MARGINAL TAX RATES AND INCOME: NEW TIME SERIES EVIDENCE*

KAREL MERTENS

Cornell University, NBER, CEPR

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Abstract

This paper estimates the dynamic effects of marginal tax rate changes on income reported on tax returns in the United States over the 1950-2010 period. After isolating exogenous variation in average marginal tax rates in structural vector autoregressions using a narrative identification approach, I find large positive effects of tax cuts in the top 1% of the income distribution. In contrast to earlier findings based on tax return data, I also find large effects in other income percentile brackets. A hypothetical tax reform cutting marginal rates only for the top 1% leads to sizeable increases in top 1% incomes and has a positive effect on real GDP. There are also spillover effects to incomes outside of the top 1%, but top marginal rate cuts lead to greater inequality in pre-tax incomes.

Keywords: Fiscal Policy, Tax Changes, Marginal Tax Rates, Income, Income Distribution

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1 Introduction

To what extent do marginal tax rates matter for individual decisions to work and invest? The answer is essential for public policy and its role in shaping economic growth. The empirical literature that uses tax return data, surveyed in Saez, Slemrod and Giertz (2012), finds that incomes before taxes react only modestly to marginal tax rates and that the response is mostly situated at the very top of the income distribution. But as Saez et al. (2012) acknowledge, there are many important challenges in identifying and interpreting these effects. This paper adopts a macro-time series approach that addresses the endogeneity of average marginal tax rates in novel ways and permits insight into dynamics. Based on this approach, I find large income responses to marginal tax rates that extend across the income distribution.

The empirical strategy makes use of structural vector autoregressions (SVARs) identified on the basis of proxies for exogenous variation in tax rates, as in Mertens and Ravn (2013a). The proxies are quantitative measures of the impact of selected historical tax reforms on average tax rates that are assumed to be contemporaneously correlated only with unanticipated latent shocks to average marginal tax rates. The selection of tax reforms is based on Romer and Romer's (2009) narrative account of US postwar tax policy, focusing on individual income tax changes legislated and implemented within a year to avoid anticipation effects. The identified aggregate tax shock is then used as an instrument to estimate the income response to changes in average marginal tax rates for different income percentile brackets using an annual sample covering sixty years (1950-2010) of postwar federal income taxation in the US.

Much of the public finance literature is concerned with estimating the elasticity of income with respect to net-of-tax rates (one minus the marginal tax rate). Regressing income measures from IRS tax returns on net-of-tax rates, as in Saez (2004) or Romer and Romer (2012), yields positive elasticities for the top 1% but insignificant and even negative elasticities for lower income percentile brackets. However, the imperfect indexation of tax brackets and the use of tax policy for macroeconomic stabilization or to finance military spending all induce misleading positive relationships between incomes and tax rates. Moreover, the impact on investment decisions and the anticipated nature of many historical tax changes create complicated intertemporal linkages between tax rates and incomes. The SVAR methodology can resolve these problems.

According to the OLS regressions, the short run elasticity of aggregate gross income (less transfers and capital gains) with respect to the net-of-tax rate is -0.3 and not significant. When controlling for endogeneity in the SVAR, the elasticity equals 1.2 and is significant. Formal tests of the SVAR parameters strongly reject the exogeneity of average marginal tax rates. After instrumentation, the short run elasticity is 1.3 for the top 1% and 1.1 for the bottom 99%, compared to 0.6 and -0.6 when using OLS. The empirical model not only identifies the effects in the first year, but also in subsequent years. An unanticipated increase in the average marginal tax rate is found to be transitory and the dynamic elasticities of aggregate income are hump-shaped with a peak at 2.0 in the third year. The dynamic elasticities across various income percentile brackets are all positive, have similar hump shapes and there is no evidence that the elasticities increase with income.

The SVAR-based estimates measure the responsiveness to marginal tax rates associated with aggregate tax reforms. While these estimates are useful to assess the implications for revenues, economic activity or income inequality, they are not realistic measures of pure microeconomic substitution effects. Since marginal rates typically change simultaneously across income brackets, even the estimates for relatively thin slices of the income distribution capture general equilibrium effects on wages, interest rates, employment, etc. To eliminate the bulk of these effects, I extend the SVAR analysis and estimate the impact of a counterfactual tax reform cutting marginal tax rates only for the top 1% using selected historical changes in top marginal rates as an additional proxy for identification. The associated elasticity with respect to the net-of-tax rate for the top 1% is 0.5 in the first year and 1.0 for the two following years. These values are less than half those for a tax reform cutting marginal rates more broadly and are at the high end of the range of micro-level estimates for top incomes.[1] A top marginal rate cut raises real GDP by up to 0.3 percent after two years and also has a positive effect on incomes outside of the top 1%. Nevertheless, marginal rate cuts targeting top incomes lead to greater income inequality.

The empirical results in this paper are relevant for several important debates. First, they reinforce the findings by a number of recent macro studies of large effects of aggregate tax changes on real GDP both in the US and

[1] See for instance Lindsey (1987), Feldstein (1995), Auten and Carroll (1999), Gruber and Saez (2002), and Giertz (2010).

internationally.[2] The results imply that raising marginal tax rates to resolve budget deficits comes at a high price and that a proportional across-the-board tax cut provides successful stimulus that does not necessarily lead to greater income concentration at the top. The large macro effects of tax changes can be reconciled with the more modest responses found in the public finance literature through general equilibrium effects and endogeneity problems. The results are also consistent with the strong negative correlation between top tax rates and top 1% income shares documented by Piketty, Saez and Stantcheva (2013). However, the positive response of real GDP and incomes outside the top 1% to a top marginal rate cut contradict explanations based on tax avoidance or on the notion that the effects come entirely at the expense of lower incomes. Finally, the results are relevant for optimal taxation, as the micro-level elasticity of income to net-of-tax rates is a crucial input in many optimal tax formulas.[3] Keeping in mind the pitfalls of identifying this elasticity from aggregate time series, the top marginal rate cut experiment suggests medium run values of around unity for the top 1%. However, after factoring in general equilibrium effects, the behavioral responses to broader tax rate changes can ultimately be substantially larger.

The remainder of this paper is organized as follows. Section 2 provides a simple motivating theoretical framework and discusses the data on average marginal tax rates. Section 3 presents the results from OLS regressions and discusses various sources of bias. Section 4 covers the SVAR analysis and presents the dynamic estimates. Section 5 extends the analysis to focus on top marginal rate changes. Section 6 concludes.

2 Income and Average Marginal Tax Rates

2.1 A Simple Theoretical Framework

To motivate the empirical specifications in this paper, it is useful to begin the analysis with a simple theoretical framework. Suppose there is a unit measure of agents indexed by $i \in [0,1]$ with a utility function as in

[2] Examples for the US are Romer and Romer (2010), Barro and Redlick (2011), Mertens and Ravn (2013a,b); for the UK, Cloyne (2013); for Germany, Hayo and Uhl (2013); Leigh, Pescatori and Guajardo (2013) find large contractionary effects of tax based fiscal consolidations in OECD countries. All of these empirical studies are based on a narrative identification strategy.

[3] See for instance Feldstein (1999), Saez (2001) or Chetty (2009).

Greenwood et al. (1988),

$$u\left(c_{it}-\frac{hx_{it}}{1+1/\varepsilon}(h_{it}/h)^{1+1/\varepsilon}\right)\ ;\ h,\varepsilon\geq 0\ , \tag{1}$$

where c_{it} and h_{it} denote consumption and hours worked. The parameter $\varepsilon \geq 0$ is the (Frisch) labor supply elasticity. To ensure that on average the utility cost of labor supply increases at the same rate as the real wage w_{it}, the utility function (1) includes an exogenous preference shifter x_{it}. The budget constraint is $c_{it} \leq e_{it} - T(e_{it}) + f_{it}$ where $e_{it} = w_{it}h_{it}$ is wage income, f_{it} is non-wage income, and $T(\cdot)$ are taxes due. For simplicity only wage income is taxable. Utility maximization yields the labor supply function,

$$h_{it} = h\left((1-T'(e_{it}))w_{it}/x_{it}\right)^{\varepsilon}\ , \tag{2}$$

where $T'(\cdot)$ is agent i's marginal tax rate. By assumption, $T'(e_{it})$ and w_{it}/x_{it} are stationary such that labor supply is stationary despite the absence of income effects on labor supply.

Consider a tax schedule of the type proposed by Heathcote et al. (2011):

$$T(e_{it}) \ = \ e_{it}-(1-\tau_t)\frac{(e_{it}/\bar{e}_t)^{1-\gamma}}{1-\gamma}\bar{e}_t\ ,\ \ 0\leq\gamma<1 \tag{3}$$

where $\bar{e}_t = \left(\int_0^1 e_{it}^{1-\gamma} di\right)^{1/(1-\gamma)}$ is an aggregate of wage income and $\tau_t = 1 - \int_0^1 (e_{it}/\bar{e}_t)(1-T'(e_{it}))di$ is the economy-wide average marginal tax rate, or AMTR. The AMTR is a weighted average of individual marginal tax rates with weights given by income shares. The parameter γ measures the progressivity in the tax system: When $\gamma = 0$ all agents face the same marginal tax rate τ_t, when $\gamma > 0$ the tax system is progressive.[4] Under the tax schedule in (3), the net-of-tax rate for agent i is $1-T'(e_{it}) = (1-\tau_t)(e_{it}/\bar{e}_t)^{-\gamma}$. Substituting into (2) and aggregating over all agents in any subset $S \subseteq [0,1]$ implies that aggregate wage income is $e_t^s = h(1-\tau_t^s)^{\varepsilon}(w_t^s)^{1+\varepsilon}(x_t^s)^{-\varepsilon}z_t^s$. where $w_t^s = \int_S w_{it}di$ is the average hourly wage for agents in S, $x_t^s = \int_S x_{it}di$ and z_t^s depends only on higher order moments of the cross-sectional distribution of (w_{it}, x_{it}) over

[4] Guner, Kaygusuz and Ventura (2012) compare (3) to other functional forms and conclude all specifications provide reasonable descriptions of effective tax functions in the US. They estimate $\gamma = 0.031$ for labor income and $\gamma = 0.036$ for total income on the basis of US tax returns for 2000.

S.[5] Taking logs and first differencing yields

$$\Delta \ln(e_t^s) \quad = \quad \varepsilon \Delta \ln(1-\tau_t^s) + r_t^s \tag{4}$$

where $\tau_t^s = 1 - \int_S (e_{it}/\bar{e}_t^s(1-T'(e_{it}))di)$ is the AMTR for all agents in S and $r_t^s = (1+\varepsilon)\Delta \ln(w_t^s) - \varepsilon \Delta \ln(x_t^s) + \Delta \ln(z_t^s)$ is stationary. When $S = [0,1]$, $\tau^s = \tau_t$ and the economy-wide average income and real wage level are correspondingly denoted by e_t and w_t respectively.

Equation (4) decomposes the determinants of earnings growth at any level of aggregation into tax and non-tax related factors. To the extent non-tax factors can be controlled for, observed variation in incomes and average marginal tax rates yields estimates of the labor supply elasticity ε. Unfortunately, in reality the income tax liability is not based on earnings alone but on taxable income, which includes capital income and allows for numerous deductions and exemptions. Tax rates may affect many decisions other than labor supply, such as the form and timing of compensation, the use of deductions, etc. For this reason, ε is typically given a broader interpretation as the elasticity of taxable income (ETI), which should exceed the labor supply elasticity. The ETI has received much attention in public finance as a measure of the distortionary effects of marginal tax rates, see Saez et al. (2012) for a survey. A key insight from (4) is that the correct empirical measures for assessing the impact on aggregated income measures are AMTRs, or income weighted averages of statutory rates.

2.2 Average Marginal Tax Rates: Data and Stylized Facts

Figure 1 shows annual time series for average marginal tax rates from 1950 to 2010 constructed from US federal tax return statistics, both for the aggregate economy as well as for different income percentile brackets. Because of data availability, the focus is exclusively on the federal individual income tax, which is the largest source of aggregate variation in marginal tax rates. The series extend existing AMTR measures using publicly available data from the annual Statistics of Income published by the Internal Revenue Service. Adjustments are made to account for non-filers such that the tax rates and income rankings reflect

[5]More precisely, $z_t^s = \left(\int_S \left((w_{it}/w_t^s)^{1+\varepsilon} (x_{it}/x_t^s)^{-\varepsilon} \right)^{\frac{1}{1+\varepsilon\gamma}} di \right) \left(\int_S \left((w_{it}/w_t^s)^{1+\varepsilon} (x_{it}/x_t^s)^{-\varepsilon} \right)^{\frac{1-\gamma}{1+\varepsilon\gamma}} di \right)^{\varepsilon\gamma/(1-\gamma)}$.

the entire population of potential tax filing units, defined as all married men and singles aged 20 and over. The first economy-wide measure, Series 1 in the left panel of Figure 1, extends data from Barro and Redlick (2011) up to 2010. The second economy-wide measure (Series 2) and the measures for top and bottom tax units (right panel of Figure 1) extend the data of Saez (2004) to include the 1950s and 2000s as well as a few missing years in the 1960s. The methodology for extending the series is based on Barro and Sahasakul (1983) and approximations of the distribution of adjusted gross income and tax rates, which are necessary to construct AMTRs for different income brackets. Economy-wide Series 1 and 2 differ by the income definition and the treatment of nonfilers. Data limitations imply that the income concept used for the weights is not entirely consistent over the whole sample.[6] However, periods of overlap reveal very high correlations between measurements. In any case, key parts of the analysis will be repeated for a shorter subsample of consistent observations (1960-2000). Full details on the data construction are given in Appendix A.1.

Much of the postwar variation in the average marginal tax rates depicted in Figure 1 reflect well known legislative changes to the federal tax code. The larger changes to statutory rates include the tax increases in the 1950s during the Korean War; the 1964 Kennedy tax cuts; the 1968-1970 surcharge during the Vietnam War; the 1980s Reagan tax cuts and in particular the 1986 Tax Reform Act; the early 1990s Clinton tax increases; and the Bush tax cuts in the early 2000s. Average marginal tax rates are not only affected by changes in statutory rates, but also by adjustments to tax brackets or changes in deductions and exemptions. Because of tax progressivity and bracket creep, average marginal tax rates vary with income levels even in the absence of legislative changes.

The effects of bracket creep due to high (nominal) income growth are most apparent during the high inflation era of the 1970s: without any major statutory tax increases, the economy-wide AMTR rose by 6 to 8 percentage points. Other episodes of relative legislative calm but rising AMTRs due to (mostly real) increases in incomes are evident in 1955-1963 as well as the mid to late 1990s. Note that the three most important rounds of statutory tax rate cuts (Kennedy, Reagan and Bush) each followed periods of signifi-

[6] Observations from Barro and Redlick (2011) from 1966-2006 are based on a broad concept of labor income. Data from Saez (1960,1962,1964, 1966-2000) are based on all income excluding capital gains and government transfers. All other observations are based on adjusted gross income.

cant bracket creep. Because bracket creep becomes irrelevant in the highest tax bracket, it does not affect all income percentile brackets equally. For instance, the right panel of Figure 1 shows that in the 1970s or 1990s the tax rate for the top 1% does not share the upward trend evident at lower income levels.[7] Tax progressivity also acts as an automatic stabilizer, which can be clearly seen for instance in the 2007-2009 recession, during which there were no major changes to the individual income tax. Another implication of imperfect indexation is that, because of economic growth, permanent cuts to statutory rates do not lead to permanent reductions in AMTRs, except at the highest tax bracket.

Table I provides some descriptive statistics. The economy-wide AMTR is quite volatile in the postwar sample, with an annual standard deviation of more than 2.0 percentage points in levels and around 1.5 percent in terms of net-of-tax rates. Table I also shows that the tax rates at the top of the income distribution have been much more volatile than for lower income groups, which facilitates the estimation for high income groups relative to lower income groups. Changes in net-of-tax rates are highly correlated across income percentile brackets. The lowest correlation, between the top 1% and bottom 90% brackets, is 0.69. AMTRs for different income levels are all highly correlated with the economy-wide measure: even the AMTR for the top 1% has a correlation of 0.78 and 0.83 with the economy-wide measures. When exploiting postwar time series variation to estimate tax elasticities, the aggregate implications of tax changes therefore need to be considered, even when focusing on the top of the income distribution. Finally, the two different measures of the economy-wide AMTR are very highly correlated and subsequent results are generally robust to which measure is chosen.

3 Univariate Time Series Regressions

A large empirical literature relies on variants of equation (4) to estimate the elasticity of income with respect to net-of-tax rates, often focusing on top incomes. Many micro level studies follow a 'natural experiment' approach and compare income changes before and after tax reforms. The key challenge is to establish the counterfactual growth in incomes that would occur in the absence of the tax change. The initial seminal

[7] Even in the 1970s, the AMTR for the top 1% remains relatively constant despite a highly graduated bracket system with statutory rates up to 70%. This is because a maximum tax rate on earned income of 50% effective during 1971-1980 (60% in 1970) protected a large fraction of top incomes from the effects of bracket creep.

study of Lindsey (1987) was benchmarked against taxable income levels simulated by a Treasury revenue model under a pre-reform tax regime. Subsequent studies have typically avoided such explicit counterfactuals and have instead relied on difference-in-difference techniques, cross-sectional regression methods and panel analysis, e.g. Feldstein (1995). Auten and Carroll (1999), Gruber and Saez (2002) or Giertz (2010). These methods effectively assume either that non-tax related sources of income growth are identical across comparison groups or that non-tax factors can be adequately controlled for by observables.[8]

An alternative approach is to look at more aggregated incomes and average marginal tax rates, as in for instance Feenberg and Poterba (1993), Slemrod (1996), Goolsbee (1999), Saez (2004) or Romer and Romer (2012). The benefit of a relatively long time series dimension is that in principle it allows for averaging out non-tax induced aggregate fluctuations in income growth. For instance, if tax changes are uncorrelated with r_t^s in (4), an OLS regression of income growth on changes in log net-of-tax rates suffices to condition on all non-tax related determinants of income growth. Results based on such a naive approach are discussed next.

