

Labor Income Tax and Output: A Structural VAR Analysis

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This paper analyzes two channels through which a change in labor income tax may affect output. First, a tax cut provides higher work incentives, thereby increasing the aggregate output through an increase in the aggregate labor supply. Second, a tax-cut increases disposable income and the aggregate demand. An increase in the aggregate demand leads to a higher level of aggregate output. The first channel is believed to have a permanent effect on output movements, while the latter has only a temporary effect. This paper captures these two effects by defining two disturbances on the basis of the existing economic theory.

Keywords: Labor Income Tax, Output Growth, Structural VAR Model, Blanchard-Quah Decomposition, Supply-Side Effect, Impulse Response Functions

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I. Introduction

The U.S. economy experienced a deep economic recession that began in 2008. To date, the economic recovery from this recession has been unusually slow as evidenced from the relatively low growth rate of the real GDP and a persistently high rate of unemployment. This anemic economic growth has renewed interest in analyzing the effectiveness of fiscal policy in restoring economic growth. Fiscal policy can either be focused on stimulating the aggregate demand, or it can be designed to affect primarily the aggregate supply of the economy subjected to a fiscal stimulus. In the U.S., the objective of the unprecedentedly large fiscal stimulus that began in 2009 has been on increasing the U.S. economy's aggregate demand. Yet in spite of all massive recent fiscal expenditures, the U.S. real GDP growth rate averaging 2.5 percent in 2011 and 1.9 percent in the first quarter of 2012 leaves many doubts about the effectiveness of fiscal policy that targets the aggregate demand in restoring economic growth. The key objective of this paper is to provide empirical evidence on the effectiveness of fiscal policy in promoting economic growth. This objective is achieved by developing a structural vector autoregressive (SVAR) model and subjecting it to empirical tests. Our paper analyses both the aggregate demand and the aggregate supply channels by which fiscal policy affects economic growth.

A large number of studies have analyzed the role of fiscal policy on aggregate economic activity. Empirical studies have been increasingly using SVAR models in tracking the dynamics of output response to unanticipated fiscal policy shocks. For example, Galí *et al.* (2007) study the effects of

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government spending shocks to several macroeconomic variables in a new Keynesian framework. Ramey and Shapiro (1997) investigate the effects of military buildups on a variety of macroeconomic variables in a multi-sector neoclassical framework. Edelberg *et al.* (1999) examine the effects of exogenous shocks to real government spending on the U.S. output. Clarida and Prendergast (1999) present some empirical findings on the dynamic effects of fiscal policy on real exchange rates in the G3 countries. Blanchard and Perotti (2002) estimate the dynamic effects of shocks to government spending and taxes on the postwar U.S. output. Fatas and Mihov (2000) analyze the role of exogenous shocks to government spending on U.S. output using an identified VAR system. Perotti (2002) investigates the effects of fiscal policy on GDP, interest rate, and prices in five OECD (Organization for Economic Cooperation and Development) countries. Although numerous studies have examined the effects of aggregate government spending on output, few studies have attempted to examine empirically the impact of other fiscal instruments, namely labor income taxation, on output. This paper provides new empirical evidence on this key economic issue by examining the dynamic response of output to exogenous shocks of labor income tax policy innovations in the U.S. economy during 1979-2006. Providing new empirical evidence on effects of income taxes on economic growth is of particular importance in the current world-wide economic decline.

In Keynesian framework, a reduction in labor income tax increases the aggregate consumption demand through higher disposable income. An increase in consumption expenditures raises the aggregate demand, and through this channel an economy's output expands. However, the supply-side economic theory maintains that a reduction in the labor income tax affects the aggregate output through a fundamentally different channel. Lower tax rates increase the work incentive of laborers by increasing their after-tax return. Hence the aggregate labor supply increases, and so does the aggregate output.

The U.S. experienced a large scale tax restructuring under the leadership of President Regan during the 1980s. Federal personal income tax rates were reduced drastically and the tax structure was simplified considerably. Prior to the enactment of the Economic Recovery Tax Act (ERTA) in 1981, the U.S. income tax structure comprised of 15 rates ranging from 14 to 70 percent. The ERTA lowered tax rates across the board by more than 20 percent, with lowered spread of rates ranging from 11 to 50 percent. Income tax rates were reduced further under the Tax Reform Act (TRA86) in 1986. The tax structure was simplified considerably to a two-rate schedule of 15 and 28 percent. The design of ERTA and TRA86 was primarily motivated by the idea of the supply-side stimulus to economic growth. The U.S. personal income tax structure was further modified in 2001 during President Bush's first term in the White House. However, unlike the previous Reagan tax cuts, the basic motivation behind the 2001 tax legislation was to provide a demand-side stimulus to a recessionary economy. President Obama also adopted the Keynesian demand-side approach to combating the economic recession that began in 2008. This policy included, among others, the record high fiscal stimulus of \$837 billion in 2009.

Clearly, as stated above, the reasons for lowering taxes can be different. There are two distinct channels through which taxes impact economic growth. In general, during sound economic environment, a lower marginal income tax rate is supposed to motivate workers to work more (supply-side stimulus), while during sluggish economic environment, a lower income tax rate is targeted to stimulate spending (demand-side stimulus). This paper explicitly identifies those two channels, and measures the relative contributions of the supply-side and the demand-side effects of unanticipated changes in labor income tax on the real output of the U.S. economy during 1979-2006. Relative lack of empirical research of this subject to date as well as the recent 2009 economic

recession make it imperative to gain a better understanding of the supply-side and demand-side effects of labor income tax changes on an economy's output.

The present paper develops a SVAR model with two variables, namely the real output growth rate and the labor income tax rate. These two variables are used to isolate the supply and the demand-side effects. We define two structural disturbances on the basis of the nature of their impact on output. The mechanism of work incentives is believed to have a "permanent effect" on output. It is captured in the supply disturbance. The mechanism of higher consumption spending is believed to have only a "temporary effect" on output. It is captured in the demand disturbance. The portion of the growth rate of the actual output due to the supply disturbance is called the supply component of the growth rate of output. The portion of the growth rate of the actual output due to the demand disturbance is called the demand component of the growth rate of output. We recover the time series of output in *level* from the time series of growth rate of output, given an initial value of output. The portion of the actual output due to the supply disturbance is called the supply component of output, while the portion of the actual output due to the demand disturbance is called the demand component of output. Time series of actual output, its supply component and its demand component, are *not* in the linear relationship because the latter two time series are recovered from their respective growth rate series. The movement in the supply component of output is regarded as the long-run trend in the actual output¹⁰ under fully flexible prices, while demand disturbance causes short-run deviations of the actual output from its long-run trend. However, under imperfectly flexible prices this assumption is unwarranted. In that event, deviations from trend arise not only due to demand disturbance, but also due to supply disturbance. The conventional view of fluctuations in output being temporary deviations from the trend does not hold (Campbell and Mankiw, 1987). Accordingly, we also investigate whether the long run trend is stochastic.¹¹

Additionally, it is also important to address the issue of the functional dependence of tax rates on output. Fiscal policy decisions are largely governed by the current or prior state of the economy. Therefore, the tax rate is endogenously influenced by the growth rate of the real output. Blanchard and Perotti (2002) use similar specifications where it is assumed that the exogenous changes in the tax rate are due to the unpredictable component of tax rates. Following the resolution of this issue, the rest of the paper is organized as follows. Section II explains the fundamentals of the supply-side and the demand-side effects of changes in the labor income tax on output. Methodological issues and the data used to analyze these effects are outlined in sections III and IV. In Section V all test results are reported and analyzed. Final conclusions on the impact of labor taxes on the U.S. economy are reached in Section VI.

II. Effects of a Change in the Labor Income Tax

A. Supply-Side Effects: Substitution Effect and Income Effect

The labor-leisure analysis is often used to describe the effect of a reduction in the labor income tax on individuals' labor supply decisions (Gwartney and Stroup, 1983; Bohanon and Cott, 1986). A reduction in the labor income tax generates two opposing impacts. First, it leads to a

¹⁰ Generally, the actual output is characterized by a unit-root process. A natural implication is that it can be decomposed into the supply (permanent) and demand (temporary) components.

¹¹ If the long-run trend is stochastic, it may generate short-run fluctuations in the actual output. Consequently, a conventional view that fluctuations in output are temporary deviations from the trend does not hold (Campbell and Mankiw, 1987).

higher real wage. This makes the consumption of leisure expensive, as the opportunity cost of leisure increases. Since leisure is a normal good, individuals substitute away from leisure. This constitutes a substitution effect. Given the similar preference function, and *ceteris paribus*, the substitution effect increases the total labor supply in the economy. Second, lower taxes increase real income. Higher real income induces individuals to increase consumption of all normal goods, including leisure. This is referred to as an income effect. Given the similar preference function, and *ceteris paribus*, the income effect reduces the total labor supply in the economy. Thus, the net effect of a reduction in the labor income tax on total labor supply depends on the relative strengths of the substitution and income effects.

B. Demand-Side Effects

The focus of the Keynesian economic theory is on the output determination in the short run. In the short run, the aggregate output is primarily determined by the aggregate demand. Tax cuts raise the consumption demand through a higher disposable income and, thereby, the aggregate demand. Over time, the effects of the aggregate demand shocks die out. The aggregate demand changes cannot influence the aggregate output in the long run. The long-run effects of a tax cut are reflected in higher prices and wages through a dynamic adjustment mechanism. The long-run adjustment in output takes place through an upward revision of an expected wage rate and consequent changes in the price level. Output eventually returns to its natural level of output. When an economy is above the natural level of output, the price level goes up. The higher price level causes a decrease in the demand and output. When economy is below the natural level of output, the price level decreases. The lower price level causes an increase in the demand and output. Thus the demand-side forces do not have a permanent effect on the aggregate output. They can only cause short-run cyclical fluctuations in output around the long-run trend (Blanchard, 2006).

