Abstract—The optimal collection of taxes and seigniorage is an important issue in public finance. For developing and emerging countries, seigniorage is particularly essential to provide an additional source for government revenue. Barro (1979) and Mankiw(1987) propose tax-smoothing and revenue-smoothing hypotheses to discuss how the government should optimally collect taxes. This paper aims to test the tax- and revenue-smoothing hypotheses with Taiwanese annual data from 1965 to 2012. Unit root tests and Johansen’s cointegration technique are employed. Our results indicate that Taiwanese data are in favor of these two hypotheses. The government may have used seigniorage as a supplement to raise tax revenue. Moreover, both fiscal policy and monetary policy are implemented in an optimal fashion to finance government expenditure.

Index Terms—Cointegration analysis, optimal seigniorage theory, tax smoothing, revenue smoothing.

I. INTRODUCTION

The optimal collection of taxes and seigniorage is an important issue in public finance. Seigniorage generally is regarded as an inflation tax. The government issues new currency, increases the price level and redistributes the wealth from the lender to the borrower. The higher the inflation rate, the more revenue the government receives from seigniorage. For developing and emerging countries, seigniorage is particularly important to provide an additional source for government revenue.

Barro (1979) [1] and Mankiw(1987) [2] propose tax-smoothing and revenue-smoothing hypotheses to discuss how the government should optimally collect taxes. Barro assumes that the government smooths the tax rates in different time periods to minimize the distortion, which is defined as the present value of excess burdens. The optimality conditions state that tax collections should follow a random walk. Mankiw proposes that the optimal tax rates are positively associated with inflation and nominal interest rates. More specifically, inflation rates, nominal interest rates, and optimal tax rates follow a random walk.

The tax smoothing theory implies that when the government anticipates an increase in future spending, it should reduce current budget deficit and accumulate more savings. On the other hand, if the government expects a decrease in future spending, it should increase current budget deficits. The government should issue debts to finance a temporary and substantial increase in government spending.

The U.S. data from year 1917 to 1976 and from year 1985 to 1985 were empirically investigated in Barro’s and Mankiw’s original models, respectively. The ordinary least squares results in both models are in accord with the hypotheses. Huang and Lin (1993) [3] reexamine Barro’s tax smoothing hypothesis using annual U.S. fiscal data from year 1929 to 1988. They employ log-linearization on government expenditure, budget deficit, and aggregate output. Then, a vector autoregression (VAR) framework is used to test the linear relation. Their results indicate that the post-1947 data support the tax smoothing hypothesis. Serletis and Schorn (1999) [4] conduct cointegration tests, unit root tests and a VAR approach on quarterly data of Canada, France, the UK and the US. The empirical evidences of these four countries support tax- and inflation-smoothing, but not revenue-smoothing hypotheses. Ricciuti (2001) [5] tests these two hypotheses using Italian data from 1861 to 1998. He defines seigniorage as the ratios of changing monetary base of the Treasury over GDP from previous period. Besides standard unit-root tests, a Granger causality analysis and a VAR approach are also implemented. The findings include that a unit root exists in tax rates, but not in seigniorage. Doğru (2013) [6] applies cointegration and vector error correction methods techniques to Turkish data. He finds that a causality relationship from inflation and tax revenue to nominal interest rates exists in the long run, but not in the short run.

This paper employs Johansen’s cointegration technique [7] to test Barro’s tax-smoothing hypothesis and Mankiw’s revenue-smoothing hypothesis with Taiwanese annual data. We find that Taiwanese data support these two hypotheses. Next section will describe the basic model. Section III provides empirical results and Section IV concludes.