3.1 Estimation Results

Table II shows results from regressions of changes in log income $\Delta \ln(e_t^s)$ on changes in the log net-of-tax rate $\Delta \ln(1-\tau_t^s)$, as suggested by equation (4). The income measures are derived from federal tax returns and are obtained from Piketty and Saez (2007). Aggregate wage income reported to the IRS is identical to 'total salaries and wage disbursements' in the national accounts. Top and bottom percentile wage incomes are based on the ranking of total income taking into account non-filers. All total income measures correspond to gross income excluding government transfers and capital gains. The series are deflated by the CPI Research Series Using Current Methods (CPI-U-RS) and expressed per tax unit. Table II presents results for two different samples: the largest effective sample, 1951-2010 in panel A, and a shorter sample, 1960-2000 in panel B. The latter not only covers years with a consistent income definition, but also facilitates comparison with earlier findings in the literature.

[8]Criticisms of the natural experiment approach have focused mainly on the role of non-tax related long run trends in income shares or the cross-sectional endogeneity of tax rates. For surveys and methodological discussions, see Slemrod (1998), Triest (1998), Goolsbee (1999) or Saez et al. (2012).

When tax rate changes are uncorrelated with the residuals in (4), the OLS coefficients are estimates of ETIs, which economic theory predicts to be nonnegative. Table II shows instead that many coefficients are negative, indicating that tax rate increases are associated with higher income growth. In both samples, the estimates are clearly increasing with income. Only for the top 1% are the coefficients positive and statistically significant, with point estimates ranging from 0.45 to 0.66 depending on the sample and type of income. In the shorter sample none of the other coefficients, including those in the economy-wide regressions, are significantly different from zero. In contrast, in the longer sample the regressions for the bottom income brackets as well as for aggregate income yield significant negative coefficients.

The results in panel B are very similar to those of Saez (2004). One possible interpretation is that only tax payers in the top 1% react to tax rates. Others studies have found elasticities that are increasing in income and much larger at the top of the income distribution, e.g. Gruber and Saez (2002) and Giertz (2010). However, the negative values in the larger sample make it clear that the OLS coefficients cannot generally be measuring behavioral responses to changes in marginal tax rates. Tax rates are correlated with non-tax determinants of income, resulting in biased coefficients. It is therefore problematic to draw any conclusions from Table II about the incentive effects of marginal tax rates or, since there is little reason to expect the bias to be identical across brackets, about how they vary with income. The literature addresses this problem by including additional controls and/or by instrumenting with only the policy induced changes in marginal tax rates, e.g. Slemrod (1996), Saez (2004), and Romer and Romer (2012). Another strategy is to focus on top incomes and/or pre WWII years because of the more volatile tax rates, e.g. Goolsbee (1999) and Romer and Romer (2012). As long as there is some basic controlling for lagged income, the results often remain largely the same and very similar to those in Table II.[9] To understand why identification issues may not have been properly resolved by these steps, the next section discusses the key problems in more detail.

3.2 Sources of Bias

Because most changes in postwar US tax policy have affected a sizeable fraction of the tax base, general equilibrium effects are a potentially important source of correlation between tax rates and the residuals in

[9] Although Romer and Romer (2012) find considerable smaller elasticities for top incomes in pre WWII regressions.

(4). These effects invalidate the coefficients as micro elasticities measuring only direct behavioral responses, because instead they also capture all indirect effects on non-tax determinants of income, such as on pre-tax wages, that make up the entire tax transmission mechanism. This problem however does not prevent a meaningful economic interpretation because the estimates remain valid measures of the total causal effect of marginal tax rates on income. More serious problems arise when average marginal tax rates depend on other factors affecting income growth. In practice, AMTRs are endogenous because of procyclical tax policies, bracket creep and other reasons that are discussed below. Reverse causality means the OLS estimates no longer have any meaningful interpretation.

The likely direction of some of the potentially more serious sources of bias can be analyzed by embedding equation (4) in general equilibrium models in which the non-tax determinants of income growth and/or the average marginal tax rates are endogenous variables. Let β^{OLS} denote the asymptotic OLS coefficient associated with the regression of aggregate income growth on the change in the economy-wide average marginal tax rate. Consider the following decomposition of the determinants of income growth,

$$\Delta \ln(e_t) \quad = \quad \eta v_t^{\tau} + \upsilon_t \;\; , \;\; E[v_t^{\tau}\upsilon_t] = 0 \; . \tag{5}$$

The first term in (5) captures the effect of purely *exogenous* changes to average marginal tax rates, denoted by v_t^{τ}. The residual υ_t captures all other determinants of income growth orthogonal to v_t^{τ}. Equation (5) differs from (4) because the elasticity η now captures also any general equilibrium effects of a change in taxes on income growth, and in general $\eta \neq \varepsilon$. In addition, when the AMTR is endogenous and depends on υ_t, simultaneity bias implies that $\beta^{OLS} \neq \eta$.

3.2.1 General Equilibrium Effects

There are many examples of dynamic general equilibrium models with exogenous tax shocks v^{τ} in which the parameter η in (5) is a complicated function of a large number of structural parameters, e.g. Braun (1994), McGrattan (1994), Leeper, Plante and Traum (2010) or Mertens and Ravn (2011). Here, I consider a much simpler model introducing two of the key sources of general equilibrium effects: a labor demand function that endogenizes wages and a labor supply function that depends on the marginal utility of consumption.

Consider a representative agent economy in which labor is the only variable input, the aggregate production function is $y_t = A_t h_t^{\alpha}$, $0 < \alpha \leq 1$ and productivity A_t grows randomly: $\Delta \ln(A_t) = v_t^a \sim N(0, \sigma_a^2)$. All markets are perfectly competitive and labor demand is $h_t = \alpha y_t / w_t$. Also, suppose that $A_t = x_t$ and that the government purchases g_t of the final good, such that market clearing requires $y_t = c_t + g_t$. Government purchases are given by $\ln(1 - g_t/y_t) = \ln(1 - s_g) + v_t^g$ where $0 \leq s_g < 1$ and $v_t^g \sim N(0, \sigma_g^2)$.

For now, assume the average marginal tax rate is independent of technology or government spending shocks v_t^a and v_t^g such that $\beta^{OLS} = \eta$. If the representative agent has utility as in (1), then equilibrium implies that

$$\eta = \frac{\alpha\varepsilon}{1 + (1-\alpha)\varepsilon} \;, \;\; \upsilon_t = v_t^a \; . \tag{6}$$

In a neoclassical labor market with a downward sloping labor demand, the real wage falls when taxes are lowered. Except when $\alpha = 1$, a wage decline reduces the overall effect of tax rates on income and $\eta < \varepsilon$.

General equilibrium effects need not be restricted to wage adjustments. Suppose that instead of (1), agents have the balanced-growth-consistent utility function

$$\ln c_t - \frac{h}{1 + 1/\varepsilon} (h_t / h)^{1 + 1/\varepsilon} \tag{7}$$

which now implies that labor supply depends on the marginal utility of consumption. Aggregate wage income becomes $e_t = h(1 - \tau_t)^{\varepsilon} w_t^{1+\varepsilon} c_t^{-\varepsilon}$ and imposing the equilibrium conditions yields

$$\eta = \frac{\alpha\varepsilon}{1 + \varepsilon} \;, \;\; \upsilon_t = v_t^a - \eta(v_t^g - v_{t-1}^g) \; . \tag{8}$$

Negative income effects temper the outward shift of labor supply following a tax cut, which further reduces the total impact of taxes on income growth.

With a neoclassical labor market and without physical capital, wage and income effects result in OLS coefficients below the compensated elasticity ε. In other settings real wages may instead rise when income taxes are cut, for instance because increased investment shifts labor demand, or when there are nominal rigidities and aggregate demand effects. Tax reforms may affect employment, labor force participation, government spending (starve-the-beast), corporate and other taxes (including at the state level) or monetary policy. Because in reality the tax transmission mechanism is complex, estimates of the macro elasticity η do not lead directly to any strong conclusions about labor supply elasticities or ETIs, except perhaps under the special assumptions that there are no income effects and that wages are independent of tax rates. Given the high correlations between tax rates for different income percentile brackets in the postwar sample, the same is true also when focusing on subgroups of tax payers, such as those at the top of the income distribution.

3.2.2 Simultaneity Bias

More problematic is that there are a number of reasons for simultaneity bias in the OLS estimates of η:

Endogenous Tax Policy A first reason is that the individual income tax has been actively used as an instrument for macroeconomic stabilization. For instance, in 1968 a temporary 10 percent surcharge was imposed to prevent the economy from overheating whereas in 1975 increases in the standard deduction and tax credits or in 2001 a new 10% low income tax bracket were introduced to cushion economic slowdowns.[10] Suppose the AMTR is targeted by the government according to the rule

$$\ln(1-\tau_t) \quad = \quad \ln(1-\tau) + \phi_y \Delta \ln(y_t) + v_t^{\tau} \;\;,\;\; v_t^{\tau} \sim N(0, \sigma_{\tau}^2) \tag{9}$$

The second term in this rule captures a systematic component of tax policy responsive to output growth whereas the last term captures exogenous shocks to tax rates. Assuming wage income is proportional to total

[10]These changes were legislated under the Revenue and Expenditure Control Act of 1968, The Tax Reform Act of 1975 and The Economic Growth and Tax Relief Reconciliation Act of 2001 respectively. The impact of the 1975 tax cut was large in terms of revenues but relatively small in terms of marginal rates. See Pechman (1987) or Romer and Romer (2009) for historical background.

output and that $E[\upsilon_t, v_{t-1}^{\tau}] = 0$, the asymptotic OLS coefficient is given by

$$\beta^{OLS} = \eta + \frac{\phi_y}{1-\phi_y\eta} \frac{Var(\upsilon_t)}{Var(\Delta \ln(1-\tau_t))} \tag{10}$$

When tax rates have a systematic procyclical component ($\phi_y < 0$), OLS produces a downward biased estimate of η. The bias is larger when non-tax sources of variation in income growth are relatively more important than changes in tax rates. Because Table II showed that the variance of tax rates is increasing in income, ceteris paribus the bias is smaller in regressions for higher income percentile brackets.

Historically, federal income tax rates have also responded to changes in government spending. For example, in the 1950s marginal tax rates were increased several times to help finance the war effort in Korea, whereas the 1968 surcharge was imposed in the context of the escalation of the Vietnam War.[11] Suppose the government targets the AMTR according to the rule

$$\ln(1-\tau_t) = \ln(1-\tau) + \phi_g \ln\left(\frac{1-g_t/y_t}{1-s_g}\right) + v_t^{\tau}\ , \ \ v_t^{\tau} \sim N(0, \sigma_{\tau}^2)\ , \tag{11}$$

and that the rest of the economy is as in Section 3.2.1. For the case where there are income effects on labor supply, a shock to government spending leads to higher labor incomes and

$$\beta^{OLS} = \eta\left(1 - \phi_g \frac{Var(\Delta \ln(1-g_t/y_t))}{Var(\Delta \ln(1-\tau_t))}\right) \tag{12}$$

If tax rates are raised in response to higher government spending ($\phi_g > 0$), the OLS estimate is downward biased. The downward direction of the bias is quite general and depends on whether increases in government spending lead to higher incomes. Most macroeconomic models as well as a large number of empirical studies support expansionary effects of government purchases.[12] Again the bias is decreasing in the variance of tax rate changes and is ceteris paribus smaller in the regressions for higher income percentile brackets.

[11] The Korean War tax increases occurred under the Revenue Acts of 1950 and 1951. More systematic time series evidence that spending increases lead to higher tax rates can be found in Burnside, Eichenbaum and Fisher (2004) and Ramey (2011a).

[12] See Ramey (2011b) for a recent overview of the literature on the expansionary effects of government spending.

Bracket Creep In practice tax brackets are imperfectly indexed to growth in nominal incomes. Prior to the mid 1980s, there was no automatic indexation. Since 1987, tax brackets and most exemptions and deductions are adjusted automatically based on the previous year growth in the consumer price index.[13] Suppose agent i's nominal tax liabilities are

$$T(E_{it}) = E_{it} - (1-\tilde{\tau}_t)\frac{(E_{it}/\bar{E}_{t-1})^{1-\gamma}}{1-\gamma}\bar{E}_{t-1} \tag{13}$$

where $\ln(1-\tilde{\tau}_t) = \ln(1-\tau) + v_t^{\tau}$, $\tilde{\tau}_t$ is an exogenous variable determined by statutory tax rates, E_{it} is nominal wage income of agent i and $\bar{E}_t \equiv \left(\int_0^1 E_{it}^{1-\gamma} di\right)^{1/(1-\gamma)}$. The tax function in (13) implies that tax rates are indexed to nominal income growth with a one year delay. While capturing the post-1987 practice of inflation indexation, the specification in (13) also implies (lagged) indexation to real income growth. Whereas no such real indexation exists in reality, the goal here is just to illustrate the main implications of imperfect indexation for the behavior of average marginal tax rates. The economy-wide AMTR is now determined by

$$\tau_t = 1 - (1-\tilde{\tau}_t)\left(\frac{\bar{e}_t}{\bar{e}_{t-1}}(1+\pi_t)\right)^{-\gamma}. \tag{14}$$

In a representative agent approximation of the economy, $\bar{e}_t = e_t = \alpha y_t$, such that

$$\ln(1-\tau_t) = \ln(1-\tau) - \gamma\Delta\ln(y_t) - \gamma\pi_t + v_t^{\tau}. \tag{15}$$

Under a progressive tax system ($\gamma > 0$), imperfect indexation implies that average marginal tax rates depend positively on income growth and inflation. The positive dependence on income growth necessarily leads to a downward bias as in (10). The bias due to inflation is ambiguous and depends on the covariance between inflation and income growth. In models with an output-inflation trade-off, demand-driven income fluctuations lead to a downward bias whereas supply-driven fluctuations instead give rise to an upward bias. In the 1950-2010 sample, the unconditional covariance between inflation and GDP growth is relatively close to zero such that on balance bracket creep probably induces a downward OLS bias. As before, the higher

[13] Annual inflation adjustments began de facto in 1985. Some components of the tax code, such as the alternative minimum tax, have not been automatically indexed to inflation even after 1987. The American Taxpayer Relief Act of 2012 starts automatic indexation of the alternative minimum tax in 2013.

variance of tax rates for top incomes means the bias decreases with income. The bias is also smaller or absent at the very top of the income distribution because bracket creep does not affect tax payers in the highest bracket, which was apparent in the AMTR series for the top 1% in Figure 1.

Anticipated Tax Changes Even statutory tax changes that are independent of the business cycle or government spending may give rise to endogeneity bias because of tax foresight. Forward looking agents have incentives to allocate consumption and income generating activities optimally across time in response to future changes in marginal tax rates. Tax changes have frequently been anticipated by economic agents, if only because they were legislated in advance of implementation.[14] For instance, the 1980s and 2001 tax reforms phased in marginal rate reductions over multiple years.[15]

Since anticipation effects are only relevant in dynamic settings, it becomes necessary to specify whether tax changes are permanent or transitory. Suppose the economy-wide AMTR evolves according to

$$\Delta \ln(1-\tau_t) \;=\; v_t^{\tau} + v_{t-1}^{a} \;,\; v_t^{\tau} \sim N(0,\sigma_{\tau}^2)\;,\; v_t^{a} \sim N(0,\sigma_a^2)\;. \tag{16}$$

Equation (16) assumes that all tax rate changes are permanent and exogenous. Some tax changes are unanticipated by agents (v_t^{τ}) whereas others are known one year in advance (v_t^{a}). In the presence of anticipated tax changes, the OLS regression yields

$$\beta^{OLS} \;=\; \eta + (\chi - \eta)\frac{\sigma_a^2}{\sigma_{\tau}^2 + \sigma_a^2} \tag{17}$$

where χ is income growth at the time that a tax change occurs that was preannounced in the year before. According to (17), the OLS coefficient is a weighted average of the true income response to an unanticipated change in tax rates (η) and the response to one that was known to occur in advance (χ), with weights determined by the relative variance of both types of tax shocks.

[14] Kueng (2011) finds evidence in municipal bond yields that financial markets forecast federal tax rates remarkably well.

[15] The Economic Recovery Tax Act of 1981 phased in marginal rate cuts over three years. The 1986 Tax Reform Act reduced rates in 1987 and again in 1988. The 2001 Economic Growth and Tax Relief Reconciliation Act scheduled rate reductions effective in 2002, 2004, and 2006.

