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ABSTRACT

In a seminal contribution, Romer and Romer (2010) (RR henceforth) estimate GDP tax multipliers of up to -3 after 3 years. These results have been criticized as implausibly large. For instance, Favero and Giavazzi (2010) (FG henceforth) argue RR's specification cannot be interpreted as a proper (truncated) moving average representation of the output process. They show that when the system is estimated in its VAR form, or its correct truncated MA representation, a unit realization of the RR shock has much smaller effects on GDP than in RR, typically about - .5 percentage points of GDP. I argue that on theoretical grounds the discretionary component of taxation should be allowed to have different effects than the automatic response of tax revenues to macroeconomic variables; existing approaches, including FG's, that do not allow for this difference, exhibit impulse responses that are biased towards 0. I show that the correct impulse responses to a RR tax shock are about half-way between the large effects estimated by RR and the much smaller effects estimated by FG: typically, a one percentage point of GDP increase in taxes leads to a decline in GDP by about 1.5 percentage points after 3 years. I also create two new datasets of tax shocks, one based on receipts and the other on liabilities; in these datasets, I distinguish between different types of taxes (personal, corporate, indirect, and social security) and their subcomponents.

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1 Introduction

In a seminal paper, Romer and Romer (2010) (henceforth, RR) construct measures of tax changes based on the original documentation accompanying tax bills, and show that they have large negative effects on output: an exogenous increase in taxes by 1 percentage point of GDP can lead to a decline in GDP by 3 percentage points after three years.

These magnitudes have been criticized as implausibly large. Favero and Giavazzi (2010) (henceforth, FG) challenge the specification used by RR, arguing that it cannot be interpreted as a proper (truncated) moving average representation of the output process. They show that when the system is estimated in its VAR form, or its correct truncated MA representation, a unit realization of the RR shock has much smaller effects on GDP, typically about - .5 percentage points.

I argue that, on theoretical grounds, one should expect the discretionary component of tax changes to have stronger effects on output than the component capturing the endogenous response of taxes to, say, output fluctuations. If this is the case, I show that the approaches of FG (2010) and of Blanchard and Perotti (2002) (henceforth, BP) generate impulse responses that are biased towards zero. By adopting a VAR approach that allows for a different impact of the discretionary and endogenous components of taxation, I show that the estimated effects of a tax change is larger (in absolute value) than that estimated by FG, although smaller than that estimated by RR. Now a one percentage point of GDP increase in taxation is typically associated with a decline in GDP by about 1.5 percentage point after three years.

Following Mertens and Ravn (2009) (henceforth, MR) I decompose the changes to current taxation into anticipated and unanticipated changes. If individuals are liquidity constrained, the responses to the two components should be the same. I show that this is indeed approximately the case. I then apply the same decomposition to shocks to future taxation, and I show that the results of MR on the effects of changes to future expected taxation are mostly due to the anticipated component.

I also extend the RR dataset in several dimensions. Conceptually, for some purposes data on liabilities are called for, while for other purposes data on receipts might be more appropriate. I construct two datasets based on these two different concepts. I also track the quarterly changes in receipts generated by each tax bill, and I distinguish between different types of taxes (personal, corporate, indirect, social security) and several subcomponents of each of these.

The outline of the paper is as follows. Section 2 describes the new dataset. Section 3 presents an overview of the construction and properties of the RR measure of discretionary tax changes. Section 4 presents several specifications used to estimate the effects of discretionary taxation, and introduces the specification I use to accommodate differences in the effects of the discretionary and endogenous changes in tax revenues. Section 5 summarizes these specifications. Estimation results are discussed in section 6. Section 7 presents a test of the assumption of this paper, that the discretionary and automatic components of taxation have different effects. Section 8 discusses the results of decomposing changes to current taxation into anticipated and surprise changes. Section 9 applies the same decomposition to changes to future taxation. Section 10 presents some robustness checks. Section 11 concludes.

2 Data description

I extend the RR data in several dimensions, and in some cases I use somewhat different rules to record the tax changes. In what follows, I detail the main features of my dataset and the main differences with the RR dataset.[1]

1. I collect data on total tax revenues, and also on individual, corporate, indirect, and social security taxes separately, and on their subcomponents, as described in Table 1.

[1] The detailed dataset is available on my website.

Table 1: **Breakdown of taxes**

	Individual	**Corporate**	**Indirect**	**Soc. Sec.**
1.	Tax rates	Tax rates	Indirect taxes	Tax rates
2.	Deductions. allowances	Employment credit		Earnings base
3.	Tax credits	Investment tax credit		Others
4.	Capital gains	Depreciation		
5.	Depreciation	Others		
6.	Earned Income Tax Credit			
7.	Rebates			
8.	Estate and gift			
9.	Others			

The distinction between the four main categories of taxes is clear and meaningful; data on the subcomponents are not always as reliable. In this paper, which focuses on methodological issues, I aggregate all taxes in one measure of total tax revenues.[2]

2. RR refer to their data as representing "liabilities". They take the first full (calendar of fiscal) year effect of the tax change as the effect of a tax measure. However, for many tax bills only the effects on receipts are documented. In other cases, the sources report both the change in liabilities and receipts. The difference between receipts and liabilities can reflect slow take-up, information and collection lags, tax evasion, and several other factors. Depending on the question, receipts or liabilities might be the more appropriate concept; hence, whenever possible, I collect data on both. When only receipts or liabilities are available, I convert one into the other using the methodology described below.

In recording liabilities, I follow the same methodology used by RR, i.e. I record the first full year effect as the effect of the tax measure. In recording receipts, I try to track the exogenous quarterly change. The methodology is described more fully below.

Note that, because I disaggregate the total effect into different components and subcomponents, and because I record both liabilities and receipts, I had to redo the RR dataset

[2]Since the dataset is based on budget documents, obviously it covers, like the RR dataset, only federal tax revenues.

from the beginning, sometimes using different sources. This accounts for the different totals relative to the RR dataset.

3. The main differences with the RR dataset are as follows.

1) I track the starting date of each individual component within a given tax bill. For instance, for the 1982 Tax Equity and Fiscal Responsibility Act, RR give a single number, $26.4bn, starting 1983:1. In the liability dataset, I have 17 different items, with starting dates varying from 1983:1 to 1984:1.

2) As mentioned, RR typically report the effect of a tax legislation as the first full year effect after enactment, and take it as the starting date of the measure. In some cases, this procedure does not capture correctly the impact of tax legislation on tax receipts and liabilities. For instance, changes to depreciation allowances, to the investment tax credit and to capital gains taxation can present a highly irregular behavior over time. Legislation that allows for accelerated depreciation causes a large change in the time profile of receipts, but a small change in their present discounted value: receipts decline initially, only to increase later. Using the first full-year effect would therefore provide a distorted picture of the effects of the tax measure.[3]

3) Even aside from the cases above, the effect of a tax measure in the first fiscal or calendar year after enactment is often much smaller than the effect in later years. On the other hand, there is a normal trend increase in the effect due to the assumed exogenous increase in GDP over time. Hence, I adopt the rule that, if in fiscal year x+1 receipts are different from year x by a factor of more than 30 percent, I display a change in x+1:1. By convention, the change is assumed to be in the first quarter, unless there is specific information that indicates otherwise.

4) By breaking down each tax bill into its components, I can trace which parts of the bill

[3]In the first 10 to 15 years of the sample, typically the sources report only the full-year effect of the tax measures; but starting around 1960, they often report receipts (and in some cases liabilities) over a longer horizon, from 5 years to – in the nineties – up to 10 years ahead.

were merely extensions of existing measures and therefore did not lead to an actual change in receipts or liabilities.

Thus, I end up with the following classification of tax changes, summarized in Table 2. A tax change is "legislated, unanticipated" ("LU" in the last column of the table) if the tax change is legislated within 90 days after enactment, and receipts or liabilities start within 90 days after the legislated tax change (row 1). It is "legislated, anticipated" ("LA") if either the tax change is legislated to go into effect within 90 days from enactment, but receipts or liabilities start more than 90 days after the legislated change (row 2.); or the legislated change starts more than 90 days after enactment (rows 2, 3 and 4). A tax change is "non legislated, anticipated" ("NLA") if it is not associated with a legislated change, and follows from the application of the 30 percent rule (rows 5 and 6). This classification generates two datasets: in the first I keep track only of changes that are explicitly legislated, i.e. of the first two categories, "LU" and "LA". In the second I also include the third category, "NLA", i.e. changes in receipts that are captured by the 30 percent rule. The results in this paper are based on this second definition; the difference with the narrower definition are minor.

RR (2010) use only legislated changes; MR (2009) also use only legislated changes, and distinguish between anticipated and unanticipated.

Table 2: **Classification of discretionary tax changes**

1.	LC within 90 days after enactment, R or L change within 90 days from LC	LU
2.	LC within 90 days after enactment, R or L change more than 90 days after LC	LA
3.	LC more than 90 days after enactment, R or L change within 90 days from LC	LA
4.	LC more than 90 days after enactment, R or Lchange more than 90 days after LC	LA
5.	LC within 90 days after enactment, R or L change (without LC) after first R change	NLA
6.	LC more than 90 days after enactment, R or L change (without LC) after first R change	NLA

LC: "Legislated change"; *R*: "Receipts"; *L*: "Liabilities"; *LU*: "Legislated, Unanticipated"; *LA*: "Legislated, Anticipated; *NLA*: "Non-Legislated, Anticipated".

4. For receipts, I try to track the exogenous quarterly changes determined by a tax

measure. Some sources not used by RR, most notably the *Survey of Current Business,* display the quarterly effects (as opposed to the annual effects used by RR) of the different tax measures. I use these sources to track quarterly changes, and I complement them with a specific methodology to infer quarterly changes in receipts from annual data on liabilities or receipts.

First, I keep track of changes in withholding rates for individuals. If these change at the time of enactment, I assume that receipts track liabilities from the time of enactment, unless receipt data indicate otherwise. If withholding rates are not changed immediately, some or all of these liabilities are paid in quarter 1 and 2 of the next calendar year, when tax declarations are filed and net settlements are carried out.[4]

For corporations, I convert liabilities into receipts, and yearly receipts into quarterly receipts, using the legislation in place in each year determining the timing of tax payments by corporations. These rules are complicated, also because they depend on the choice of the tax year. Most corporations (currently about 85 percent) choose the calendar tax year, and I will present results for this case. Presently, calendar year corporations are required to pay their CY x estimated liabilities in four equal installments in CY x. But these rules have changed over time. Until 1949 corporations paid 25 percent of their year x tax liability in each of the quarters of year x+1. In 1950 a new system was introduced, whereby corporations would move gradually to a payment of 50 percent of their year x tax liability in each of the first two quarters of year x+1; the transition lasted until 1954. But in 1954 a new system was again adopted: by 1959, a corporation would pay 25 percent of estimated tax liability for year x in each of quarters 3 and 4 of year x, and quarters 1 and 2 of year x+1. Any difference between estimated and actual tax liabilities would be paid or credited in March and June of year x+1. In the new system adopted in 1964, corporations would eventually pay 25 percent of their estimated year x liability in each quarter of year x. The transition was accelerated in 1966, so that the new system was fully operational in 1967.