II. BASIC MODEL

In Barro’s (1978) model, government expenditure is assumed to be exogenous. Seigniorage is combined with other government tax revenue. The government aims to minimize the tax distortion defined as (1) with respect to \( \{T_t, B^r_{1:1}\}_{t=0}^\infty \) subject to a budget constraint (2).

\[
E_t \sum_{i=0}^{\infty} \beta^i L(T_{t+i}, Y_{t+i})
\]

\[
B_{t+i} = (1+r)B_t + G_t - T_t
\]

where \( Y_t \) is the national income at time \( t \), \( T_t \) is the total tax revenue at time \( t \), \( B_t \) is the interest-bearing government debt at time \( t \), \( G_t \) is the exogenous real government expenditure, \( L \) is the loss function, \( (1+r) \) is the gross real interest rate,
\( \beta \) is the discount factor.

Combined with the non-Ponzi-game condition (3), equation (2) can be written as the intertemporal budget constraint (4).

\[
\lim_{t \to \infty} \frac{B_t}{(1 + r)^t} = 0 \tag{3}
\]

\[
\sum_{i=0}^{\infty} \frac{1}{(1 + r)^t} E T_{t+i} = B_t + \sum_{i=0}^{\infty} \frac{1}{(1 + r)^t} E G_{t+i} \tag{4}
\]

The Euler equations are obtained as follows.

\[
L(T_t) = (1 + r) \beta E L(T_{t+1}) \tag{5}
\]

As \( \beta = \frac{1}{1 + r} \), equation (5) becomes

\[
L(T_t) = E L(T_{t+1}) \tag{6}
\]

\[
T_t = E T_{t+1} \tag{7}
\]

Equation (6) implies that the excess burden from raising tax revenue should be equalized in different periods. If a quadratic loss function is used, equation (6) also implies (7).

The collection of tax revenue follows a random walk. Let \( T_t \) be a proportion of \( Y_t \). Equation (7) predicts that tax rates will be smoothed by means of deficits over time.

Mankiw (1987) [2] assumes that the government finances its expenditure with a mix of direct tax revenue and seigniorage. Suppose the money demand is proportional to the output.

\[
M_t \over P_t = kY_t \tag{8}
\]

where \( M_t \) is the outside money at time \( t \), \( P_t \) is the price level at time \( t \), \( k \) is a constant. The tax revenue from seigniorage is

\[
M_t \over P_t = kY_t \over \over Y_t + \over Y_t \over Y_t = kY_t (\pi + g) \tag{9}
\]

where \( \pi \) is the inflation rate, and \( g \) is the growth rate of output. The total tax revenue is defined as

\[
T_t = \tau Y_t + (\pi + g)kY_t \tag{10}
\]

where \( \tau \) is the effective tax rate.

The government minimizes the distortion from direct tax, \( f(\tau_{t+i}) \) and from seigniorage \( h(\pi_{t+i}) \) in equation (11) subject to the intertemporal budget constraint (12).

\[
E_t \sum_{i=0}^{\infty} \beta^i [f(\tau_{t+i}) + h(\pi_{t+i})]Y_t \tag{11}
\]

\[
\sum_{i=0}^{\infty} \beta^i G_{t+i} + B_t = \sum_{i=0}^{\infty} \beta^i T_{t+i} \tag{12}
\]

Three first-order conditions can be derived as follows.

\[
E_t \sum_{i=0}^{\infty} \beta^i [f(\tau_{t+i})] = f'(\tau_t) \tag{13}
\]

\[
E_t \sum_{i=0}^{\infty} \beta^i [h(\pi_{t+i})] = h'(\pi_t) \tag{14}
\]

\[
h'(\pi_t) = kf'(\tau_t) \tag{15}
\]

Equations (13) coincides with Barro’s [1] tax smoothing of optimal fiscal policy. Equation (14) equates the marginal social cost of inflation across time. Equation (15) equates the marginal social costs of the two revenue sources. The tax-smoothing hypothesis can be tested by examining whether the tax rate and the inflation rate have a unit root, respectively. Whether these two tax rates are cointegrated can be used to validate the revenue-smoothing hypothesis.