The sign of the bias due to tax foresight is ex ante ambiguous. On the one hand incomes may increase prior to the implementation of a tax cut such that little income growth occurs in the actual period of the tax cut. In this case $\chi < \eta$ and the OLS coefficient is downward biased. If all tax shocks are anticipated ($\sigma_\tau^2 = 0$) and all behavioral responses occur prior to the tax change ($\chi = 0$), the OLS coefficient will be zero even though the true impact of tax shocks may be very large. On the other hand, agents may shift income towards time periods with low tax rates such that incomes decline prior to an anticipated tax cut. Income then grows more strongly in the period the tax cut becomes effective such that $\chi > \eta$. In this case OLS overestimates the true impact of an unanticipated tax cut. A number of studies analyze whether anticipated tax changes are contractionary or expansionary in the context of DSGE models.[16] Appendix B provides a simple theoretical illustration of how the sign of $\chi - \eta$ depends on the strength of intertemporal substitution effects and is generally ambiguous. However, independent structural VAR evidence by Mertens and Ravn (2012) and Leeper, Walker and Yang (2013) suggests that news of a future tax cut leads to reduction in real GDP, implying that tax foresight generates an upward bias. High income households may be more responsive to tax news than lower income households, for instance because of greater opportunities for income shifting, better information about tax policies or better access to financial markets. If this is the case, the upward anticipation bias may be stronger for high income tax units.

Endogeneity of the Income Distribution The specification of the tax function in (3) implies that the AMTR for any subset S of agents is linked to the economy-wide AMTR by

$$\ln(1-\tau_t^s) \;=\; \ln(1-\tau_t) - \gamma \ln\left(\bar{e}_t^s/\bar{e}_t\right) \ . \tag{18}$$

This expression makes explicit that in a progressive tax system ($\gamma > 0$) the average marginal tax rates for different income percentile brackets depend on the incomes shares $\bar{e}_t^s/\bar{e}_t$. Suppose there is perfect indexation, statutory rates are exogenous and that $\Delta \ln e_t^s = \eta \Delta \ln(1-\tau_t^s) + \rho^s \upsilon_t$ where υ_t are non-tax determinants of aggregate income growth. Assuming $E[\upsilon_t, v_{t-1}^\tau] = 0$, the OLS coefficient in the regressions of $\Delta \ln e_t^s$ on

[16] See for instance Yang (2005), House and Shapiro (2006), Mertens and Ravn (2011) or Born, Peter and Pfeifer (2013).

$\Delta\ln(1-\tau_t^s)$ is approximately[17]

$$\beta_s^{OLS} \approx \eta + (1-\rho^s)\frac{\gamma\rho^s}{1+\eta\gamma}\frac{Var(\upsilon_t)}{Var(\Delta\ln(1-\tau_t^s))} . \tag{19}$$

Even though the economy-wide regression in this case yields an unbiased estimate of η, the regressions for individual income groups yield biased estimates when income shares vary systematically with υ_t and $\rho^s \neq 1$. When the income share of bracket S is procyclical (countercyclical) and $\rho^s > 1$ ($\rho^s < 1$), there is an downward (upward) bias. Parker and Vissing-Jørgensen (2010) document how the top income shares have become highly procyclical since the early 1980s. Ceteris paribus, the observed cyclical behavior of income shares therefore leads to downward bias for higher incomes and upward bias for lower incomes.

Other Sources of Bias In dynamic settings, income growth generally depends on past tax rates and $E[\upsilon_t v_{t-1}^{\tau}] \neq 0$. If average marginal tax rates are stationary, overdifferencing leads to additional bias, the direction of which is generally ambiguous. There may also be downward bias because AMTRs are to some extent measured with error. This could be a relatively more serious concern in the larger sample in which the AMTR series relies in part on more aggregated data. Finally, the regressions only estimate the short run impact elasticity. Tax changes occasionally are only effective for part of the year and this is imperfectly reflected in the construction of the AMTR series, which is based on the tax code at the time of filing. As a result, there may be a downward time aggregation bias in the OLS coefficients.

4 Dynamic Estimates of the Income Response to Marginal Tax Rate Changes

This section describes a structural vector autoregressive model (SVAR) in which exogenous changes to marginal tax rates are identified using the legislative history of federal income tax changes and the approach described more generally in Mertens and Ravn (2013a) and Stock and Watson (2008, 2012). There are several ways in which this approach differs from any of the existing empirical specifications. First, the SVAR model includes a much richer set of lagged macroeconomic controls to isolate unanticipated variation in tax rates and income. Second, exogenous unpredicted variation in tax rates is identified using only policy changes that are less likely to be driven by other contemporaneous events, such as recessions or wars, and

[17] The formula is approximate because it assumes $\bar{e}_t^s = e_t^s$ and $\bar{e}_t = e_t$.

that are not obviously anticipated because they were legislated in previous years. Instruments in previous work are typically based on all tax policy changes in the sample, regardless of their motivation and anticipated nature. Finally, all of the right hand side variables are treated as endogenous variables in a dynamic system of equations. Unlike existing specifications this allows for the estimation of the full dynamic effects.

4.1 Methodology and Data

Consider a general representation of the dynamics of aggregate income

$$\ln(e_t) = d_{1t} + A_1(L)v_{t-1} + \zeta_e v_t^o + \eta v_t^\tau \tag{20}$$

where d_{1t} captures all deterministic terms, $A_1(L)$ is a lag polynomial of infinite order and $v_t = [v_t^\tau, v_t^{o\prime}]'$ is a vector that contains structural shocks with $E[v_t] = 0$, $E[v_t v_t'] = \Sigma_v$ is a diagonal matrix and $E[v_t v_{t-j}'] = 0$ for $j \neq 0$. The vector of shocks consists of exogenous innovations in tax rates v_t^τ as well as all other impulses v_t^o to income dynamics. As before, η is the elasticity measuring the contemporaneous impact of an unanticipated change in taxes on income. Let X_t be a vector of control variables and consider

$$\ln(1-\tau_t) = d_{2t} + A_2(L)v_{t-1} + \xi_e \ln(e_t) + \xi_x X_t + v_t^\tau\ , \tag{21}$$

$$X_t = d_{3t} + A_3(L)v_{t-1} + \zeta_x v_t^o + \theta v_t^\tau\ , \tag{22}$$

where d_{2t}, d_{3t} capture deterministic terms and $A_2(L), A_3(L)$ are infinite order lag polynomials. The first equation specifies the behavior of the economy-wide log net-of-tax rate as a function of (i) the entire history of shocks; (ii) a contemporaneous shock v_t^τ; and (iii) additional variables X_t. The parameters ξ_e and ξ_x capture any contemporaneous feedback from income levels or any element of X_t on tax rates. The second equation describes the dynamics of X_t with θ measuring the short run impact of tax shocks on X_t. Together, equations (20)-(22) provide a representation of all the variables as functions of histories of unobserved i.i.d. random variables, one of which is an aggregate shock to marginal tax rates. Since the system allows for all possible causal effects, essentially any linear dynamic model yields a representation of this general form.

Identifying the structural shock v_t^τ requires some assumptions. The first key assumption is that there exists a finite order vector autoregressive (VAR) representation of the joint dynamic behavior of $\ln(e_t), \ln(1-\tau_t)$ and X_t. This requires that there are (at least) as many shocks as endogenous variables, $dim(X_t) = dim(v_t^o) - 1$, and that a finite number of lags of the endogenous variables contains (approximately) the same information as the entire history of shocks. The VAR representation is given by

$$\begin{bmatrix} \ln(1-\tau_t) \\ \ln(e_t) \\ X_t \end{bmatrix} = d_t + B(L) \begin{bmatrix} \ln(1-\tau_{t-1}) \\ \ln(e_{t-1}) \\ X_{t-1} \end{bmatrix} + \begin{bmatrix} u_t^\tau \\ u_t^e \\ u_t^x \end{bmatrix}, \tag{23}$$

where d_t contains deterministic terms, $B(L)$ is a lag polynomial of finite order $p-1$ and p is the lag length. If the set of endogenous variables is informationally sufficient, then the reduced form residuals u_t^τ, u_t^e and u_t^x are related to the structural shocks v_t^τ and v_t^o by

$$\begin{aligned} u_t^\tau &= v_t^\tau + \xi_e u_t^e + \xi_x u_t^x \\ u_t^e &= \eta v_t^\tau + \zeta_e v_t^o \\ u_t^x &= \theta v_t^\tau + \zeta_x v_t^o \end{aligned} \tag{24}$$

The validity of (24) is in practice determined by the selection of variables included in X_t and the lag length p, both of which determine the span of the conditioning information set. An appropriate choice of X_t and p ensures that the VAR residuals correspond to unpredictable variation in the variables and therefore that all anticipated changes in marginal tax rates are controlled for.

The VAR residuals u_t^τ, u_t^e and u_t^x are straightforward to estimate by OLS, but more assumptions are needed to identify the exogenous innovation to tax rates v_t^τ. The identification strategy follows Mertens and Ravn (2013a,b) and relies on the availability of a narrative series of policy changes as a proxy measure m_t for the latent structural tax shock v_t^τ. The identifying assumptions are

$$E[m_t v_t^\tau] \neq 0 , \tag{25}$$

$$E[m_t v_t^o] = 0 . \tag{26}$$

The first condition states that the proxy is contemporaneously correlated with the aggregate shock to marginal tax rates. The second condition requires the proxy to be contemporaneously uncorrelated with all other structural shocks. When these conditions hold, the proxy variable can be used for identification of η, θ, ξ_e and ξ_x and v_t^τ as follows:

1. Regress u_t^e and u_t^x on u_t^τ using m_t as instruments. Define the residuals in these regressions n_t^e and n_t^x.

2. Regress u_t^τ on u_t^x and u_t^e using n_t^e and n_t^x as instruments, which yields unbiased estimates of ξ_e and ξ_x. The residual is v_t^τ.

3. Regress u_t^e and u_t^x on v_t^τ to obtain unbiased estimates of η and θ.

Once the short run impact of a tax shock is obtained, the dynamic response can be traced according to (23).

The proxy measure contains a number of historical legislative changes to federal individual tax rates, selected to comply with the identification assumptions in (25)-(26). The methodology thus combines the event study approach with traditional structural VAR analysis. There are two important advantages of the proxy identified SVAR that enable the estimation of the effects of marginal tax rates. First, no direct measures of exogenous changes in average marginal tax rates are required, only a proxy that is correlated with the true latent shock. The proxy SVAR therefore permits the use of existing narrative measures for *average* tax rates and is robust to general forms of measurement error in those measures. In addition, the proxy is only required to be contemporaneously uncorrelated with all other shocks, but may still be correlated with past economic shocks. Tax reforms that address inherited government debt or bracket creep can therefore still yield valid proxies as long as there is an unpredictable component to the tax change. They would however not be valid instruments in the regressions of Section 3 .

The VAR specifications include the log net-of-tax rate $\ln(1-\tau_t)$ based on the Series 1 measure of the AMTR for all tax units, see Figure 1.[18] The income measure $\ln(e_t)$ is either total reported income (excluding capital gains and government transfers), or total wage income, both per tax unit. The VARs also include a fixed set of controls X_t: (i) *Log real GDP per tax unit*, *inflation* and the *federal funds rate*. These variables generally capture business cycle conditions, interactions with monetary policy as well as the effects of bracket creep; (ii) *Log real government spending per tax unit* (purchases and net transfers) and the *change in the log of real federal government debt per tax unit*. These variables are included to capture interactions with other current and past fiscal policies, in particular since tax changes are often motivated out of concern with government deficits; Finally, X_t includes (iii) the *log of average capital gains per tax unit* declared on income tax returns. Capital gains on tax returns are very responsive to the timing of tax changes and contain useful predictive information for purely anticipated tax changes.[19] Each VAR includes a constant term and two lags $(p = 2)$ of eight endogenous variables over the effective sample 1952 -2010.

The proxy for exogenous unanticipated changes in average marginal tax rates is based on an annual version of the quarterly narrative measures of legislative changes in federal individual income taxes described in Mertens and Ravn (2013a). The series is a decomposition of Romer and Romer's (2009) measures of the impact on tax liabilities of all major legislative changes to the federal tax code after WWII. Using the same sources as Romer and Romer (2009) supplemented with additional information from congressional records, the Economic Report of the President, CBO reports, etc. only those legislative changes with an impact on individual income tax liabilities are retained. To comply with condition (26), which requires the proxy to be contemporaneously uncorrelated with all other shocks, only those changes in tax liabilities that were unrelated the current state of the economy are valid. Whether a legislative change meets this criterion is based on Romer and Romer's (2009) classification of the motivation for the legislative action either as ideological or as arising from inherited deficit concerns. All tax changes that were spending driven or business cycle related are omitted. To focus on unanticipated changes in taxes, the proxy measure also excludes tax changes that were legislated at least one year before they became effective. Of the twelve selected tax changes over

[18]Appendix C reports all the results when the alternative Series 2 measure is used instead.
[19]Precise variable definitions and sources are given in Appendix A.2.

the period 1950-2010, all included changes in statutory income tax rates.[20] Figure 2 depicts the narrative measure, defined as the estimated change in individual tax liabilities as a percentage of total reported income in the previous year, as well as the change in the economy-wide AMTR ($\Delta\tau_t$). The proxy used for identification in the VAR is the narrative measure after subtracting the mean from the nonzero observations.

Figure 3 shows the relationship between the proxy and the structural shocks to $\ln(1-\tau_t)$ identified ex post in the SVAR. There is a visible negative relationship and the R squared of the associated regression line is 0.54. A closely related metric to judge the quality of the proxy is its reliability, which is 0.60 (see Mertens and Ravn (2013a,b)). Both measures indicate a relatively close relationship between the proxy and the identified aggregate tax shock.

4.2 The Response of Aggregate Income to Marginal Tax Rate Changes

Figure 4 depicts the impulse responses to a one percent shock to the net-of-tax rate together with the 90% and 95% bootstrapped confidence intervals for a horizon up to 6 years.[21] The income responses are on a scale directly comparable to the coefficients in the static OLS regressions of Section 3 .

Figure 4 shows that an unanticipated decrease in taxes has transitory effects on the average marginal tax rate. On average, the initial increase in the net-of-tax rate of one percent is reduced to 0.5 percent after three years. Although most of the statutory changes in tax rates are legislated to be permanent, the drop in the average marginal tax rate is thus found to be temporary in practice. The transitory response of the AMTR suggests that in expectation policy changes tend to be reversed by policymakers, but also simply reflects the bracket creep caused by a positive income response. A cut in the marginal tax rate leads to a significant increase in real GDP per capita. Output rises by 0.67 percent on impact and by 1.27 percent in the second

[20] Appendix A.3 provides a list of the tax changes and their projected impact on individual income tax liabilities. The Revenue Act of 1971 is excluded because it did not change statutory rates. Including the Revenue Act of 1971 has virtually no impact on the results.

[21] The intervals are computed using a recursive wild bootstrap using 10,000 replications, see Gonçalves and Kilian (2004). Define $Y_t = [\ln(e_t), \ln(1-\tau_t), X_t']'$ and $u_t = [u_t^\tau, u_t^e, u_t^{x\prime}]'$. Bootstrap draws Y_t^b are generated recursively using $\hat{B}(L)$ and $\hat{u}_t e_t^b$, where $\hat{B}(L)$ and $\hat{u}_t$ denote the VAR estimates and e_t^b is the realization of a random variable taking on values of -1 or 1 with probability 0.5. I also generate a draw for the proxy variable $m_t^b = m_t e_t^b$, re-estimate the VAR for Y_t^b and apply the identifying restrictions. The percentile intervals are for the resulting distribution of impulse response coefficients. This procedure requires symmetric distributions for u_t and m_t but is robust to conditional heteroscedasticity. It also takes into account uncertainty about identification and measurement.

year. The output response is hump-shaped and more persistent than the change in tax rates. These results are consistent with those of Barro and Redlick (2011) and Mertens and Ravn (2013a).

Both total and wage income per tax unit react positively to the unanticipated decrease in the AMTR. The impact response provides an estimate of η, the short run tax elasticity of income, and equals 1.16 for total income and 0.94 for wage income. Both estimates are significant at the 95% level and contrast sharply with the negative OLS coefficients in the first two columns of Table II. The medium run elasticities are greater than in the short run: both income responses peak at values of 2.00 and 1.65 respectively in the third year. The response of total income remains significant at the 95% level for three years, whereas the wage income response is significant at the 90% level in the two years following the shock. From the fourth year onwards, incomes gradually decrease to levels expected prior to the shock.

The SVAR estimates differ strongly from the OLS coefficients and this is not surprising given that there is clear statistical evidence against the exogeneity of average marginal tax rates. First, average marginal tax rates are generally forecastable on the basis of lagged values of macroeconomic variables. A test of the null hypothesis that X_{t-1} and X_{t-2} do not Granger cause $\ln(1-\tau_t)$ has an asymptotic p-value of 0.03. The same test after first-differencing nonstationary variables in X_t has an asymptotic p-value of 0.02. In bivariate dynamic regressions, two variables with strong predictive content for the AMTR are inflation and the average capital gains realization reported on tax returns. Second, there are also strong indications that the AMTR interacts contemporaneously with macroeconomic aggregates. Table III reports the estimates of the elasticities ξ_e and ξ_x with respect to income and the variables in X_t, see (24). All coefficients have the expected sign: the AMTR increases in response to highly procyclical variables such as GDP, nominal interest rates, personal income and capital gains; the AMTR also increases with higher inflation and with higher government spending and debt. None of the individual coefficients is statistically significant at the 95% level. However, the coefficients are jointly highly significant. The last column of Table III reports the p-value based on 10,000 bootstrap replications associated with the Wald statistic testing the joint hypothesis that $\xi_e, \xi_x = 0$. This hypothesis is strongly rejected.[22]

[22]Using different methodologies, Jones (2002) and Leeper, Plante and Traum (2010) similarly find evidence for the endogeneity of effective average tax rates.

