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Article

The Relative Tax Gap Hypothesis: An Exploratory Analysis and Application to U.S. Financial Markets

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ASBTRACT

This study empirically investigates the "relative tax gap hypothesis," which posits that the greater the size of the relative tax gap, the greater the degree to which the U.S. Treasury must borrow from domestic and/or other credit markets and hence the higher the *ex ante* real interest rate yield on the Bellwether 30 year U.S. Treasury bond. The study uses the most current data available for computing what is referred to here as the "relative tax gap," which is the ratio of the aggregate tax gap (the loss in federal income tax revenue resulting from personal income tax evasion) to the GDP level. For each year of the study period, the nominal value of the tax gap is scaled by the nominal GDP level and expressed as a percentage. The study period runs from 1982 through 2016, reflecting data availability for all of the variables. The estimation results provide strong support for the hypothesis. In addition, in separate estimations, evidence is provided that the relative tax gap also acts to elevate the *ex ante* real interest rate yield on Moody's Baa-rated long-term corporate bonds. It logically follows, then, that to the extent that a greater relative tax gap leads to higher *ex ante* real interest rates, it may contribute to the crowding out of corporate investment in new plant equipment associated heretofore with government budget deficits *per se*.

KEYWORDS

aggregate personal income tax evasion; the relative tax gap; *ex ante* real interest rate yield on the Bellwether bond; Moody's Baa-rated long-term corporate bonds; reduced investment in new plant and equipment

J.E.L. Codes: E26; E43; H26

INTRODUCTION

In any nation having a personal income tax in place, personal income tax evasion consists largely of taxable income that is either unreported or underreported by households to the Internal Revenue Service (IRS) or to its counterpart government tax collection authority outside the U.S. Insofar as the U.S. is concerned, personal income tax evasion can also consist of either spurious or inflated tax deductions or fabricated exemptions or other misrepresentations on various IRS tax forms. Such IRS forms might include Form 1040 itself or Form 1040-EZ and/or Form 1040 Schedules A, C, C-EZ, and E, among others (Phillips, 2014). Scholarly research inquiries into the various dimensions of income tax evasion, especially personal income tax evasion but to some degree corporate tax evasion as well, fall into a number of distinct and rather broad categories.

One of the primary avenues of this tax evasion-related research is the essentially theoretical, largely mathematical models of personal income tax evasion behavior, although corporate tax evasion behavior is also addressed to a limited degree. Studies found in this string of the literature include works by Cebula (1997), Sandmo (2005), and Richardson (2006). Some of these frameworks have in fact laid the

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groundwork for subsequent empirical research in one form or another regarding the identification of factors that are determinants of (exert influence upon) income tax evasion.

Another, quite different, dimension of tax evasion studies involves endeavors that either conduct experiments on personal income tax evasion/compliance behavior or, in a few cases, assume the form of surveys and questionnaires. Included within this research grouping are a variety of works undertaken using an array of different contexts, such as the relatively recent studies by Yalami and Gumus (2013), Tarun and Jasmin (2013), Awan and Hannan (2014), Bayer and Sutter (2008), Obafemi (2014), and Ameyaw, et al. (2015). Such studies are largely empirical in nature, deriving their data from the experiments (or from the questionnaires and surveys) involved in the studies. On the one hand, certain of these studies indicate an aversion to the prospect of being audited while, on the other hand, a number of alternative studies reveal a lack of such risk-averse behavior. Still other of these scholarly papers find that some portion of taxpayers may be averse to tax evasion on moral or ethical grounds, whereas certain people are opposed to tax compliance due to secondary gains they receive from evasion. Moreover, some studies find evidence that taxpayers use tax evasion as a means of expressing dis-satisfaction with government policies and/or actions. Additionally, in several such studies, an increased incentive to evade personal income taxation by underreporting income is attributed to higher marginal income tax rates, a finding not by any means restricted to the U.S. (Chan, Troutman, and O'Bryan, 2000; Tarun and Jasmin, 2013; Obafemi, 2014; Awan and Hannan, 2014; and Ameyaw, et al., 2015).

The remaining broad categories of income tax evasion studies consist of those that largely or, in some cases exclusively, adopt what may be referred to as "official data," i.e., data secured from either the IRS and/or from some other "official," i.e., typically a central government agency or one form or another of provincial government source, and/or from a recognized and acknowledged publicly available non-governmental origin. Among the types of information thusly obtained and analyzed are data on income tax evasion *per se*, unreported income, income tax rates, IRS audit rates, IRS penalties, income detection technology, government deficits and/or debt, and indices expressly indicating dissatisfaction with government.

This line of scholarly inquiry can be broken into at least two component parts. The first of these takes the form of endeavors to quantify the magnitude or impacts of the aggregate degree of federal income tax evasion in the macro-economy (Frey, Weck, and Pommerehne, 1982; Isachsen and Strom, 1985; Bajada, 1999; Giles, 1999; Fisman and Wei, 2004; Ledbetter, 2004, 2007; Cebula, 2018, 2019; Gale and Krupkin, 2019). The second component attempts to identify factors that influence the degree/extent of aggregate federal personal income tax evasion or compliance (Kirchgaessner, 1983; Hill and Kabir, 1996; Cebula, 1997, 2004; Friedman, Johnson, Kaufmann, and Zoido-Labton, 2000; Ali, Cecil, and Knoblett, 2001; Fisman and Wei, 2004; Martinez-Vazquez and Rider (2005); Richardson, 2006; Dell'Anno, 2007; Engstrom and Holmlund, 2009; Cebula and Feige, 2012; Ariyo and Belcoe, 2012; Phillips, 2014; Ameyaw and Dzaka, 2016; Chatzimichael, Kalaitzidakis, and Tzouvelekas, 2019). Some of these studies focus upon individual tax returns, such as the relatively recent study by Phillips (2014), although most focus on more aggregative data. However, despite the substantial breadth, diversity, and depth of this tax evasion literature, to date no scholarly study has addressed the impact of the tax gap *per se* on the market for U.S. Treasury debt issues.

