The Tax Spending Nexus: Evidence from a Panel of US State-Local Governments

Saeid Mahdavi
Department of Economics, The University of Texas at San Antonio,
One UTSA Circle, San Antonio, TX 78249;
E-mail address: smahdavi@utsa.edu.


Joakim Westerlund
Department of Economics, Lund University,
P.O. Box 7082, S-220 07 Lund, Sweden.
Telephone: +46 46 222 8670; Fax: +46 46 222 4118;
E-mail address: joakim.westerlund@nek.lu.se .

*Department of Economics,*
*University of Texas at San Antonio,*
*San Antonio. TX 78249. U.S.A*

# The Tax-Spending Nexus: Evidence from a Panel of US State-Local Governments*

**Saeid Mahdavi** [†]     **Joakim Westerlund** [‡]

**May 20, 2008**

## Abstract

We re-examine the tax-spending nexus using, for the first time, a panel of fifty US state-local government units over the period 1963-97 and panel techniques that allow for cross-sectional dependence. We find that, unlike tax revenues, expenditures adjust to revert back to a long-term equilibrium relationship. The evidence on the short-term dynamics is also consistent with the tax-and-spend hypothesis at the one percent level of significance. One implication of this finding is that the size of the government at the state-local level is not determined by expenditure demand, but rather by resource supply. This is consistent with the fact that many US state and local governments operate under constitutional or legislative limitations that seek to constrain deficits.

[†] Department of Economics, The University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249; E-mail address: smahdavi@utsa.edu.
[‡] Corresponding author: Department of Economics, Lund University, P.O. Box 7082, S-220 07 Lund, Sweden. Telephone: +46 46 222 8670; Fax: +46 46 222 4118; E-mail address: joakim.westerlund@nek.lu.se .

**1. Introduction**

Persistently large public sector budget deficits have to be eventually corrected through fiscal adjustments in the form of government expenditure cuts and/or tax revenue increases. In practice, however, addressing the deficit problem may be complicated by the several issues.

One issue is the division of the burden of adjustment between the expenditure and revenue sides of the budget during periods of fiscal retrenchment. This requires an evaluation of the initial level of taxes and expenditures to determine whether it is politically and economically feasible to change them in the desired direction. Tax hikes, for example, may be easier to justify than expenditure cuts if the current level of tax revenues is relatively low based on historical or some other standards.

Another issue is the temporal causality between taxes and expenditures. In particular, in order to determine which variable should be given temporal priority, one basically has to know whether changes in expenditures precede, follow, are independent of, or occur simultaneously with changes in taxes. For example, if expenditure decisions adjust to prior tax revenue changes, then controlling tax revenues is required to rein in spending and eventually shrink the deficits.

The main objective of the current paper is to re-examine this issue of causality between taxes and expenditures. The paper contributes to the existing tax-spending literature in several ways. Firstly, unlike most previous studies, the empirical evidence reported herein is based on a panel of multiple time series, rather than just a single time series, which greatly increases the amount of information available. In particular, we employ a panel consisting of 50 US combined state and local government units,

henceforth referred to as state-local governments, over 35 years. Secondly, our empirical model is very flexible in the sense that it is able to control for a number of important factors that are likely to influence taxes and expenditures, and hence the relationship between them. It is also very general in the sense that it accounts not only for the nonstationarity, but also for the panel structure of our data. Thirdly, our approach to causality relies on the fact that if taxes and expenditures are cointegrated, then their levels must be related in the long run with causality running in at least one direction. This long-run level behavior, therefore, provides another channel of causality in addition to the traditional one based on the short-term dynamics of the variables in their differences. To exploit this channel, we adopt the panel error-correction approach of Westerlund (2007a). Finally, we employ alternative variable definitions in order to check the robustness of our results.

The rest of the paper proceeds as follows. Section 1 briefly reviews some of the major theories regarding the tax-spending nexus along with the empirical evidence. Section 2 then describes the data and empirical methodology employed, while Section 3 presents the results obtained. Section 4 concludes.

## 2. Theoretical and empirical background

The relationship between tax and spending is typically discussed in the literature within the framework of four competing hypotheses, namely the tax-and-spend hypothesis, the spend-and-tax hypothesis, the fiscal synchronization hypothesis, and the institutional separation hypothesis. In this section, we begin with a brief explanation of these four hypotheses and then we go on to present the empirical evidence.