[4]When the source reports the quarterly pattern of receipts, this is indeed the pattern that one observes.

Table 3 summarizes the rules in place in different years, determining when a dollar of liabilities on corporate income received in CY x would be paid. There are four regimes, separated by a transition trajectory from each other. I will assume that Regime 1 lasts until 1950 included, Regime 2 from 1951 to 1957, Regime 3 from 1958 to 1965, and Regime 4 from 1966 onwards.

Table 3: **Tax payments by corporations**

	Income year				**Following year**			
	April	June	Sept.	Dec.	April	June	Sept.	Dec.
1945					25	25	25	.25
1946					25	25	25	25
1947					25	25	25	25
1948					25	25	25	25
1949					25	25	25	25
1950					25	25	25	25
1951					30	30	20	20
1952					35	35	15	15
1953					40	40	10	10
1954					45	45	5	5
1955					50	50		
1956			5	5	50	50		
1957			10	10	45	45		
1958			15	15	40	40		
1059			20	20	35	35		
1960			25	25	30	30		
1961			25	25	25	25		
1962			25	25	25	25		
1963			25	25	25	25		
1964			25	25	25	25		
1965	9	9	25	25	16	16		
1966	12	12	25	25	12	12		
1967	25	25	25	25				

Each cell displays the percentage of the income earned in the "Income year" to be paid in the quarter indicated by the cell.

5. These rules are important not only to calculate the correct time path of receipts, but also the retroactive components. Several tax changes have retroactive components, i.e. they apply to a period before the time of enactment. RR assume that all retroactive liabilities

are paid in one installments in the first quarter after enactment. This is the assumption I also make for the liability dataset. In reality, individuals and corporations pay retroactive liabilities in a variety of ways.

Individuals typically pay retroactive liabilities in the first two quarters of the first calendar year after enactment, when filing tax returns, although different laws sometimes specify different timings. As an example, suppose a law is signed on October 1 of calendar year (CY) x, and it is retroactive to January 1 of year x; suppose that the withholding rates were changed immediately on enactment. The source reports an effect on receipts in fiscal year[5] (FY) x+1 of $1400mn, thus FY x+1 contains 7 quarters worth of receipts: the three retroactive quarters x:1 to x:3, all paid in x+1:1 and x+1:2, and the four non-retroactive quarters x:4 to x+1:3. Hence, the annualized retroactive component is 1400*(3/7)*(4/2) = $1200mn, to be attributed to each of x+1:1 and x+1:2, while the annualized non-retroactive component is 1400*(4/7)*(4/4) = $800mn, to be attributed to each quarter starting x:4.

Suppose instead the tax measure was enacted on July 1 of CY x, retroactive to January 1 of the same year. Suppose again that withholding rates are adjusted immediately. Receipts in FY x contain one quarter's worth of receipts, the non-retroactive receipts paid in x:3. The retroactive part (two quarters' worth of receipts) is again paid in x+1:1 and x+1:2. Hence we have to sum the effects from FY x and FY x+1: this sum contains again 7 quarters worth of data. Suppose this sum is again $1400mn. The retroactive part is now two quarters, spread over x+1:1 and x+1:2; hence it is 1400*(2/7)*(4/2) = $800mn; the non-retroactive part is 5 quarters, spread over 5 quarters: hence 1400*(5/7)*(4/5) = $800mn. The point of this second example is that sometimes one needs the sum of the effects in the first two fiscal years to compute the retroactive component.

Take the case of the 1950 Revenue Act. It was enacted on September 23, 1950, retroactive to July 1, 1950. In CY 1951, calendar year corporations would pay their CY 1950 liabilities

[5] From 1975, fiscal year x starts on October 1 of calendar year x-1. Before 1975, a fiscal year started on July 1 of year x-1.

in four equal installments. The effect on full year liabilities was estimated to be \$1500mn. I calculate the CY 1951 effect on receipts as follows. The retroactive component is one quarter, hence one fourth of \$1500mn, to be paid over four quarters of CY 1951. Hence the quarterly annualized retroactive effect on receipts in CY 1951 is \$375mn. The non-retroactive effect is also \$375mn. From 1952:1, the effect on receipts is the full-year effect on liabilities, \$1500mn.

Now take the case of the corporate tax rate increases in the 1993 Omnibus Budget Reconciliation Act. It was enacted on August 10, 1993, retroactive to January 1, 1993. The first reported effect on receipts is \$4400mn for FY 1994. This includes 7 quarters worth of receipts: 3 quarters of retroactive effects, and 4 quarters of non-retroactive effects. Under the rules in place in 1993, calendar year corporations would have to pay changes in their CY 1993 tax liability in equal installments in the remaining quarters of CY 1993. Hence, in this case all the retroactive component would have to be paid in 1993:4. This implies a annualized retroactive effect on receipts in 1993:4 of 4400*(3/7)*4 = \$7550mn. The non-retroactive component, that also starts in 1993:4, is 4400*(1/7)*4 = \$2517mn.

Consider instead another example, from the 2002 Jobs Creation and Workers Assistance Act. This act was signed on March 9, 2002, and its provisions on accelerated depreciation applied to all capital put in place after September 10, 2001. The decrease in revenues of the retroactive component (2 quarters' worth of receipts) was implemented in three equal installments in 2002:2, 2002:3, and 2002:4. Over the same period taxes would decrease also because of the non-retroactive component, over the last three quarters of CY 2002. Because these quarters span two different fiscal years, one needs FY 2002 and FY 2003 estimates to compute the effects. The sum of FY 2002 and FY 2003 receipts contains 8 quarters' worth of receipts: 2 are retroactive (and received in the last three quarters of CY 2003).and 6 are non-retroactive. Since the sum of FY 2002 and FY 2003 receipts is -35239-32738 = -\$67976mn, the annualized retroactive component is (-67976)/8*2*(4/3) = -\$22659mn, in 1992:2, 1992:Q3 and 1992:4. The annualized non-retroactive component is (-67976)/8*4 = -\$33989mn, in all quarters from enactment.

3 Estimates of discretionary taxation

Narrative estimates of tax changes are based on "discretionary" changes in taxation (also sometimes called changes in "cyclically adjusted" revenues, or "fiscal impulse"). Discretionary changes in taxation are meant to capture the intentional action of policymakers, as opposed to the automatic effects of the cycle on revenues. In this section, I introduce the notation and describe the construction of measures of discretionary taxation.

To understand this notion, it is useful to start from the following question: what would tax revenues be if they changed only because of the automatic effects of movements in output? Denote the log of this hypothetical level of revenues by $\widetilde{S}_t$, the logs of actual revenues and output by S_t and Y_t, respectively, and the elasticity of revenues to output by η. Then

$$\widetilde{S}_t = S_{t-1} + \eta(Y_t - Y_{t-1}) \tag{1}$$

The difference $S_t - \widetilde{S}_t$, which I denote by $d_{t/t}$, is the change in revenues we would observe if output had remained constant at its reference level Y_{t-1}, in other words, it is the change in revenues that is not explained by the change in output from Y_{t-1} to Y_t. This difference is what is usually referred to as the "discretionary change in taxation". Thus, if $D_{i/j}$ is the log level of discretionary taxation at date i as estimated at date j, the discretionary change in taxation $d_{t/t}$ is:

$$\begin{aligned} d_{t/t} &\equiv D_{t/t} - D_{t-1/t-1} && (2)\\ &= S_t - \widetilde{S}_t && (3)\\ &= S_t - S_{t-1} - \eta(Y_t - Y_{t-1}) && (4) \end{aligned}$$

If one has an outside estimate of the elasticity η, the standard procedure to estimate $d_{t/t}$ is precisely to subtract from the actual change in revenues the change in output, and possibly other determinants of revenues like inflation, each multiplied by its own elasticity. Conceptually, this is what BP (2002) do, except that they use innovations estimated from a VAR rather than actual changes in revenues and output.

RR (2010) turn this procedure around by starting from estimates of $d_{t/t}$ as provided by official documents, and based on the specific provisions of each tax bill enacted by Congress. Let this estimate be $\widehat{d}_{t/t}$; hence the actual change in revenues can be decomposed into the discretionary change in taxation plus a second component, consisting of the automatic response of revenues to changes in output and a white noise error:

$$S_t - S_{t-1} = \widehat{d}_{t/t} + \eta y_t + \mu_t \tag{5}$$

where y_t is the log change of output, $Y_t - Y_{t-1}$, and μ_t is i.i.d. with mean 0 and variance σ^2_μ. From now on, I will drop the hat "^" from $\widehat{d}_{t/t}$, as it will be evident that I will refer to the measure constructed using the RR methodology and not to the measure obtained as the difference between the actual revenue change and ηy_t. Also, and with a slight abuse of terminology, I will call the term $\eta y_t + \mu_t$ the "endogenous component".