On a somewhat related topic, over the last half century, the unified (total) federal budget has been in a state of deficit in all but four years (see Table 1). Largely as a consequence of this circumstance, a scholarly literature has been generated that focuses upon the interest rate yield effects of these budget deficits, especially with respect to the yields on relatively longer-term Treasury debt issues[1]

[1] Short-term issues would be typified by U.S. Treasury bills, whereas longer-term issues would include Treasury notes (especially 10-year maturities), and Treasury bonds (especially, 30-year maturities).

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and longer-term corporate debt issues[2] (Hoelscher, 1986; Zahid, 1988; Ostrosky, 1990; Swamy, Kolluri, and Singamsetti, 1990; Cebula and Saltz, 1998; Gissey, 1999; Vamvoukas, 2002; Mukhtar and Zaharia, 2002; Aisen and Hauner, 2008; Kameda, 2014; Cebula, 2018). It is noteworthy that, however, none of the published interest rate literature has explored the potential impact of the tax gap *per se* on interest rate yields.

Table 1. The Total/Unified Federal Budget Deficit as Percentage of GDP, 1968-2016

Year	Deficit/GDP (%)	Year	Deficit/GDP (%)
1968	2.8	1992	4.5
1969	-0.3	1993	2.8
1970	0.3	1994	2.8
1971	2.1	1995	2.2
1972	2.1	1996	1.3
1973	1.1	1997	0.3
1974	0.4	1998	-0.8
1975	3.3	1999	-1.3
1976	4.1	2000	-2.3
1977	2.6	2001	-1.2
1978	2.6	2002	1.5
1979	1.6	2003	3.3
1980	2.6	2004	3.4
1981	2.5	2005	2.5
1982	3.9	2006	1.8
1983	5.9	2007	1.1
1984	4.7	2008	3.1
1985	5.0	2009	9.8
1986	4.9	2010	8.7
1987	3.1	2011	8.5
1988	3.0	2012	6.8
1989	2.7	2013	4.1
1990	3.7	2014	2.8
1991	4.4	2015	2.5
		2016	3.3

Source: Council of Economic Advisors (2018, Table B-18).

Accordingly, the objective of this study is to contribute to the bodies of scholarly literature on both interest rates and income tax evasion by empirically investigating the impact of aggregate federal personal income tax evasion in the form of the *relative tax gap* on the bellwether *ex ante real* interest rate yield on 30-year U.S. Treasury bonds. In order to measure the aggregate degree of federal personal income tax evasion in a useful fashion, we adopt what is referred to here as the *relative tax gap*, which is defined in this study as the "tax gap," i.e., the value of the difference between actual nominal Treasury *tax collections* and what those nominal tax collections would have been in the absence of income tax evasion, *relative* to, i.e., *scaled by*, the nominal GDP level. The relative tax gap, which is discussed in further detail in Section 2 of this study, is converted from decimal form and expressed as a percentage. In this study, the *fundamental* hypothesis under investigation is that the

[2] Including yields on Moody's Aaa-rated and Baa-rated long-term corporate bonds.

larger the relative tax gap (taken here as the measure of aggregate personal federal income tax evasion), the higher the *ex ante* real interest rate yield on 30-year U.S. Treasury bonds, *ceteris paribus*. The study period runs from 1982 through 2016, which reflects the availability of the expected inflation series available to permit the generation of the *ex ante* real interest rate series and the series needed to compute the relative tax gap.

It is worth stressing that the *relative tax gap* is quite different from the *AGI Gap*. The latter is simply an estimate of the degree to which households *underreport their taxable income* to the IRS and other tax authorities (such as, within the U.S., state departments of revenue). Hence, the AGI Gap differs from the tax gap in that AGI Gap is *not* the value of *lost tax revenues/collections* to the U.S. Treasury resulting from personal tax evasion (Gale and Krupkin, 2019). Furthermore, in order to generate the relative tax gap, the nominal tax gap is expressed in this study, unlike other studies, as a percent of the nominal GDP level, whereas the AGI Gap found in other studies is expressed as the ratio of the aggregate unreported adjusted gross income to the estimated actual aggregate adjusted gross income.

THE RELATIVE TAX GAP AND THE BASIC FRAMEWORK

To begin the analysis, we provide a description of how the Tax Gap and Relative Tax Gap measures of aggregate income tax evasion are computed. The construction of the Relative Tax Gap involves, most fundamentally, the use of the AGI Gap, which (as noted above) is defined as the percentage of aggregate adjusted gross income that is either unreported or underreported on personal income tax returns submitted to the Internal Revenue Service (IRS). For computational purpose, the AGI Gap is expressed as a decimal, *AGIGAPDEC*. The Relative Tax Gap construction also involves the aggregate federal personal income tax (in current dollars) actually paid by households to the IRS, *AFPINCTXPD*. Together, these data are used first to estimate the magnitude of the total (aggregate) federal personal income tax liability of households (in current dollars) in the absence of tax evasion, AGGFPITL: *AGGFPITL = AFPINCTXPD/*(1.00 – *AGIGAPDEC*).

The difference between the amount owed to the IRS in the absence of tax evasion and the amount actually paid to the IRS is the nominal Tax Gap. In particular, the nominal Tax Gap, which is estimated aggregate nominal *unpaid* federal personal income liabilities, is then computed, as follows: *Tax Gap = AGGFPITL – AFPINCTXPD*. Finally, the Relative Tax Gap is the nominal Tax Gap scaled by, i.e., expressed as a percentage of, nominal gross domestic product, GDP, so as to permit comparisons of the Tax Gap over time: *Relative Tax Gap = Tax Gap/GDP*. This variable is the key variable of interest in this study. The interested reader can find the relative tax gap values for each year of the study period in Table 2.