III. Methodology

Our modeling of the time-series data is based upon the methodology pioneered by King *et al.* (1991), Galí (1992), Enders and Lee (1997), and Claus (1999), among others. We develop a SVAR model with long-run identifying restrictions proposed by Blanchard and Quah (1989). First, we construct a two-variable VAR model where output and tax affect each other. Effects of a tax cut on output are realized through the supply and demand channels. Effects of output on tax rates are due to the fact that fiscal policy decisions are influenced by the aggregate state of the economy. Tax policy decisions are contingent on a government's prevailing budgetary circumstances. The feedback of output and tax rate is inherent in the dynamic analysis of the Laffer curve. Followers of the supply-side economics claim that higher economic growth resulting from a tax cut can be large enough to make tax rate even lower.¹² This assumption is used by Blanchard and Perotti (2002) who attribute the unexpected movements in output to the unexpected movements in tax rates and *vice versa*.

¹² Mankiw and Weinzierl (2005) examine the extent to which tax cuts are capable of generating higher revenue through economic growth.

A. Identification

The VAR approach is often criticized for having little economic content in its results. That is why numerous empirical studies in recent years impose a theoretical structure on the joint process of the constituent variables. This paper uses the *a priori* restriction that the demand disturbance does not affect the output in the long run. This restriction follows from the natural rate hypothesis developed in the mid-1950s by Friedman (1968).¹³ Only one restriction is required to identify a structural model with two endogenous variables. No *a priori* assumption is made about the effects of the two disturbances on the tax rate, and the effect of the supply disturbance on output. We further assume that these two disturbances are uncorrelated at all leads and lags.

Let y_t and z_t denote the logarithm of the real GDP and the first difference of tax rates, respectively. Since y_t is the logarithm of the real GDP, Δy_t is the growth rate of real GDP. Our data suggests that both the growth rate in real GDP, Δy_t , and the first difference of tax rates, z_t , are stationary. This result is a necessary condition for constructing a VAR model. We consider a bivariate system where $\{\Delta y_t\}$ is affected by the current and the past realizations of $\{z_t\}$ along with its own past realizations, and likewise $\{z_t\}$ is affected by the current and the past realizations of $\{\Delta y_t\}$ along with its own past realizations. Structural equations are written as

$$\Delta y_t = \gamma_{z0} z_t + \gamma_{y1} \Delta y_{t-1} + \gamma_{z1} z_{t-1} + \dots + \gamma_{yk} \Delta y_{t-k} + \gamma_{zk} z_{t-k} + v_{1t} \quad (1)$$

$$z_t = \beta_{y0} \Delta y_t + \beta_{y1} \Delta y_{t-1} + \beta_{z1} z_{t-1} + \dots + \beta_{yk} \Delta y_{t-k} + \beta_{zk} z_{t-k} + v_{2t} \quad (2)$$

where v_{1t} and v_{2t} are uncorrelated white noise structural disturbances, γ s are structural coefficients in Δy_t equation, and β s are structural coefficients in z_t equation. Both structural equations are considered without an intercept and have a finite lag order k . A shock to either of the structural disturbances affects both $\{\Delta y_t\}$ and $\{z_t\}$ simultaneously. Using matrix algebra, the above bivariate system can be written as

$$A_0 X_t = A_1 X_{t-1} + \dots + A_k X_{t-k} + v_t \quad (3)$$

where X is the column vector $(\Delta y, z)'$, v is the column vector of unobserved structural disturbances $(v_1, v_2)'$, and

$$A_0 = \begin{bmatrix} 1 & -\gamma_{z0} \\ -\beta_{y0} & 1 \end{bmatrix}, A_1 = \begin{bmatrix} \gamma_{y1} & \gamma_{z1} \\ \beta_{y1} & \beta_{z1} \end{bmatrix}, \dots, A_k = \begin{bmatrix} \gamma_{yk} & \gamma_{zk} \\ \beta_{yk} & \beta_{zk} \end{bmatrix}$$

Using lag operator on X_t , Equation (3) can be rewritten as

$$A_0 X_t = A_1 L X_t + \dots + A_k L^k X_t + v_t \quad (4)$$

Alternatively,

$$A(L) X_t = v_t \quad (5)$$

where $A(L) = (A_0 - A_1 L - \dots - A_k L^k)$.

Therefore,

$$X_t = A(L)^{-1} v_t \quad (6)$$

or

¹³ For detailed outline of the natural rate hypothesis, see Friedman (1968).

$$X_t = S(L)v_t \quad (7)$$

where $S(L) = A(L)^{-1}$ is a matrix polynomial of infinite order and for which we assume that the bivariate invertibility conditions hold. Equation (7) is a bivariate moving average representation of structural equations of (3). Each equation in (7) can then be written as

$$\Delta y_t = \sum_{p=0}^{\infty} s_{11}(p)v_{1t-p} + \sum_{p=0}^{\infty} s_{12}(p)v_{2t-p} \quad (8)$$

$$z_t = \sum_{p=0}^{\infty} s_{21}(p)v_{1t-p} + \sum_{p=0}^{\infty} s_{22}(p)v_{2t-p} \quad (9)$$

Equations (8) and (9) express $\{\Delta y_t\}$ and $\{z_t\}$ as linear combinations of the current and past structural shocks.

In a more compact form, equations (8) and (9) can be written as

$$\begin{bmatrix} \Delta y_t \\ z_t \end{bmatrix} = \begin{bmatrix} S_{11}(L) & S_{12}(L) \\ S_{21}(L) & S_{22}(L) \end{bmatrix} \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix} \quad (10)$$

$S_{ij}(L)$ in Equation (10) are polynomials in the lag operator, where individual coefficients are denoted by $s_{ij}(p)$ in equations (8) and (9), and p is the lag length of infinite order.

We further assume unit variance for each of the disturbances (normalization assumption). This along with the assumption of uncorrelated white noise structural disturbances gives a diagonal variance-covariance matrix of the structural disturbance:

$$E(v_t v_t') = \begin{bmatrix} \text{var}(v_{1t}) & \text{cov}(v_{1t}, v_{2t}) \\ \text{cov}(v_{2t}, v_{1t}) & \text{var}(v_{2t}) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = I \quad (11)$$

v_{1t} is regarded as the aggregate supply disturbances and v_{2t} is regarded as the aggregate demand disturbances, and $s_{ij}(p)$'s are impulse responses of aggregate shocks. For instance, $s_{11}(1)$, $s_{11}(2)$, $s_{11}(3)$, ... etc. are separate impulse responses of $\{\Delta y_t\}$ to an aggregate supply shock on $\{v_{1t}\}$, and $S_{11}(L)$ is the corresponding cumulative impulse response. Specifications of (8) and (9) do not assume that supply component (permanent component) of output follows a random walk.¹⁴

We impose an identifying restriction that the aggregate demand disturbance v_{2t} has no effect on the *level* of output (logarithmic scale) y_t in the long run. This indicates that the cumulative effects of v_{2t} on $\{\Delta y_t\}$ must be equal to zero:

$$\sum_{p=0}^{\infty} s_{12}(p) = 0 \quad (12)$$

¹⁴ Lippi and Reichlin (1994) argue that the assumption of the permanent component of output being stationary is inconsistent with the true nature of technological adoption. For example, the random-walk characterization of a permanent component of the output precludes the possibility of learning by doing at the firm level. Moreover, a false random walk characterization of a permanent component of output, when in fact it is not, may mislead policy makers.

It is important to understand how Equation (12) ensures that demand shock v_2 has no effect on the *level* of output in logarithmic scale (y), hence on the *level* of output (Y). The proof of this assertion is presented in the following part of this paper in a simple example.

Let the sequence of growth rate of real GDP $\{\Delta y_t\}$ be governed by shocks on v_2 only. The corresponding moving average representation of $\{\Delta y_t\}$ is $\Delta y_t = \sum_{p=0}^{\infty} s_{12}(p)v_{2t-p}$. For expositional

purpose, we set upper limit of p arbitrarily at 1. Then the sequence of $\{\Delta y_t\}$ follows $\Delta y_t = s_{12}(0)v_{2t} + s_{12}(1)v_{2t-1}$, where $s_{12}(p)$ is the effect of v_{2t-p} for $p = 0, 1$ on Δy_t . We can write

$$y_t = y_{t-1} + s_{12}(0)v_{2t} + s_{12}(1)v_{2t-1} \quad (13)$$

Notice that the left-hand side of Equation (13) is the *level* of output. Successive substitutions of expressions y_{t-j} , $j = 1, 2, \dots, \infty$ in Equation (13) by moving backward through time after setting initial shock value v_{20} at zero yields

$$y_t = y_0 + s_{12}(0)v_{2t} + \left[\sum_{p=0}^1 s_{12}(p)v_{2t-1} + \sum_{p=0}^1 s_{12}(p)v_{2t-2} + \dots \right] \quad (14)$$

The term within the parentheses on the right-hand side of Equation (14) captures the long-run effect of past shocks in v_2 on the logarithm of output (y), and $s_{12}(0)$ captures the contemporaneous effect of shocks in v_2 on y . Clearly, for v_2 to have no effect on the level of output in log scale (y), and hence on the level of output (Y) in the long run, we must have $\sum_{p=0}^1 s_{12}(p) = 0$. Thus for $p = 0, 1, \dots, \infty$, the long-run restriction of demand shock on output level is equivalent to Equation (12).

In Equation (10), structural shocks $\{v_t\}$ are unobservable. So, $S(L)$ is not directly estimable. In order to recover the series of $\{v_t\}$, we construct the reduced form VAR from Equation (3), then estimate it in its unrestricted form. From Equation (3), we can write:

$$X_t = A_0^{-1}A_1X_{t-1} + \dots + A_0^{-1}A_kX_{t-k} + A_0^{-1}v_t \quad (15)$$

Using lag operator on X_{t-1} , Equation (15) can be written as

$$X_t = A_0^{-1}A_1X_{t-1} + \dots + A_0^{-1}A_kL^{k-1}X_{t-1} + A_0^{-1}v_t \quad (16)$$

or

$$X_t = A_0^{-1}(A_1 + \dots + A_kL^{k-1})X_{t-1} + A_0^{-1}v_t \quad (17)$$

or

$$X_t = \Phi(L)X_{t-1} + e_t \quad (18)$$

where $\Phi(L) = A_0^{-1}(A_1 + \dots + A_kL^{k-1})$ and $e_t = A_0^{-1}v_t$.