How is $d_{t/t}$ constructed in practice? A law enacted at time t specifies a path of revisions to discretionary taxation, from time t onward: $D_{t/t} - D_{t/t-1}$, $D_{t+1/t} - D_{t+1/t-1}$, $D_{t+2/t} - D_{t+2/t-1}$ up to time $t + M$, where M is the maximum horizon for a law (of course, many of these revisions will be 0).[6]

Let $u_{t/t-i}$ be the difference between the revisions of the expectation of discretionary

[6] In practice, I set $M = 20$; this leaves out only a few tax tax changes that occurred more than 20 quarters after enactment on the bill. Specifically, five reductions of the telephone excise tax set by the P.L. 91-614 of 1970 for 1976, 1977, 1978, and 1979, each for $160mn; the end of the repeal of the 1985 and 1986 increases in accelerated cost recovery deductions, set by the 1982 TEFRA for 1988, for a total of $15.9bn; and the imcrease in the social security tax rate decided in 1972:3 for 1978:1, for $3.3bn.

taxation at time t and $t-1$, on the basis of two laws enacted at time $t-i$ and $t-i-1$:[7]

$$u_{t/t-i} \equiv (D_{t/t-i} - D_{t/t-i-1}) - (D_{t-1/t-i} - D_{t-1/t-i-1}) \tag{6}$$

$d_{t/t}$ is equal to the sum of all such revisions, enacted by all laws between t and $t-M$:

$$\begin{aligned} D_{t/t} - D_{t-1/t-1} &= \underbrace{[D_{t/t} - D_{t/t-1}]}_{\mathbf{u}_{t/t}} + \underbrace{[(D_{t/t-1} - D_{t/t-2}) - (D_{t-1/t-1} - D_{t-1/t-2})]}_{\mathbf{u}_{t/t-1}} \\ &+ \underbrace{[(D_{t/t-2} - D_{t/t-3}) - (D_{t-1/t-2} - D_{t-1/t-3})]}_{\mathbf{u}_{t/t-2}} + ... \\ &+ \underbrace{[(D_{t/t-M} - D_{t/t-M-1}) - (D_{t-1/t-M} - D_{t-1/t-M-1})]}_{\mathbf{u}_{t/t-M}} \\ &= \sum_{i=0}^{M} u_{t/t-i} \end{aligned} \tag{7}$$

(Note that, if M is the maximum horizon, $D_{t/t-M-1} = D_{t-1/t-M-1}$).[8]

In expression (7), the first component, $u_{t/t}$, is unanticipated, the rest is known at date t:

$$\begin{aligned} d_{t/t} &= \underbrace{u_{t/t}}_{\textbf{contemp. revision to change in } \mathbf{D}_{t/t}} + \underbrace{\sum_{i=0}^{M-1} u_{t/t-i-1}}_{\textbf{sum of all past revisions to change in } \mathbf{D}_{t/t}} \\ &= u_{t/t} + d_{t/t-1} \end{aligned} \tag{8}$$

In fact, the second term on the rhs of (8), $d_{t/t-1}$, is the sum of all revisions to the discretionary change in taxation known at date $t-1$ and implemented at date t. Thus, the RR observations

[7] Note that when $i = 0$, $u_{t/t} = D_{t/t} - D_{t/t-1}$ because $D_{t-1/t-1} = D_{t-1/t}$.

[8] More generally, the discretionary change in date $t+i$'s taxation, expected at date $t-s$, is the the sum of all revisions to the changes in date $t+i$'s discretionary taxation, decided up to date $t-s$

$$\begin{aligned} d_{t+i/t-s} &\equiv D_{t+i/t-s} - D_{t+i-1/t-s} \\ &= \sum_{j=0}^{M-s-i} u_{t+i/t-j-s} \qquad i+s \leq M \end{aligned}$$

Obviously when $s = i = 0$ we have expression (7), given that $D_{t-1/t} = D_{t-1/t-1}$.

are not strictly speaking tax "shocks" in the usual sense, because they contain an anticipated component.[9]

4 Alternative models of the effects of discretionary taxation

The key methodological point of this paper is that, when estimating the effects of changes in revenues, one should allow the discretionary component $d_{t/t}$ and the endogenous component $\eta y_t + \mu_t$ to have different effects on output. One can think of $d_{t/t}$ as capturing mostly changes to tax rates, rules about deductions, tax credits, depreciation, etc.; the endogenous component, $\eta y_t + \mu_t$, captures instead the automatic effects of deviations of output from its reference level, which occur without any intervention on the part of the policymaker[10], plus an error term.

There are at least two reasons why a change to the discretionary component should have a different effect on output than a change to the endogenous component. First, it is more distortionary, since it consists of changes in tax rates and tax rules. Second, it is more persistent; in fact, if deviations of output from its reference level sum to 0 over the cycle (such as when the reference level is trend output or potential output), and if agents are not liquidity constrained, then the non-discretionary component of taxation should have no effect on the agents' behavior.

An important caveat is that a change in tax rates could also affect the elasticity η. and therefore it could contaminate the estimation of the discretionary and the endogenous

[9] In addition, they could easily be serially correlated. In fact, $d_{t-1/t-1}$ contains terms like $u_{t-1/t-1}$ which is likely to be correlated with the term $u_{t/t-1}$ appearing in the definition of $d_{t/t}$: the same law approved in $t-1$ can decide changes in discretionary taxation for t and $t-1$. Empirically, as we will see $d_{t/t}$ is not serially correlated, because tax laws are few and far between.

[10] Of course, the distinction is not so clear-cut as it might appear: one could object that the policymaker could always have prevented, by a suitable change in rules, the automatic effect of the deviation of output from its reference level.

components. Observe, however, that if taxes are proportional a change in tax rates does not affect the elasticity η. Hence, this effect is likely to be second order. One could also argue that, as output changes over the cycle, so does the elasticity of tax revenues, because individuals are moved into different tax brackets. Hence a purely cyclical source of changes in revenues could impact on the behavior of individuals. This effect too is likely to be second order. In the end, any measure of the elasticity of tax revenues, whether estimated as here or constructed from the tax code as international organizations do, is bound to be affected by measurement error.

4.1 A small model with differentiated effects of discretionary taxation

To put it all together, I consider a minimalist model of output that however has all the ingredients one needs. As in RR (2010), initially I will assume that there is no anticipation effect from expectations of changes in future taxation.

Thus, I assume that the "true" model includes an equation for the log change in tax revenues

$$s_t = d_{t/t} + \eta y_t + \mu_t \tag{9}$$

and an equation for the log change in output[11]

$$y_t = \alpha y_{t-1} + \gamma_1 d_{t/t} + \gamma_1'(s_t - d_{t/t}) + \gamma_2 d_{t-1/t-1} + \gamma_2'(s_{t-1} - d_{t-1/t-1}) + \varepsilon_t \tag{10}$$

where ε_t is i.i.d. with 0 mean and variance σ_ε^2.

If $\gamma_1 = \gamma_1'$ and $\gamma_2 = \gamma_2'$, equation (10) reduces to

$$y_t = \alpha y_{t-1} + \gamma_1 s_t + \gamma_2 s_{t-1} + \varepsilon_t \tag{11}$$

[11] Obviously this is a simplified model; in the empirical application I will allow for more endogenous variables, and for more lags of the endogenous variables and of $d_{t/t}$ in equation (10).

and output depends on total revenues; this is the assumption e.g. of BP (2002). If at the other extreme $\gamma_1^{'} = \gamma_2^{'} = 0$, equation (10) becomes

$$y_t = \alpha y_{t-1} + \gamma_1 d_{t/t} + \gamma_2 d_{t-1/t-1} + \varepsilon_t \tag{12}$$

and output depends only on discretionary taxation; this is the assumption of RR (2010). Orthogonality of $d_{t/t}$ to ε_t is the first identifying assumption of RR. A second assumption is that $d_{t/t}$ is unpredictable using lagged variables in the information set of the econometrician.[12] When $\gamma_1^{'} = \gamma_2^{'} = 0$, these assumptions are sufficient to identify the response of y_t to $d_{t/t}$ from an OLS estimate of (12).

However, in the more general case they are no longer sufficient. When $\gamma_1 \neq \gamma_1^{'}$, $\gamma_2 \neq \gamma_2^{'}$ and $\gamma_1^{'} \neq 0$, $\gamma_2^{'} \neq 0$, using (9) equation (10) becomes

$$y_t = \frac{\alpha + \gamma_2^{'}\eta}{1-\gamma_1^{'}\eta} y_{t-1} + \frac{\gamma_1}{1-\gamma_1^{'}\eta} d_{t/t} + \frac{\gamma_2}{1-\gamma_1^{'}\eta} d_{t-1/t-1} + \frac{\gamma_1^{'}}{1-\gamma_1^{'}\eta} \mu_t + \frac{\gamma_2^{'}}{1-\gamma_1^{'}\eta} \mu_{t-1} + \frac{1}{1-\gamma_1^{'}\eta} \varepsilon_t \tag{13}$$

I call this the "**MR specification**", where "MR" comes from Mertens and Ravn (2009).[13]

Under the identifying assumptions of RR (2010), if one estimates equation (13) by regressing y_t on y_{t-1}, $\mathrm{d}_{t/t}$ and $d_{t/t-1}$, the resulting estimates will be biased and inconsistent, because μ_{t-1} is correlated with y_{t-1}. One can obtain consistent estimates by taking μ_t and its lag out of the error term. An estimated series for μ_t can be obtained by instrumental variable estimation of (9): $d_{t-1/t-1}$ and y_{t-1} are natural instruments, as they are excluded variables from (9) that are correlated with y_t but uncorrelated with μ_t. The estimates of the series μ_t and μ_{t-1} can then be used as regressors in (13). A sufficient condition for identification, in addition to the RR conditions, is therefore that ε_t is uncorrelated with current

[12] RR (2010) estimate two versions of (12). The benchmark specification includes lags 0 to 12 of $d_{t/t}$ and no lagged endogenous variable. The second specification includes also lags 1 to 4 of y_t. They interpret both specifications as truncated versions of the MA representation; see below for a discussion.

[13] MR (2009) estimate a version of this specification that also includes expected changes to future discretionary taxation (see below), in addition to other endogenous variables. They do not allow for different effects of discretionary taxation and the remaining component, hence they estimate the equation by OLS.

and past values of μ_t.

To fix ideas, I will call an OLS estimate of (13), i.e. a regression of y_t on y_{t-1}, $d_{t/t}$ and $d_{t-1/t-1}$ "OLS estimate of the MR specification"; if the regressors also include the estimates of μ_t and μ_{t-1}, I will call this, with some impropriety, "IV estimate of the MR specification".

It should also be clear that in general one would want to estimate a multidimensional system of equations, instead of just the output equation. Suppose that tax revenues respond automatically not only to output, but also to inflation:

$$s_t = d_{t/t} + \eta y_t + \delta \Delta \pi_t + \mu_t \tag{14}$$

If there is no equation for inflation, the term $\delta \Delta \pi_t$ and its first lag would end up in the error term of the output equation. Thus, I will estimate a version of the model that includes also the log change of government spending per capita, the change in the inflation rate, and the change in the interest rate as endogenous variables. These variables also appear in the revenue equation (14), and their lags 1 to 4 are used as instruments.