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TABLE 2. Relative Tax Gap, by Year, 1982-2016 Study Period*

1982	1.211862	1999	1.137057
1983	1.188234	2000	1.170243
1984	1.184111	2001	1.264393
1985	1.122022	2002	1.220207
1986	1.168484	2003	1.159931
1987	1.034173	2004	1.063993
1988	0.854023	2005	1.230051
1989	0.984020	2006	1.257119
1990	0.923881	2007	1.106253
1991	0.886181	2008	1.051318
1992	0.956774	2009	0.849262
1993	1.073845	2010	0.764936
1994	1.117190	2011	1.023240
1995	1.087886	2012	1.065787
1996	1.123419	2013	1.126630
1997	1.086484	2014	1.294455
1998	1.227838	2015	1.287756
		2016	1.324740

* Sources: Ledbetter (2004, 2007), Foertsch (2016), Internal Revenue Service (2014), and the Council of Economic Advisors (2004; 2018).

Given this backdrop, we adopt the open-economy loanable funds model specification found in Madura (2008, esp., pp. 24-32), modified in order to accommodate the relative tax gap. It is within this context that the real interest rate yield on 30-year Treasury bonds is, assuming all other bond markets are in equilibrium, determined by the following condition:

$$S + DEF/GDP = D + MB/GDP + NCI/GDP \quad (1)$$

where: S = the supply of 30-year Treasury bonds;
DEF/GDP = the total/unified federal budget deficit, expressed as a percentage of GDP;
D = the private sector demand for 30-year Treasury bonds;
MB/GDP = the monetary base, expressed as a percentage of GDP; and
NCI/GDP = net international financial capital inflows, expressed as a percent of GDP.

Following Madura (2008, esp. pp. 24-32), Hoelscher (1986), and Cebula (2018), while also integrating the tax gap into the specification, it is hypothesized that:

$$D = D\,(EAR30,\ EAR3YR,\ EARTF,\ Y),\ D_{EAR30} > 0,\ D_{EAR3YR} < 0,\ D_{EARTF} < 0,\ D_Y < 0 \quad (2)$$
$$S = S\,(EAR30,\ TAXGAP/GDP),\ S_{EAR30} < 0,\ S_{TAXGAP/GDP} > 0 \quad (3)$$

where: $EAR30$ = the *ex ante real* interest rate yield on 30-year Treasury bonds;
$EAR3YR$ = the *ex ante real* interest rate yield on three-year Treasury notes;
$EARTF$ = the *ex ante real* interest rate yield on high grade municipal bonds;
Y = the percentage growth rate in real GDP; and
$TAXGAP/GDP$ = the relative tax gap, i.e., the ratio of lost nominal tax revenue to the coffers of the U.S. Treasury resulting from personal income tax evasion to the GDP, expressed as a percent.

Since the specification is expressed in terms of the *ex ante* real interest rate yield, this study required a measure of *expected* future price inflation. Various such measures exist, including those derived from the adaptive expectations and rational expectations models and from other analytical frameworks, as well as from pure survey data (Swamy, Kolluri, and Singamsetti, 1990). Model-based measures of expected future inflation rates rely fundamentally on empirical estimations, within the context of which both economic theory and statistical methods are combined and then applied to data. The latter data typically include a variety of financial variables and inflation series, although other information can be incorporated in accordance with the specified model.

On the other hand, survey-based measures of expected future inflation are directly obtained by soliciting the views of respondents regarding the future inflation outlook. There are differences across these surveys such as: the types/traits (such as age, educational attainment, gender, and income) of people who are contacted for the survey; the forecast time horizon; the variables of concern in the survey; and even in how the pertinent inflation expectations questions are posed. These considerations can influence the interpretation, validity, and usefulness of the survey responses. For example, one well-known series on expected future inflation, The Livingston Survey, a widely-used survey gathered for many years by the Federal Reserve Bank of Philadelphia, was found by Swamy, Kolluri, and Singamsetti (1990) to be fundamentally flawed in several ways in the study.

Based on the observations above, it can be reasonably argued that it may be useful to adopt fundamentally model-based, as opposed to purely survey-based, data on expected future inflation. Interestingly, since 1982, the Federal Reserve Bank of Cleveland (2019) has reported estimates of the average expected future inflation rates of the CPI in the U.S. in each year for the ensuing ten years. These are calculated by the Federal Reserve Bank of Cleveland principally by using a model that integrates various financial market data as well as survey-based data.[3] Accordingly, the present study adopts these calculated data as the measure of expected future price inflation, so that the *ex ante* real interest rate yields adopted in this study are expressed in the form of the percentage nominal interest rate minus this expected percentage future inflation rate.[4]

According to this framework, the private sector demand for 30-year Treasury bonds is modeled as being an increasing function of *EAR30* since bond buyers would logically prefer a higher real rate of return on their investment, *ceteris paribus*. On the other hand, in theory, the Treasury (as the issuer of 30-year Treasury bonds) would supply/issue fewer 30-year bonds to the financial marketplace in response to a higher *EAR30*, *ceteris paribus*, this being because a higher value for *EAR30* would imply elevated debt service costs.