Alternatively,

$$\begin{bmatrix} \Delta y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (19)$$

In Equation (19), e is the vector of reduced form disturbances $(e_1, e_2)'$, $\Phi(L)$ is the 2×2 matrix whose elements are the polynomials $\Phi_{ij}(L)$ in Equation (19), for example, $\Phi_{11}(L) = \phi_{11}(0) + \phi_{11}(1)L + \phi_{11}(2)L^2 + \dots$, where $\phi_{ij}(p)$ are coefficients of $\Phi_{ij}(L)$, and p is the lag length. The residuals of a reduced form VAR, e_{1t} and e_{2t} are the composites of structural disturbances v_{1t} and v_{2t} . Hence, they are correlated, and an exogenous shock to one structural disturbance affects both variables simultaneously. Since v_{1t} and v_{2t} are white-noise innovations, both e_{1t} and e_{2t} have zero means, constant variances, and are individually serially uncorrelated (Enders, 2003, pp. 264-266). Estimation of Equation (18) is preceded by choosing an optimal number of lags by applying a lag-length selection criterion, such as Akaike Information Criterion (AIC) or Schwarz's Bayesian Criterion (SBC). Appropriately selected lag length eliminates serial correlation from reduced form residuals. Since the right-hand side of Equation (18) contains only predetermined variables, each error term has constant variance and error terms are serially uncorrelated. Therefore, each equation in the system can be estimated using OLS. The estimated unrestricted reduced form VAR can then be inverted to the vector moving average (VMA) representation using the Wold decomposition theorem (Hamilton, 1994, pp. 108-109).

$$\begin{bmatrix} \Delta y_t \\ z_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{21}(L) & C_{22}(L) \end{bmatrix} \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (20)$$

or

$$X_t = C(L)e_t \quad (21)$$

where $C(L) = (I - \Phi(L)L)^{-1}$.

Now we establish the relationship between the reduced form disturbances e and the structural disturbances v . One-step ahead forecast error of Δy_t in Equation (19) is $e_{1t} = \Delta y_t - E_{t-1}\Delta y_{t-1}$. Equivalent expression in Equation (8) is $s_{11}(0)v_{1t} + s_{12}(0)v_{2t}$. Thus,

$$e_{1t} = s_{11}(0)v_{1t} + s_{12}(0)v_{2t} \quad (22)$$

Similarly by comparing one-step ahead forecast errors of z_t in equations (20) and (9),

$$e_{2t} = s_{21}(0)v_{1t} + s_{22}(0)v_{2t} \quad (23)$$

equations (22) and (23) can be represented in a more compact form as

$$\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = \begin{bmatrix} s_{11}(0) & s_{12}(0) \\ s_{21}(0) & s_{22}(0) \end{bmatrix} \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix} \quad (24)$$

or

$$e_t = S(0)v_t \quad (25)$$

Equation (25) forms the crucial relationship between reduced form disturbances e and structural disturbances v that will help recover unobservable structural disturbances v . It is clear from Equation (25) that a recovery of structural disturbances v requires coefficient estimates of $S(0)$,¹⁵ which is the matrix of a contemporaneous effect of the structural disturbances v_t on X_t . In order to estimate four coefficients of $S(0)$ viz, $s_{11}(0)$, $s_{12}(0)$, $s_{21}(0)$ and $s_{22}(0)$, we use equations (22) and (23) along with the assumptions in Equation (11) and obtain the following three equations:

$$\text{var}(e_{1t}) = s_{11}(0)^2 + s_{12}(0)^2 \quad (26)$$

$$\text{var}(e_{2t}) = s_{21}(0)^2 + s_{22}(0)^2 \quad (27)$$

$$\text{cov}(e_{1t}, e_{2t}) = s_{11}(0)s_{21}(0) + s_{12}(0)s_{22}(0) \quad (28)$$

Equations (26), (27) and (28) can be viewed as three equations in four unknowns. We need one more equation to identify $S(0)$. The long-run restriction of Equation (12) provides that additional equation.

Using equations (10), (20) and (24),

$$\begin{bmatrix} S_{11}(L) & S_{12}(L) \\ S_{21}(L) & S_{22}(L) \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{21}(L) & C_{22}(L) \end{bmatrix} \begin{bmatrix} s_{11}(0) & s_{12}(0) \\ s_{21}(0) & s_{22}(0) \end{bmatrix} \quad (29)$$

or

$$S(L) = C(L)S(0) \quad (30)$$

Application of the long-run restriction of Equation (12) replaces $S_{12}(L)$ in the left-hand side of Equation (29) by zero and makes $S(L)$ lower triangular. Consequently, we obtain an additional equation:

$$C_{11}(L)s_{12}(0) + C_{12}(L)s_{22}(0) = 0 \quad (31)$$

Thus, equations (26), (27), (28), and (31) comprise the set of four equations that can be used to identify four coefficients of $S(0)$. Once $S(0)$ is estimated, the entire $\{v_{1t}\}$ and $\{v_{2t}\}$ sequences can be identified using Equation (25), $v_t = e_t S(0)^{-1}$, hence $v_{t-i} = e_{t-i} S(0)^{-1}$. Also, the elements of $S(L)$, namely $S_{11}(L)$, $S_{21}(L)$ and $S_{22}(L)$ can be recovered using Equation (29). For instance, $S_{11}(L) = C_{11}(L)s_{11}(0) + C_{12}(L)s_{21}(0)$.

Upon estimation of $S(0)$ and $S(L)$, we conduct historical decomposition of $\{\Delta y_t\}$. In order to construct a series that reflects only the effects of supply disturbances, we set all realizations of $\{v_{2t}\}$ to zero. Accordingly, the supply component of the growth rate in $\{y_t\}$ is given by

¹⁵ $S(0)$ has a straight forward interpretation as the Cholesky factor of the variance-covariance matrix of the vector of reduced form disturbances (Lucas, 1990). Let the variance-covariance matrix of the vector of reduced form disturbances be Ω . Then, $\Omega = E(e_t e_t') = S(0)E(v_t v_t')S'(0) = S(0)S'(0)$, since $E(v_t v_t') = I$. Hence $S(0)$ is identified.

$$\Delta y_t^{Supply} = S_{11}(L)v_{1t} \quad (32)$$

Similarly a series reflecting only the effects of demand disturbances is obtained by setting all realizations of $\{v_{1t}\}$ to zero. Accordingly, the demand component of the growth rate in $\{y_t\}$ is given by

$$\Delta y_t^{Demand} = S_{12}(L)v_{2t} \quad (33)$$

From Equation (32), the level of output due to the supply disturbance $\{Y_t^{Supply}\}$ is generated by an appropriate transformation of $\{\Delta y_t^{Supply}\}$. First, $\{y_t^{Supply}\}$ is generated by taking a starting value of $\{y_{t-1}^{Actual}\}$. Then, $\{Y_t^{Supply}\}$ is obtained by taking antilog of $\{y_t^{Supply}\}$. The level of output due to the demand disturbance $\{Y_t^{Demand}\}$ is generated in either of the two ways: first, $\{\Delta y_t^{Demand}\}$ is computed using Equation (33), then $\{y_t^{Demand}\}$ is obtained by initiating the series with $\{y_{t-1}^{Actual}\}$, correspondingly $\{Y_t^{Demand}\}$ is obtained by taking antilog of $\{y_t^{Demand}\}$; alternatively, by $\{\Delta y_t^{Demand}\} = \{\Delta y_t^{Actual}\} - \{\Delta y_t^{Supply}\}$. Then $\{y_t^{Demand}\}$ and $\{Y_t^{Demand}\}$ are obtained successively. Choice of $\{y_{t-1}^{Actual}\}$ as an initial point is somewhat arbitrary.

In the same way, we generate the level of tax rates due to the supply disturbance $\{\tau_t^{Supply}\}$ and the level of tax rates due to the demand disturbance $\{\tau_t^{Demand}\}$ after computing

$$z_t^{Supply} = S_{21}(L)v_{1t} \quad (34)$$

and

$$z_t^{Demand} = S_{22}(L)v_{2t} \quad (35)$$

IV. Data

The data are obtained from the National Income and Product Accounts (NIPA) collected by the Bureau of Economic Analysis for the period from 1978:I to 2006:III. Focusing our research on this particular time period enables us to analyze fully the impact of recent tax changes on the U.S. economy's output. Average tax rates on the labor income (τ_t) are calculated following Jones (2002), and Mendoza *et al.* (1994). The data are the quarterly U.S. observations on the Real Gross Domestic Product (Y_t), Personal Current Taxes of Federal Government in billions of dollars (FIT_t), Personal Current Taxes of State and Local Government in billions of dollars (SIT_t), Wage and Salary Disbursements in billions of dollars (W_t), Proprietor's Income with Inventory Valuation and Capital Consumption Adjustment in billions of dollars (PRI_t), Rental Income of Persons with Capital Consumption Adjustment in billions of dollars (RI_t), Personal Interest Income (PII_t), and Personal Dividend Income (PDI_t). Real Gross Domestic Product (Y_t) is obtained as Seasonally Adjusted Quantity Indexes measured at the base year 2000. Personal Current Taxes of Federal Government (FIT_t) include the dividend tax for 1933-34, and the automobile use tax for 1942-46. All other series are expressed in billions of dollars and are seasonally adjusted at annual rates.