Under the stated assumptions the SVAR resolves the simultaneity bias due to endogenous policy, bracket creep, anticipation effects, etc. However, the potential downward bias caused by time aggregation remains present in the short run impact coefficients. Such time aggregation bias may in part explain the hump shape of the impulse response functions. Another important consideration is that legislative changes to the individual tax code frequently coincide with changes to corporate taxes in the same direction. The impulse responses in Figure 4 may thus to some extent reflect the effects of corporate tax changes. Appendix D extends the model to control for simultaneous changes in corporate taxes using the methodology of Mertens and Ravn (2013a). The results remain very similar, although the point estimates are somewhat smaller.

4.3 The Response to Marginal Tax Rate Changes at Different Income Levels

Aggregate income rises significantly following cuts in marginal tax rates, but how does the response vary across income percentile brackets? The changes in marginal rates that are part of tax reforms are not identical for all tax brackets. Adjustments to statutory rates in the highest brackets are typically much larger in size, whereas low income individuals without tax liabilities do not face any change at all. Evaluating how much the average income within a particular percentile bracket increases after a marginal tax rate cut first requires knowing the impact on the AMTR for that bracket. The general shape of the income response can be found by regressing income on a distributed lag of the aggregate tax shock v_t^τ identified in the SVAR. To express the dynamic response in terms of elasticities to an initial one percent rise in the net-of-tax rate, the estimates can be rescaled by the coefficient in a regression of the net-of-tax rate on v_t^τ.

Estimating the short run elasticity is especially straightforward and simply amounts to using v_t^τ as an instrument in the regressions of Section 3 . Figure 5 shows the exogenous shock v_t^τ estimated in the SVAR, together with the actual changes in the economy-wide log net-of-tax rate $\Delta(\ln(1-\tau_t))$.[23]

Table IV reports the IV estimates of the short run tax elasticities as well as the associated first stage F-

[23]The correlation between both series in Figure 5 is 0.49. The serial correlation of the identified shock is -0.03 whereas it is 0.29 for $\Delta\ln(1-\tau_t)$. Figure 5 only shows the shock for the VAR that includes total income. The estimated shock in the specification with wage income is very similar.

statistics.[24] The impact of controlling for endogeneity can be seen by comparing with the OLS results in Table II. Note that the IV regression for aggregate income replicates the SVAR estimator, and therefore the numbers in the first column of panel A are identical to the estimates of η in the SVARs.

In contrast to the OLS estimates and consistent with economic theory, all of the IV estimates in Table IV are positive. In most cases, the elasticities for total income exceed those for wage income. The elasticities for the top 1% bracket are highly statistically significant and relatively large. In the longest sample (panel A), the point estimates are 1.27 for both wage and total income, compared to 0.45 and 0.58 in the OLS regressions. A key result is that there are also statistically significant income responses outside of the top 1% bracket. The elasticities for both total and wage income of the top 5% and top 10% are significant at the 95% level, whereas the other estimates are significant at the 90% level. The evidence for a broader response of wage income is weaker: Of all the brackets that do not include the top 1%, only the elasticity for the top 10 to 5% is significant at the 90% level. Another consequence of controlling for endogeneity is that the coefficients no longer increase with income. The point estimates for total income range from 0.65 for the top 5-1% to 1.33 for the bottom 90%. The estimates for wage income are all around unity, except for the much lower value of 0.34 for the top 5 to 1% group. Overall, the results suggest that the endogeneity bias differs importantly in size across the income percentile brackets and is much larger for the bottom income groups.

The results in the short sample in panel B of Table IV are roughly similar to those in the larger sample. Although the point estimates of the tax elasticities are somewhat lower, they are all considerably higher than the OLS coefficients. The elasticities for the top 1% are around one and are highly statistically significant. There is again evidence that income is responsive to marginal tax rate changes across percentile brackets, although primarily for total income, and there is no obvious correlation between the estimates and the level of income. Comparing OLS and IV results in both samples, it is clear that the effects of instrumentation are particularly large in the longer sample. This is not surprising: much of the variation in marginal tax rates in the 1950s was related to the Korean War and coincided with large changes in military spending. Similarly, much of the variation in average marginal tax rates in the 2000s was related to the 2001 and 2007-2009

[24] The estimates for wage income are instrumented with the shock in the VAR with aggregate wage income, whereas the estimates for total income use the shock in the VAR with total income. Interchanging instruments yields very similar results.

recessions, either because of explicit policy responses or reverse bracket creep. This is also reflected in the first stage F-statistics. The exogenous SVAR shock appears uniformly strongly relevant for AMTR changes in the shorter sample, but is more weakly relevant in the longer sample.

Figure 6 depicts the dynamic tax elasticities for the different income percentile brackets. The estimates are cumulative responses obtained from regressions of income growth on the contemporaneous value and 5 lags of v_t^τ, rescaled by the coefficient in the regression of the net-of-tax rate on v_t^τ in order to normalize the size of the net-of-tax rate change. The shape of the dynamic responses is overall remarkably similar across the income percentile brackets. The total income responses are hump-shaped, peaking in the third year at values ranging from 1.74 for the top 5-1% bracket up to 3.27 for the bottom 90% bracket. Similarly, the wage income responses all peak in the third year with values ranging from 0.98 for the top 5-1% bracket up to 2.52 for the bottom 90% bracket. From the fourth year onwards the estimates gradually return to zero, reflecting the transitory nature of the change in marginal rates. The peak effects on total and wage income in the top 1% bracket are 2.26 and 1.85 respectively. Interestingly, the response of the top 1% bracket is the most persistent, which may reflect that marginal rate changes are more persistent in the highest tax bracket.

There obviously remains considerable uncertainty associated with the estimates above, as all of the confidence intervals cover a relatively wide range of values. This is unavoidable given the sample size and the extent of the postwar variation in marginal tax rates that can plausibly be classified as exogenous. The results for top incomes are the most precise, which is natural given the higher variability of top tax rates. Overall, the empirical results support the following conclusions: (i) Income responses to marginal tax rate changes are not restricted to the top 1% of tax payers but are much more broad based; (ii) There is no systematic evidence that top 1% incomes respond more strongly to marginal rate changes than incomes below the top 1%; (iii) The income responses are hump-shaped and are larger in the first couple of years following a change in marginal rates than in the first year, although this again to some extent reflects a time aggregation bias.

It is important to keep in mind that the results in Table IV and Figure 6 measure responses associated with aggregate tax shocks, which generally imply changes in marginal tax rates for all percentile brackets.

Only under very special assumptions (no income effects, independent pre-tax wages, etc.) do the estimates in Table IV have the interpretation of compensated substitution elasticities. Given the broad response to average marginal tax rates, the estimates above more likely reflect a host of general equilibrium effects on wages, interest rates and dividends, employment, etc. The next section looks at the narrower experiment of a shock to top marginal rates only, for which these effects should be less significant.

5 The Dynamic Effects of Cutting Top Marginal Tax Rates

Many of the postwar tax reforms have made particularly large changes in top marginal tax rates. This variation in top statutory rates may be used to estimate the effects of a hypothetical tax reform that only alters marginal tax rates for the top 1%. The key empirical challenge is to control for simultaneous exogenous changes in tax rates for the bottom 99%, while at the same time preserving all endogenous feedback that arises because of changes in relative incomes, bracket creep, etc. To address this challenge, I enlarge the VAR specification and replace the economy-wide AMTR and income level with the corresponding separate series for the top 1% and bottom 99%. The identification strategy also relies on an additional proxy variable that consists of a selection of historical changes in the top statutory marginal rate. The selection is motivated as before: only those changes that were part of postwar legislative actions classified as 'exogenous' and 'unanticipated' are included.[25] Out of the twelve actions, seven include changes in the top statutory rate. These are shown in Figure 7 together with the change in the top 1% AMTR . The additional proxy used for identification is the series shown in Figure 7 after subtracting the mean from the nonzero observations.

Consider a vector of two (correlated) innovations to the top 1% and bottom 99% average marginal tax rates, $\bar{v}_t^\tau = [v_t^{\tau,1}, v_t^{\tau,99}]'$ with $E[\bar{v}_t^\tau] = 0$, $E[\bar{v}_t^\tau \bar{v}_t^{\tau\prime}] = \Sigma_\tau$ nonsingular but not necessarily diagonal, and $E[\bar{v}_t^\tau \bar{v}_{t-j}^{\tau\prime}] = 0$ for $j \neq 0$. Also, let $\bar{u}_t^\tau = [u_t^{\tau,1}, u_t^{\tau,99}]'$ and $\bar{u}_t^e = [u_t^{e,1}, u_t^{e,99}]'$ collect the VAR residuals associated with the AMTR and income equations for the top 1% and bottom 99%. Analogous to (24), the VAR residuals are related to

[25] See Appendix A.3 for the list of legislative actions. The largest changes in the statutory top rate are those associated with the Kennedy tax cuts in 1964, the Tax Reform Act of 1986 and the Clinton tax hikes of the 1990s.

the structural shocks by

$$
\begin{aligned}
\bar{u}_t^\tau &= \bar{v}_t^\tau + \xi_e \bar{u}_t^e + \xi_x u_t^x \\
\bar{u}_t^e &= \eta \bar{v}_t^\tau + \zeta_e v_t^o \qquad (27) \\
u_t^x &= \theta \bar{v}_t^\tau + \zeta_x v_t^o \; .
\end{aligned}
$$

Let $\bar{m}_t$ collect the two available proxies. The identifying assumptions are

$$E[\bar{m}_t \bar{v}_t^{\tau\prime}] = \Phi \; , \qquad (28)$$

$$E[\bar{m}_t v_t^{o\prime}] = 0 \; . \qquad (29)$$

where Φ is a unknown nonsingular 2×2 matrix. The first condition states that the two proxy variables are contemporaneously correlated with the tax shocks. The second condition requires that the proxy variables are contemporaneously uncorrelated with all other shocks. Conditions (28)-(29) do not suffice to identify $v_t^{\tau,1}$ and $v_t^{\tau,99}$ separately. This would require that each of the proxies correlates with only one of the shocks and Φ is diagonal, which would be an entirely arbitrary assumption. As long as Φ is nonsingular, it is nonetheless possible to identify impulse responses associated with any linear combination $\lambda' \bar{v}_t^\tau$ of tax shocks. The combination of interest here is $\lambda' \bar{v}_t^\tau = [1 \; , \; 0]'$, which corresponds to a tax reform leading to an exogenous change in the AMTR for the top 1% but not for the bottom 99%. The impulse response function to such an orthogonalized shock can be estimated as follows:

1. Regress $\bar{u}_t^e$ and u_t^x on $\bar{u}_t^\tau$ using m_t as instruments. Define the residuals in these regressions $\bar{n}_t^e$ and n_t^x.

2. Regress $\bar{u}_t^\tau$ on u_t^x and $\bar{u}_t^e$ using $\bar{n}_t^e$ and n_t^x as instruments. Define the residuals in these regressions $\bar{n}_t^\tau$. The covariance of $\bar{n}_t^\tau$ is an estimate of Σ_τ.

3. Let C be the upper triangular Choleski decomposition of Σ_τ. Regress $\bar{u}_t^\tau$, $\bar{u}_t^e$ and u_t^x on $C^{-1} n_t^\tau$. The coefficients associated with the first element of $C^{-1} n_t^\tau$ is the impact of the orthogonalized tax shock.

The dynamic response can subsequently be traced from the estimated VAR coefficients. An important feature of the resulting impulse response function is that it allows for indirect endogenous feedback on the bottom 99% tax rate through the elasticities ξ_e and ξ_x, which are identified by the IV regressions in step 2.

The enlarged VAR systems add two additional endogenous variables relative to before. To avoid an unnecessarily large number of parameters, I drop the government deficit variable from the vector of macro controls X_t.[26] The specification thus includes 9 endogenous variables each entering with two lags. Figure 8 displays the response to a one percent rise in the net-of-tax rate of the top 1% in the income distribution. The top 1% income responses are therefore in units that are directly comparable to those of Section 4 .

The top marginal rate shock causes a persistent but transitory increase in the top 1% net of tax rate. The increase is more persistent than in the case of an aggregate tax shock, which in part reflects that bracket creep is less relevant at the top of the income distribution. The tax cut leads to significant increases in average top 1% incomes, which rise on impact by 0.52 percent and by 0.97 and 1.02 percent in the following two years, after which there is a gradual decline. As before, the lower number on impact may to some extent be due to time aggregation. Whereas the impact response is not significant at conventional confidence levels, the responses for the subsequent two years are highly significant. Wage income also increases, but never significantly and not as much as total income.

Interestingly, the cut in top 1% tax rates leads to a statistically significant increase in real GDP of up to 0.34 percent in the third year. This suggests that the positive response of top incomes, which comes to a large extent from the non-wage component, is not purely income shifting from corporate to personal income, as is sometimes argued.[27] There are also spillover effects to incomes outside of the top 1%. Average incomes of the bottom 99% rise by 0.15 percent on impact and by up to 0.35 percent in the third year. The positive spillover effects are significant at the 90% level in the first and second years after the shock. Average wage income of the bottom 99% also reacts positively and with similar magnitude. However, the effects are not significant. Despite the spillover effects, a top marginal rate cut unambiguously leads to greater inequality in pre-tax income. These results are consistent with the fact that top marginal rates correlate negatively

[26] Appendix E shows the results of the 10-variable VAR that retains the government deficit variable. This has no major effect on the point estimates but widens the confidence intervals somewhat. The main implication is that the GDP response is only significant at the 90% level, and the income response of the bottom 99% is no longer significant at conventional levels.

[27] See for instance Slemrod (1996).

with top income shares more widely across countries, see Piketty et al. (2013), but also suggest explanations beyond tax avoidance or changes in bargaining efforts.

There is also a statistically significant but quantitatively small positive reaction of the net-of-tax rate of the bottom 99%. The small 18 basis points rise is the estimated net feedback from incomes and the variables in X_t. Based on the estimates of ξ_e and ξ_x (not reported), there are two effects that ultimately lead to a net decrease in the bottom 99% AMTR after an exogenous decrease in the top 1% AMTR: First, the cut in top marginal rates lowers inflation, which in turn reduces the bottom 99% AMTR below the level expected prior to the shock. This is consistent with a bracket creep effect. A larger negative effect on the bottom 99% AMTR comes from a reaction to the rise in top 1% incomes. This effect is harder to interpret but could for instance reflect redistribution motives of policy makers.

The main conclusions of the counterfactual experiment are that top marginal rate cuts lead to sizeable increases in top incomes, generate positive effects on real GDP, have spillover effects on lower incomes but nonetheless contribute to income inequality. The results also yield insights regarding the relevance of general equilibrium effects caused by changes in marginal tax rates. When the effects of changes in tax rates for lower percentile brackets are controlled for, the dynamic tax elasticities for the top 1% associated with top marginal rate cuts are 0.5 on impact and around one in the following two years. These values are less than half as large as those associated with an aggregate shock to marginal tax rates (see Figure 6) and are at the high end but within the range of estimates found for top incomes by micro-level studies, see Saez et al. (2012).[28] This substantial difference cautions against interpreting the reduced form estimates from aggregate time series as measuring pure substitution effects. The top marginal rate cut experiment is conceptually similar to Romer and Romer (2012), who also focus on top marginal rate changes but are able to control for general equilibrium effects by focusing on the interwar period, during which only top incomes effectively paid income taxes.[29]

The identification of the responses to top marginal rate cuts in Figure 8 relies crucially on instances of

[28] However, elasticities are often only found to be relatively large for narrower income concepts such as taxable income.

[29] In regressions of net income growth on net-of-tax rate changes, Romer and Romer (2012) find elasticities of around 0.2.

large changes in top rates but relatively smaller changes in economy-wide average marginal tax rates. The effects of the reverse experiment of a cut to marginal tax rates for the bottom 99% but not for the top 1% are extremely imprecisely estimated by the model. Unfortunately, there is not enough identifying variation in the data for such an experiment, and the results are therefore not reported.

6 Concluding Remarks

Using an SVAR methodology and a narrative identification strategy, this paper estimates large and broad based effects of marginal tax rates on reported income. This is consistent with recent macro studies detecting large effects of tax changes on real GDP in the US and other countries using similar identification approaches. However, it conflicts with empirical studies in public finance that are based on aggregate time series constructed from IRS tax returns. The difference can be explained by the fact that the SVAR models better resolve the endogeneity of postwar US average marginal tax rates due to tax policy being responsive to spending and the business cycle, bracket creep, anticipation effects, etc. The results are important for assessing the role of income taxation for macroeconomic stabilization and the impact of austerity programs, for understanding the empirical relationship between income taxes and inequality, and for optimal tax policy.