Next, the variable *EAR3YR* is included in this study as a measure of the yield on a shorter-term taxable, high quality debt issue that would compete in the financial marketplace with 30-year Treasury bonds, whereas the variable *EARTF* is included in the specification to represent the yield on a bond issue that is fundamentally different from 30-year Treasuries insofar as its interest payments are exempt from federal income taxation while also directly competing with 30-year Treasuries by virtue of its being both longer-term and of high quality. In any case, it is hypothesized that the higher the value of either *EAR3YR* or *EARTF*, the greater the degree to which investors *substitute* either three-year Treasury notes or high grade municipal bonds, respectively, for 30-year Treasury bonds in their portfolios and thereby reduce their demand for the 30-year Treasuries, *ceteris paribus*. Clearly, then, the lower the demand for 30-year bonds, the lower the 30-year bond price and hence the higher the 30-year bond yield. It is noteworthy that as an alternative to the variable *EAR3YR*, three other shorter term *ex ante* real Treasury bill interest

[3] The Federal Reserve Bank of Cleveland expected future inflation data are based on data from Blue Chip, Bloomberg, the Bureau of Labor Statistics, the Federal Reserve Bank of Philadelphia, the Federal Reserve Board, and Haver Analytics.
[4] Related to the expected inflation series and ex ante real interest rate, see also the model developed by Haubrich, Pennacchi, and Ritchken (2012).

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rate yields were considered, namely, those on the three-month Treasury bill, the six-month Treasury bill, and the one-year Treasury bill. In all three cases, the variable in question introduced significant multi-collinearity and hence each was discarded in favor of *EAR3YR*.[5]

During times of more rapid real GDP growth, the transactions demand for money is expected to rise more rapidly (Madura, 2008, p. 31). The scenario would in turn be expected to lead to rising interest rates in the financial markets and thereby to reduce the demand for 30-year government bonds, *ceteris paribus*. This is because longer-term bonds carry a greater degree of "interest rate risk" during such times. In other words, the higher the growth rate of real GDP, *Y*, the greater the demand for equities, real estate, and other assets that appreciate in value rather than for 30-year bonds, which depreciate in value during such times. Hence, the demand for these 30-year bonds is a decreasing function of *Y*, *ceteris paribus*. In any case, the greater the value of *Y*, the lower the demand for these long-term Treasuries, and consequently the lower their market price will be and the higher their real interest rate yield will be. As Madura (2008, p. 32) observes, greater "…economic growth puts upward pressure on interest rates…"

As summarized in the text above, the tax evasion measure is defined in this study as the *relative tax gap*, *TAXGAP/GDP*. This variable is the nominal tax gap (the difference between actual nominal Treasury income tax collections and what those nominal tax collections would have been in the absence of personal income tax evasion in the form of underreporting of taxable income) expressed as a percent of nominal GDP. Alternatively stated, $(TAXGAP/GDP)_t$ is the nominal tax gap in year t scaled by the nominal GDP in year t and then converted to a percent. Measuring the tax gap in this fashion permits judging the size of the tax gap relative to the size of the economy over time. As hypothesized in equation (3) above, in this study, the greater the extent of federal personal income tax evasion thusly measured, the greater the degree to which the Treasury must issue/supply new securities, including issues such as 30-year Treasury bonds, and, accordingly, the lower the price and hence the higher the real yield on those 30-year issues will be in the financial marketplace, *ceteris paribus*.

The aggregate domestic supply of loanable funds, which by its nature, can be available for the purchase of myriad alternative financial investments (including 30-year Treasury bonds), can be reflected in various ways. In this study, the aggregate *domestic* supply of loanable funds is treated as being reflected in large part by the monetary base (*MB*), with the monetary base expressed by the ratio (*MB/GDP*), i.e., expressed as a percent of GDP. This specification permits evaluation of the monetary base relative to the size of the economy. Moreover, in the U.S., for the period December, 2008 through October, 2014, the Federal Reserve engaged in three stages of "quantitative easing:" QE1, QE2, and QE3. In turn, these forms of quantitative easing exercised a positive impact on the size of the monetary base; therefore, adopting this variable as a measure of the availability of loanable funds, as opposed to, say, the M2 money supply, possesses the advantage that it, in theory, measurably reflects the degree of quantitative easing (Cebula, 2018). In any case, the greater the magnitude of the monetary base variable, the greater the availability of loanable funds in the aggregate and hence the lower the real interest rate (*EAR30*) should be, *ceteris paribus* (Madura, 2008, p. 34).

Net financial capital inflows (*NCI*) are also included in the model. Naturally, when there is a net inflow of financial capital, the funds can be directed towards a wide variety of alternative investment options, including if not especially those offered in the financial markets. More specifically, within the latter context, net capital inflows may be used to purchase any of a variety of equities issues and/or bonds. Thus, other things held constant, the greater the volume of *NCI* relative to GDP that is used to purchase bonds in the U.S., the greater the downward pressure on interest rate yields in the economy's financial

[5] For example, if the ex ante real three-month Treasury bill yield were adopted in place of EAR3YR in the estimate, the resulting VIF (Variance Inflation Factor) for this variable would be 41.08, far in excess of the maximum value of 10 recommended in most standard econometrics textbooks (e.g., Hair, et al,, 2006; Greene, 2008; Wooldridge, 2009).

markets as a whole, including that for 30-year Treasury issues. Consequently, consistent with the conventional wisdom (Madura, 2008, pp. 35-36), it is hypothesized that the *ex ante real* interest rate yield on 30-year Treasury bonds is a decreasing function of (*NCI/GDP*), *ceteris paribus*.