Average tax rates on labor income are calculated using the

$\tau_t = \frac{FIT_t + SIT_t}{W_t + PRI_t + RI_t + PII_t + PDI_t}$ expression. The denominator of this expression comprises

Labor Income (LI_t) and Capital Income (CI_t), where $LI_t = W_t + PRI_t / 2$ and $CI_t = PRI_t / 2 + RI_t + PII_t + PDI_t$. The division of Proprietor's Income into labor and capital income is somewhat arbitrary (Joines, 1981).

For the purpose of cross-verification, the data on Personal Income (PI_t) and Personal Current Taxes (PCT_t) are also obtained. An *ad hoc* measure of the labor income tax rates (τ_t^a) is calculated taking the ratio of PCT_t and PI_t . The correlation coefficient between τ_t and τ_t^a is found to be more than 98 percent.¹⁶ In the following section, Real GDP in logarithmic scale is denoted by y i.e., $y_t = \log(Y_t)$, and the first difference of labor income tax rates is denoted by z i.e. $z_t = \tau_t - \tau_{t-1}$.

V. Results and Analysis

A. Unit-Root Test

The initial step in analyzing any time-series data necessitates stationarity testing of each individual time-series. The objective of stationarity tests is to determine the degree of integration of all time-series data used in any subsequent econometric modeling. This determination is made upon establishing the number of unit roots in all data series under empirical investigation. Only stationary time-series data can be used in any subsequent econometric modeling. Numerous unit-root tests are outlined in econometric literature. The most commonly used unit-root tests are the Augmented Dickey-Fuller (Fuller, 1976), Dickey and Fuller (1979) (ADF) test and the Phillips-Perron (1988) (PP) test. We used initially the ADF test to examine the presence of unit roots (non-stationarity) in the series of real GDP (Y_t), the natural logarithm of real GDP (y_t), the first difference of natural logarithm of real GDP (Δy_t), the average tax rate (τ_t) and the first difference of the average tax rate (z_t). The first difference of natural logarithm of real GDP (Δy_t) is the growth rate of real GDP.

Table 1 reports the ADF test results at the 5 percent significance level. The Schwarz's information criterion is used to determine the lag length p in each series. The first row of the table indicates the selected lag lengths of each series with 'no trend' and 'trend' specifications. The critical value (t -critical) corresponding to a test with 5 percent level of significance changes depending on model specifications of each series (even though the number of observations remains the same).¹⁷

¹⁶ The NIPA data source on each variable stated above is as follows, Y - Table 1.1.3: line 1, FIT - Table 3.2: line 3, SIT - Table 3.3: line 3, W - Table 2.1: line 3, PRI - Table 2.1: line 9, RI - Table 2.1: line 12, PII - Table 2.1: line 14, PDI - Table 2.1: line 15, PI - Table 2.1: line 1, PCT - Table 2.1: line 25.

¹⁷ Appropriate critical values depend on both the model specification and the sample size.

Table 1: Augmented Dickey-Fuller (ADF) Test Results^a of Output Series

	Y		γ		Δy	
	No Trend	Trend	No Trend	Trend	No Trend	Trend
p	2	2	2	2	1	1
a_0	-0.0285 (-0.1578) ^b	1.8649 (2.5830)	0.0003 (0.0269)	0.3909 (3.5159)	0.0041 (4.0876)	0.0034 (2.3289)
a_2	---	0.0266 (2.7038)	---	0.0008 (3.5290)	---	0.00001 (0.6317)
γ	0.0045 (1.8456)	-0.0397 (-2.4032)	0.0009 (0.3485)	-0.1000 (-3.4853)	-0.5757 (-5.4324)	-0.5798 (-5.4461)
$\gamma+1$	1.0045 (1.8456)	0.9603 (-2.4032)	1.0009 (0.3485)	0.9000 (-3.4853)	0.4243 (-5.4324)	0.4202 (-5.4461)
ADF Test Statistic	1.8456	-2.4032	0.3485	-3.4853*	-5.4324*	-5.4460*
t -critical (5% level)	-2.8874	-3.4504	-2.8874	-3.4504	-2.8874	-3.4504
Observations	112	112	112	112	112	112

Note: Y , y and Δy represent real GDP, the natural logarithm of real GDP and the first difference of real GDP (i.e. the growth rate of real GDP), respectively.

^a All test regressors include a constant.

^b t -statistics are in parentheses.

* Reject the null hypothesis of the presence of unit root at 5 percent significance level.

ADF test statistics show that we fail to reject the null of the presence of a unit root for the series of real GDP (Y_t) with both ‘no trend’ and ‘trend’ specifications. Additionally, test results reject the null hypothesis of the presence of a unit root in the series of the natural logarithm of real GDP (y_t) with ‘trend’, and the first difference of the natural logarithm of real GDP (Δy_t) under both ‘no trend’ and ‘trend’ assumptions. Therefore, real GDP (Y_t) is non-stationary and the growth rate of real GDP between two consecutive quarters (Δy_t) is trend stationary.

We also deployed the ADF analysis to test for the presence of a unit root in tax rates in *level* (τ_t), and the first difference of tax rates (z_t). Although these tabulated results are not reported, they are available upon request. They indicate that average tax rate (τ_t) is non-stationary, but its first difference (z_t) is stationary. In order to test further the robustness of our unit-root tests, we subjected all our time-series data to two additional tests, the Phillips-Perron (1988) (PP) test and

the Zivot-Andrews (1992) (ZA) test. The PP tests yielded the same stationarity conclusions for our time-series data as those obtained by using the ADF tests. The ZA test supported stationarity conclusions reached by both the ADF and the PP tests. Due to space constraint, the individual PP and AZ test results are not reported. However, they will be made available upon request to interested readers.

B. Estimation

Having identified two stationary processes, $\{\Delta y_t\}$ and $\{z_t\}$, we use the AIC and the SBC methods to select the lag order p in the reduced form representations of the VAR system (corresponding to Equation (19) in Section III). We obtain the AIC and the SBC numbers of each series for a lag length of 2 through 8 quarters. Table 2 shows that the minimum AIC occurs at a lag length of 3 for both $\{\Delta y_t\}$ and $\{z_t\}$. The minimum SBC occurs at a lag length of 3 for $\{\Delta y_t\}$ and a lag length of 1 for $\{z_t\}$. We choose the lag length of 3.

Table 2: Lag Length Selection

Lag Length	AIC		SBC	
	Δy	z	Δy	z
2	-7.0012	-7.7582	-6.9041	-7.6611*
3	-7.0974*	-7.0974*	-6.9266**	-7.5976
4	-6.9586	-7.7462	-6.7622	-7.5499
5	-6.9231	-7.7016	-6.6762	-7.4546
6	-6.9052	-7.6945	-6.6072	-7.3964
7	-6.8732	-7.6556	-6.5235	-7.3059
8	-6.8498	-7.6429	-6.4478	-7.2409

* AIC and SC are minimum.

Since both equations in the reduced form VAR have the same regressors, and each regressor is independent of disturbances, then each equation can be estimated separately using OLS. Coefficient estimates of an unrestricted reduced form VAR are given in Table 3. Reduced form coefficients, also known as *impact multipliers*, measure the response of endogenous variables to changes in the predetermined (lagged) variables. All three coefficients of lagged z in Δy equation are negative, indicating that a tax cut in the past causes higher output growth. The coefficient of Δy_{t-1} in z equation is also negative, indicating that a higher output-growth rate in the last quarter causes reduced current tax rate.

Table 3: Coefficient Estimates of Unrestricted Reduced Form VAR

Regressors	(Δy_t)	(z_t)
Δy_{t-1}	0.4326 (4.4896) ^a	-0.0647 (-0.9979)
Δy_{t-2}	0.2750 (2.7369)	0.0544 (0.8045)
Δy_{t-3}	0.0839 (0.9265)	0.0505 (0.8299)
z_{t-1}	-0.0418 (-0.2971)	-0.4330 (-4.5736)
z_{t-2}	-0.0715 (-0.4784)	0.1740 (1.7302)
z_{t-3}	-0.1931 (-1.3777)	0.2276 (2.4132)
$Var(e_{it})$	0.0005	0.0002

^a t -statistics are in parentheses.

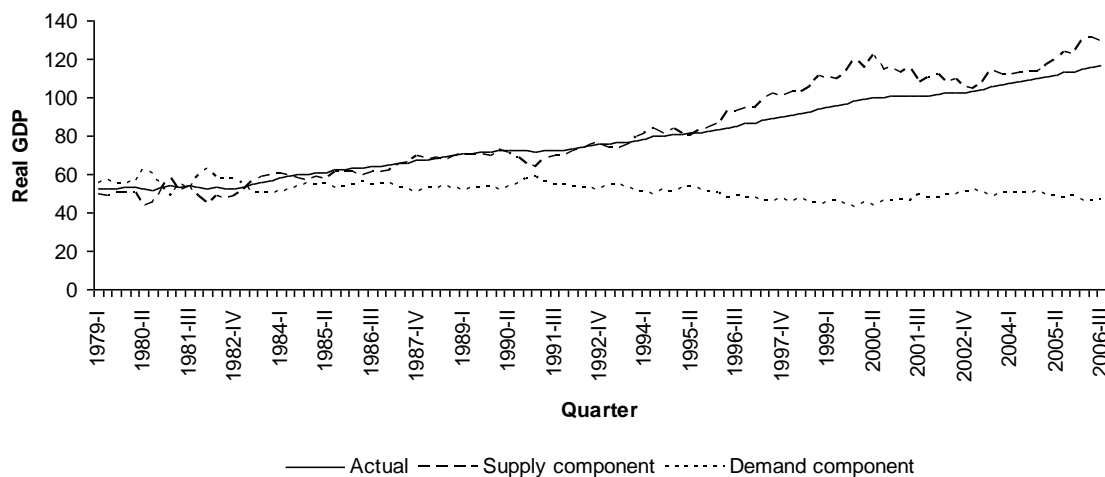
C. Decomposition of Output

Estimation of the joint process of $\{\Delta y_t\}$ and $\{z_t\}$ along with the long-run identifying restriction entails a recovery of the unobserved supply and demand disturbances (corresponding to Equation (25) in Section III). The ‘supply component’ and the ‘demand component’ of real GDP and the tax rates in level are recovered by an appropriate transformation of the series generated by Equation (32) to Equation (35). Figure 1 presents the decomposition of the actual real GDP into its supply and demand components in level.¹⁸ The supply component of the real GDP is the time