4.2 Relation with Favero and Giavazzi (2010)

FG (2010) argue that one should estimate a VAR in y_t and s_t (plus the other endogenous variables, omitted here and in what follows for expository purposes) with $d_{t/t}$ as an exogenous term:

$$y_t = \theta_{11} y_{t-1} + \theta_{12} s_{t-1} + \theta_{13} d_{t/t} + \varphi_t^y \tag{15}$$

$$s_t = \theta_{21} y_{t-1} + \theta_{22} s_{t-1} + \theta_{23} d_{t/t} + \varphi_t^s \tag{16}$$

and then trace the response to a shock to $d_{t/t}$. In terms of the coefficients and error terms of the true model (9) and (10), equations (15) and (16) are equivalent to:

$$y_t = \frac{\alpha + \gamma_2'\eta - \gamma_2\eta}{1-\gamma_1'\eta} y_{t-1} + \frac{\gamma_1}{1-\gamma_1'\eta} d_{t/t} + \frac{\gamma_2}{1-\gamma_1'\eta} s_{t-1} + \frac{\gamma_1'}{1-\gamma_1'\eta}\mu_t + \frac{\gamma_2'-\gamma_2}{1-\gamma_1'\eta}\mu_{t-1} + \frac{1}{1-\gamma_1'\eta}\varepsilon_t \tag{17}$$

$$s_t = \eta\frac{\alpha + \gamma_2'\eta - \gamma_2\eta}{1-\gamma_1'\eta} y_{t-1} + \frac{1+\eta(\gamma_1-\gamma_1')}{1-\gamma_1'\eta} d_{t/t} + \frac{\eta\gamma_2}{1-\gamma_1'\eta} s_{t-1} + \frac{1}{1-\gamma_1'\eta}\mu_t + \frac{\eta(\gamma_2'-\gamma_2)}{1-\gamma_1'\eta}\mu_{t-1} + \frac{\eta}{1-\gamma_1'\eta}\varepsilon_t \tag{18}$$

I will call (17) and (18) the "**FG specification**".

If equations (17) and (18) are estimated by an OLS regression of y_t and s_t on y_{t-1}, s_{t-1} and $d_{t/t}$, as in FG (2010),[14] once again the resulting estimates are inconsistent, because μ_{t-1} is correlated with both y_{t-1} and s_{t-1}. The first source of the correlation is the same as in the MR specification above. There is now also a second source, instead of using $d_{t-1/t-1}$ as in the true model, this specification uses s_{t-1}, which is obviously positively correlated with μ_{t-1}. As I show below, OLS FG impulse responses deliver consistently weaker negative output effects than OLS MR impulse responses.

Once again, consistent estimates can be obtained by taking μ_t and μ_{t-1} out of the error term, leading to IV estimates of the FG specification. In fact, it is easy to show that the IV FG responses are *identically* equal to the IV MR responses if one uses the same instruments for (9).

Note that when $\gamma_1' = \gamma_2' = 0$, from (13) OLS MR responses are consistent, while OLS FG responses continue to be inconsistent. When instead $\gamma_1 = \gamma_1'$ and $\gamma_2 = \gamma_2'$, it is OLS FG responses that are consistent: in (17) and (18) the term in μ_{t-1} disappears from the error term. Also, in this case the forecast error variance in the output equation is lower in the FG approach, for obvious reasons: given $\gamma_1 = \gamma_1'$ and $\gamma_2 = \gamma_2'$, there is no need to decompose s_{t-1} into the discretionary and the remaining component.

[14] Obviously FG (2010) allow for more endogenous variables and longer lags: see below.

4.3 Predetermined $d_{t/t}$

Now assume that $d_{t/t}$ is not unpredictable. There are at least two reasons why $d_{t/t}$ can be predetermined. First, as pointed out by FG (2010), by selecting those changes that were motivated by concerns about the level of debt, RR (2010) have automatically selected changes that are correlated with variables in the intertemporal government budget constraint. However, FG also show that in practice this does not seem to be an issue in this sample, because controlling for debt does not change the impulse responses appreciably. Second, and quite simply, the selection criterion of RR might prove less than air-tight. Policymakers might declare that they are solely concerned about the deficit or debt, while in reality they are responding to a number of cyclical factors.

If $d_{t/t}$ is predetermined, one can fit a reaction function to it by estimating a VAR that includes $d_{t/t}$ as an endogenous variable. The true model would then consists of (9), (10) and

$$d_{t/t} = k_1 y_{t-1} + k_2 d_{t-1/t-1} + k_2'(s_{t-1} - d_{t-1/t-1}) + \zeta_t \tag{19}$$

and the reduced form VAR is

$$d_{t/t} = \delta_{11} y_{t-1} + \delta_{12} d_{t-1/t-1} + \nu_t^s \tag{20}$$

$$y_t = \delta_{21} y_{t-1} + \delta_{22} d_{t-1/t-1} + \nu_t^y \tag{21}$$

Since by assumption $d_{t/t}$ does not respond to contemporaneous innovations in y_t, impulse responses are obtained from a Choleski decomposition in which $d_{t/t}$ is placed first. I call this the "**VAR specification**".

As Swanson (2006) points out, however, it is not clear how to interpret a shock to $d_{t/t}$ in this specification. This is the residual of a regression of the private sector's estimate of an innovation in discretionary taxation on lags of itself and other endogenous variables. It is even more difficult to interpret the impulse response to such a shock. Finally, it is inherently difficult to fit a reaction function to what one could interpret as a series of specific policy episodes; indeed, one could argue that the whole purpose of the RR exercise is to capture the policy shocks without having to fit a reaction function, as in BP (2002).

Note that in this specification too estimates of the VAR coefficients in general will be inconsistent, unless one takes the moving average of μ_t out of the error terms. Thus, once again I will distinguish between OLS and IV estimates of the VAR specification.

4.4 Relation with Romer and Romer

From equation (13), by recursive substitution one can derive the truncated MA representation

$$\begin{aligned} y_t &= \lambda_2 d_{t/t} + (\lambda_3 + \lambda_1\lambda_2) d_{t-1/t-1} + \lambda_1\lambda_3 d_{t-2/t-2} + \lambda_1^2 y_{t-2} + \\ &\quad \lambda_4\mu_t + (\lambda_5 + \lambda_1\lambda_4)\mu_{t-1} + \lambda_1\lambda_5\mu_{t-2} + \lambda_6\varepsilon_t + \lambda_1\lambda_6\varepsilon_{t-1} \end{aligned} \tag{22}$$

where

$$\begin{aligned} \lambda_1 &\equiv \frac{\alpha + \gamma_2'\eta}{1 - \gamma_1'\eta}; \qquad \lambda_2 \equiv \frac{\gamma_1}{1 - \gamma_1'\eta} \qquad \lambda_3 \equiv \frac{\gamma_2}{1 - \gamma_1'\eta}; \qquad \mu_t \equiv \frac{1}{1 - \gamma_1'\eta}\varepsilon_t \\ \lambda_4 &\equiv \frac{\gamma_1'}{1 - \gamma_1'\eta}; \qquad \lambda_5 \equiv \frac{\gamma_2'}{1 - \gamma_1'\eta} \qquad \lambda_6 \equiv \frac{1}{1 - \gamma_1'\eta}; \end{aligned} \tag{23}$$

and where the second line of (22) represents the error term. Like FG (2010), I call (22) the "**augmented RR specification**". FG (2010) estimate by OLS the first line of (22); RR (2010) do the same, but omit the lagged endogenous variable y_{t-2}; I call (22) without the term y_{t-2} the "**RR specification**".

As FG (2010) note, omitting y_{t-2} can lead to inconsistent estimates if y_{t-2} is correlated with other terms in the truncated MA representation. Since $d_{t-2/t-2}$ enters the expression for y_{t-2}, we can see from (22) that this must be the case;[15]

However, the inclusion of y_{t-2} does not solve all problems: like in the MR and FG specifications, the presence of μ_t and its lags in the error terms causes an additional bias, because of the correlation between y_{t-2} and μ_{t-2}. The solution here too is to take the terms μ_{t-i} out of the error term, leading as usual to distinguishing between an OLS and an IV estimate of the augmented RR specification. In contrast, an IV estimate of the RR specification is still inconsistent, as the bias emanating from the exclusion of y_{t-2} persists.

Note that the inclusion of y_{t-2} eliminates the inconsistency under FG's assumptions. In fact, they implicitly assume $\gamma_i = \gamma_i^{'}$, hence they use s_{t-2} instead of $d_{t-2/t-2}$ as the lagged tax variable in (22). Given $\gamma_i = \gamma_i^{'}$, it follows that $\lambda_2 = \lambda_4$ and $\lambda_3 = \lambda_5$ and (22) can be rewritten as

$$\begin{aligned} y_t \;=\; & \lambda_2 d_{t/t} + (\lambda_3 + \lambda_1\lambda_2) d_{t-1/t-1} + \lambda_1\lambda_3 s_{t-2} + (\lambda_1^2 - \lambda_1\lambda_3\eta) y_{t-2} + \\ & \lambda_4\mu_t + (\lambda_3 + \lambda_1\lambda_2)\mu_{t-1} + \lambda_6\varepsilon_t + \lambda_1\lambda_6\varepsilon_{t-1} \end{aligned} \tag{24}$$

which is the truncated MA representation that FG estimate by OLS. Now the terms in $d_{t-2/t-2}$ and μ_{t-2} have disappeared into s_{t-2}, hence there is no correlation between the error term and the lagged endogenous variables y_{t-2} and s_{t-2}.[16]

[15] The presence of this correlation is a small sample result, but one that can potentially be important in practice.

[16] FG (2010) notice a large difference in the OLS impulse responses of (24), depending on whether the lagged endogenous variables y_{t-2} and s_{t-2} are omitted or included. They attribute this difference to $d_{t/t}$ being predetermined, so that there is a correlation between $d_{t/t}$ and $d_{t-1/t-1}$ on one hand and s_{t-2} and y_{t-2} on the other. However, this is not necessarily so: in small samples, the inclusion of s_{t-2} and y_{t-2} could have effects even if they were uncorrelated with $d_{t/t}$ and $d_{t-1/t-1}$.

An indication that this is indeed the case is the following. FG (2010) estimate a truncated MA representation using 12 lags of $d_{t/t}$, and lags 13 to 16 of s_t and y_t, and a second MA representation omitting lags 13 to 16 of the endogenous variables. They note that the two impulse responses start diverging precisely after about 12 quarters. This is when the effects of the lagged endogenous variables would start kicking in, regardless of whether they are correlated with the shocks $d_{t/t}$ and its lags.