Substituting equations (2) and (3) into equation (1) and then proceeding to solve for *EAR30* (after including an interaction term for *DEF/GDP* and *TAXGAP/GDP*, namely, *INTER*) yields the model initially underlying this study:

$$EAR30 = f(DEF/GDP, MB/GDP, NCI/GDP, EAR3YR, EARTF, Y, TAXGAP/GDP, INTER),$$
$$f_{DEF/GDP} > 0,\ f_{MB/GDP} < 0,\ f_{NCI/GDP} < 0,\ f_{EAR3YR} > 0,\ f_{EARTF} > 0,\ f_{Y} > 0,\ f_{TAXGAP/GDP} > 0 \quad (4)$$

The first of these hypothesized signs involves the federal budget deficit, expressed in this study as a percentage of GDP. The hypothesized sign on $f_{DEF/GDP}$ is positive, which reflects the "conventional wisdom" that when the Treasury attempts to finance a budget deficit (whether through the sale of bills, notes, bonds, or other debt instruments), it forces market interest rate yields upwards as it *competes* for funds in the financial markets (Carlson and Spencer, 1975; Madura, 2008, esp. pp. 34-35; Ball, 2012). The second and third signs for the variables shown in equation (4) reflect the conventional wisdom regarding the impact of a greater availability of loanable funds, as reflected in either a relatively larger monetary base or greater international capital inflows, respectively, each of which enables the financial markets to absorb more government sector (as well as private sector) debt and thereby acts to diminish upward pressure on interest rates (Madura, 2008, pp. 34-36). The next three hypothesized signs for the explanatory variables expressed in equation (4) are predicated directly upon equations (2) and (3) and the discussions thereof provided above. Finally, given the presence of income tax evasion and budget deficits in the model, an interaction term (*INTER*) for these two variables was initially included in the system, as follows:

$$INTER = DEF/GDP * TAXGAP/GDP \quad (5)$$

However, the coefficient on the interaction term was statistically insignificant across all estimations; hence, it was omitted from the final estimations (Hair, et al, 2006; Wooldridge, 2009).

THE INITIAL EMPIRICAL MODEL

Based on (4), the initial model to be estimated in this study is provided by:

$$EAR30_t = \alpha_o + \alpha_1 (DEF/GDP)_t + \alpha_2 (MB/GDP)_t + \alpha_3 (NCI/GDP)_t + \alpha_4 EAR3YR_t + \alpha_5 EARTF_t + \alpha_6 Y_t + \alpha_7 (TAXGAP/GDP)_t + \alpha_8 AR(1) + \varepsilon_t \quad (6)$$

where:
$EAR30_t$ = the *ex ante real* average interest rate yield on 30-year Treasury bonds in year t, expressed as a percent per annum;
α_o = constant term;
$(DEF/GDP)_t$ = the ratio of the unified /total nominal federal budget deficit to the nominal GDP in year t, expressed as a percent;
$(MB/GDP)_t$ = the ratio of the nominal monetary base to the nominal GDP in year t, expressed as a percent;
$(NCI/GDP)_t$ = the ratio of the nominal value of net international financial capital inflows to the nominal GDP level in year t, expressed as a percent;

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$EAR3YR_t$ = the *ex ante real* average interest rate yield on three-year Treasury notes in year t, expressed as a percent per annum;
$EARTF_t$ = the *ex ante real* average interest rate yield on high grade tax-exempt municipal bonds in year t, expressed as a percent per annum;
Y_t = percentage growth rate of real GDP during year t;
$(TAXGAP/GDP)_t$ = the relative tax gap in year t, expressed as a percentage;
AR(1) = the autoregressive term; and
ε_t = stochastic error term.
The expected signs on the coefficients in equation (6) are summarized, as follows:

$$\alpha_1 > 0, \alpha_2 < 0, \alpha_3 < 0, \alpha_4 > 0, \alpha_5 > 0, \alpha_6 > 0, \alpha_7 > 0 \quad (7)$$

Naturally, it is the result for coefficient α_7 that is of greatest interest to this study (along with, albeit to a much lesser degree, given the objective of this study, the result for coefficient α_1). The data for computing the tax evasion variable are available in the form of annual data through 2016. Full definitions of each of the variables considered in this study, along with their respective data sources, are provided in Table 3.

TABLE 3. Definitions and Data Sources for Variables

Dependent Variable	Definition and Data Source
$EAR30_t$	the *ex ante real* average interest rate yield on 30-year Treasury bonds in year t, expressed as a percent per annum; Federal Reserve Bank of St. Louis (2017) and Federal Reserve Bank of Cleveland (2019)
Explanatory Variables from equation (6)	
$(DEF/GDP)_t$	the ratio of the unified /total nominal federal budget deficit to the nominal GDP in year t, expressed as a percent; Council of Economic Advisors (2002, 2004, 2010, 2013, 2018)
$(MB/GDP)_t$	the ratio of the nominal monetary base to the nominal GDP in year t, expressed as a percent; Federal Reserve Bank of St. Louis (2017)
$(NCI/GDP)_t$	the ratio of the nominal value of net international financial capital inflows to the nominal GDP level in year t, expressed as a percent; Federal Reserve Bank of St. Louis (2017)
$EAR3YR_t$	the *ex ante real* average interest rate yield on three-year U.S Treasury notes in year t, expressed as a percent per annum; Federal Reserve Bank of St. Louis (2017) and Federal Reserve Bank of Cleveland (2019)
$EAR10YR_t$	the *ex ante real* average interest rate yield on ten-year U.S. Treasury notes in year t, expressed as a percent per annum; Federal Reserve Bank of St. Louis (2017) and Federal Reserve Bank of Cleveland (2019)
$EARTF_t$	the *ex ante real* average interest rate yield on high grade tax-exempt municipal bonds in year t, expressed as a percent per annum; Federal Reserve Bank of St. Louis (2017) and Federal Reserve Bank of Cleveland (2019)
Y_t	percentage growth rate of real GDP during year t; Federal Reserve Bank of St. Louis (2017)
$(TAXGAP/GDP)_t$	the nominal tax gap in year t, expressed as a percent of nominal GDP in the same year; Ledbetter (2004, 2007), Foertsch (2016), and the Council of Economic Advisors (2004, 2018)

$(PRIMARYDEF/GDP)_t$	the ratio of the nominal federal primary budget deficit to the nominal GDP in year t, expressed as a percent; Federal Reserve Bank of St. Louis (2017)
$EARBAA_t$	the *ex ante* real interest rate yield on Moody's Baa-rated interest rate yield in year t, expressed as a percent per annum; Federal Reserve Bank of St. Louis (2017) and Federal Reserve Bank of Cleveland (2019)

Descriptive statistics for the all of the variables in equation (6) as well as for those in equations (8), (10), and (11) for the 1982-2016 study period, are provided in Table 4.