¹⁸ Our sample ranges from 1978:I to 2006:III. Blanchard-Quah technique yields the series $\{\Delta y_t^{Supply}\}$. From this term we generate the series $\{y_t^{Supply}\}$ by taking y_{1978IV}^{Actual} as the initial value (since the first four observations are lost due to taking the first difference of $\{y_t\}$ and choosing the lag length of 3. By appropriate scaling (taking antilog) of $\{y_t^{Supply}\}$, we recover the series $\{Y_t^{Supply}\}$. In order to recover the series $\{Y_t^{Demand}\}$, we proceed by generating the series $\{\Delta y_t^{Demand}\} = \{\Delta y_t^{Actual}\} - \{\Delta y_t^{Supply}\}$. From this equation we generate $\{y_t^{Demand}\}$ in the same way as we do for $\{y_t^{Supply}\}$. An appropriate scaling of $\{y_t^{Demand}\}$ yields $\{Y_t^{Demand}\}$. Figure 2 depicts the time series plots for $\{Y_t^{Actual}\}$, $\{Y_t^{Supply}\}$ and $\{Y_t^{Demand}\}$. A visual inspection indicates that $\{Y_t^{Supply}\}$ is non-stationary and $\{Y_t^{Demand}\}$ is stationary.

path of the real GDP that would have been obtained in the absence of a demand disturbance. The supply component is obtained by setting the demand innovations at zero. By the same token, the demand component of the real GDP is the time path of the real GDP that would have been obtained in the absence of a supply disturbance. The latter can be achieved in two ways: (a) by setting the supply innovations at zero, or (b) by taking the difference between $\{\Delta y_t^{Actual}\}$ and $\{\Delta y_t^{Supply}\}$. Figure 1 follows (b). However, either approach yields almost identical results. The time path of the supply component and the demand component of the real GDP are consistent with the identifying restriction that the demand disturbance has no long-run effect on real GDP. The demand component of the real GDP in level (Y_t^{Demand}) is mean reverting (stationary) whereas the supply component of the real GDP (Y_t^{Supply}) exhibits a trend (non-stationary). A close look at the supply component of output reveals that the trend is not deterministic.¹⁹ It exhibits a higher growth in the 1990s compared to the growth in the 1980s. Periods for which the actual real GDP falls short of its supply component are characterized by the lack of sufficient demand. Thus the supply component of output can also be viewed as the level of the ‘potential output’. The opposite interpretation holds when the actual output is above the supply component. These are the periods of an overheated economy with an increasing demand pressure. Figure 1 indicates that after the mid-1990s, the U.S. economy has operated below its potential. This is the period when either the demand-side stimulus due to a tax cut is not significant or there is a negative demand effect due to a tax hike. In fact, the U.S. experienced a tax increase under the Deficit Reduction Act of 1993.

Figure 1: Decomposition of Actual Real GDP into Supply and Demand Components



¹⁹ Appendix A reports the ADF test results.

D. Business Cycles

Commonly the supply component of output is considered as ‘trend’, that part of an output that would be realized under perfectly flexible prices. All temporary deviations of the actual output from its trend due to demand disturbances are ‘business cycles’. Under the assumption of perfectly flexible prices, the trend is deterministic. Nelson and Plosser (1982) challenged the assumption of a constant trend over time. In real life, prices are imperfectly flexible. The presence of nominal rigidities in prices may change the long-run adjustment mechanism in the output. A time-varying trend is called the stochastic trend. Results in our sample indicate that the supply component of the output exhibits a stochastic trend. Therefore, both the supply and the demand disturbances contribute to business cycles.

Figure 2: Deviations of Actual Real GDP from Supply Component of Real GDP

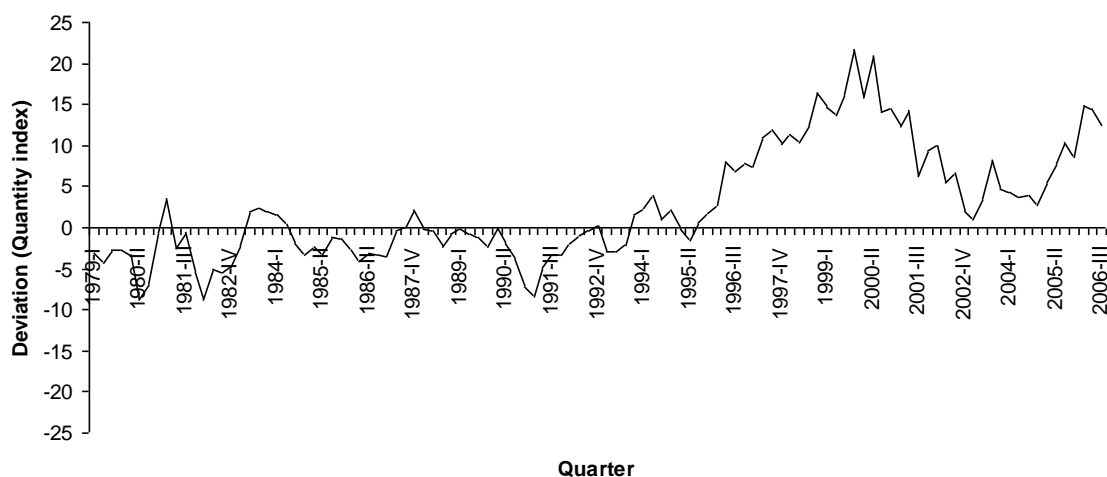


Figure 2 presents deviations of the actual output from its supply component *in levels* ($Y_t^{Supply} - Y_t^{Actual}$). However, identifying separately the effects of a stochastic trend and business cycles on these deviations is difficult. Tax cuts contribute to output deviations from the long-run trend through both the supply and the demand channels. Our sample indicates a marked difference in deviations in two different phases. Deviations became more volatile after mid-1990s. This is mainly due to the volatility in the supply component of output.

It is difficult to identify business cycles and the trend separately because of the stochastic nature of the supply component of output. However, it is important to analyze the movements in the demand component of output over time because business cycles are primarily driven by the demand side factors, such as the consumption effect of a tax cut.

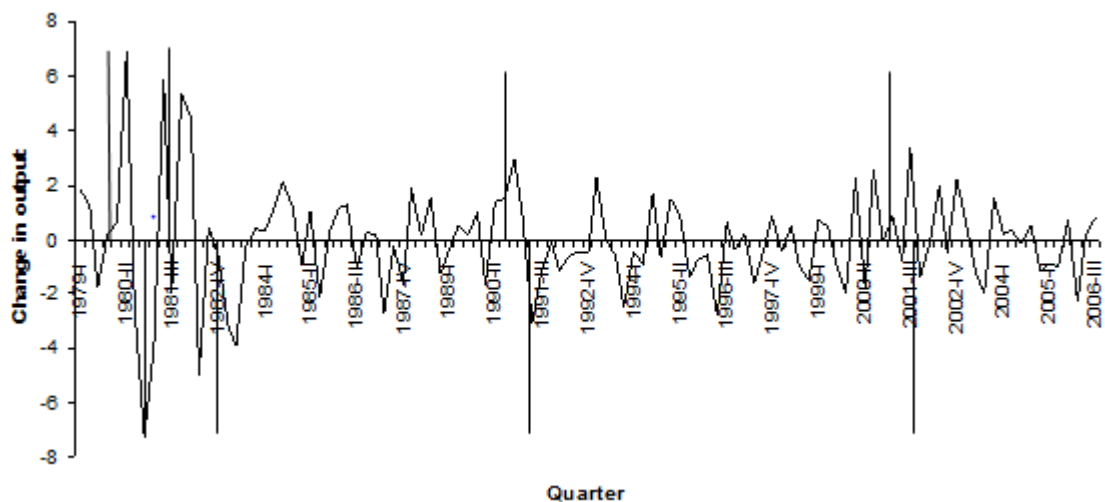
Figure 3: Output Fluctuations Due to Demand

Figure 3 magnifies output fluctuations in the short run by taking the difference in the demand component of output in two consecutive quarters. The peaks and troughs of the demand component of output match closely with the NBER peaks and troughs.²⁰ The NBER peaks and troughs are marked by vertical lines. The recession of 1980 deserves a special mention. Results of our study indicate that historically large fluctuations in the U.S. output are mainly demand driven.

E. Decomposition of Tax Rates

Figure 4 shows the decomposition of the actual tax rate *in level* into its supply and demand components. The time path of the supply component of the tax rate is obtained by setting all demand disturbances at zero. The time path of the demand component of the tax rate (τ_t^{Demand}) is obtained by generating the series $\{z_t^{Demand}\} = \{z_t^{Actual}\} - \{z_t^{Supply}\}$, then $\{\tau_t^{Demand}\}$ is obtained by taking τ_{1978IV}^{Actual} as the initial value. Since there is no restriction on the short-run and long-run effects of the supply and the demand disturbances on the tax rate, some implications of this relationship can be derived informally.

²⁰ The NBER peaks and troughs as reported in <http://www.nber.org/cycles/cyclesmain.html> after 1979 are as follows: Peak – 1980:1, 1981:3, 1990:3, and 2001:1; Trough – 1980:3, 1982:4, 1991:1, and 2001:4.

