax structure and the distribution of taxable income across *all* taxpayers. This complete taxable income distribution is unlikely to be adequately described by the Pareto form. The next section provides some orders of magnitude for these effects, based on data for New Zealand.

4 Illustrative Examples

To provide an illustration of the nature of the relationships involved and the sensitivity to variations in the elasticity of taxable income, this section considers changes to the New Zealand income tax structure, made in the 2010 Budget. Conveniently for present purposes, this reduced all income tax rates but left income thresholds unchanged.

[14] For the US, Saez *et al.* (2012) find values for $\left(\frac{\bar{y}_K - a_K}{\bar{y}_K}\right)$ around 1.5; that is, $\left(\frac{\bar{y}_K}{\bar{y}_K - a_K}\right) \simeq 0.67$.

Table 2 provides summary information regarding the distribution of annual personal taxable incomes in the 2008/09 tax year, the most recent available year.[15] The overall arithmetic mean taxable income is $35,507. The thresholds shown in the table also relate to the structure in 2009/10.

Table 2: The Distribution of Taxable Income in New Zealand: 2008/09 Tax Year

k	a_k	$\bar{y}_k$	Prop of people	Prop of income
1	1	6748.82	0.241	0.046
2	14000	24080.76	0.434	0.294
3	48000	52414.34	0.224	0.331
4	70000	115480.70	0.101	0.329

Table 3 provides summary information about the pre- and post-2010 Budget tax structures, for the taxable income distribution of Table 2. The Budget 2010 reductions in all tax rates, and especially the top rate, are shown in Table 3. Given the relatively low value of the income threshold above which the top rate applies ($70,000). Table 3 shows that this tax bracket contributes a higher proportion of total income tax revenue than the other brackets, even though it contains only ten per cent of taxpayers (Table 2). This compares with the second tax bracket which contains over forty per cent of all taxpayers. The final column of Table 3 reports the revenue elasticity, $\eta_{T,y}$, in each tax bracket, evaluated at arithmetic mean income within the bracket. For each tax structure, this elasticity is highest in the third tax bracket because the value of $\bar{y}_3$ is relatively closer to the effective income threshold, a_3^* than for the other brackets. For those in the first tax bracket, the average and marginal tax rates are equal (New Zealand has no initial tax-free threshold) and hence the revenue elasticity is unity. The Budget changes in the marginal tax rates can be seen to have little effect on the revenue elasticities.

Figures 4 and 5 show the variations in the elasticity of revenue with respect to τ_k, η_{R,τ_k}, for each tax bracket, as the elasticity of taxable income, $\eta_{y,1-\tau_k}$, increases. The lines marked 'all MTRs' in these figures show the elasticity of total revenue with respect to a simultaneous equal proportionate change in all marginal tax rates. These must begin at $\eta_{R,\tau} = 1$ when the elasticity of taxable income is zero at all income

[15] The table is obtained from unpublished Inland Revenue Department data covering 3,304,210 individuals.

Table 3: The New Zealand Income Tax Structure Before and After the 2010 Budget

k	τ_k	a_k^*	R_k/P_k	R_k/R	$\eta_{T(\bar{y}_k),y}$
Tax rates pre-2010 Budget					
1	0.125	1.00	843.48	0.027	1.000
2	0.210	5667.26	3866.83	0.222	1.308
3	0.330	21060.99	10346.61	0.306	1.672
4	0.380	27500.33	33432.53	0.446	1.313
Tax rates post-2010 Budget					
1	0.105	1.00	708.52	0.026	1.000
2	0.175	5600.60	3234.03	0.217	1.303
3	0.300	23267.02	8744.20	0.303	1.798
4	0.330	27515.47	29028.52	0.454	1.313