TABLE 4. Descriptive Statistics, 1982-2016

Variable	Mean	Standard Deviation	Maximum	Minimum
EAR30	3.402	1.631	7.59	0.69
DEF/GDP	3.203	2.649	9.80	-2.30
MB/GDP	85.39	55.05	225.7	47.6
NCI/GDP	2.62	1.58	5.73	-0.049
EAR3YR	2.116	2.37	7.17	-1.22
EARTF	2.836	1.142	5.81	1.14
Y	2.686	1.899	7.3	-2.8
TAXGAP/GDP	1.103	0.136	1.325	0.765
PRIMARYDEF/GDP	0.947	2.96	9.40	-4.70
EARBAA	5.292	1.80	10.35	2.85

The dependent variable, $EAR30_t$, is contemporaneous with all seven of the explanatory variables in the model. Accordingly, in order to address potential endogeneity problems, the model is estimated by auto-regressive two stage least squares (AR/2SLS). The instruments are the two-year lags of each of the explanatory variables (Hair, et al, 2006; Greene, 2008; Wooldridge, 2009); interestingly, the adoption of "more distant" lags, such as three-year lags, on the instruments yields nearly the very similar results and the very same conclusions (see, e.g., Hair, et al. 2006; Wooldridge, 2009, Chapter 15).

RESULTS OF THE INITIAL AR/2SLS ESTIMATION

Using the model provided in equation (6), the estimation technique adopted in this study involves in part the AR(1) autoregressive process. This procedure is of interest and relevance and has numerous times-series applications, with the autoregressive process being arguably best applicable to time-series data that exhibit more volatile behavior. Examples of the latter would include stock market (equity) indices, individual stock (equity) prices, and, as is the focus in this study, interest rate yields (Hair, et al., 2006; Wooldridge, 2009). Furthermore, the 2SLS estimation is adopted in order to address the potential simultaneity/endogeneity issues referred to above.

The AR/2SLS estimation of equation (6) is provided in Table 5, where coefficients, standard errors, t-values, and prob. values can be found, along with other pertinent estimation information, including the J-statistic. Based on the Breusch and Pagan (1979) test, a heteroscedasticity correction was necessary; accordingly, the reported results reflect the application of the Newey and West (1987) heteroscedasticity correction. As shown in Table 5, all seven of the estimated coefficients exhibit the hypothesized signs. Five of these estimated coefficients are statistically significant at the 1% level, and two are significant at the 2.5% level. In addition, the J-statistic, which is significant at nearly the 5% level, favorably attests to the exogeneity of the instrumental variables. Furthermore, the inverted root is -0.21, a value that implies the estimation involves a stationary autoregressive process.

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TABLE 5. Initial AR/2SLS Estimation Results, Unified Deficit

Dependent Variable: *EAR30*				
Explanatory Variables	Coefficient	Std. Error	t-statistic	Prob.
TAXGAP/GDP	1.683**	0.6437	2.61	0.0147
DEF/GDP	0.167***	0.0322	5.20	0.0000
MB/GDP	-0.007***	0.0019	-3.41	0.0021
NCI/GDP	-0.1001**	0.0367	-2.72	0.0114
EARTF	0.0489***	0.1732	2.83	0.0089
EAR3YR	0.306***	0.1036	2.95	0.0066
Y	0.134***	0.0269	4.97	0.0000
Constant	-0.574	0.7004	-0.82	0.4200
AR(1)	-0.212			
Inverted AR Root	-.21			
J-statistic	11.35#			0.0780

***statistically significant at the 1% level; **statistically significant at the 2.5% level; #statistically significant at the 10% level.

Regarding the control variables, the estimation results imply that the *ex ante real* interest rate yield on 30-year U.S. Treasury bonds has been an increasing function of both the *ex ante real* interest rate yields on three-year Treasury notes (*EAR3YR*) and high grade municipal bonds (*EARTF*). The real interest rate yield on 30-year Treasuries is also shown to have been an increasing function of the percentage growth rate of real GDP, *Y*, while being a decreasing function of the monetary base variable, *MB/GDP*, and the net international capital inflows variable, *NCI/GDP*. All of these results are consistent with the signs hypothesized in Sections 2 and 3.

Attention is now directed at the explanatory variables of principal interest in this study, first and foremost being the tax evasion variable $(TAXGAP/GDP)_t$ and, to a lesser degree, being the budget deficit variable, $(DEF/GDP)_t$, which can reasonably be regarded as a *de facto* control variable. Regarding these two variables, the *ex ante real* interest rate yield on 30-year Treasury bonds is found to be an increasing function (at the 2% level) of the relative tax gap variable, (*TAXGAP/GDP*)t, whereas it is also found to be an increasing function (at the 1% level) of the unified/total federal budget deficit variable, (*DEF/GDP*)t.[6] Although the latter finding is of interest, of greatest interest and relevance to this study is the heretofore unexplored outcome implying that the greater the degree of aggregate federal personal income tax evasion, as measured here by the *relative tax gap*, the higher the *ex ante real* market interest rate yield on 30-year Treasury bonds. This finding vis-à-vis variable $(TAXGAP/GDP)_t$ in particular would seem to raise the very real possibility that personal income tax evasion *per se* may well contribute to the degree of crowding out, an issue heretofore associated typically only with government budget deficits *per se* (Carlson and Spencer, 1975; Cecchetti, 2006, p. 562; Madura, 2008, pp. 34, 106; Cebula, 2018).