There are several ways for future research to verify and extend the results. The identification of exogenous variation in marginal tax rates ultimately relies on a limited number of postwar tax reforms in the US. Tax returns data and narrative datasets become increasingly available for other countries, e.g. Piketty et al. (2013), Cloyne (2013), Hayo and Uhl (2013) and Leigh et al. (2013), which allows for replication of the results. Second, the empirical models in this paper are linear. There may instead be important nonlinearities in the relationship between marginal tax rates and economic activity, both in the short and long run, see Auerbach and Gorodnichenko (2012) or Jaimovich and Rebelo (2013). Finally, the results in this paper are based on reduced form models and should be combined with realistic structural models to gain greater insight into the tax transmission mechanism. I leave these and other extensions for future work.

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Table I Average Marginal Tax Rates 1950-2010: Descriptive Statistics

		$\tau_t \times 100$		$\Delta \ln(1-\tau_t) \times 100$										
		Mean	*St. Dev.*	*St. Dev.*	*Correlation*									
					[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
[1]	All, Series 1	23.69	2.05	1.51	1.00								
[2]	All, Series 2	24.38	2.39	1.54	0.95	1.00							
[3]	Top 1%	44.72	8.10	4.39	0.78	0.83	1.00						
[4]	Top 5%	37.10	4.68	2.97	0.85	0.91	0.95	1.00					
[5]	Top 10%	33.74	3.85	2.45	0.88	0.94	0.92	0.99	1.00				
[6]	Top 5-1%	31.56	4.95	2.39	0.86	0.92	0.80	0.93	0.96	1.00			
[7]	Top 10-5%	26.92	3.88	1.80	0.89	0.93	0.74	0.86	0.92	0.92	1.00		
[8]	Bottom 99%	22.09	2.58	1.44	0.94	0.99	0.75	0.84	0.89	0.90	0.94	1.00	
[9]	Bottom 90%	19.19	1.98	1.33	0.92	0.96	0.69	0.76	0.81	0.81	0.87	0.98	1.00

Table II OLS Regression Results

	All Tax Units Series 1	All Tax Units Series 2	Top 1%	Top 5%	Top 10%	Top 5-1%	Top 10-5%	Btm. 99%	Btm. 90%
					A. *1951-2010*				
Wage Inc.	−0.57*	−0.63**	0.45	0.13	−0.01	−0.15	−0.32	−0.75**	−0.97***
	(−1.18, 0.03)	(−1.19, −0.07)	(−0.10, 0.99)	(−0.32, 0.59)	(−0.43, 0.42)	(−0.40, 0.11)	(−0.86, 0.22)	(−1.33, −0.16)	(−1.66, −0.28)
Total Inc.	−0.33	−0.42	0.58*	0.28	0.14	−0.14	−0.27*	−0.60**	−0.80***
	(−0.89, 0.23)	(−0.95, 0.11)	(−0.08, 1.25)	(−0.37, 0.94)	(−0.44, 0.72)	(−0.46, 0.17)	(−0.58, 0.04)	(−1.08, −0.12)	(−1.37, −0.23)
					B. *1960-2000*				
Wage Inc.	−0.01	−0.17	0.54*	0.26	0.18	−0.03	−0.03	−0.27	−0.38
	(−0.43, 0.41)	(−0.56, 0.22)	(−0.03, 1.11)	(−0.16, 0.68)	(−0.19, 0.54)	(−0.22, 0.15)	(−0.34, 0.29)	(−0.71, 0.16)	(−1.03, 0.28)
Total Inc.	0.21	0.02	0.66*	0.43	0.32	−0.01	−0.08	−0.16	−0.22
	(−0.22, 0.64)	(−0.37, 0.42)	(−0.06, 1.38)	(−0.22, 1.09)	(−0.25, 0.90)	(−0.24, 0.24)	(−0.28, 0.12)	(−0.51, 0.19)	(−0.71, 0.28)

In parentheses are Newey-West 95% intervals with 8 lags. Asterisks denote 10%, 5% or 1% significance.

Table III Contemporaneous Endogeneity of Tax Rates (Estimates of ξ_x and ξ_e)

GDP	Infl.	FF rate	Govt. Sp.	Δ Debt	Cap. Gains	Total Inc.	Joint Test Wald p-value
-0.17	-0.31	-0.09	-0.20	-0.09	-0.02^{*}	-0.11	< 0.01
$(-0.75, 0.38)$	$(-1.22, 0.36)$	$(-0.75, 0.61)$	$(-0.46, 0.05)$	$(-0.38, 0.13)$	$(-0.05, 0.01)$	$(-0.70, 0.30)$	

Values in parenthesis are bootstrapped 95% percentiles.

Table IV Estimates of Short Run Tax Elasticities using IV

	All Tax Units Series 1	Series 2	**Top 1%**	**Top 5%**	**Top 10%**	**Top 5-1%**	**Top 10-5%**	**Btm. 99%**	**Btm. 90%**
					A. *1952-2010*				
Wage Inc.	0.94**	1.12*	1.27***	0.82**	0.96**	0.34	1.31*	0.98	1.08
	(0.09, 1.80)	(−0.06, 2.30)	(0.43, 2.11)	(0.01, 1.63)	(0.13, 1.79)	(−0.29, 0.98)	(−0.13, 2.74)	(−0.31, 2.27)	(−0.69, 2.85)
1st Stage F	*15.31*	*8.96*	*8.61*	*8.27*	*8.71*	*6.92*	*6.57*	*5.99*	*6.36*
Total Inc.	1.16**	1.37**	1.27***	1.12**	1.11**	0.65*	0.83*	1.13*	1.33*
	(0.25, 2.08)	(0.12, 2.61)	(0.41, 2.12)	(0.18, 2.07)	(0.13, 2.09)	(−0.12, 1.42)	(−0.14, 1.80)	(−0.03, 2.29)	(−0.01 − 2.67)
1st Stage F	*16.39*	*10.01*	*10.57*	*9.79*	*10.04*	*7.13*	*6.85*	*6.21*	*7.28*
					B. *1960-2000*				
Wage Inc.	0.53*	0.59	1.01**	0.62	0.71**	0.25	0.95*	0.44	0.33
	(−0.06, 1.11)	(−0.12, 1.30)	(0.18, 1.84)	(−0.13, 1.37)	(0.05, 1.38)	(−0.29, 0.79)	(−0.04, 1.94)	(−0.37, 1.24)	(−0.91, 1.57)
1st Stage F	*33.59*	*19.31*	*9.14*	*10.28*	*11.32*	*11.21*	*8.45*	*19.91*	*18.08*
Total Inc.	0.84**	0.94**	0.96**	0.81**	0.79**	0.47*	0.61	0.82**	0.96**
	(0.14, 1.54)	(0.10, 1.79)	(0.14, 1.78)	(0.02, 1.59)	(0.01, 1.57)	(−0.07, 1.01)	(−0.13, 1.36)	(0.03, 1.60)	(0.06, 1.87)
1st Stage F	*36.91*	*22.02*	*11.46*	*13.00*	*13.98*	*11.46*	*8.26*	*18.11*	*16.18*

In parentheses are Newey-West 95% intervals with 8 lags. Asterisks denote 10%, 5% or 1% significance.

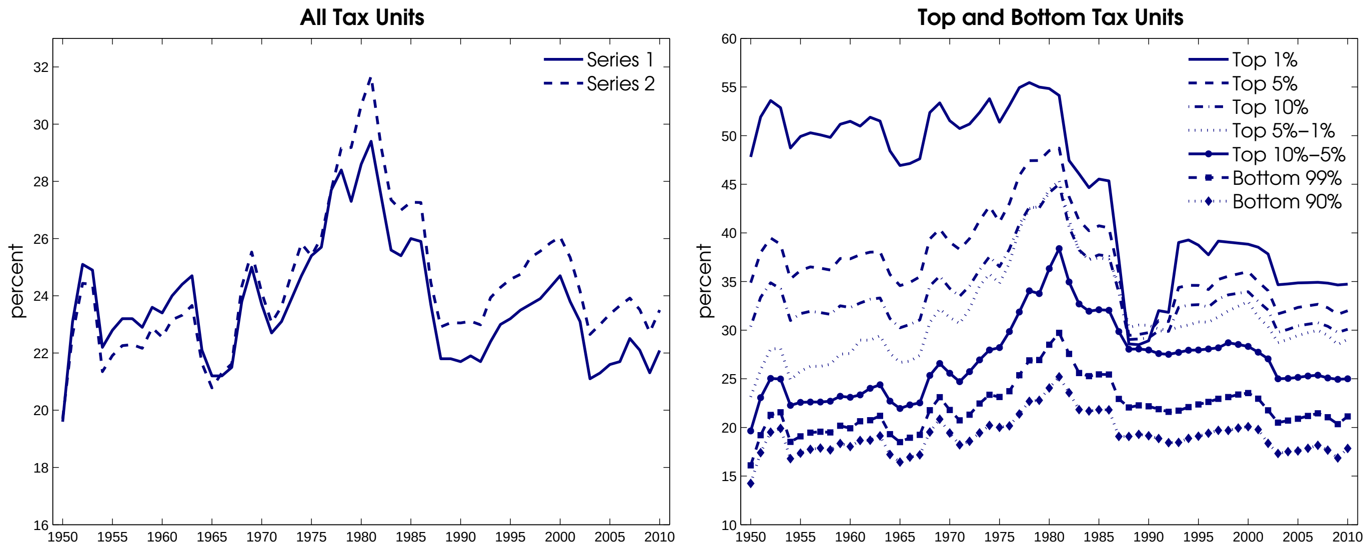


Figure 1 Average Marginal Tax Rates 1950-2010

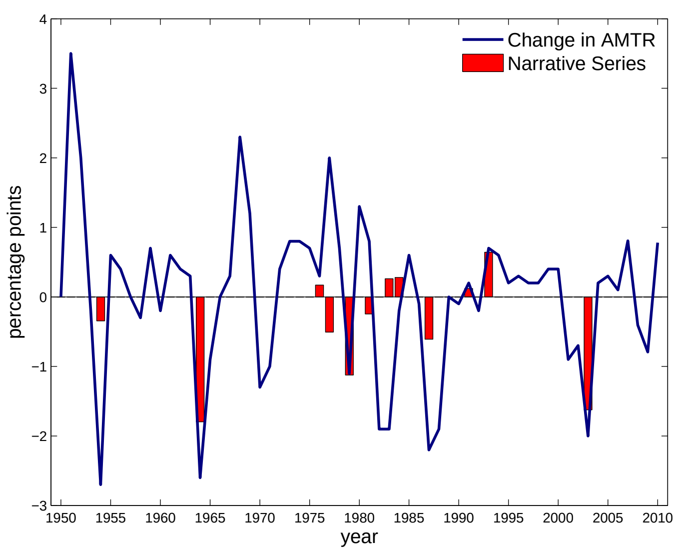


Figure 2 Narrative Series and AMTR Changes

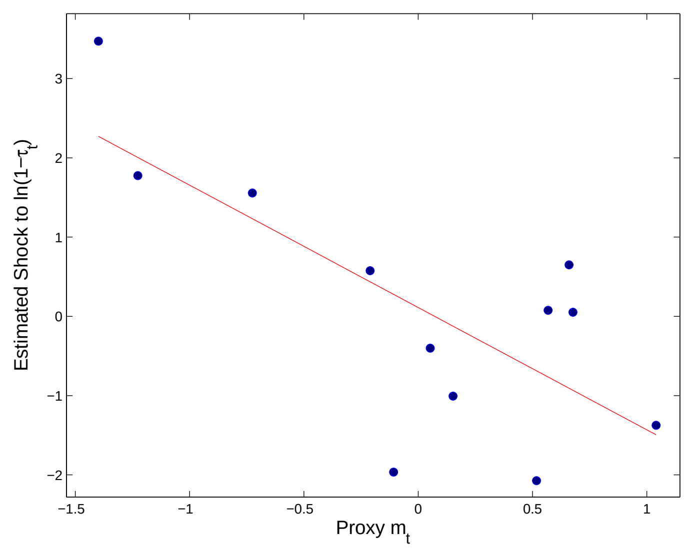


Figure 3 Proxy and Shock to $\ln(1-\tau_t)$

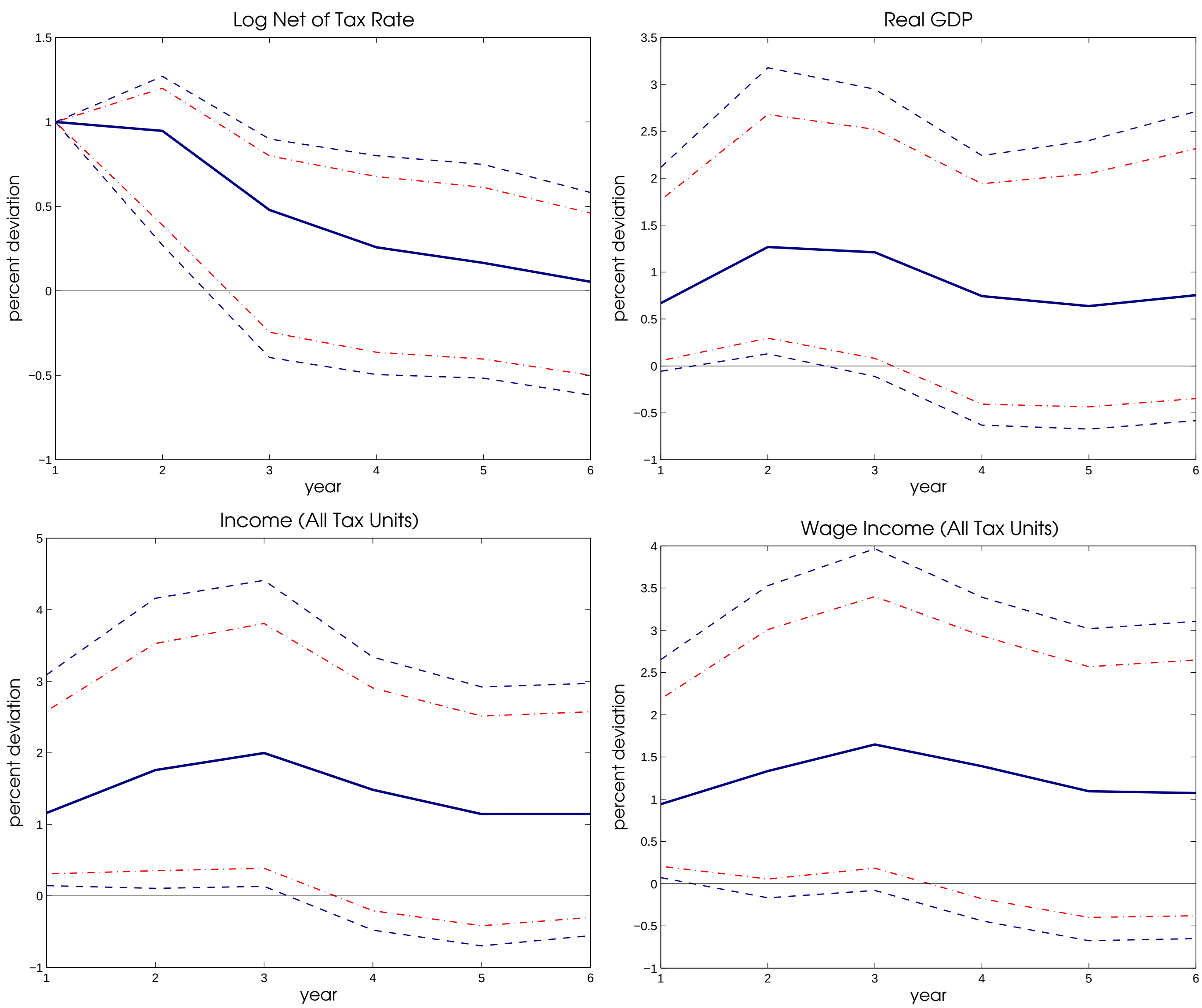


Figure 4 Response to unit shock to the log net-of-tax rate. Broken lines are 90% and 95% confidence bands based on 10,000 wild bootstrap replications.

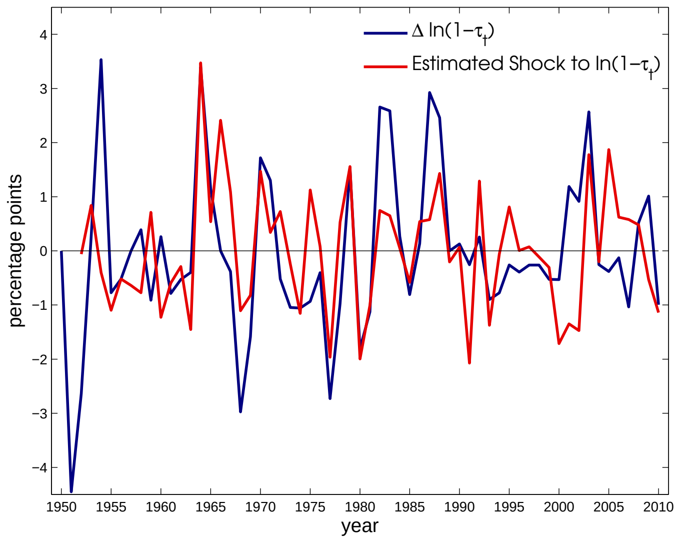


Figure 5 SVAR-identified shock and changes in the log net-of-tax rate.