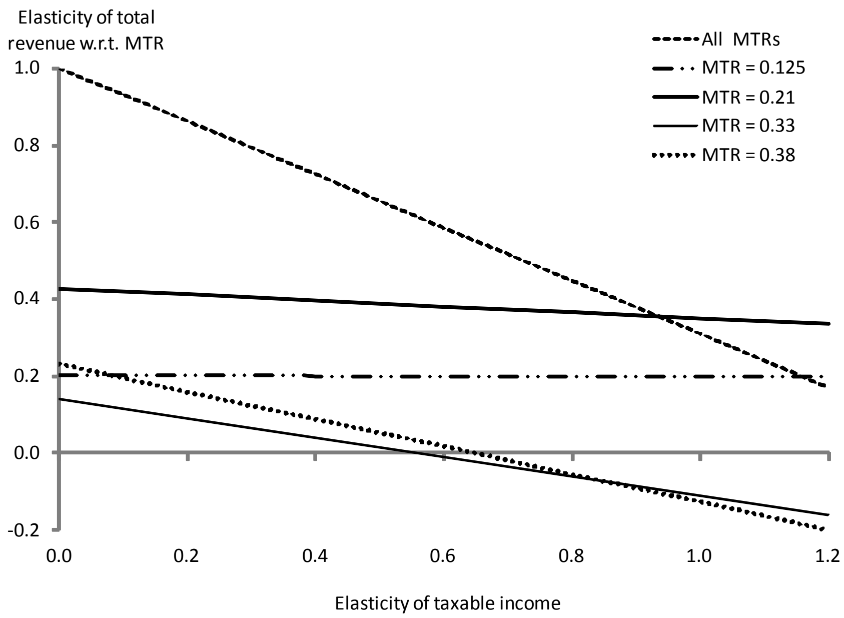

Figure 4: Elasticity of Total Tax Revenue wrt Tax Rates: Pre-2010 Budget

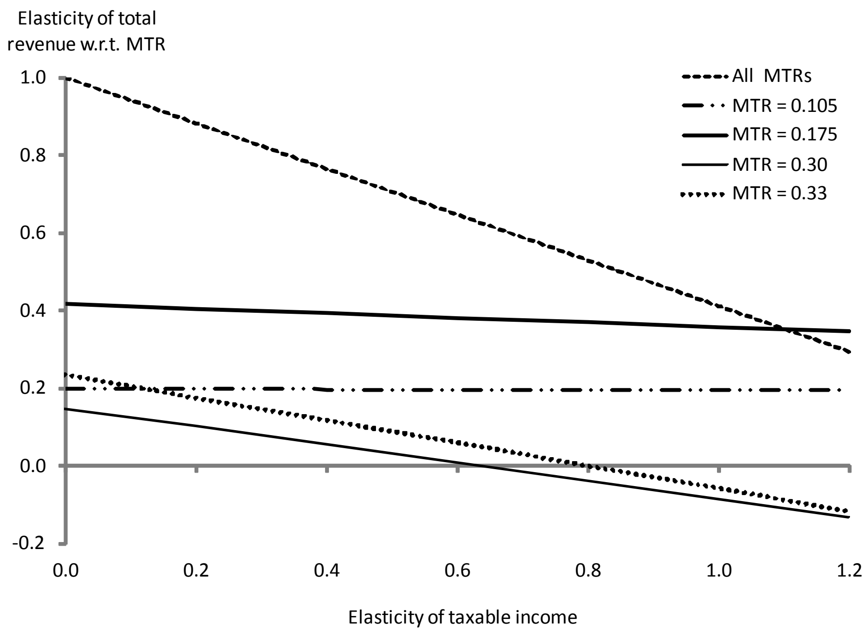

Figure 5: Elasticity of Total Tax Revenue wrt Tax Rates: Post-2010 Budget

levels. The other lines in the figures indicate, for each tax bracket, the variation in the elasticity, η_{R,τ_k}, when only the kth marginal tax rate is increased, with other rates held constant.

As demonstrated by equation (23) above, the value of each η_{R,τ_k} falls linearly with $\eta_{y,1-\tau_k}$, but the rate of decrease is less in the post-2010 Budget structure. This reflects the impact of the Budget on terms in equation (23) involving τ_k and a_k^*, as well as effects on the revenue share terms. In each case the elasticity, η_{R,τ_k}, for the lowest income tax bracket remains approximately constant across different ETI values. The change in this marginal rate has an income effect on those in higher tax brackets, but this, by assumption, does not affect their taxable income; hence increasing the elasticity of taxable income has a smaller effect on the total revenue elasticity than for other tax brackets. The revenue elasticity is highest in the third tax bracket; see Table 3. Nevertheless, the value of η_{R,τ_k} falls slightly faster in the top marginal rate bracket. This is because the value of $\tau_k/(1-\tau_k)$ is higher for the top marginal tax rate, along with the fact that the top-rate bracket contributes a higher proportion of aggregate tax revenue; see Table 3. The reduction in the two highest marginal tax rates in the 2010

Budget implies that the elasticity, η_{R,τ_k}, continues to be positive, for higher values of the elasticity of taxable income than the equivalent pre-2010 cases.