4.5 Relation with Blanchard and Perotti

BP (2002) estimate the reduced form system

$$y_t = \rho_{11} y_{t-1} + \rho_{12} s_{t-1} + \chi_t^y \tag{25}$$

$$s_t = \rho_{21} y_{t-1} + \rho_{22} s_{t-1} + \chi_t^s \tag{26}$$

Essentially, BP (2002) estimate the FG specification (17) and (18), except that $d_{t/t}$ ends up in the error terms. Hence, in terms of the true model's coefficients and errors, the error terms in the BP specification are:

$$\chi_t^y = \frac{\gamma_1}{1-\gamma_1'\eta} d_{t/t} + \frac{\gamma_1'}{1-\gamma_1'\eta}\mu_t + \frac{\gamma_2' - \gamma_2}{1-\gamma_1'\eta}\mu_{t-1} + \frac{1}{1-\gamma_1'\eta}\varepsilon_t \tag{27}$$

$$\chi_t^s = \frac{1+\eta(\gamma_1 - \gamma_1')}{1-\gamma_1'\eta} d_{t/t} + \frac{1}{1-\gamma_1'\eta}\mu_t + \frac{\eta(\gamma_2' - \gamma_2)}{1-\gamma_1'\eta}\mu_{t-1} + \frac{\eta}{1-\gamma_1'\eta}\varepsilon_t \tag{28}$$

BP (2002) then construct a measure of the discretionary shock by computing the "discretionary" or "cyclically adjusted" tax residual, $\chi_t^{s,CA} = \chi_t^s - \eta\chi_t^y$, which is equal to $d_{t/t} + \mu_t$. Note the symmetry: in the RR, MR and FG approaches, one starts from external estimates of $d_{t/t}$ and derives η as part of the estimation of the model. BP (2002) do not have estimates of $d_{t/t}$, but they use an external estimate of η[17] to estimate the change in discretionary taxation $\chi_t^{s,CA}$.

The impact effect on output of a unit realization of $\chi_t^{s,CA}$ is given by the coefficient h of the regression $\chi_t^y = h\chi_t^{s,CA} + \nu_t$. This gives

$$\widehat{h} = \frac{\frac{\gamma_1'}{1-\gamma_1'\eta} Var(\mu_t) + \frac{\gamma_1}{1-\gamma_1'\eta} Var(d_{t/t})}{Var(\mu_t) + Var(d_{t/t})} \tag{29}$$

[17] The OECD computes the elasticity based on the tax codes and the distribution of taxable income in the population.

If $|\gamma_1'| < |\gamma_1|$ this coefficient implies a smaller (in absolute value) impact multiplier than the correct one. To this, one should add the bias caused by the same error in variable problem that is present in the FG approach. However, the FG approach has a smaller forecast error variance: if one knows the shocks of interest, there is no reason not to use them in estimation.

5 Specifications

In the empirical part, I estimate and compare the specifications described above, with more realistic lag lengths and sets of endogenous variables.

1) The "**RR specification**":

$$y_t = A(L)d_{t/t} + \varepsilon_t \tag{30}$$

where y_t is the log difference of real GDP per capita. As in RR, the order of the lag-polynomial $A(L)$ is 13 (that is, $A(L)$ includes powers 0 to 12 of the lag operator L).

2) The "**augmented RR specification**":

$$X_t = A(L)d_{t/t} + B(L)X_{t-13} + \varepsilon_t \tag{31}$$

where $A(L)$ is of order 13 and $B(L)$ of order 4. Besides y_t, the vector X_t includes also the log change of real primary government spending per capita g_t, the first difference of the inflation rate $\Delta\pi_t$, and the first difference of the interest rate Δi_t.[18] All the specifications that follow will also be estimated in the two versions.

3) The "**MR specification**":

$$X_t = \ A(L)\ d_{t/t} + B(L)\ X_{t-1} + \varepsilon_t \tag{32}$$

[18] These are the variables used by FG, except that they also include the log change of of real government revenues.

where $A(L)$ and $B(L)$ are of order 5 and 4, respectively.

4) The "**VAR specification**":

$$X_t = \ B(L)\ X_{t-1} + \varepsilon_t \tag{33}$$

where X_t now includes also $d_{t/t}$ and $B(L)$ is of order 4.

5) The "**FG specification**":

$$X_t = \ \alpha d_{t/t} + B(L)\ X_{t-1} + \varepsilon_t \tag{34}$$

with $B(L)$ again is of order 4.

All specifications also include a constant. To maximize comparability with RR (2010), in the baseline case I estimate all these specifications in first differences. All these specifications are estimated by both OLS and IV.

In the latter case, the set of regressors includes also the moving average (lags 0 to 4) of the series μ_t obtained by IV estimation of

$$s_t = d_{t/t} + \eta y_t + \delta_1 \Delta\pi_t + \delta_2 \Delta i_t + \delta_3 g_t + \mu_t \tag{35}$$

The set of instruments in equation (35) includes lags 0 to 4 of $d_{t/t}$ and lags 1 to 4 of y, g_t, $\Delta\pi_t$ and Δi_t.[19]

I estimate all these specifications with three sets of data: the original RR dataset, and the receipts and liabilities datasets described in section 2, using both the legislated changes and the non legislated changes. In the benchmark case, I use the version of these data that excludes the retroactive changes. In all cases I use only the exogenous changes as defined by RR (2010), that include deficit-driven and growth-driven tax changes in the terminology of

[19] In the case of the FG specification, the set of instruments includes also lags 1 to 4 of s_t and only lag 0 of $d_{t/t}$.

these authors.

6 The effects of taxes on GDP with no anticipation effects

The sample of RR's data on $d_{t/t}$ is 1947:1 - 2006:2; the sample of my data on $d_{t/t}$ is 1945:1 - 2009:4. The other constraints on the sample are the series on the log change in GDP, government spending, and revenues per capita, that start on 1948:2 and end in 2009:4,[20] while the series on the interest rate starts in 1947:1 and ends in 2007:1.[21] With four lags of the endogenous variables as instruments, the estimated series μ_t from (9) starts in 1949:2; and since at least four lags of the endogenous variables appear in each specification, the earliest starting date of an IV estimate is 1950:2.

Table 4: **Elasticities**

	RR dataset	Receipts	Liabilities
Unrestricted	1.84	1.79	1.76
	(7.79)	(7.60)	(7.37)
Restricted	1.80	1.77	1.78
	(7.44)	(7.63)	(7.57)

Estimates of elasticity η in equation (35), t-statistics in parentheses. "RR dataset": data from Romer and Romer (2010); "Receipts" and "Liabilities": datasets described in section 2 and Table 2, include all changes in taxation ("LU + LA + NLA"). "Restricted": the coefficient of $d_{t/t-1}$ is constrained to be 1.

[20] The NIA income account data on the levels of these variables start in 1947:1, but in the FRED dataset the data on population starts in 1948:1.

[21] This series is defined as the average cost of servicing the debt, and it is constructed by Favero and Giavazzi (2010) by dividing net interest payments at time t by the federal government debt held by the public at time $t-1$.

Table 4 displays the estimates of the elasticity of revenues to GDP from equation (35). I estimate this equation in two versions, an unrestricted one an a restricted one, in which the coefficient of $d_{t/t}$ is forced to be 1. The difference between the two versions, and among the different datasets, is minimal: the estimate of η ranges between 1.76 and 1.84. As a comparison, the elasticity calculated by BP (2002) based on the elasticities provided by the OECD has an average value between 1946:1 and 1997:4 of 2.06.

Tables 5 and 6 display the OLS and IV responses, respectively, of the different models at 6 quarters and 3 years, two typical horizons of interest to policymakers. Columns 1 and 2 display impulse responses using RR data; columns 3 and 4, using my data on receipts; columns 5 and 6, using my data on liabilities. In the latter two cases, the data include all changes, i.e. LU, LA, and NLA in terms of Table 2.

Table 5: **Impulse responses, OLS estimates**

		RR dataset		Receipts		Liabilities	
		6 qrts	12 qrts	6 qrts	12 qrts	6 qrts	12 qrts
		1	2	3	4	5	6
1	RR	–1.17**	-2.74**	-1.07**	-2.02**	-.72*	-1.74**
2	augm. RR	-1.33*	-1.45*	-1.85**	-1.75**	-1.36**	-1.59**
3	MR	-1.55**	-1.80**	-1.39**	-1.40**	-1.40**	-1.46**
4	VAR	-1.60*	-1.96**	-1.41*	-1.48*	-1.42**	-1.56**
5	FG	-0.62*	-0.69*	-0.40*	-0.40*	-0.48*	-0.52*

"$*$": significant at 32 percent level; "$**$": significant at 5 percent level.

There are 66 quarters with non-zero observations on $d_{t/t}$ in the RR data; 82 in the receipts data; and 71 in the liabilities data. In all three cases, the significance level of the Ljung-Box Q test for serial correlation with 20 lags is always above .60; no partial correlation at any of lags 1, 2, 3, 4, 8 and 12 is ever significant.

The tables display significance of the impulse responses at two levels of confidence: 32 percent (equivalent to one standard error bands on each side of the impulse response), denoted with a single star "*"; and 5 percent (two standard error bands), denoted with a

Table 6: **Impulse responses, IV estimates**

		RR dataset		Receipts		Liabilities	
		6 qrts	12 qrts	6 qrts	12 qrts	6 qrts	12 qrts
		1	2	3	4	5	6
1	augm. RR	-1.22*	-1.50*	-1.67**	-1.52**	-1.15**	-1.49**
2	MR	-1.83**	-2.32**	-1.26*	-1.41**	-1.37**	-1.56**
3	VAR	-1.88**	-2.46**	-1.30**	-1.51**	-1.40**	-1.68**
4	FG	-1.85**	-2.29**	-1.23**	-1.32**	-1.35**	-1.50**

"$*$": significant at 32 percent level; "$**$": significant at 5 percent level..

double star "**".[22] The change in taxes is scaled by GDP, so that the initial impulse is an increase in discretionary taxes by 1 percentage point of GDP.

Row 1, columns 1 and 2 of Table 5 display the responses in the original RR specification with the original RR data. The response at 3 years is extremely large, a decline of almost 3 percent; it falls by 1 percentage point in absolute value as one moves rightward, from the RR data to the receipts data (columns 3 and 4) and then to the liabilities data (columns 5 and 6), although it remains economically and statistically significant.

The effect at three years is consistently weaker in all other specifications. With my data, either on receipts or liabilities, the effect is about -1.5 in the augmented RR, MR and VAR specifications (rows 2, 3 and 4), and significant at the 5 percent level. In contrast, the FG response (row 5) is very small, at about -.5 percentage points of GDP, and significant only at the 32 percent level.

Thus, as FG (2010) remark, a specification that takes into account the correct truncation of the MA representation, like theirs, would seem to lead to a much smaller tax multiplier than estimated by RR (2010).

However, if $\gamma_i \neq \gamma_i'$ an OLS estimation of the FG specification suffers from attenuation bias. In fact, consider now Table 6, which displays the IV estimates (because the IV estimate of the RR specification does not make sense, it is omitted in this table). The augmented RR,

[22] Standard errors are computed on the basis of 1000 bootstrap replications.