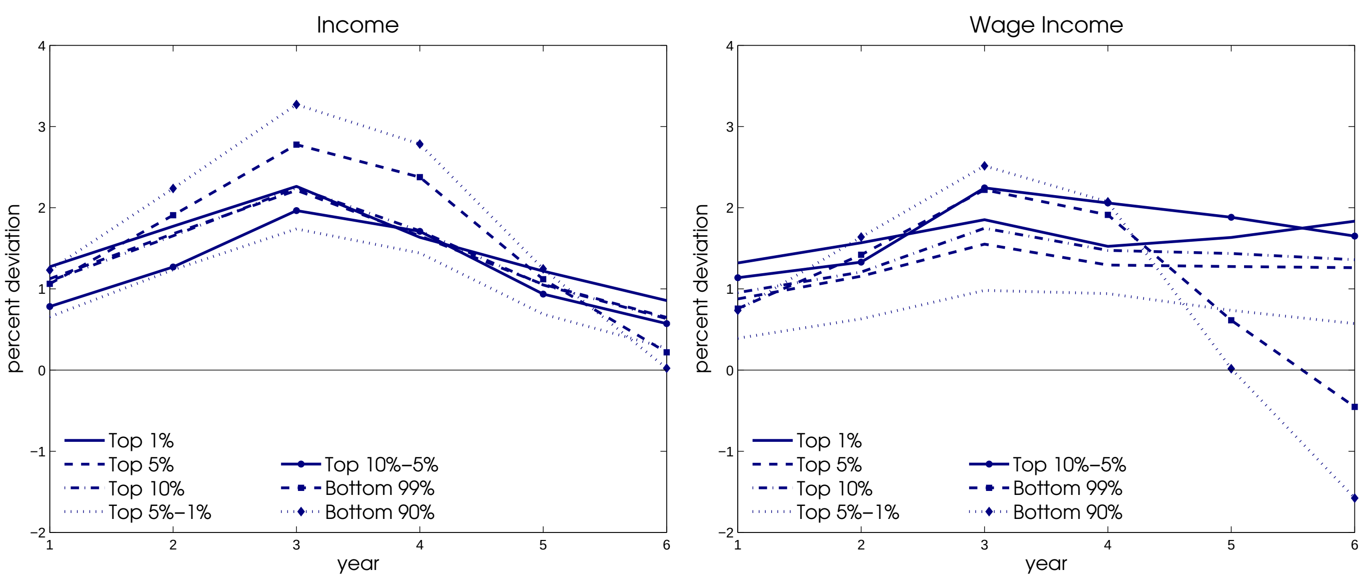


Figure 6 Dynamic Estimates of Tax Elasticities

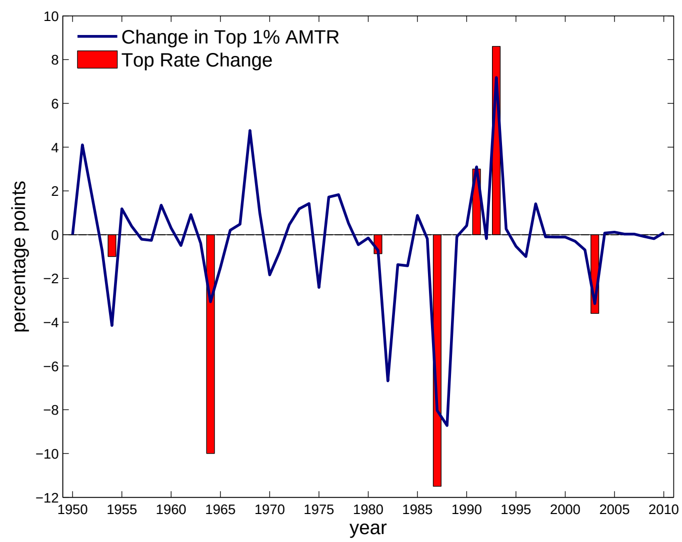


Figure 7 Selected Top Marginal Rate and Top 1% AMTR Changes

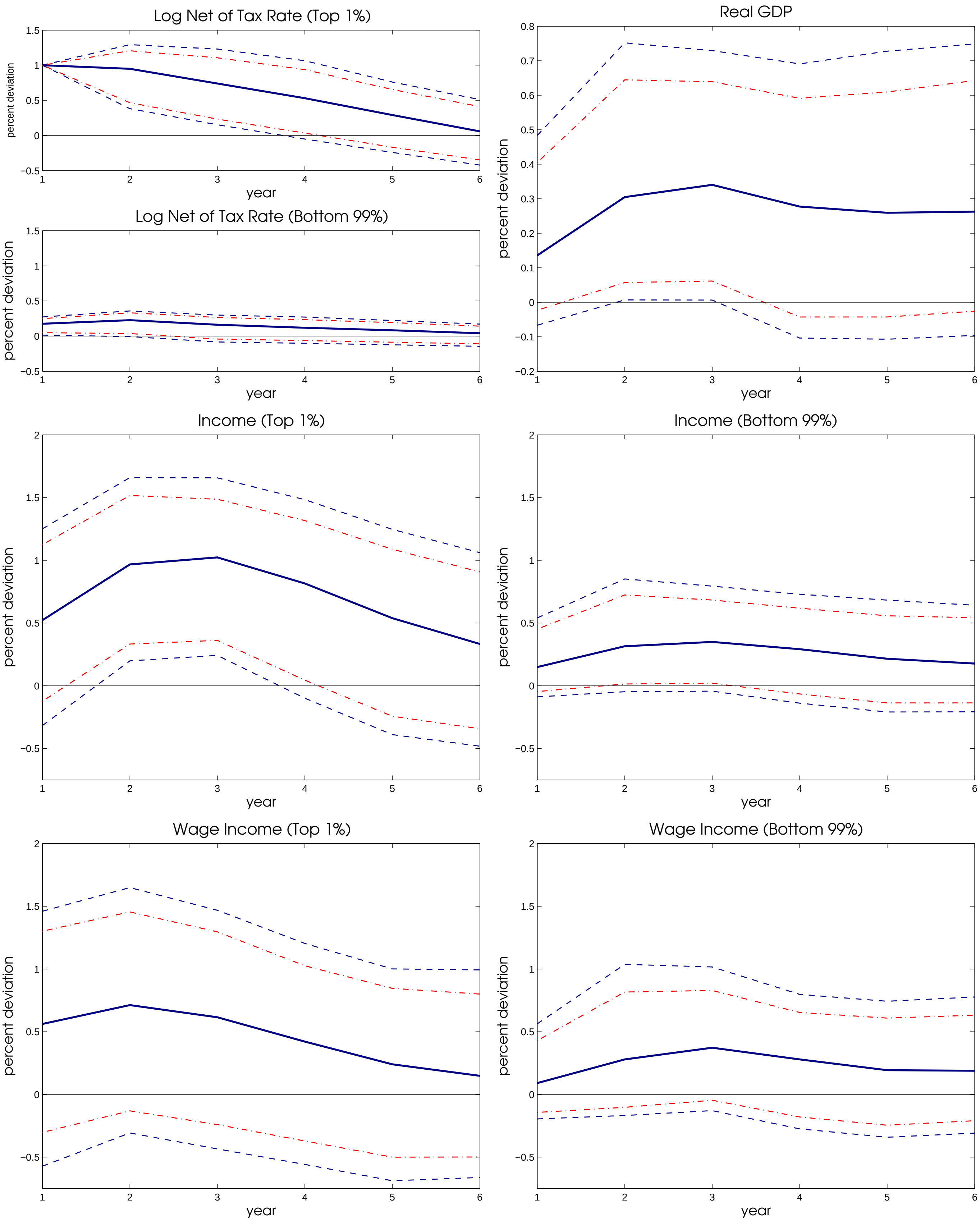


Figure 8 Response to unit shock to the Top 1% log net-of-tax rate. Broken lines are 90% and 95% confidence bands based on 10,000 wild bootstrap replications.

APPENDIX

A Data Construction and Sources

A.1 Average Marginal Tax Rates

This section details the construction of the average marginal tax rates measures for 1950-2010. The AMTR for all income groups Series 1 extends the measure of Barro and Redlick (2011) from 2006 to 2010. The other measures (Series 2 and AMTRs for different income groups) extend the series described in Saez (2004) to include the following years: 1950-1959, 1961/1963/1965 and 2001-2010. From 1966 onwards, all AMTR series are based on a large sample of tax returns and the NBER's TAXSIM program to calculate the marginal tax rate for each return. In case of Barro and Redlick (2011), the income weights are based on a concept of labor income that includes wages as well as self-employment, partnership and S-corporation income. Saez (2004) uses a broader income concept based on adjusted gross income (AGI) before adjustments but excluding government transfers and capital gains. His series reflects different assumptions on the income of non-filers and also includes TAXSIM-based observations for 1960, 1962 and 1964. Unfortunately, TAXSIM is not consistently available prior to 1966. The series are therefore extended based on data in the annual Statistics of Income (SOI) from the IRS, available at `http://www.irs.gov/uac/SOI-Tax-Stats-Archive`, using a methodology analogous to Barro and Sahasakul (1983) and using adjusted gross income for weighting.

The SOI contain tables with information on the number of returns, total AGI, and taxable income for different ranges of AGI per return. In most years, these data are available separately for each filing status (married filing jointly/separately, single person, head of household or surviving spouse). For each year and filing status, I fit a probability distribution function $D(y)$ for adjusted gross income per return y,

$$D(y) = \sum_{i=1}^{n} w(i) \int_{b(i)}^{\min\{y,b(i+1)\}} f_i(x)dx \quad , \tag{A.1}$$

$$f_i(x) = \begin{cases} \text{Beta}(a(i),1) & \text{if } m(i) \geq (b(i)+b(i+1))/2 \text{ and } i<n \\ \text{Beta}(1,a(i)) & \text{if } (b(i)+b(i+1))/(2+c) \leq m(i) < (b(i)+b(i+1))/2 \text{ and } i<n \\ \text{BoundPar}(a(i)) & \text{if } m(i) < (b(i)+b(i+1))/(2+c) \text{ or } i=n \end{cases}$$

where n is the total number of brackets, $b(i)$ is the bracket floor and $b(n+1) = \infty$, $w(i)$ is the fraction of returns in bracket i and $m(i)$ is the mean AGI within bracket i. $D(y)$ approximates the AGI distributions by piecewise combinations of Beta (power function) distributions switching to (Bounded) Pareto distributions in the right tail. For each bracket the parameter $a(i)$ is set to match $m(i)$. Many brackets have $a(i) \approx 1$ such that the distribution is locally approximately uniform. The scalar c determines the location of the switch from a positively-skewed Beta to a Pareto distribution and is set to 0.25. Computing floors on various percentiles for all returns with positive AGI yields numbers that with few exceptions are well within 1% of those reported for 1986-2009 by the IRS. The percentiles used for the calculations of tax rates are for all potential tax units, see section A.2. Nonfilers' AIG is assumed to equal 20% of average reported AGI per return.

Method 1 for computing AMTRs is based on SOI tables that for each filing status report the total AGI and number of returns for which a given statutory rate is the highest marginal rate. The distributions $D(y)$ are used to interpolate for each filing status the total AGI taxed at each statutory rate applicable to returns exceeding the percentile floor. This method only considers returns with a regular tax rate as the highest marginal rate, which comprise the vast majority of returns, and does not reflect that certain types of income have a lower marginal rate.[30] Nonfilers and untaxed returns carry a zero marginal rate. **Method 2** for computing AMTRs uses the data on taxable income in combination with the statutory tax rates and brackets, including surcharges and reductions, to calculate the marginal rate for each AGI level and filing status. The AMTRs are subsequently computed using numerical integration based on the distributions $D(y)$. This method is again an approximation because all taxable income is assumed to be taxed at the regular rates.

Figures A.1 and A.2 show the AMTRs obtained using both methods. The SOI statistics are not reported consistently over time and missing observations reflect absent or inadequate data. For instance, the tables listing statutory rates and AGI taxed which are required for Method 1 are only available for 1961-1973, 1974-1977 and 1979-2010. AGI distributions disaggregated by filing status are to varying degrees incomplete for 1979-2002. Figure A.2 omits 1971-1980 because in those years a maximum rate on earnings (60% in 1971, 50% in 1972-1980), which is not captured by either method, is quantitatively important for the top

[30]Method 1 omits returns for which the capital gains rate is the highest marginal rate and returns with alternative tax computations.

income percentiles. In the overlapping years shown, both measures of AMTRs are highly correlated with the series of Saez (2004) and Barro and Redlick (2011). The missing values in their series are interpolated by OLS regressions on the Method 1 series when available, and else on the Method 2 series. Matlab code as well as spreadsheets with the underlying IRS SOI data are available online. This method was used to obtain the economy-wide AMTR and the AMTR for the top 1%, 5% and 10%. The remaining AMTRs are calculated residually using the income shares in Piketty and Saez (2007).

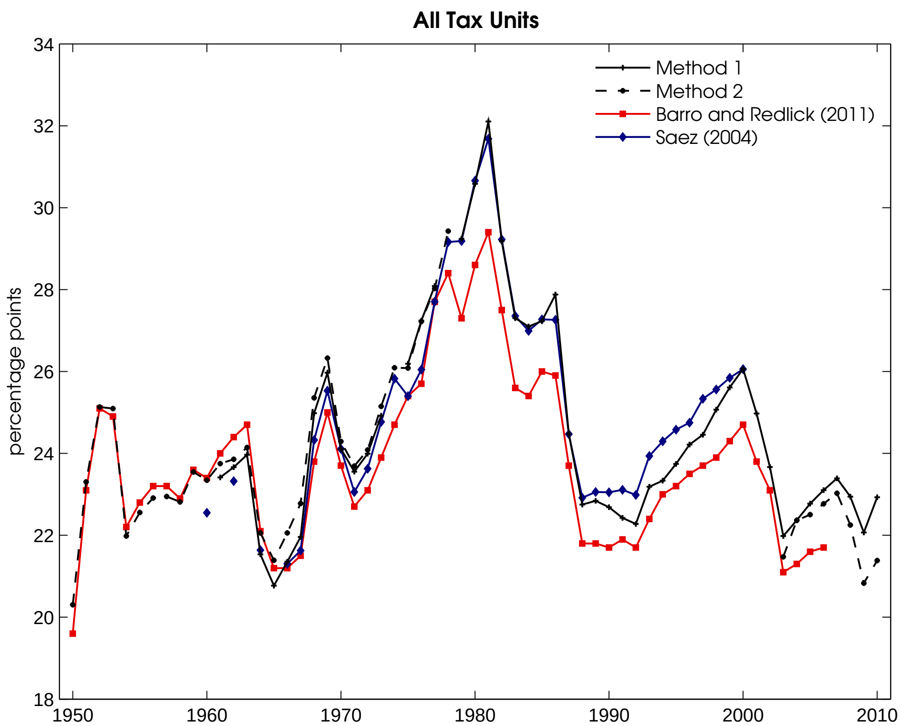


Figure A.1 Measuring Average Marginal Tax Rates: All Tax Units

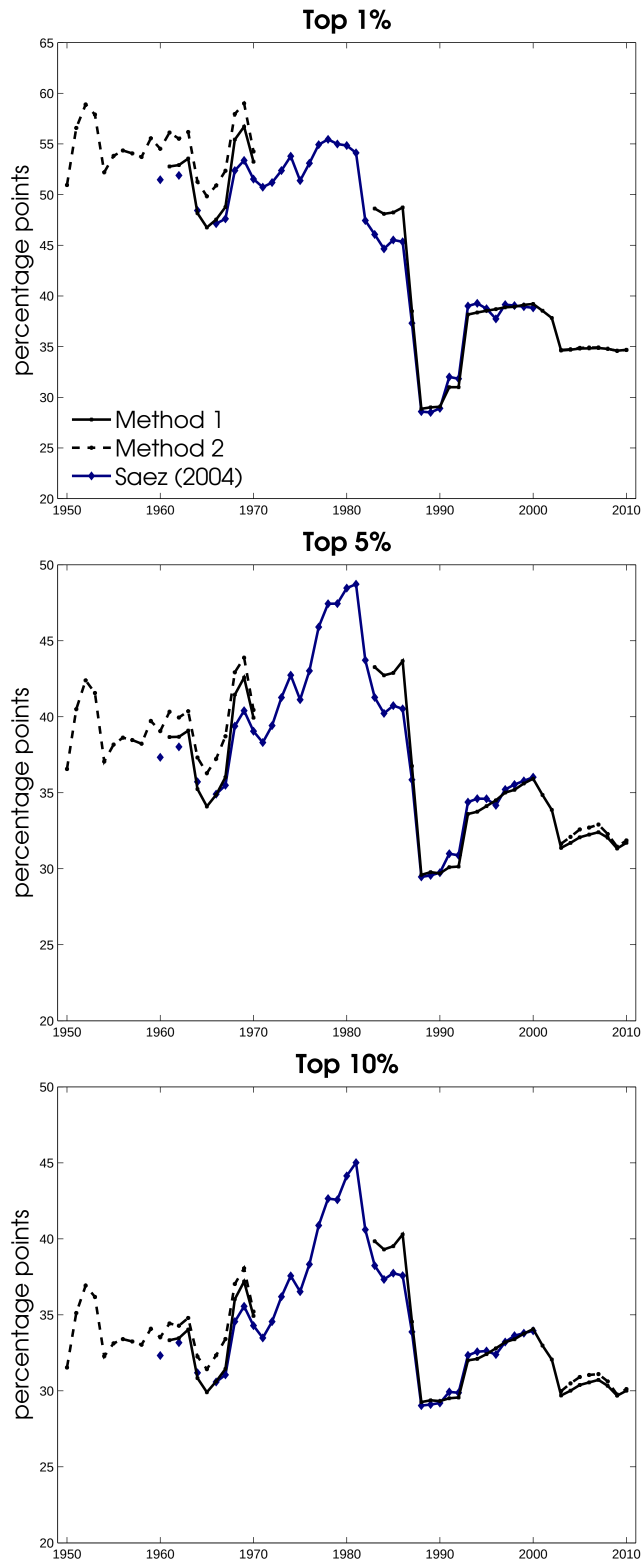


Figure A.2 Measuring Average Marginal Tax Rates: Different Income Percentile Brackets

A.2 Other Time Series

Potential Tax Units is all married men and singles aged 20 or over, obtained from Piketty and Saez (2007); **Real GDP per tax unit** is NIPA 1.1.3 line 1 divided by potential tax units; **Inflation** is the log change in the Bureau of Labor Statistics' CPI Research Series Using Current Methods (CPI-U-RS), obtained from Piketty and Saez (2007). The **Federal Funds Rate** is the annual average effective federal funds rate from the Board of Governors with observations prior to 1954 from Romer and Romer (2010). **Government Debt per Tax Unit** is Federal Debt Held by the Public (FYGFDPUN) from FRED, extended prior to 1970 using the federal surplus (NIPA 3.2 line 46), divided by the CPI-U-RS and potential tax units. **Government Spending per Tax Unit** is the sum of federal government purchases, net interest rate expenditures and net transfers (NIPA 3.2 line 46 less lines 3,4,7,10 and 11 plus NIPA 3.12U line 25), divided by the CPI-U-RS and potential tax units. All wage and total income series, as well as the **Average Capital Gains per Tax Unit** is based on updates of the data provided in Piketty and Saez (2007).