AN ALTERNATIVE SPECIFICATION: THE PRIMARY BUDGET DEFICIT

In order to provide further potential insight into the impact of income tax evasion on the long-term real Treasury bond yield, we next estimate an alternative specification of the model shown in equation (6) and described in (7). Specifically, the new specification [(8) and (9) below] differs from the original model considered above insofar as it includes, in place of the unified/total deficit, the primary federal budget

[6] The latter finding, like that shown in Table 5, is consistent at least in principle with several prior studies of interest rate yields (of varying maturities) and federal budget deficits for earlier time periods (e.g., Hoelscher, 1986; Swamy, Kolluri, and Singamsetti, 1990; Cebula, 2018).

deficit, $(PRIMARYDEF/GDP)_t$, which is the unified/total budget deficit minus net interest payments by the Treasury. Accordingly, the new model to be estimated, which excludes the interaction term between the primary budget deficit and the relative tax gap, which was found once again to be statistically insignificant (Wooldridge, 2009), is provided in equation (8):[7]

$$EAR30_t = b_0 + b_1 (PRIMARYDEF/GDP)_t + b_2 (MB/GDP)_t + b_3 (NCI/GDP)_t + b_4 EAR3YR_t + b_5 EARTF_t + b_6 Y_t + b_7 (TAXGAP/GDP)_t + b_8 AR(1) + \varepsilon_t, \quad (8)$$

The hypothesized signs on the coefficients in equation (8) are, as follows:

$$b_1 > 0, b_2 < 0, b_3 < 0, b_4 > 0, b_5 > 0, b_6 > 0, b_7 > 0 \quad (9)$$

Once again, it is the finding for coefficient b_7 that is of greatest interest to this study.

The AR/2SLS estimation of equation (8) is provided in Table 6. As shown, all of the estimated coefficients exhibit the hypothesized signs, with five being significant at the 1% level, one being significant at the 2.5% level, and one being significant at the 5% level. The J-statistic, which is significant at beyond the 5% level, attests very favorably to the exogeneity of the instruments. The AR root is -0.17, which implies the estimation involves a stationary autoregressive process. The estimation results imply, among other things, that $EAR30_t$ is an increasing function of $EAR3YR_t$, $EARTF_t$, and Y_t, while being a decreasing function of both $(MB/GDP)_t$ and $(NCI/GDP)_t$. In addition, $EAR30_t$ is found to be an increasing function of the *primary* federal budget deficit-to-GDP variable.

TABLE 6. Alternative AR/2SLS Estimation Results, Primary Deficit

Dependent Variable: *EAR30*

Explanatory Variables	Coefficient	Std. Error	t-statistic	Prob.
TAXGAP/GDP	1.279*	0.5748	2.22	0.0350
DEF/GDP	0.128***	0.0259	4.95	0.0000
MB/GDP	-0.006***	0.0018	-3.41	0.0042
NCI/GDP	-0.1189**	0.0447	-2.66	0.0132
EARTF	0.592***	0.1434	4.13	0.0003
EAR3YR	0.292***	0.0900	3.24	0.0032
Y	0.152***	0.0323	4.70	0.0001
Constant	-0.028	0.4860	-0.06	0.9551
AR(1)	-0.134			
Inverted AR Root	-.13			
J-statistic	14.21*			0.0476

***statistically significant at the 1% level; **statistically significant at the 2.5% level; # statistically significant at the 10% level.

Furthermore, and most relevant to the objective of this study, there is the empirical finding summarized in Table 6 that the greater the relative tax gap, the higher the real interest rate yield on 30-year Treasury bonds.[8] This estimation result, like that in Table 5, would seem to imply the existence of an income-tax-evasion induced crowding out. Once again, it is observed that this interest rate impact attributable expressly to the *relative tax gap* measure of personal income tax evasion is unique among studies of U.S. Treasury yields and studies of U.S. income tax evasion.

[7] The instruments in this estimation are the two-year lags of the explanatory variables in equation (8).

[8] Interestingly, estimating equations (6) and (8) using "more distant lags," , e.g., three-year lags, on the instruments (as suggested in Wooldridge, 2009, Chapter 15, p. 23) in the potential presence of auto-correlated errors, yielded the same conclusions as we have inferred from Tables 5 and 6. Indeed, the outcomes shown in Tables 7 and 8 reflect instruments with three-year lags.

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FURTHER INQUIRY: MOODY'S BAA-RATED CORPORATE BOND YIELDS

Tables 5 and 6 provide empirical evidence supportive of the relative tax gap hypothesis in terms of the *ex ante* real interest rate yield on long-term, i.e., 30 year Treasury bonds. In this section, we inquire whether there is evidence that the relative tax gap also exerts upward pressure on the yield for long-term corporate bond issues. More specifically, the empirical investigation summarized in this section of the study addresses whether the hypothesis in question applies to say, the *ex ante* real interest rate yield on Moody's Baa-rated corporate bonds, *EARBAA*. Paralleling the analysis underlying Tables 5 and 6, it is hypothesized that the upward pressure from the relative tax gap on the *ex ante* real interest rate yield on 30-year Treasury bonds will also, *through competition in the financial markets* (Carlson and Spencer, 1975; Cebula, 1994; Haubrich, Pennacchi, and Ritchken, 2012), exert upward pressure on private sector longer-term corporate yields, such as the *EARBAA*.