MR and VAR responses are very close (and, with my receipts or liabilities data, virtually identical) to the OLS estimates. As we have seen, a small difference between the OLS and IV responses of these specifications is consistent with γ_i' being small in absolute value. But now the FG response increases substantially, and it is almost identical to the MR response.[23] A large difference between the OLS and IV responses of the FG specification suggests that $\gamma_i \neq \gamma_i'$, because when $\gamma_i = \gamma_i'$ the OLS estimate of the FG response is consistent.

Thus, in all four IV specifications, with my data the range of the IV responses at three years is again surprisingly tight, between -1.30 and -1.7, and substantially larger than the OLS response estimated by FG (2010).

7 A test of the null $\gamma_i = \gamma_i'$

We have seen that, if $\gamma_i = \gamma_i'$, even OLS estimates of the FG specification are consistent, while OLS estimates of the other specifications remain inconsistent. In contrast, if $\gamma_i' = 0$, OLS estimates of the MR, VAR, and augmented RR specifications are consistent, while OLS estimate of the FG specification are inconsistent. Tables 5 and 6 suggest that a value of $\gamma_i' = 0$ is approximately correct, as moving from OLS to IV estimates makes little difference for the MR, VAR, and augmented RR specifications but a large difference for the FG specification.

Two formal tests of the null $\gamma_i = \gamma_i'$ are available. First, in the MR specification one can simply compare the coefficients of $d_{t-i/t-i}$ and μ_{t-i}, and similarly for other specifications. Performing this test has the usual problem that these coefficients are estimated imprecisely, individually.

Second, from (13) or (22), one implication of the joint hypothesis that $\gamma_i = \gamma_i'$ pairwise

[23] As noted above, if one used the same instruments in equation (9), the MR and FG responses would be identically equal. Because I use as instruments all the exogenous and lagged endogenous variables of the model, in the MR specification I use lags 0 to 4 of $d_{t/t}$ and lags 1 to 4 of y_t, g_t, $\Delta\pi_t$, and Δi_t; in the FG specification I use only lag 0 of $d_{t/t}$ and I also use lags 1 to 4 of s_t.

is that impulse responses to $d_{t/t}$ and to μ_t are the same. Figure 1 displays such responses from the IV estimate of the MR specification with liabilities data, with one standard error bands (left panel) and two standard error bands (right panel). The solid lines display the response to μ_t, the broken line the response to $d_{t/t}$. The former is essentially 0, while the latter is negative and large, reaching a trough of -1.5 after about 2 years.[24] At both levels of significance, after a few quarters the standard error bands of the two responses are entirely apart. Thus, the evidence suggests that indeed the effects of the discretionary component of taxation are different from the effects of at least one part of the endogenous component.

8 Anticipated vs. surprise changes to current taxation

From (8), $d_{t/t}$ can be written as the sum of surprise changes $u_{t/t}$ and anticipated changes $d_{t/t-1}$. The specifications displayed in Tables 5 and 6 assume that surprise changes in taxation have the same effects as anticipated changes. For instance, in a world of hand-to-mouth consumers as in Galí et al. (2007), $u_{t/t}$ and $d_{t/t-1}$ should have the same effects: future changes are irrelevant to agents' behavior, they have an impact only when they occur.

One can test this hypothesis by IV estimation of the following version of the MR specification[25]

$$X_t = B(L)\, X_{t-1} + C(L)\, u_{t/t} + F(L)\, d_{t/t-1} + \varepsilon_t \tag{36}$$

Figure 2 displays the two impulse responses, from IV estimates of (36) with liabilities data (the responses at 6 and 12 quarters are also reported in rows 1 and 2, columns 1 and 2 of Table 9). The solid lines display the response to $d_{t/t-1}$ with its standard error bands, the broken line the response and standard error bands to $u_{t/t}$. The response to $d_{t/t-1}$ is slightly stronger and more significant than the response to $u_{t/t}$, but the difference is not large.

[24] This is the same response displayed in row 3, columns 5 and 6 of Table 6.

[25] MR (2009) estimate by OLS the same specification, and they also include the expectation of future changes to discretionary taxation (see equation 39 below).

9 Anticipated vs. surprise changes to future taxation

9.1 Changes to future taxation

In their regressions, RR (2010) use the contemporaneous and lagged value of $d_{t/t}$. But at each date t we have more information than this. Consider the following decomposition (recall that M is the maximum forecast horizon of a tax law):

$$D_{t+M/t} - D_{t-1/t-1} = \underbrace{(D_{t+M/t} - D_{t+M-1/t})}_{d_{t+M/t}} + \underbrace{(D_{t+M-1/t} - D_{t+M-2/t})}_{d_{t+M-1/t}} + ... \tag{37}$$

$$..... + \underbrace{(D_{t+1/t} - D_{t/t})}_{d_{t+1/t}} + \underbrace{(D_{t/t} - D_{t-1/t-1})}_{d_{t/t}} \tag{38}$$

MR (2009) use this breakdown to estimate an expanded version of equation (36)

$$X_t = B(L)X_{t-1} + C(L)u_{t/t} + F(L)d_{t/t-1} + \sum_{i=1}^{K} G_i d_{t+i/t} + \varepsilon_t \tag{39}$$

To better understand the rationale behind this equation, Table 7 lists the values of $u_{t+i/t-j}$ included in each of the variables that appear in (39) and in their lags; it also lists the coefficients associated with each variable. For illustrative purposes, the table assumes $K = 2$, $M = 3$, while $C(L)$ and $F(L)$ are of order 3. The surprise change to future discretionary taxation $u_{t+2/t}$ is part of $d_{t+2/t}$, and so is the anticipated change to future discretionary taxation $u_{t+2/t-1}$; similarly, $u_{t+1/t}$ is part of $d_{t+1/t}$, and so are $u_{t+1/t-1}$ and $u_{t+1/t-2}$. The effects over time of a unit realization of $u_{t+2/t}$ are then traced by the coefficients G_1, G_0, F_0, F_1 and F_2. The effects of $u_{t/t}$ are instead captured by C_0, C_1, and C_2.

In practice, like MR (2009) I assume $K = 6$ and set both $C(L)$ and $F(L)$ of order 5. Figure 3 and columns 3 and 4 of Table 9 display IV responses, with liabilities data, from equation (39) to $u_{t/t}$, $d_{t/t-1}$, and to $d_{t+1/t}$ up to $d_{t+6/t}$. The responses to $u_{t/t}$ and $d_{t/t-1}$ are virtually the same as those from equation (36), in columns 1 and 2 and in Figure 2; like in

Table 7: **Composition of shocks to future taxation, I**

	$u_{t/t}$	$d_{t/t-1}$	$d_{t+1/t}$	$d_{t+2/t}$
lag 0	$u_{t/t}$	$\underbrace{u_{t/t-1}+u_{t/t-2}+u_{t/t-3}}$	$\underbrace{u_{t+1/t}+u_{t+1/t-1}+u_{t+1/t-2}}$	$\underbrace{u_{t+2/t}+u_{t+2/t-1}}$
coeff. of lag 0	C_0	F_0	G_0	G_1
lag 1	$u_{t-1/t-1}$	$\underbrace{u_{t-1/t-2}+u_{t-1/t-3}+u_{t-1/t-4}}$		
coeff. of lag 1	C_1	F_1		
lag 2	$u_{t-2/t-2}$	$\underbrace{u_{t-2/t-3}+u_{t-3/t-4}+u_{t-4/t-5}}$		
coeff. of lag 2	C_2	F_2		

Coefficients of the lag polynomials $C(L)$, $F(L)$ and $G(L)$ in equation (39) associated with each variable and the lag specified in column 1.

MR (2009), the responses to $d_{t+i/t}$ rise initially above 0, before declining to about -2.5, hence below the long run response to $d_{t/t}$ estimated in Tables 5 and 6.

Hence, one interpretation of these results, as advocated for instance by MR (2009), is that there is an initial positive response of output to a *positive* revision in expected future taxes, followed by a large decline in output.

9.2 Separating surprise and anticipated changes to future taxation

One problem with this interpretation is that the variables $d_{t+1/t}$ to $d_{t+6/t}$ include surprise and anticipated changes to future discretionary taxation. Just as $d_{t/t}$ can be decomposed into $u_{t/t}$ and $d_{t/t-1,}$ the same reasoning should be applied to changes to future taxation. In fact

$$\begin{aligned} d_{t+i/t} &\equiv D_{t+i/t} - D_{t+i-1/t} && (40) \\ &= \underbrace{(D_{t+i/t} - D_{t+i/t-1})}_{\textbf{surprise change in D}_{t+i}} - \underbrace{(D_{t+i-1/t} - D_{t+i-1/t-1})}_{\textbf{surprise change in D}_{t+i-1}} + \underbrace{(D_{t+i/t-1} - D_{t+i-1/t-1})}_{\textbf{anticipated change in D}_{t+i}} && (41) \\ &= u_{t+i/t} + d_{t+i/t-1} \end{aligned}$$

The algebraic sum of the first and second term in (41) is $u_{t+i/t}$, the innovation in the expected change in D_{t+i}, or the surprise change in the slope of future taxation. The third term is

$d_{t+i/t-1}$, the anticipated change in D_{t+i}, or the anticipated change in the slope of future taxation.

Thus, I estimate the IV version of:

$$X_t = B(L)X_{t-1} + C(L)u_{t/t} + F(L)d_{t/t-1} + \sum_{i=1}^{K} H_i u_{t+i/t} + \sum_{i=1}^{K} L_i d_{t+i/t-1} + e_t \tag{42}$$

which derives from (39) after breaking down $d_{t+i/t}$ into $u_{t+i/t}$ and $d_{t+i/t-1}$. Like before, it is useful to summarize the values of $u_{t+i/t-j}$ included in each variable that appears in (42), again assuming $K = 2$ for illustrative purposes. Table 8 makes the important point that now each surprise change to future discretionary taxation appears by itself as a regressor, so that its coefficient is not contaminated by an anticipated component. Now a unit realization to $u_{t+2/t}$ is captured by the coefficient H_2, then its effects over time are traced by the coefficients L_1, F_0, F_1 and F_2.