A.3 The Narrative Measure of Tax Rate Changes

The following are the legislative changes used to construct the narrative measure of tax rate changes:

1. **Internal Revenue Code of 1954** Signed: 8/16/54; ***Estimated Impact***: -\$0.8 billion in 1954

   This law was a comprehensive reform of the individual income tax system: it lowered rates and combined the 3 percent normal tax and the reduced surtax into a single comprehensive rate schedule, permitted three new tax credits (retirement income, dividends and tax exempt interest), introduced new concepts of taxable income and adjusted gross income, altered or introduced tax deductions (medical expenses, dependent care) and changed filing requirements. (SOI 1954, page 8 -9). The 1954 Treasury Annual Report (p. 44) provides an estimate of the structural changes of the income tax and states the bill reduced taxes on individuals by \$0.8 billion in fiscal year 1955 and I use the same number for calendar 1954.

2. **Revenue Act of 1964** Signed: 2/26/64; ***Estimated Impact***: -\$6.7 billion in 1964

   The Revenue act of 1964 substantially reduced statutory marginal tax rates across the board. It also changed the adjustments made to gross income (excluding sick pay, allowing higher dividend exclusion), created a new deduction (employee moving expenses), introduced income averaging and the minimum standard deduction and made various other changes (SOI 1964). Taxes on individual were reduced in two stages (1964 and 1965). The

1965 Economic Report (p.65) reports the effect on individual income tax liabilities of the first round of cuts, made retroactive to January 1964, as $6.7 billion in calendar 1964.

3. **Tax Reform Act of 1976** Signed 10/4/76; ***Estimated Impact***: $1.65 billion in 1976

   The law contained various changes to the individual income tax code, including an increase in the minimum tax, a new child care credit, an increase in the general tax credit and various measures to close loopholes (see SOI 1976, p iv.). The 1977 Economic Report contains at an annualized $2.4 billion total increase in revenues for 1976. The 1978 Budget (p. 60) provides numbers for the separate individual income tax effects of the bill for fiscal 1977 that are very much consistent with the aggregate numbers for 1977 in the Economic Report. The 1978 Budget breaks down the revenue effects of the reform for fiscal 1977. Tax shelter provisions and tax simplification measures canceling each other out with an impact of $0.4 billion and -$0.4 billion for fiscal 1977, respectively (p. 60). The net effect is zero, therefore only the figures provided for the increase in the minimum tax for individuals ($1.1 billion in fiscal 1977), out of total increase in liabilities of $1.6 billion, is included. The same proportions are used to deduce the effect for calendar 1976, i.e. $(1.1/1.6) \times 2.4$ or $1.65 billion increase in individual tax liabilities due to the higher minimum tax.

4. **Tax Reduction and Simplification Act of 1977** Signed 5/23/77; ***Estimated Impact***: -$5.4 billion in 1977

   The Tax Reduction and Simplification Act of 1977 established the "zero bracket amount", a simplified single deduction amount based-on marital status, the zero tax bracket and a new jobs credit. The Act also extended several temporary provisions of the Tax Reform Act of 1976 (see SOI 1977 p. vi.). The 1978 Economic Report (p.52) provides estimates for individual tax liabilities effects in calendar 1977 of -$3.3 billion for calendar. I subtract another $2.1 billion in individual income tax revenues to account for the withholding effect on individual taxpayers (see 1979 Budget (p. 50) and Romer and Romer (2009)).

5. **Revenue Act of 1978** Signed 11/6/78; ***Estimated Impact***: -$14.8 billion in 1979

   The Revenue Act of 1978 lowered the schedule individual tax rates. It widened and reduced the number of brackets, increased the personal exemption and the zero bracket amount, expanded the earned income tax credit and made several other changes (see SOI 1979 p. viii, CBO 1998 Projecting Federal Tax Revenues and the Effect of Changes in the Law, p.11). The 1979 Economic Report (p.93) describes the effect of the bill as a $14.1 billion cut in personal taxes and a $0.7 increase in outlays for the earned income tax credit in calendar 1979.

6. **Economic Recovery Tax Act of 1981** Signed 8/13/81; ***Estimated Impact***: -$4 billion in 1981

   The Economic Recovery Tax Act of 1981 consisted for the main part of permanent, across-the-board reductions in marginal tax rates in several stages and also instituted the indexing of the bracket structure. Effective in 1981 were changes to the minimum tax, the alternative tax and several other changes to the tax code (see SOI 1981 p 6, CBO 1998 Projecting Federal Tax Revenues and the Effect of Changes in the Law, p.14). The 1983 Budget (p.4-9 and 4.10) provides the decomposition of the decline in tax liabilities for 1981 and puts the reduction in individual income tax liabilities at a total of $4.0 billion for calendar 1981.

7. **Tax Equity and Fiscal Responsibility Act of 1982** Signed 9/3/82; ***Estimated Impact***: $5 billion in 1983

   The act repealed the add-on minimum tax, added several new tax preferences to the alternative minimum tax, restructured the treatment if itemized deductions in the minimum tax, established a flat rate of 20 percent for the minimum tax, and increased the minimum tax exemption, as well as other changes. The CBO provides an estimated impact on individual income tax liabilities of $5 billion for fiscal 1983 and as calendar year numbers are not available, I use this number as the calendar year estimate. (CBO 1998 Projecting Federal Tax Revenues and the Effect of Changes in Tax Law p.18-19).

8. **Deficit Reduction Act of 1984** Signed 7/18/84; ***Estimated Impact***: $5.6 billion in 1984

   The Deficit Reduction Act of 1984 postponed or repealed several tax reductions scheduled to take effect after 1984 (e.g. the net interest exclusion, made changes to thresholds for income averaging and a large number of minor provisions that raised revenues from corporate and individual taxpayers (SOI 1984 p. 3 and CBO 1998 Projecting Federal Tax Revenues and the Effect of Changes in Tax Law p. 16). As calendar year numbers are not available, the revenue effects adopted are for fiscal year 1985 from the 1986 Budget, p. 4-8, which are also identical to those reported in the 1987 Budget (p. 4-6).

9. **Tax Reform Act of 1986** Signed 10/22/86 ; ***Estimated Impact***: -$15 billion in 1987

   The Tax Reform Act of 1986 significantly reduced individual income tax liabilities, broadened the individual tax base (eliminating the itemized deductions for state sales taxes paid and expanding the alternative minimum tax) and was the first complete revision of the Internal Revenue Code since 1954 (CBO, Projecting Federal Tax Revenues and the Effect of Changes in Tax Law p. 21). The revenue effects of the tax change in 1987 are generally hard to discern, see Romer and Romer (2009). I adopt the CBO (Projecting Federal Tax Revenues and the Effect of Changes in Tax Law p. 25) estimate of a projected reduction of $15 billion in individual income tax revenues. This is similar the reduction of 16.9 billion in the report of the Joint Committee on Taxation (p.25) on TRA 1986.

10. **Omnibus Budget Reconciliation Act of 1990** Signed 11/5/90; ***Estimated Impact***: $4 billion in 1991

The Omnibus Budget Reconciliation Act of 1990 increased income taxes for upper-income taxpayers by three provisions: a higher top tax rate, a revised phaseout of personal exemptions, and a limit on itemized deductions. It also imposed a new statutory rate of 31 percent on certain income of high-income taxpayers and replaced a set of provisions enacted in TRA-86 that had created an implicit 33 percent statutory tax rate over a limited range but that had resulted in a top marginal rate of 28 percent for the highest-income taxpayers. (CBO, Projecting Federal Tax Revenues and the Effect of Changes in Tax Law p. 27,31).

11. **Omnibus Budget Reconciliation Act of 1993** Signed 8/10/93; ***Estimated Impact***: $22.8 billion in 1993

    The Omnibus Reconciliation Act of 1993 increased income taxes, mostly for higher earners. A Joint Committee on Taxation document (Estimated Budget Effects of the Revenue Provisions of H.R. 2264 (The Omnibus Reconciliation Act of 1993) as Agreed to by the Conferees, JCX-11-93, 8/4/93) provides a by-component breakdown of the revenue implications, including details on the retroactive components. The revenue effects for the first stage of the tax reform are almost entirely due to the increase in tax rates paid by high-income individuals, which was retroactive until 1/1/93. We therefore classify the entire revenue effect for 1993 as an increase in individual income taxes.

12. **Jobs and Growth Tax Relief Reconciliation Act of 2003** Signed 8/10/03; ***Estimated Impact***: -$ 94.6 billion in 2003

    The Jobs and Growth Tax Relief Reconciliation Act of 2003 affected both Federal individual and corporate income taxes lowered Federal income taxes by a reduction in marginal tax rates, an expansion of the 10 percent tax bracket, reductions in rates on married couples, an increase in child credit, as well as lower taxes on dividends and capital gains. The revenue impact is from Romer and Romer (2009).

B The Ambiguous Effects of Anticipated Tax Changes on Income

This appendix describes a simple theoretical example to illustrate that the effects of anticipated changes in marginal tax rates on income are generally ambiguous.

A representative household with rational expectations has preferences represented by

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left(c_t^{1-\sigma}\left(1+(\sigma-1)\frac{h}{1+1/\varepsilon}(h_t/h)^{1+1/\varepsilon}\right)^{\sigma}\right)-1}{1-\sigma} \text{ , } h,\sigma,\varepsilon,>0; \tag{B.1}$$

where c_t is consumption and h_t denotes hours of work. Note that for $\sigma \to 1$ the instantaneous utility function collapses to (7). The household's flow budget constraint is

$$c_t + k_{t+1} = (1-\tau_t)w_t h_t + r_t k_t + (1-\delta)k_t + tra_t \text{ , } k_0 \text{ given , } 0 < \delta \leq 1 \tag{B.2}$$

where k_t denotes the physical capital stock owned by the household, r_t is the rental rate of capital, w_t is the real wage, tra_t are lump-sum government transfers to the households, τ_t is the average marginal tax rate (for simplicity capital income is not taxed). Firms produce the final good according to $y_t = Ah_t^{\alpha}k_t^{1-\alpha}$ and maximize profits. Tax rates are set randomly by the government according to

$$\ln(1-\tau_t) = \ln(1-\tau_{t-1}) + v_t^{\tau} + v_{t-1}^{a} \text{ , } \tau_0 \text{ given} \tag{B.3}$$

where v_t^{τ} and v_t^{a} are a mean zero i.i.d. shocks. All tax revenue is transferred to the household $tra_t = \tau_t w_t h_t$.

The equilibrium conditions are

$$\begin{aligned}
h_t &= h\left(\mu_t(1-\tau_t)w_t/c_t\right)^{\varepsilon} \\
w_t &= \alpha A(k_t/h_t)^{1-\alpha} \\
(\mu_t/c_t)^{\sigma} &= \beta E_t\left[(\mu_{t+1}/c_{t+1})^{\sigma}((1-\alpha)A(k_{t+1}/h_{t+1})^{-\alpha}+(1-\delta)\right] \\
Ah_t^{\alpha}k_t^{1-\alpha} &= c_t + k_{t+1} - (1-\delta)k_t
\end{aligned}$$

where $\mu_t = \left(1 + (\sigma - 1)\frac{h}{1+1/\varepsilon}(h_t/h)^{1+1/\varepsilon}\right)/\sigma$. Fixed parameter values are $\alpha = 0.66$, $\beta = 0.97$ and $\delta = 0.1$. The equilibrium dynamics are approximated around the steady state of the non-stochastic model with $\tau = 0.24$ and labor supply equal to 0.33.

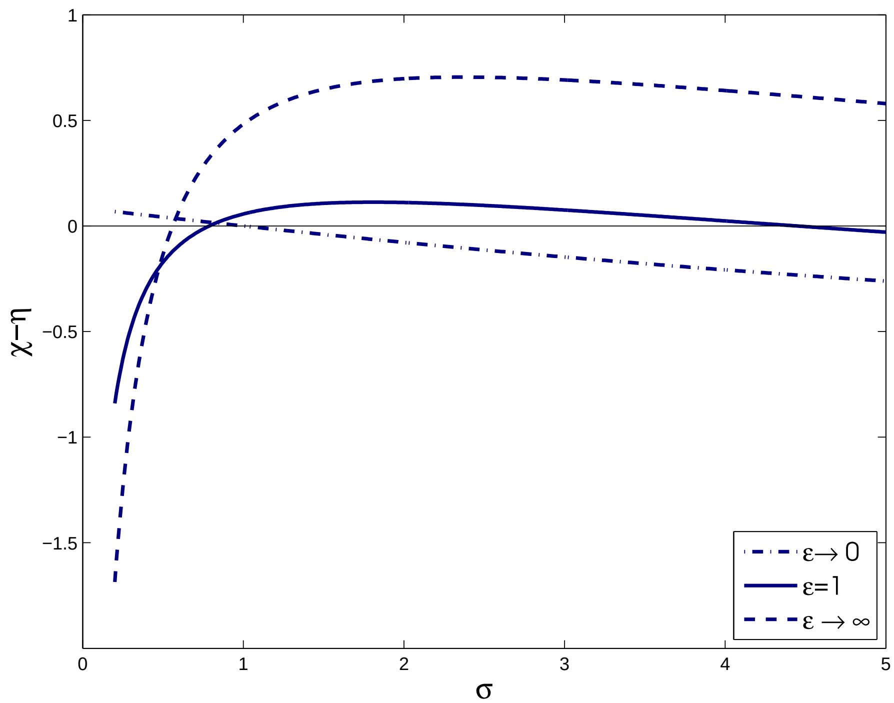


Figure B.1 Direction of OLS Bias as Determined by the Sign of $\chi - \eta$.

Figure B.1 plots the values of $\chi - \eta$ implied by the model for different values of the parameters σ and ε determining the elasticities of intertemporal substitution. The coefficient η is the period t percent growth in labor income following a *surprise* one percent permanent increase in $1 - \tau_t$, whereas χ is period t percent growth in income following an *anticipated* permanent increase in $1 - \tau_t$. The sign of $\chi - \eta$ determines the direction of bias in OLS regressions of log income growth on changes in log net-of-tax rates. When labor supply is completely inelastic $\varepsilon \to 0$, values of σ below (above) 1 lead to upward (downward) bias. When $\sigma < 1$ substitution effects dominate wealth effects and agents reduce consumption and increase investment in response to tax news, leading to higher wages and wage income in the period of the tax cut. When $\sigma > 1$ wealth effects dominate substitution effects and lower investment leads to wage declines in the period when taxes are cut. When labor supply is elastic $\varepsilon > 0$ and σ is relatively low (high), hours and investment increase (decrease) in response to an expected future permanent tax cut and the bias is in the downward (upward) direction.

C Results based on the Alternative Measure of the Economy-Wide AMTR

Figure C.1 shows the impulse responses and associated confidence bands when the other available series of the economy-wide AMTR is used (Series 2 in Figure 1). The VAR specifications are identical to what is described in Section 4 . Table C.1 provides the IV estimates of the tax elasticities when the instrument is the shock identified in the VARs using the alternative economy-wide AMTR series. Figure C.2 shows the dynamic responses to a one percent increase in the net-of-tax rate at different income levels. The results are very similar those in the main text.