These diagrams show the effect on aggregate revenue for alternative assumed values of the elasticity of taxable income in each tax brackets. The appropriate empirical value of the ETI is, however, likely to vary across tax brackets. Some evidence for New Zealand taxpayers is reported in Claus *et al.* (2010), who found that for those in the lower tax brackets, the estimated elasticities were very small, while for the top marginal tax rate the responses were substantial, with values mainly in the range 0.5 to 1.2.

These findings have potentially important implications. For the higher marginal tax rates, the diagrams show that if the elasticity is above around 0.6, further increases in the rates could lead to reductions in total income tax revenue. Aggregate revenue is clearly most responsive to changes in the second marginal rate even if, as seems unlikely, the elasticity of taxable income is relatively high. Diagrams such as Figures 4 and 5 therefore provide a convenient way to identify the revenue effects of changes to different marginal tax rates for alternative assumptions regarding the taxable income responses of taxpayers in different tax brackets.

5 Conclusions

This paper has examined the joint role of the elasticity of taxable income (which refers to the behavioural effect on taxable income of a marginal tax rate change) and the revenue elasticity (which reflects the structural effect on revenue of a change in taxable income) in influencing the revenue effects of tax rate changes. Traditionally, the revenue elasticity has been the central concept when examining fiscal drag, and obtaining local measures of tax progressivity. But it has an additional role in the context of the revenue effects of tax changes when incomes respond to rate changes. Though 'mechanical' and behavioural effects have been distinguished in the literature, this separate revenue effect has not previously been discussed explicitly within the context of typical multi-rate income tax regimes.

The paper has examined the elasticity of tax revenue with respect to a rate change, in such multi-rate systems, at both the individual and aggregate levels and shown that tractable expressions can be derived for the revenue consequences of various marginal tax rate changes with associated income responses. When a single marginal tax rate in a multi-rate income tax structure is changed, those in the relevant tax bracket adjust their incomes in accordance with the elasticity of taxable income, and this affects the tax paid via the revenue elasticity. There is also a revenue effect on those individuals who are in higher tax brackets, since marginal rate changes in lower tax brackets imply a change in their effective income threshold. But there are no marginal incentive effects on higher-rate taxpayers because only their average tax rate changes. Only if there were no incentive effects would an equal proportional change in all marginal tax rates produce the same proportional increase in total revenue.

Illustrations were provided using the New Zealand income tax structures before and after the 2010 Budget. This reduced all marginal rates while leaving income thresholds unchanged and, in particular, reduced the top marginal rate substantially. The elasticity of total tax revenue with respect to a single tax rate change was found to be particularly sensitive to the elasticity of taxable income in the top two tax brackets. In the pre-Budget structure, an elasticity of taxable income in excess of about 0.6 was found to produce a negative tax revenue response to an increase in the top two marginal rates. When these rates are lower, as in the post-Budget structure, the elasticity of taxable income needs to be over 0.8 before tax revenue in the highest tax bracket is expected to fall in response to an increase in the marginal rate. However, recent estimates of the elasticity of taxable income in the top tax bracket in New Zealand are in the range (with some estimates in excess of 1) where tax revenue may fall.

These results for New Zealand illustrate how detailed empirical investigation of the elasticity of taxable income for taxpayers in different income tax brackets can be important to assess whether cuts in some marginal tax rates are likely to be revenue-enhancing.

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About the Authors

John Creedy is Visiting Professorial Fellow at Victoria Business School, Victoria University of Wellington, New Zealand, and a Principal Advisor at the New Zealand Treasury. He is on leave from the University of Melbourne where he is The Truby Williams Professor of Economics.
Email: john.creedy@vuw.ac.nz

Norman Gemmell is Professor of Public Finance at Victoria Business School, Victoria University of Wellington, New Zealand.
Email: norman.gemmell@vuw.ac.nz