Table 8: **Composition of shocks to future taxation, II**

	$u_{t/t}$	$d_{t/t-1}$	$u_{t+1/t}$	$u_{t+2/t}$	$d_{t+1/t-1}$	$d_{t+2/t-1}$
lag 0	$u_{t/t}$	$\underbrace{u_{t/t-1} + u_{t/t-2} + u_{t/t-3}}$	$u_{t+1/t}$	$u_{t+2/t}$	$\underbrace{u_{t+1/t-1} + u_{t+1/t-2}}$	$u_{t+2/t-1}$
coeff. of lag 0	C_0	F_0	H_1	H_2	L_1	L_2
lag 1	$u_{t-1/t-1}$	$\underbrace{u_{t-1/t-2} + u_{t-1/t-3} + u_{t-1/t-4}}$				
coeff. of lag 1	C_1	F_1				
lag 2	$u_{t-2/t-2}$	$\underbrace{u_{t-2/t-3} + u_{t-3/t-4} + u_{t-4/t-5}}$				
coeff. of lag 2	C_2	F_2				

Coefficients of the lag polynomials $C(L)$, $F(L)$ and the coefficients H_i and L_i in equation (42) associated with each variable and the lag specified in column 1.

Figure 4 displays the various responses from equation (42); Table 9, columns 5 and 6 displays the responses at 6 and 12 quarters. The responses to $u_{t/t}$ and $d_{t/t-1}$ are once again similar to those from equations (36) and (39). Regarding the responses to future changes in taxation, here too we observe the same pattern as in the contemporaneous changes: at least at 3 years, the responses to the anticipated components $d_{t+i/t-1}$ track quite closely the responses to $d_{t+i/t}$ from equation (39). The responses to the surprise changes $u_{t+i/t}$ display an erratic behavior; for instance, when $i = 5$ the response at 3 years is essentially -.9 and insignificant, while when $i = 6$ it is about -5. In addition, the standard errors are large; one reason is that, the higher i, the smaller the number of non-zero entries for $u_{t+i/t}$: for instance, there are only 5 non-zero values of $u_{t+6/t}$.

Thus, the responses to changes in future expected taxation estimated from (39) seem to be driven in large part by the anticipated component.

9.3 Changes in government spending

As several authors have pointed out, it is not obvious how to interpret responses to changes in taxation. If the present discounted value of government spending changes together with taxation, then the coefficients G_i's, H_i's and L_i's in equations (39) and (42) do not just capture the intertemporal substitution effect of tax changes. In fact, from the intertemporal government budget constraint, the shock to wealth caused by a change in the present discounted value of government spending is given by a term that includes

$$\sum_{i=0}^{\infty}(1+r)^{-i}\left[D_{t+i/t} - D_{t+i/t-1})\right] \tag{43}$$

The terms in $D_{t+i/t} - D_{t+i/t-1}$ are of the type

$$D_{t/t} - D_{t/t-1} = u_{t/t} \tag{44}$$

$$D_{t+1/t} - D_{t+1/t-1} = u_{t/t} + u_{t+1/t} \tag{45}$$

Table 9: **Responses to shocks to contemporaneous and future taxation**

		eq. (36)		eq. (39)		eq. (42)	
		(1)	(2)	(3)	(4)	(5)	(6)
		6 qrts	12 qrts	6 qrts	12 qrts	6 qrts	12 qrts
1	$u_{t/t}$	-1.36*	-1.16*	-1.49*	-1.08*	-1.66*	-0.94
2	$d_{t/t-1}$	-1.51**	-1.68**	-1.71*	-1.60*	-2.18**	-1.79**
3	$d_{t+1/t}$			-2.19**	-2.44**		
4	$d_{t+2/t}$			-2.09**	-2.75**		
5	$d_{t+3/t}$			-1.19**	-2.90**		
6	$d_{t+4/t}$			-0.24	-2.50**		
7	$d_{t+5/t}$			0.02	-2.39**		
8	$d_{t+6/t}$			0.53	-1.98**		
9	$d_{t+1/t-1}$					-2.58**	-2.53**
10	$d_{t+2/t-1}$					-2.25**	-2.80**
11	$d_{t+3/t-1}$					-1.21*	-3.04**
12	$d_{t+4/t-1}$					0.40	-2.32**
13	$d_{t+5/t-1}$					0.76	-2.42**
14	$d_{t+6/t-1}$					0.80	-2.45**
15	$u_{t+1/t}$					-2.28	-1.84
16	$u_{t+2/t}$					-2.72*	-3.39*
17	$u_{t+3/t}$					-0.63	-2.26*
18	$u_{t+4/t}$					0.20	-2.12
19	$u_{t+5/t}$					1.57	-0.90
20	$u_{t+6/t}$					-1.46	-4.80*

Responses at 6 and 12 quarters to a unit realization of the variables indicated in the first column of each panel. IV estimates. "$*$": significant at 32 percent level; "$**$": significant at 5 percent level. Liabilities. See section 2 and Table 2).

$$D_{t+i/t} - D_{t+i/t-1} = \sum_{j=0}^{i} u_{t+j/t} \qquad i \leq M \tag{46}$$

$$= \sum_{j=0}^{M} u_{t+j/t} \qquad i > M \tag{47}$$

Thus, the terms $u_{t+i/t}$ appear repeatedly in these formula; hence, in the regression they pick up both substitution effects and the effects of the shock to wealth caused by the change in government spending. The only way to try to resolve this question is precisely to control for the change in the present value of government spending on goods and services.

Table 10, columns 1 and 2, displays responses to current anticipated and surprise shocks to $d_{t/t}$ controlling for the present value of revisions to expectations of government spending on goods and services, using the Survey of Professional Forecasters.[26] Since the available sample is much shorter (the survey starts in 1981:3), I display only estimates from the baseline MR specification and from equation (36). Columns (3) and (4) display the same responses, but not controlling for the change in the present value of government spending, on the same sample (hence, these responses are the same as those in rows 1 and 2, columns 1 and 2 of Table 9, but on a shorter sample). Note that in this shorter sample the response at three years to both $d_{t/t}$ and to $d_{t/t-1}$ is larger than before. But this is entirely caused by the different sample: controlling for the revision in the present value of government spending makes a minuscule difference to the results.

10 Robustness

Table 11 displays the results of a few robustness checks. For brevity, the table reports only the RR responses and the IV MR responses. In the first panel, the data are in levels, with a linear and a quadratic trend. As expected, these responses display less persistence than

[26] In each quarter t, this surveys presents forecasts up to 4 quarters ahead. I include forecasts both of federal and of state and local spending.

Table 10: **Controlling for the expectations of government spending**

		PDV of G		no PDV of G	
		(1)	(2)	(3)	(4)
		6 qrts	12 qrts	6 qrts	12 qrts
1	$d_{t/t}$	-1.84**	-1.96**	-1.85**	-1.97**
2	$u_{t/t}$	-0.88*	-1.21**	-0.97*	-1.21*
3	$d_{t/t-1}$	-2.03*	-2.63**	-2.04*	-2.62*

Responses at 6 and 12 quarters to a unit realization of the variables indicated in the first column of each panel. Columns (1) and (2): the regression includes the revision to the expectation of the PDV of government spending. Columns (3) and (4): the regression does not include the revision to the expectation of the PDV of government spending. IV estimates. "$*$": significant at 32 percent level; "$**$": significant at 5 percent level. Sample: 1981:3 - 2007:1. Liabilities. See section 2 and Table 2).

those in first differences: at three years, the effect is about -1 percentage points of GDP. Note that the RR responses are significant, statistically and economically, only with the original RR data.

The next panel displays responses using data that include also the retroactive changes. In all three specifications the differences with the baseline estimates are small.[27]

Finally, the last panel displays responses over the two subsamples, 1950:1 - 1979:4 and 1980:1 - 2007:1. Perotti (2002) showed that the spending and tax multipliers seem to have decreased in the second subsamples in the US, UK, Canada and Australia. FG (2010) also shows some evidence that this is the case for the tax multiplier in their specification. However, this holds only at 6 quarters; at 3 years, the responses in the two samples are very similar, although in both the standard errors are larger than in the whole sample.

[27]Note, however, that now the RR data display significant negative serial correlation.

Table 11: **Robustness**

	RR dataset		Receipts		Liabilities	
	6 qrts	12 qrts	6 qrts	12 qrts	6 qrts	12 qrts
	1	2			5	6
	Linear and quadratic trends					
RR	-1.39*	-1.30*	-0.56	-.09	-0.13	-0.30
IV MR	-1.38**	-1.15**	-1.15**	-0.91**	-1.13**	-0.99**
	Including retroactive changes					
RR	-0.68*	-1.50*	-1.31**	-1.22*	-0.72*	-0.89*
IV MR	-1.39*	-1.63**	-1.09**	-1.28**	-1.11**	-1.37**
	Subsamples					
IV MR, 50:1-07:1	-1.83**	-2.32**	-1.26*	-1.41**	-1.37**	-1.56**
IV MR, 50:1-79:4	-3.22*	-2.70*	-2.27*	-1.71*	-2.65*	-1.44
IV MR, 80:1-07:1	-1.60**	-2.00*	-1.52**	-1.48*	-1.56**	-1.51**

"$*$": significant at 32 percent level; "$**$": significant at 5 percent level.

11 Conclusions

RR (2010)'s seminal contribution has been criticized because it implies implausibly large negative effects of exogenous changes in taxation on GDP - a decline by 3 percent in response to a one percent of GDP increase in taxation. The contribution of this paper is twofold. First, I introduce a novel dataset that expands on the RR dataset in several dimensions, including a breakdown of aggregate taxation into its major components, and a distinction between receipts and liabilities.

Second, I argue that on theoretical grounds the discretionary component of taxation should be allowed to have different effects on output than the endogenous component, namely the automatic response of tax revenues to macroeconomic variables. Existing approaches to study the effects of the RR shocks do not allow for this difference. In particular, FG (2010) correctly argue that the specification estimated by RR is not a truncated MA representation of any process, and it is likely to be biased; the impulse response from the correct MA representation delivers much smaller effects on GDP, in some cases insignificantly different from 0.

However, I show that when the discretionary and the automatic components of taxation have different effects on GDP, the FG impulse responses are biased towards 0. I derive a VAR model that accommodates the different impacts of the discretionary and endogenous components of taxation, and I then show that the impulse responses to a RR shock implied by this specification are about half-way between the large effects of RR and the much smaller effects of FG: typically, a one percentage point of GDP increase in taxes leads to a decline in output by about 1.5 percentage points after 12 quarters.