Accordingly, we investigate this hypothesis by estimating the following two equations by AR/2SLS:

$$EARBAA_t = c_0 + c_1 (DEF/GDP)_t + c_2 (MB/GDP)_t + c_3 (NCI/GDP)_t + c_4 EAR3YR_t + c_5 EARTF_t + c_6 Y_t + c_7 (TAXGAP/GDP)_t + c_8 AR(1) + \varepsilon_t" \quad (10)$$

$$EARBAA_t = d_0 + d_1 (PRIMARYDEF/GDP)_t + d_2 (MB/GDP)_t + d_3 (NCI/GDP)_t + d_4 EAR3YR_t + d_5 EARTF_t + d_6 Y_t + d_7 (TAXGAP/GDP)_t + d_8 AR(1) + \varepsilon_t" \quad (11)$$

The estimates of equations (10) and (11) are provided in Tables 7 and 8, respectively. As shown in Table 7, the J-statistic is significant at the 5% level, implying exogeneity of the lagged instrumental variables (lag=3), and the autoregressive root (-.31) indicates a stable autoregressive process. In Table 7, it also is revealed that the relative tax gap is found to exercise a positive and statistically significant (at the 4% level) impact on the *ex ante* real interest rate yield on Moody's Baa-rated long-term corporate bonds. This result is entirely compatible with its counterparts in Tables 5 and 6. Furthermore, as shown in Table 8, where the primary budget deficit is considered in place of the unified deficit, there is further evidence that the relative tax gap exercises a statistically significant (at the 2% level) positive impact on the real Moody's Baa-rated corporate bond yield.

TABLE 7. New AR/2SLS Estimation Results, Unified Deficit

Dependent Variable: *EARBAA*

Explanatory Variables	Coefficient	Std. Error	t-statistic	Prob.
TAXGAP/GDP	2.528*	0.9958	2.27	0.0320
DEF/GDP	0.162#	0.0839	1.93	0.0642
MB/GDP	-0.006*	0.0026	-2.28	0.0309
NCI/GDP	-0.1283#	0.0752	-1.71	0.1000
EARTF	0.763**	0.3021	2.53	0.0180
EAR3YR	0.283	0.1755	1.61	0.1193
Y	-0.162	0.0607	-1.08	0.2891
Constant	0.224	0.9936	0.22	0.8268
AR(1)	-0.314			
Inverted AR Root	-.31			
J-statistic	14.24#			0.0470

***statistically significant at the 1% level; **statistically significant at the 2.5% level; *statistically significant at the 5% level; # statistically significant at the 10% level.

TABLE 8. New AR/2SLS Estimation Results, Primary Deficit

Dependent Variable: *EARBAA*

Explanatory Variables	Coefficient	Std. Error	t-statistic	Prob.
TAXGAP/GDP	3.058*	0.9320	2.50	0.0191
PRIMARYDEF/GDP	0.135#	0.0715	1.89	0.0697
MB/GDP	-0.006***	0.0020	-2.94	0.0068
NCI/GDP	-0.1317	0.0811	-1.62	0.1166
EARTF	1.016***	0.3414	2.98	0.0062
EAR3YR	0.211	0.1533	1.37	0.1808
Y	-0.059	0.0534	-1.12	0.2719
Constant	-0.543	0.8853	-0.61	0.5445
AR(1)	0.066			
Inverted AR Root	.07			
J-statistic	12.19#			0.0943

***statistically significant at the 1% level; **statistically significant at the 2.5% level; *statistically significant at the 5% level; # statistically significant at the 10% level.

CONCLUSION

The principal objective of this exploratory study is to empirically investigate the relative tax gap hypothesis that, *ceteris paribus*, the higher the relative tax gap, the higher the real interest rate yield on 30 year U.S. Treasury bonds. The potential impact of federal personal income tax evasion in the form of the relative tax gap *per se* on *ex ante* real Treasury debt (or, for that matter, on long-term corporate debt) interest rate yields has not heretofore been explored in either the income tax evasion literature or the interest rate literature.

As shown in Tables 5 and 6, the AR/2SLS estimations find that higher values of the *relative tax gap* measure of income tax evasion elevate the *ex ante real* interest rate yield on 30-year Treasury bonds.[9] According to the conventional wisdom (Carlson and Spencer, 1975; Cebula, 1994; Haubrich, Pennacchi, and Ritchken, 2012), this upward pressure from the relative tax gap on the *ex ante* real interest rate yield on 30-year Treasury bonds would in theory also, through competition in the financial markets, exert upward pressure on longer-term corporate interest rates as well. It is not surprising then, as shown in Tables 7 and 8, that there is also empirical evidence that the larger the relative tax gap, the higher the *ex ante* real interest rate yield on Moody's Baa-rated long-term corporate bonds. Separately as well as in combination, these findings raise the possibility that income tax evasion in the form of the relative tax gap may well contribute, by raising real interest rates, to the crowding out of private sector investment in new plant and equipment most commonly associated with federal government budget deficits *per se* (Carlson and Spencer, 1975; Cecchetti, 2006, p. 562; Madura, 2008, pp. 34, 106; Cebula, 2018). Hence, the empirical results suggest the existence of a "tax-evasion-induced crowding out effect."

Accordingly, it would seem that policymakers and politicians could better serve the public good if they were more and better informed and, correspondingly, more efficiently proactive in taking steps to reduce federal personal income tax evasion in the U.S. To the extent that new or modified public policies are implemented and are successful in curbing the degree of personal income tax evasion, there arguably is reason to believe that the upward pressure on long-term *ex ante* real interest rates might

[9] Furthermore, although it is not the central focus of this project, the empirical findings imply that, even in the explicit presence of income tax evasion, the greater the federal budget deficit, whether measured as the total/unified deficit as a percent of GDP or as the primary budget deficit as a percent of GDP, the higher the ex ante real interest rate yield on 30-year Treasury bonds as well.

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very well be alleviated and, furthermore, that the growth rate of the national debt could be diminished. Needless to say, further empirical research regarding the issues considered in this study is necessary in order to establish confidence in the relative tax gap hypothesis. Indeed, more elaborate modeling and more sophisticated econometrics are two obvious paths for subsequent related future research; furthermore, a longer study period and a possible refocus on *ex post* real or nominal interest rates may yield interesting and useful results.

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