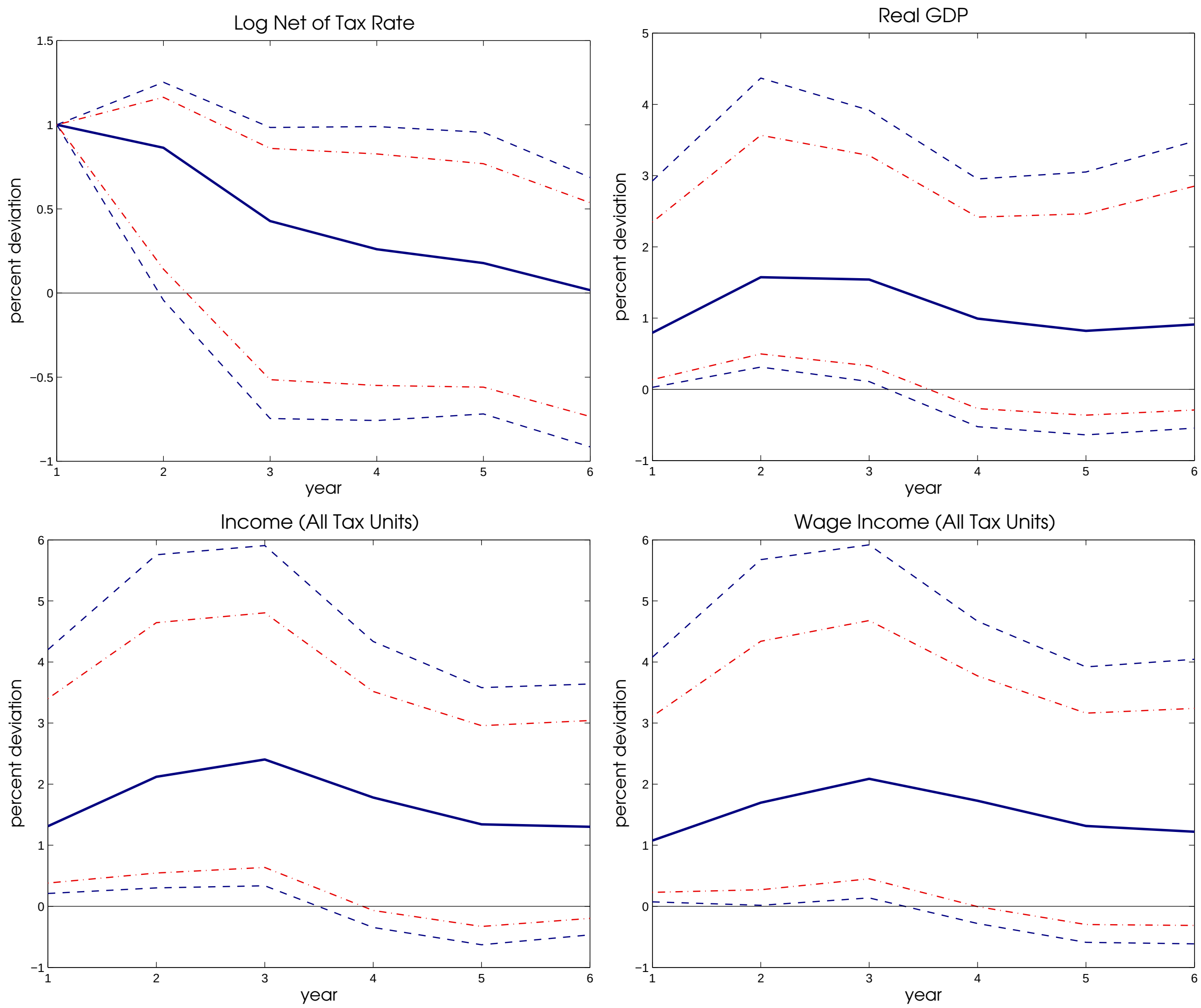


Figure C.1 Response to unit shock to the log net-of-tax rate. Broken lines are 90% and 95% confidence bands based on 10,000 wild bootstrap replications.

Table C.1 IV Estimates of Short Run Tax Elasticities: 1952:2010

	All Tax Units Series 1	All Tax Units Series 2	Top 1%	Top 5%	Top 10%	Top 5-1%	Top 10-5%	Btm. 99%	Btm. 90%
Wage Inc.	1.07*	1.08	1.27***	0.84*	0.94**	0.28	1.13**	0.89	0.99
	(−0.13, 2.28)	(−0.29, 2.45)	(0.39, 2.15)	(−0.03, 1.71)	(0.09, 1.79)	(−0.43, 0.99)	(0.03, 2.23)	(−0.55, 2.32)	(−1.00 − 2.98)
1st Stage F	*10.23*	*9.04*	*8.98*	*8.60*	*8.86*	*6.48*	*6.69*	*6.37*	*7.92*
Total Inc.	1.33*	1.31*	1.24**	1.16*	1.15*	0.68	0.78	1.02	1.13
	(−0.08, 2.73)	(−0.23, 2.85)	(0.22, 2.26)	(−0.03, 2.35)	(−0.08, 2.37)	(−0.38, 1.75)	(−0.26, 1.81)	(−0.40, 2.43)	(−0.45, 2.73)
1st Stage F	*10.66*	*9.93*	*10.44*	*9.81*	*9.87*	*6.65*	*6.95*	*6.64*	*9.02*

In parentheses are Newey-West 95% intervals with 8 lags. Asterisks denote 10%, 5% or 1% significance.

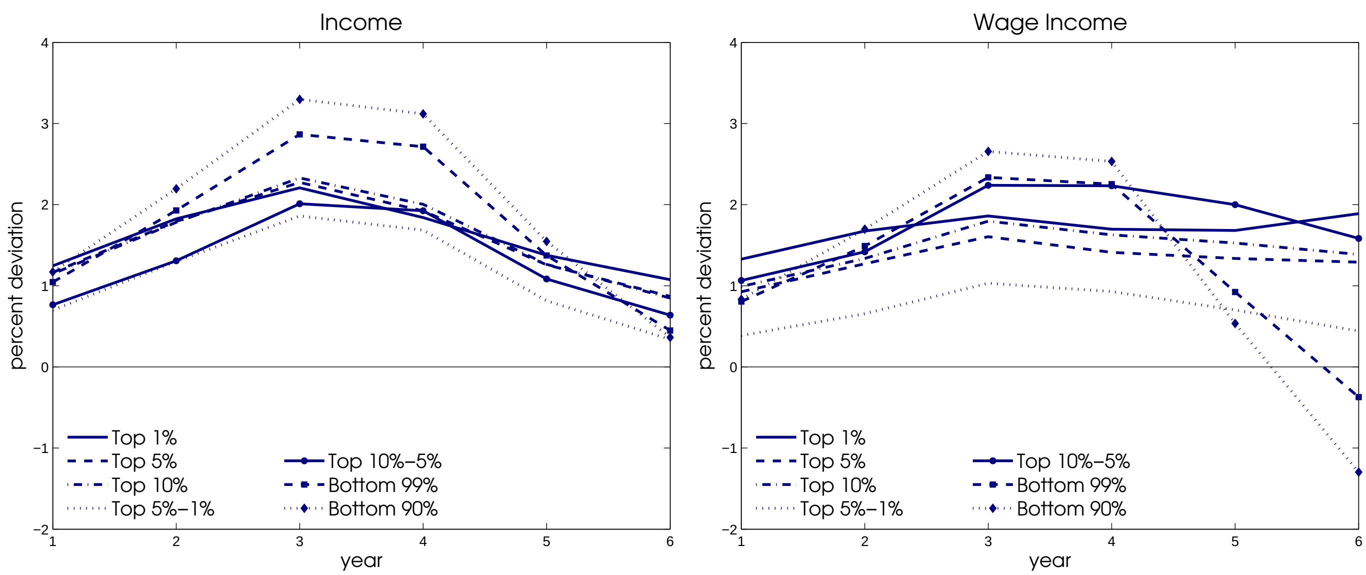
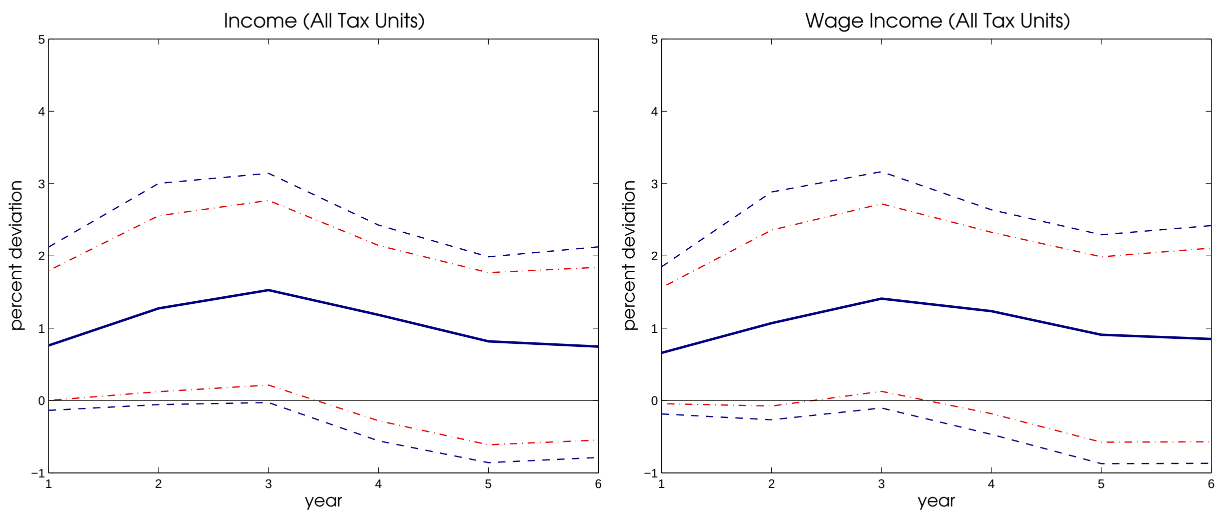


Figure C.2 Dynamic Estimates of Tax Elasticities

D Controlling for Simultaneous Corporate Tax Changes

Figure D.1 shows the income responses when controlling for simultaneous changes in corporate income taxes. The methodology is identical to Mertens and Ravn (2013a) and relies on an annualized version of the quarterly narrative series for corporate tax changes described in that paper. The VAR specifications now also include the log of one minus the average corporate income tax rate, defined as corporate tax revenues (NIPA Table 3.2 line 9) divided by corporate profits (NIPA 1.12 line 13) both after excluding the Federal Reserve, but omit the government deficit variable. Panel A and B show the income responses for each of the measures of the economy-wide AMTR.

A. Using AMTR Series 1



B. Using AMTR Series 2

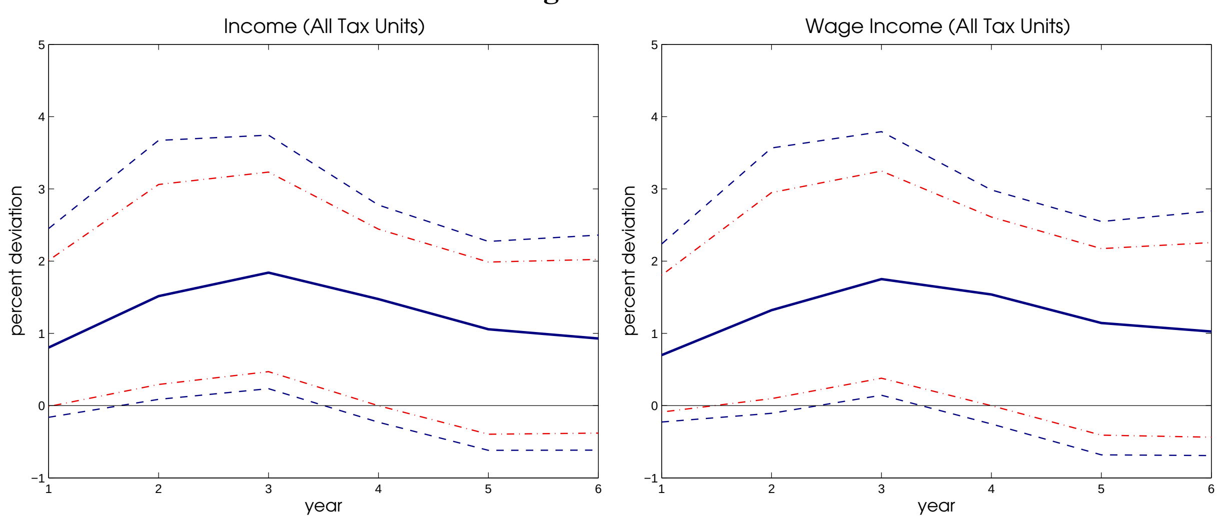


Figure D.1 Response to unit shock to the log net-of-tax rate. Broken lines are 90% and 95% confidence bands based on 10,000 wild bootstrap replications.

The responses are to a one percent increase in the individual income net-of-tax rate while keeping the average corporate tax rate constant in cyclically adjusted terms. The income responses are again large and positive and have similar hump shapes to the benchmark specification in Section 4 . Controlling for simultaneous corporate tax changes yields point estimates in the first year that are somewhat smaller than the specification in Section 4 and that are marginally insignificant. The responses in subsequent years remain significant either at the 90 or 95% confidence level.

E Robustness of The Dynamic Effects of Cutting Top Marginal Tax Rates

Figure E.1 displays the responses to a one percent shock to the top 1% net-of tax rate in a 10-variable VAR system that retains the government deficit variable. The point estimates are very similar to those in Section 5 . However, the confidence intervals are wider, the GDP response is only significant at the 90% level, and the income response of the bottom 99% is no longer significant at conventional levels.

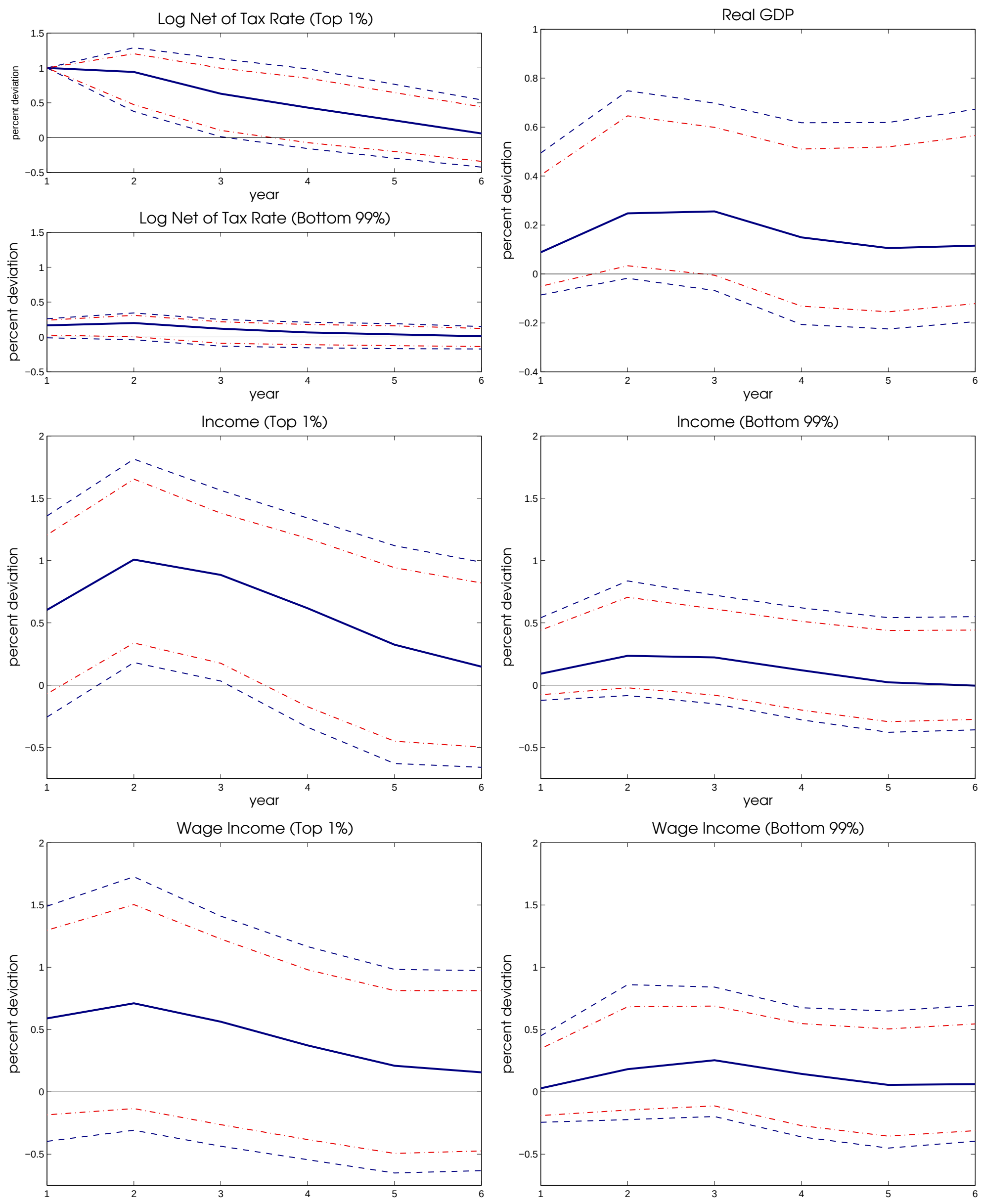


Figure E.1 Response to unit shock to the Top 1% log net-of-tax rate. Broken lines are 90% and 95% confidence bands based on 10,000 wild bootstrap replications.