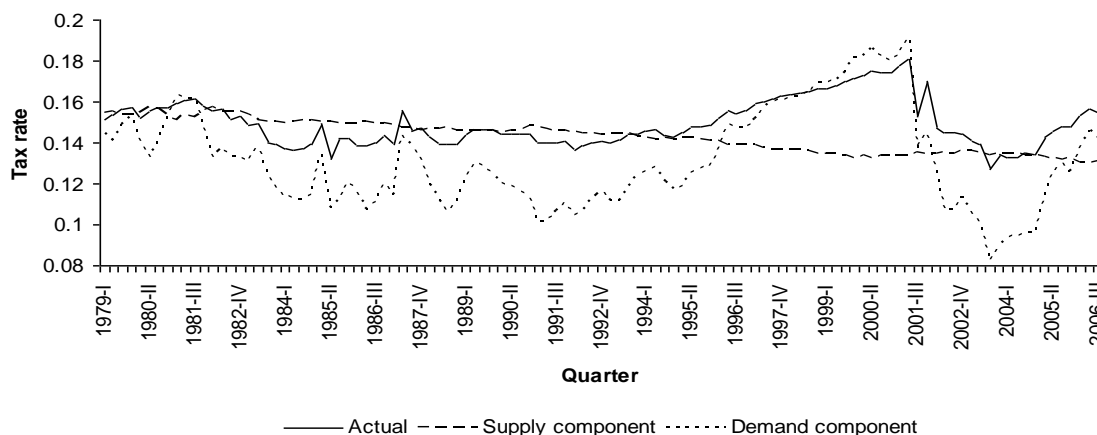
Figure 4: Decomposition of Actual Tax Rate into Supply and Demand Components

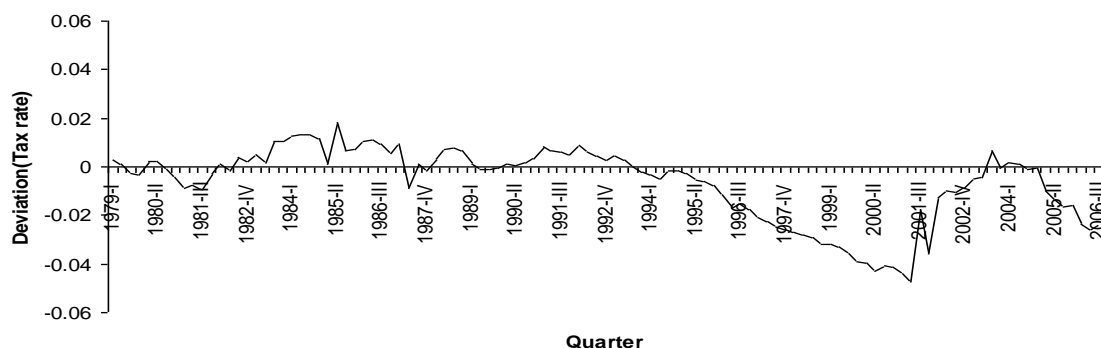
Figure 4 indicates that the time series of the actual tax rate and its demand component seem to move together. The correlation coefficient between these variables is 0.87. This result suggests that tax policies are mainly influenced by the demand disturbances. Table 4 reports the standard deviation and the mean of the times series of the actual tax rate, the supply component of the tax rate and the demand component of the tax rate, respectively. Clearly, the variation in the demand component is higher than the variation in the supply component by more than 97 percent. At the same time, it is clear that the variations in the demand component account for almost all variation in the actual tax rates. The supply component of the tax rate exhibits a slightly declining trend over time, averaging approximately 15 percent. This trend is deterministic. The declining trend along with a low standard deviation (0.0077) indicates that the demand disturbances of the tax rate changes are reduced slowly over time. Therefore, tax policies are not effective. Since the demand component of tax rate has a unit root, and it is difference stationary (not reported), any change in the tax policy due to demand disturbance seems to have a long-run effect on future tax rates.

Table 4: Contribution of Supply and Demand Disturbances in Tax Policy

	Actual	Supply	Demand
Standard Deviation	0.0133	0.0077	0.0152
Mean	0.1495	0.1430	0.1593

Figure 5 shows the time path of the deviations of the actual tax rate from its supply component ($\tau_t^{Supply} - \tau_t^{Actual}$). Since, $\{\tau_t^{Supply}\}$ exhibits a deterministic trend, any such variations are due to the demand disturbance only. Also when figures 2 and 5 are compared, it is evident that the demand components of the output and the tax rate are near mirror images of each other. This result is consistent with the pattern of the relationship between the two variables in the short run.

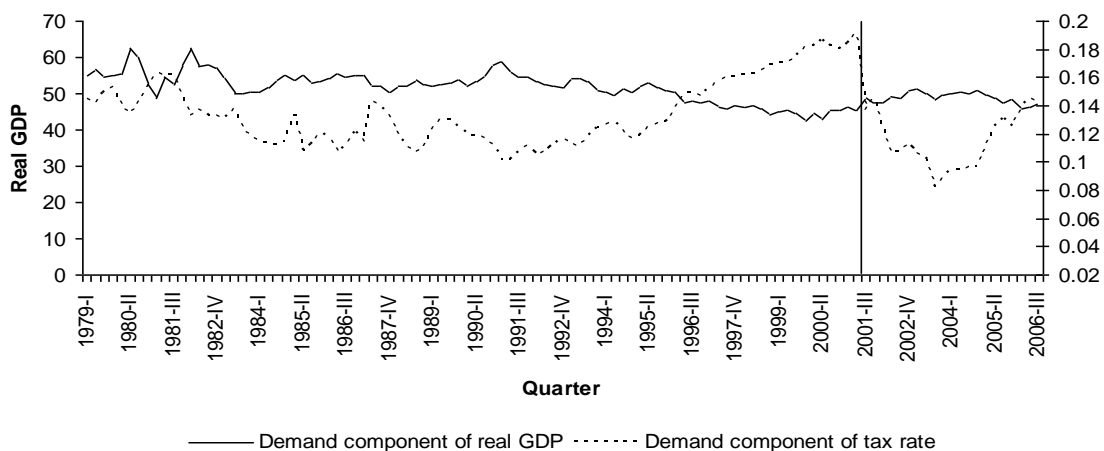
Figure 5: Deviations of Actual Tax Rate from Supply Component of Tax Rate



F. Demand Components of the Output and the Tax Rate

Since it is clear from the above analysis that the demand disturbance has a dominant influence on tax rates, it would certainly be of interest to examine the patterns of the short-run movements in the demand components of output and the tax rates. This objective is accomplished in Figure 6. This figure presents the time paths of the demand components of the real GDP (measured along the vertical axis on the left) and the tax rate (measured along the vertical axis on the right) for the time period 1979:I-2006:III. The correlation coefficient of -0.78 indicates a significant negative relationship between the two time series. However, the negative strength of this relationship declines after the third quarter of 2001 (marked by a vertical line at 2001:III). The correlation coefficient between the demand component of output and the tax rates during 2001:III-2004:IV is -0.43. This coefficient is -0.79 during 1979:I-2001:II. This result indicates a behavioral change in the pattern of the relationship between the tax rate and output in the short run after the third quarter of 2001. This result also provides a plausible explanation for the relative ineffectiveness of the first 2001 Bush’s tax cut and the need to reduce taxes further in 2003.

Figure 6: Movements of Demand Components of Real GDP and Tax Rate



— Demand component of real GDP - - - - - Demand component of tax rate

G. Relative Contributions of Supply and Demand Disturbances

G.1. Variance Decomposition

The next obvious step in analyzing the impact of tax changes on the real GDP in the U.S. necessitates undertaking a statistical assessment of the relative contributions of the supply and the demand disturbances on the U.S. output. This objective can be accomplished by computing the variance decompositions of the forecast error for the growth rate of output (Δy_t) and the change in tax rates (z_t) at various time horizons. The forecast error variance decompositions provide estimates of proportions of movements in $\{\Delta y_t\}$ due to the supply shocks in $\{v_{1t}\}$ and the demand shocks in $\{v_{2t}\}$ at various time horizons. The proportions of movements in $\{z_t\}$ due to each of these two shocks at different time horizons can also be measured using this method. Our long-run identification restriction on the demand disturbance has a connotation for variance decompositions, namely the contributions of the supply disturbance to the variance of the output movements tend to hundred percent as the horizon increases.

Variance decompositions of the two endogenous variables are given in tables 5 and 6. Numbers are computed as follows. First, the k -quarter, $k = 1, 2, \dots, 40$, ahead of forecast errors in Δy_t and z_t are calculated by the difference between the observed value of the variable and its forecast. A reduced form VAR of Equation (19) is used for these computations. The resulting forecast error is due to both the supply and the demand disturbances because the reduced form disturbances are composites of structural disturbances. Second, structural disturbances are identified in the forecast error variance using Equation (25). Third, the percentages of the forecast error variance due to the supply and demand disturbances are obtained against each k . For instance, the percentage of one-step ahead forecast error variance due to supply disturbance in the growth rate of output is 96.0972. In both tables 5 and 6, the numbers under the second and the third columns for each k add up to hundred.

Table 5: Variance Decomposition of Growth Rate of Output

Percentage of Variance Due to Supply and Demand Disturbances		
Quarters	Supply	Demand
1	96.0972	3.9028
5	97.1001	2.8999
10	97.2622	2.7378
15	97.2769	2.7231
20	97.2788	2.7212
25	97.2791	2.7209
40	97.2792	2.7208

Table 6: Variance Decomposition of Change in Tax Rates

Percentage of Variance Due to Supply and Demand Disturbances		
Quarters	Supply	Demand
1	2.2875	97.7125
5	1.8541	98.1459
10	2.0766	97.9234
15	2.1413	97.8587
20	2.1538	97.8462
25	2.1561	97.8439
40	2.1566	97.8434

Several important conclusions about the relative importance of the supply and demand disturbances on the U.S. economy's output emerge from tables 5 and 6. First, the relative contribution of the supply disturbance to output is very significant even in the shorter run. It amounts to 96 percent at one quarter horizon. Second, the effects of the demand disturbance on output die out at a faster pace than the effects of the supply disturbance increase over time. For instance, the proportion of the forecast error variance due to the demand disturbance decreases by thirty percent from one to forty quarter horizon whereas the proportion of the forecast error variance due to supply disturbance increases by one percent during the same time span. Third, the effect of the demand disturbance on tax rates starts declining gradually after the fifth quarter. However, it remains high at all horizons.