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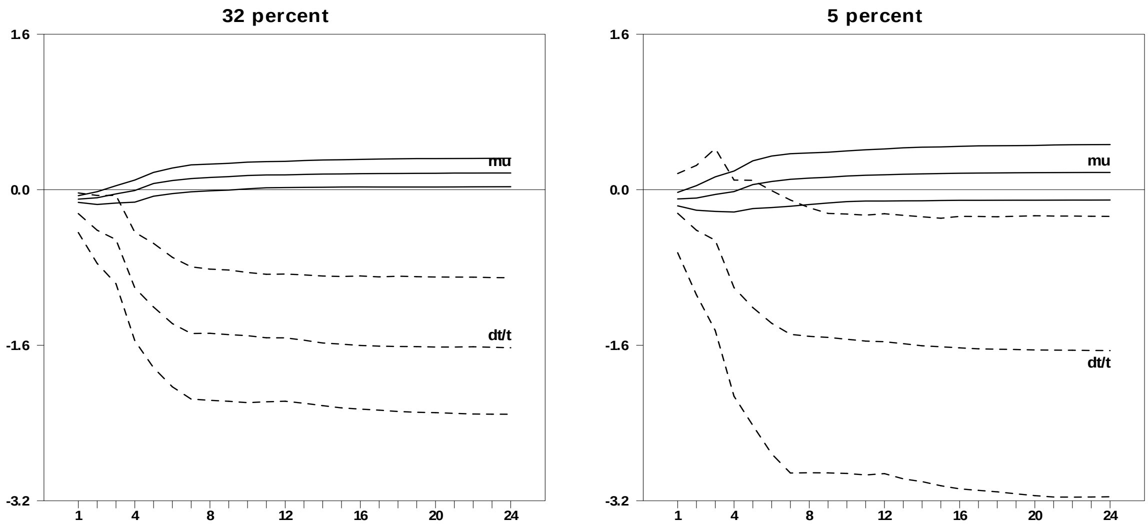

Figure 1: A test of $\gamma_i = \gamma_i'$

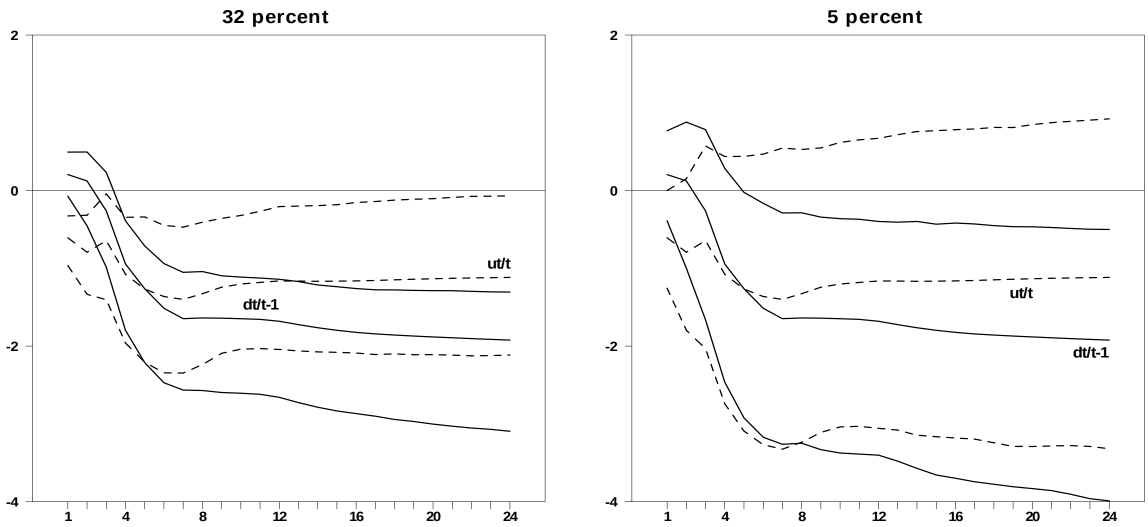

Figure 2: A test of liquidity constraints

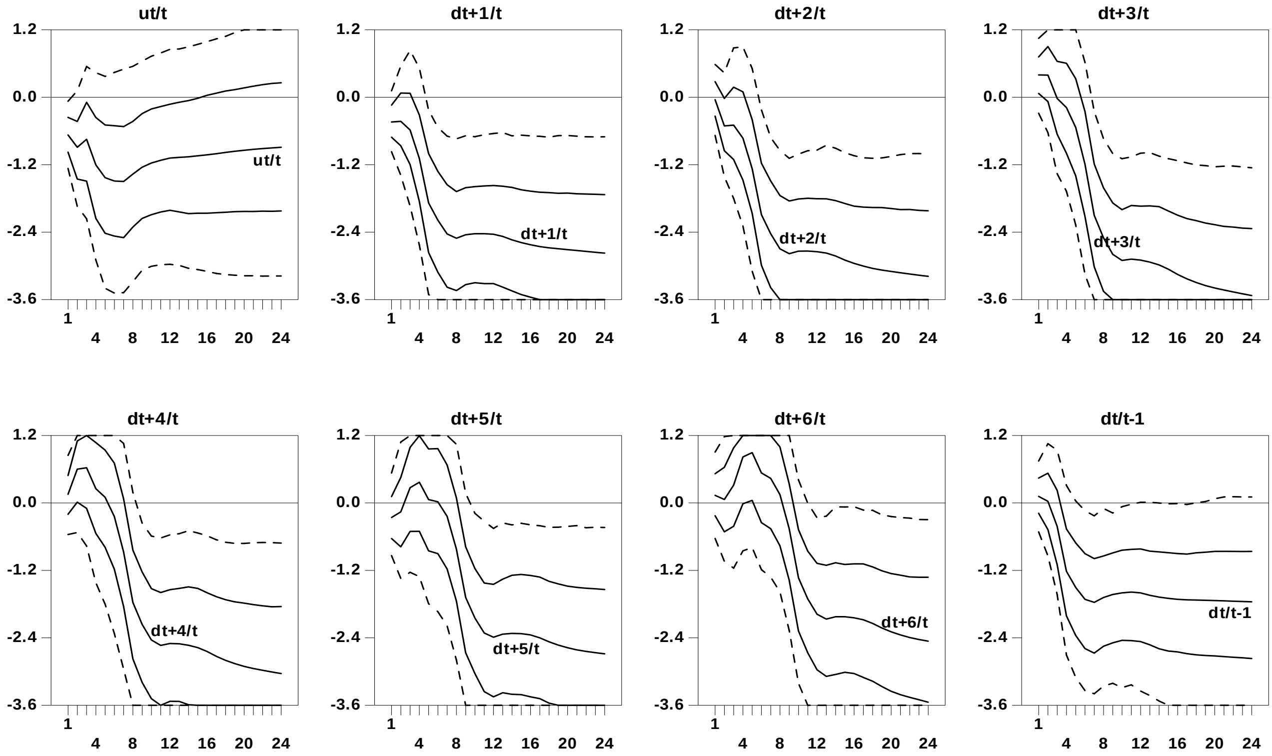

Figure 3: Shocks to future taxation

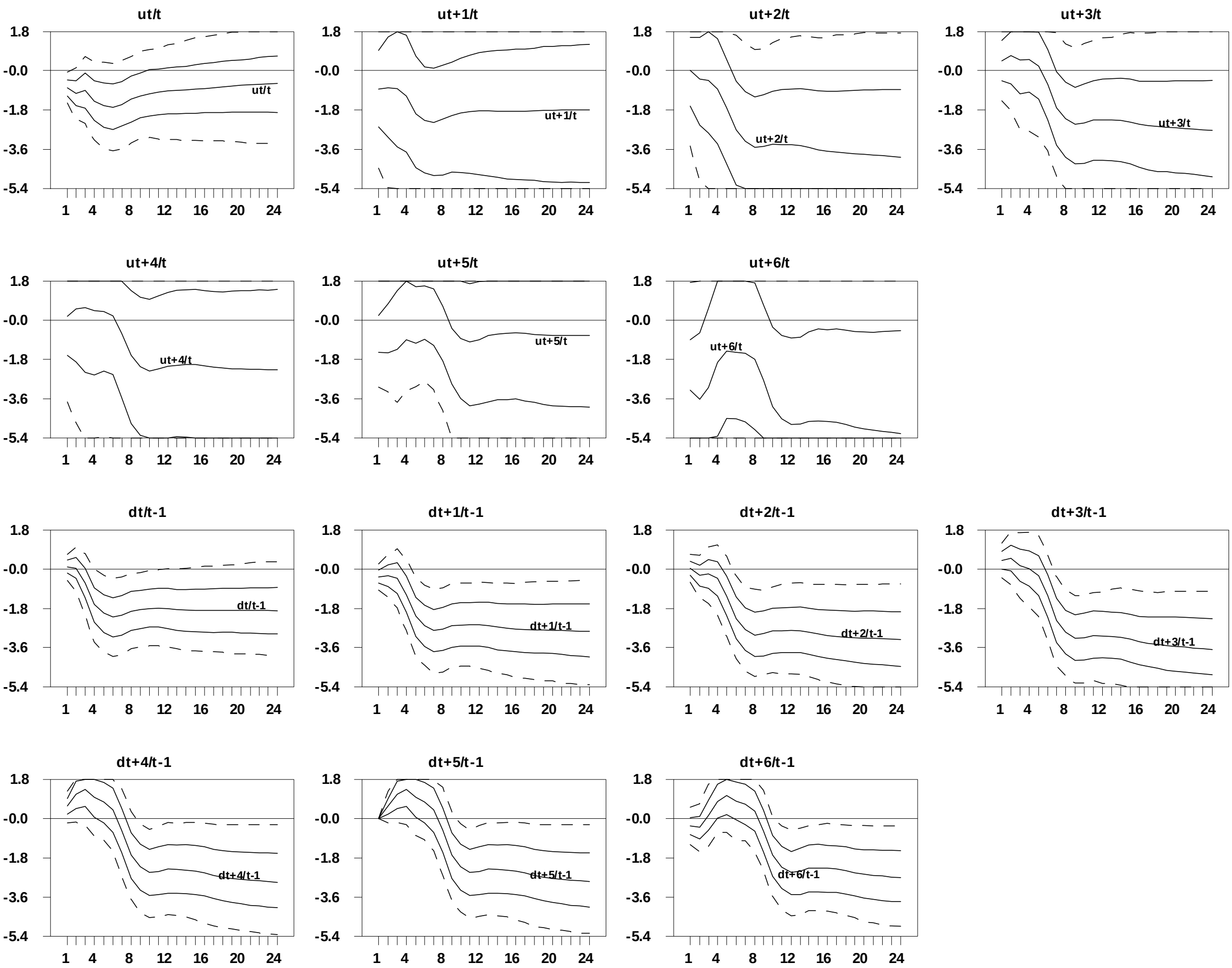

Figure 4: Anticipated and surprise changes in future taxation