III. EMPIRICAL RESULTS

In this paper, the inflation rate (INF) is calculated by the changes of consumer price index. The effective tax rate, defined as the ratio of tax revenue to GDP (TAX), is considered as a tax variable in the estimation. Fig. 1 depicts these two variables from year 1965 to 2012. With respect to the tax burden (the ratio of tax revenue to GDP), Taiwan had almost 20% in the early 1990s. It fell to 13.9% in 2008, relatively lower than that in other OECD countries. In the midst of the 2008 global economic recession, Taiwan government proposed tax cuts in motor vehicle excise tax, corporate and personal income taxes, aiming to stimulate the economy.

![Fig. 1. Inflation and tax revenue as a share of GDP, Taiwan 1965-2012.](image)

Taiwan is a small open economy with scarce natural resources. The domestic producers heavily depend on imported raw materials. In the midst of oil crisis, its inflation rates reached around 47%. Except for the 1970s, the inflation rates were stably low. The averages of effective tax rates and inflation rates over the 47 years are 15.78% and 4.22%, respectively.

Table I and Table II present the descriptive statistics and
correlation coefficients of variables. There are 48 observations in our sample. The correlation coefficient between INF and TAX is around 0.41.

Prior to conducting cointegration analysis, we need to verify whether the time series are stationary. We report four unit root test results, the augmentedDickey and Fuller (1979, 1981; ADF) [8], [9]; Phillips and Perron (1988; PP) [10]; Elliott, Rothenberg, and Stock’s (1996) [11] Dickey–Fuller GLS detrended (DF-GLS); and Kwiatkowski, Phillips, Schmidt, and Shin (1992; KPSS) [12] in Table III. After TAX is differenced once, the hypothesis of unit root is rejected by three tests at the 5% significance level. The null hypothesis that INF has a unit root is rejected via PP test at the 5% significance level.

We further conduct a cointegration vector coefficient significance test. Table V indicates that the effect of inflation on equation (16) is significant at the 5% level.

We employ Johansen’s (1988) [7] maximum likelihood estimation method to examine the long-term relationship between tax revenue as a share of GDP and inflation. The lag length selection is an important issue in the cointegrated vector autoregressive models. Long lag length may cause overparameterization and lead to a loss in efficiency. Short lag length fails to yield white noise residuals and results in estimation bias. We start with a lag length, \( k = 1 \). If the null hypothesis of no serial autocorrelation cannot be rejected, a bigger \( k \) is needed until all residuals become white noise. We use the Breusch–Godfrey serial correlation LM test to choose an appropriate lag length. The null hypothesis of no serial correlation is accepted at the 5% significance level when \( k = 1 \).

After choosing the optimal lag length, we test the number of cointegration relations with Johansen and Juselius’s (1990) [13] methodology. The trace and maximum eigenvalue statistics are reported in Table IV. Both statistics indicate at least one cointegration at the 5 percent significance level. This suggests that there is one long-term relationship between inflation rates and effective tax rates.

Equation (16) presents the results of the cointegration coefficients of the long-run relationship equation. At the 5% significance level, \( INF_i \) has a significantly positive effect on \( TAX_i \). Higher inflation rates are associated with higher tax rates.

\[
TAX_i = 12.364 + 0.806 \cdot INF_i, \tag{16}
\]

We regard this paper as a primal research. Further extension includes adding additional variables in accordance with the distortion of taxation.

We examine the tax-smoothing and revenue-smoothing hypotheses with Taiwanese annual data from 1965 to 2012. We conduct Johansen’s cointegration technique to investigate the long-run relationship between inflation and tax revenue as a share of GDP. Our results indicate that Taiwanese data are in favor of these two hypotheses. The government may have used seignorage as a supplement to raise tax revenue.

In addition, according to our result, both fiscal policy and monetary policy are implemented in an optimal fashion to finance government expenditure. The government issues debt to finance temporary increases in government expenditure. The budget deficits are accordingly incurred so as to minimize the distortion of taxation.

We regard this paper as a primal research. Further extension includes adding additional variables in accordance with the Taiwanese data, or employing more advanced econometric techniques to test these two hypotheses.

**REFERENCES**


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