G.2 Impulse Response Functions

The dynamic effects of structural disturbances on the growth rate of output (Δy_t) and the changes in tax rate (z_t) can be analyzed most effectively by impulse response functions. These functions are illustrated in figures 7 and 8. The vertical axis in figures 7 and 8 denote the growth rate of output while the horizontal axes denote time in quarters. Figure 7 depicts the time path Δy_t due to a one standard deviation shock on the supply disturbance v_{1t} . The growth rate of output (also level of output) cumulates steadily over time. The peak response is approximately four times the initial effect, and it takes place after twenty two quarters. This effect dies out and stabilizes eventually at a growth rate of 3.2 percent. This result indicates that the supply disturbance has a permanent effect on the output in the long run. Figure 8 depicts the time path Δy_t due to a one standard deviation shock on the demand disturbance v_{2t} . For expositional purpose, Figure 8 has an amplified vertical axis. The demand disturbance has a hump shaped effect on Δy_t . This effect peaks during the third quarter. It decays slightly between the third and fourth quarters. It rises again during the fifth quarter, and gradually declines thereafter. Dynamic effects of output changes to demand disturbances are consistent with the traditional adjustment view that assumes that the

initial demand disturbance is followed by dynamic adjustments in prices and wages. These adjustments lead the economy back to its original steady-state value.

Figure 7: Response of Growth Rate of Output to Supply Shock

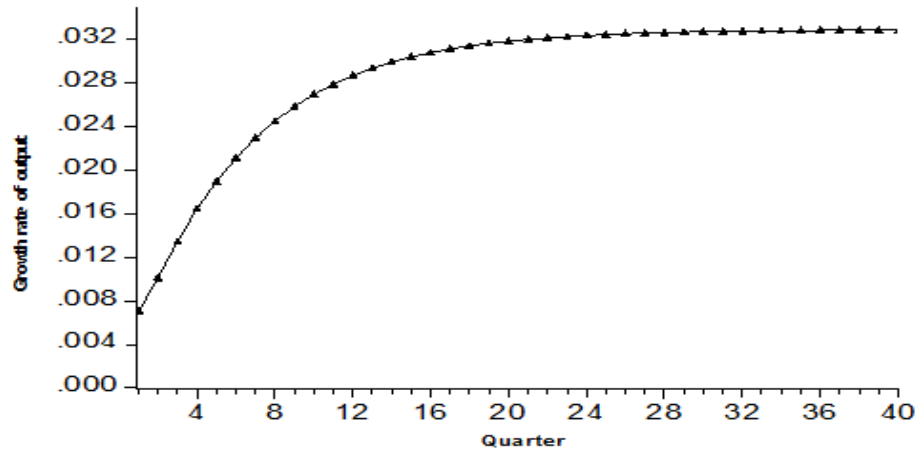
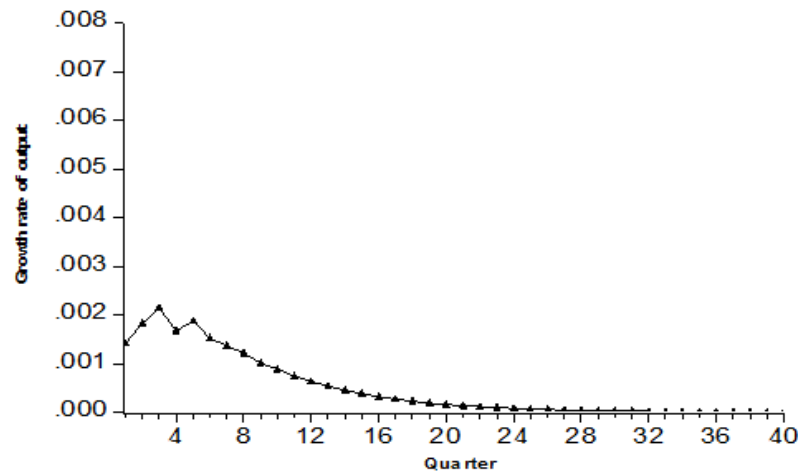


Figure 8: Response of Growth Rate of Output to Demand Shock



Figures 9 and 10 present dynamic effects of the supply and the demand disturbances respectively, on changes in the tax rate (z_t). In Figure 9, a positive supply disturbance decreases the tax rate slightly initially. This effect peaks up after the second quarter and it stabilizes approximately the same time as the supply effect of output stabilizes (after twenty two quarters).

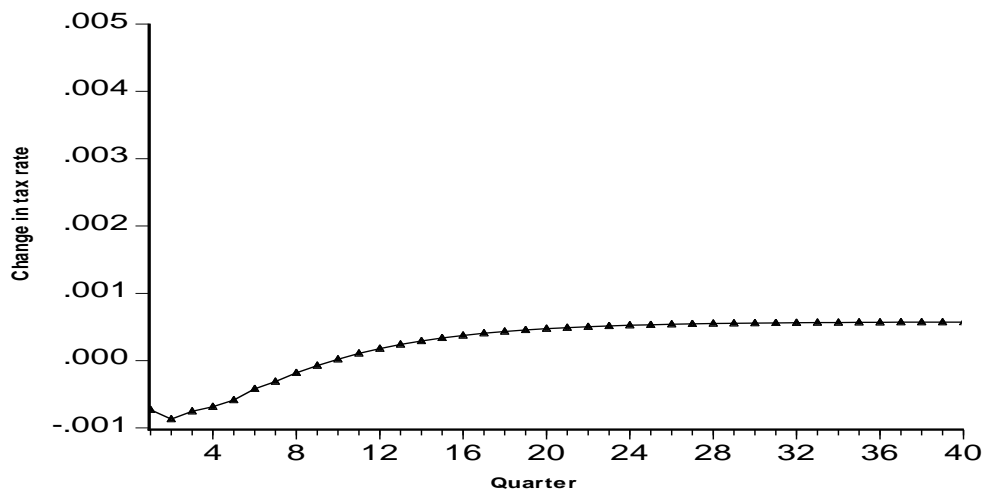
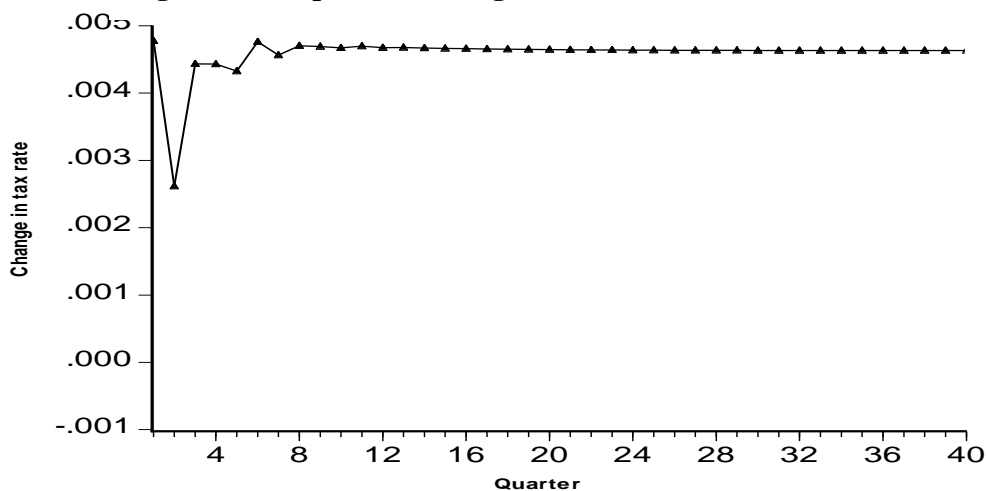
Figure 9: Response of Change in Tax Rate to Supply Shock**Figure 10: Response of Change in Tax Rate to Demand Shock**

Figure 10 suggests that an exogenous shock to the demand disturbance results in a steep drop in the tax rate in the second quarter, followed by a steep rise in the third quarter. The tax rate returns to its original level after eight quarters.

Conclusion

This study provides new empirical evidence on the effects of a change in the labor income tax on the U.S. economy's output. A SVAR model comprising the real output growth rate and the labor income tax rate is developed to achieve this objective. The novelty of the present research is its extensive analysis of both the supply-side and the demand-side channels through which labor income tax affects real output. The first channel, namely the supply-side effect, is based on the premise that a tax cut provides higher work incentives, thereby increasing the aggregate labor supply in the economy. This increase in the labor supply leads to a higher aggregate output. Thus

the supply-side effect operates through the aggregate production function. Theoretically, the supply-side impact of a labor income tax-cut is permanent. It can be viewed as the long run, permanent effect on an economy's output. However, the assertion that the labor income tax-cut contributes permanently to economic growth, although undoubtedly extremely important, is thus far only a theoretical possibility. As such, it is not universally accepted in economic literature. Empirical evidence on this key economic issue is also mixed and far from satisfactory. The present research provides new empirical evidence on this issue.

The second channel through which a labor income tax cut affects the aggregate output, namely the demand-side effect, is based on the Keynesian theory of the aggregate demand. A tax cut results in higher disposable income, thereby increasing the aggregate consumption and the aggregate demand. The demand-side effect of a tax cut is based on the premise that demand changes determine output only in the short run. This channel of the tax-cut impact on the aggregate output is well documented in economic literature. The impact of a tax cut on consumption expenditures may be lesser if consumers maximize their utility subject to their life time budget constraint. If consumers anticipate that taxes will have to be increased to finance current budget deficit, then the current tax cut may not cause an increase in the current consumption and output (Ricardian equivalence). A tax cut will also not increase consumption unless it is perceived to be a permanent tax cut. However, most empirical studies do not support the Ricardian equivalence hypothesis. Given the preceding theoretical controversies and regardless of the channel of transmission, tax cuts may have an ambiguous effect on output.²¹

Empirical research can help to resolve the above outlined theoretical controversies. The present paper provides new empirical evidence on this issue. As mentioned above, this objective is accomplished by constructing a two-variable (output growth and labor tax rate) SVAR model that investigates the effects of an exogenous shock of the tax policy on the aggregate output. The Blanchard-Quah decomposition technique is used in our data analyses. We define the demand and the supply disturbances according to their assumed theoretical impact on the output dynamics. The demand disturbance is believed to have a temporary effect on the output, whereas the supply disturbance affects output permanently. Both endogenous variables in the VAR system are affected by the two disturbances along with their own current and lagged values. An exogenous shock to either of the disturbances affects both endogenous variables simultaneously.

Given the above stated conditions, we generate a non-stationary permanent component and a stationary temporary component of output. Variance decomposition and impulse response functions techniques are deployed to analyze the supply and the demand effects of labor income tax cuts on the aggregate output. These analyses provide new startling evidence on the impact of tax cuts on the U.S. economy. Variance decomposition and impulse response tests indicate that the contribution of the supply disturbances to output is very significant even in the short run. The supply-side effect on the output reaches its maximum after approximately five to six years. We also conclude that demand disturbances cause a substantial contribution to output fluctuations in the short run. The demand-side effect disappears after approximately the same time as the supply-side effect reaches its peak. Consequently, it would appear that labor income tax cuts impact positively the U.S. economy's output not only in the long run, but also in the short run. When analyzing the effects of the supply and the demand disturbances on the tax rates, our research indicates that most of the fluctuations in the tax rate are due to demand disturbances.

²¹ On the contrary, most economists are in agreement on the effects of capital gains taxation on an economy. Harberger (1966), Chamley (1981), Jorgenson and Yun (1990), and Lucas (1990) argue strongly against taxing any form of income from capital.

The results of our research have important implications for the use and the effectiveness of the aggregate demand and aggregate supply fiscal policies in the U.S. Our research indicates that the supply-side fiscal policy is more effective in promoting economic growth than the fiscal policy that focuses on stimulating the aggregate demand. It appears that reducing labor income taxes affects the U.S. economy's output not only in the long run, but also in the short run. At the same time, it is evident that the traditional Keynesian side effect of tax policies primarily impacts the U.S. economy in the short run. Given these results, it is fair to conclude that reducing the labor income tax may be the most appropriate economic policy to implement for achieving economic growth in the U.S. One additional general advantage of relying on the supply-side economic policies for the purposes of economic stabilization is the fact that such policies, unlike the traditional Keynesian aggregate demand policies, do not have an inflationary bias.

References

- Blanchard, Olivier, and Roberto Perotti.** 2002. "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output." *The Quarterly Journal of Economics*, 117(4): 1329-68.
- Blanchard, Olivier Jean, and Danny Quah.** 1989. "The Dynamic Effects of Aggregate Demand and Supply Disturbances." *American Economic Review*, 79(4): 655-73.
- Blanchard, Olivier.** 2006. *Macroeconomics*, 4th ed., New York: Prentice Hall.
- Bohanon, Cecil E., and T. Norman Van Cott.** 1986. "Labor Supply and Tax Rates: Comment." *American Economic Review*, 76(1): 277-9.
- Bureau of Economic Analysis** (<http://www.bea.gov/national/nipaweb/>)
- Campbell, John Y., and N. Gregory Mankiw.** 1987. "Are Output Fluctuations Transitory?" *The Quarterly Journal of Economics*, 102(4): 857-80.
- Chamley, Christophe.** 1981. "The Welfare Cost of Capital Income Taxation in a Growing Economy." *Journal of Political Economy*, 89(3): 468-96.
- Clarida, Richard, and Joe Prendergast.** 1999. "Fiscal Stance and the Real Exchange: Some Empirical Estimates." NBER Working Paper No. 7077.
- Claus, Iris.** 1999. "Estimating Potential Output for New Zealand: A Structural VAR Approach." Federal Reserve Bank of New Zealand Discussion Paper 2000/03.
- Dickey, David A., and Wayne A. Fuller.** 1979. "Distribution of the Estimators for Autoregressive Time Series with Unit Root." *Journal of American Statistical Association*, 74(366a): 427-31.
- Edelberg, Wendy, Martin Eichenbaum, and Jonas D. M. Fisher.** 1999. "Understanding the Effects of a Shock to Government Purchases." *Review of Economic Dynamics*, 2(1): 166-206.
- Enders, Walter.** 2003. *Applied Econometric Time Series*, 2nd ed. New York: John Wiley and Sons.
- Enders, Walter, and Bong-Soo Lee.** 1997. "Accounting for Real and Nominal Exchange Rate Movements in the Post-Bretton Woods Period." *Journal of International Money and Finance*, 16(2): 233-54.
- Fatás, Antonio, and Ilian Mihov.** 2000. "The Macroeconomic Effects of Fiscal Policy." Working Paper.
- Friedman, Milton.** 1968. "The Role of Monetary Policy." *American Economic Review*, 58(1): 1-17.
- Fuller, Wayne A.** 1976. *Introduction to Statistical Time Series*. New York: John Wiley and Sons.
- Galí, Jordi.** 1992. "How Well Does the IS-LM Model Fit Post-War U.S. Data." *The Quarterly Journal of Economics*, 107(2): 709-38.

- Galí, Jordi, J. David López-Salido, and Javier Vallés.** 2007. "Understanding the Effects of Government Spending on Consumption." *Journal of the European Economics Association*, 5(1): 227-70.
- Gwartney, James D., and Richard Stroup.** 1983. "Labor Supply and Tax Rates: A Correction of the Record," *American Economic Review*, 73(3): 446-51.
- Hamilton, James D.** 1994. *Time Series Analysis*. Princeton University Press.
- Harberger, Arnold C.** 1966. "Efficiency Effects of Taxes on Income from Capital" in *Effects of the Corporation Income Tax*, ed. Marian Krzyzaniak. Detroit: Wayne State University Press, 107-17.
- Joines, Douglas H.** 1981. "Estimates of Effective Marginal Tax Rates on Factor Incomes." *Journal of Business*, 54(2): 191-226.
- Jones, John Bailey.** 2002. "Has Fiscal Policy Helped Stabilize the Postwar U.S. Economy?" *Journal of Monetary Economics*, 49(4): 709-46.
- Jorgenson, Dale W., and Kun-Young Yun.** 1990. "Tax Reform and U.S. Economic Growth," *Journal of Political Economy*, 98(5): S151-93.
- King, Robert G., Charles I. Plosser, James H. Stock, and Mark W. Watson.** 1991. "Stochastic Trends and Economic Fluctuations." *American Economic Review*, 81(4): 819-40.
- Lippi, Marco, and Lucrezia Reichlin.** 1994. "Diffusion of Technical Change and the Decomposition of Output into Trend and Cycle." *Review of Economic Studies*, 61(1): 19-30.
- Lucas Jr., Robert E.** 1990. "Supply-Side Economics: An Analytical Review." *Oxford Economic Papers*, 42: 293-316.
- Mankiw, N. Gregory., and Matthew Weinzierl.** 2005. "Dynamic Scoring: A Back-of-the-Envelope Guide." Harvard Institute of Economic Research, Discussion Paper No. 2057.
- Mendoza, Enrique G., Assaf Razin, and Linda L. Tesar.** 1994. "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption." *Journal of Monetary Economics*, 34(3): 297-323.
- Nelson, Charles R., and Charles R. Plosser.** 1982. "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications." *Journal of Monetary Economics*, 10(2): 130-62.
- Perotti, Roberto.** 2002. "Estimating the Effects of Fiscal Policy in OECD Countries." European Central Bank Working Paper No. 168.
- Phillips, Peter C.B., and Pierre Perron.** 1988. "Testing for a Unit Root in Time Series Regression." *Biometrika*, 75(2): 335-46.
- Ramey, Valerie A., and Matthew D. Shapiro.** 1997. "Costly Capital Reallocation and the Effects of Government Spending." NBER Working Paper No. 6283.
- Zivot, Eric, and Donald W. K. Andrews.** 1992. "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis." *Journal of Business and Economic Statistics*, 10(3): 251-70.

Appendix A

The ADF test results conducted on the supply component of the output under the ‘no trend’ and the ‘trend’ (deterministic) assumptions as well as on the demand components of output under the random walk and the random walk with drift assumptions are reported in Table 7. We fail to reject the null of the presence of a unit root for both specifications of the supply component of output at 5 percent level. The presence of a unit root in the supply component of output under the ‘trend’ (deterministic) specification is indicative of a stochastic trend. Also, we reject the null hypothesis of the presence of a unit root for both specifications of the demand component of output at 5 percent level.

**Table 7: Augmented Dickey-Fuller (ADF) Test Results
of the Permanent and the Cyclical Components**

	Y_t^{Supply}		Y_t^{Demand}	
	No Trend	Trend	Without Constant	With Constant
p	1	0	0	0
a_0	0.5936 (0.5936) ^a	5.6067 (2.8827)	---	6.1323 (2.5879)
a_2	---	0.1081 (2.9620)	---	---
γ	0.0034 (0.2766)	-0.1339 (-2.8487)	-0.0022 (-0.5925)	-0.1210 (-2.6273)
$\gamma+1$	1.0034 (0.2766)	0.8661 (-2.8487)	0.9978 (-0.5925)	0.8790 (-2.6273)
ADF Test Statistic	0.2766	-2.8487	-0.5925*	-2.6273*
t -critical (5% level)	-2.8882	-3.4512	-1.9438	-2.8879
Observations	109	110	110	110

Note: Y_t^{Supply} and Y_t^{Demand} represent the supply component of real GDP and the demand component of real GDP respectively.

^a t -statistics are in parentheses.

* Reject null hypothesis of the presence of unit root at 5 percent significance level.