**2.1 The tax-and-spend hypothesis**

According to the tax-and-spend hypothesis championed by Friedman (1978), the level of spending adjusts to the level of tax revenues available. Thus, an increase in tax will not lead to lower budget deficits.[1] This hypothesis implies a positive relationship between tax changes and the spending changes that will follow. On this basis, Friedman favors a reduction in taxes to force subsequent spending cuts.[2]

Buchanan and Wagner (1977, 1978) put forward an alternative version of the tax-and-spend hypothesis. In contrast to Friedman (1978), they argue that tax increases would lead to spending reductions. The building block of the Buchanan and Wagner (1977, 1978) version of the tax-and-spend hypothesis is that taxpayers suffer from fiscal illusion. According to the authores, tax cuts lower the perceived price of government provided goods and services by the public, which in turn boosts the public demand for these goods and services. However, the public may actually incur even higher costs. One reason for this is the indirect inflation taxation that results if the government resorts to excessive money creation. Another reason is higher interest rates associated with government debt financing may crowd out private investment. To reduce expenditures, Buchanan and Wagner favor limiting the ability of the government to resort to deficit financing.[3]  In

---

[1] In an interview in Washington Times (June 2, 1982; C3), Friedman contends that "Political Rule Number One is: government spends what government receives, plus much more as it can get away with…Increasing taxes would mean that you'd have just as large a deficit but a higher level of government spending."

[2] Niskanen (1988, p.109) notes that "Milton Friedman promoted a view that tax rates should be reduced at every opportunity, believing that the resulting in the deficit would increase pressures to reduce federal spending..." This approach to shrinking the size of government spending has come to be known as "starve the beast" approach.  Romer and Romer (2007) found no evidence in support of this approach based on their analysis of federal fiscal data.

[3] Lee and Vedder (1992. p.726) contend that the conflict between the two versions noted above is more apparent than real: "Friedman is and Buchanan positions are similar in that they both call for increasing the political cost of acquiring revenue for political purposes." According to their interpretation, Friedman (1978) and Buchanan and Wagner (1977, 1978) favor an increase in the "marginal political cost of taxation" and the "marginal political cost of deficit financing," respectively. The authors develop a model of taxation and deficit determination, which suggests that tax cuts as advocated by Friedman will be

sum, while tax changes as before drive spending changes, the relationship between the two is a negative one.

## 2.2 The spend-and-tax hypothesis

According to the spend-and-tax hypothesis, the level of spending is first determined by the government and then tax policy and revenue are adjusted to accommodate the desired level of spending. A version of this hypothesis is suggested by Roberts (1978), and Peacock and Wiseman (1979) according to whom crisis situations (due to for example wars, natural disasters, or deep recessions) justify temporary increases in expenditures and taxes to pay for them. However, tax increases may become permanent, reflecting an upward adjustment in the level of tax tolerance of the citizens and their attitude towards the proper size of the government after the crisis has passed. This in turn allows for a permanent increase in the level of government expenditures.

Another version of this hypothesis is based on the works of Barro (1974, 1979, 1986). In his tax smoothing hypothesis, government spending is considered as an exogenous variable to which taxes adjust. Moreover, the intertemporal budget constraint requires that an increase in current expenditures be matched by higher future taxes. Barro, therefore, rejects the notion that the taxpayers suffer from fiscal illusion. Quite the contrary, within the framework of the Ricardian equivalence theorem, he maintains that taxpayers are sophisticated, or rational, enough to see that an increase in the current debt in nothing but a delayed form of taxation. Taxpayers are, therefore, expected to fully capitalize the future tax liability.

---

associated with reduced expenditures and lager deficits, while tax hikes as advocated by Buchanan and Wagner will be associated with reduced expenditures and smaller deficits.

As pointed out by von Furstenburg et al. (1992), changes in spending can precede changes in taxes if a political majority raises pre-election expenditures, which are then paid for by subsequent post-election tax increases, or if they cut taxes as a compensation for earlier decisions to restrain expenditures. Since it is changes in expenditures that drive changes in taxes in this scenario, the preferred approach to fiscal deficit reduction relies on cutting expenditures.

## 2.3 The fiscal synchronization hypothesis

Reflecting the traditional theories for the demand for public goods (Musgrave, 1966; Meltzer and Richard, 1981), the fiscal synchronization hypothesis states that changes in taxes and expenditures occur concurrently. It is postulated that the desired level of public expenditures and the level of taxation needed to support it are jointly determined by the electorates based on appraisal and comparisons of the marginal costs and benefits associated with alternative packages of government spending programs. The implication of this hypothesis is that causal relationship between government revenue and spending is bidirectional.

## 2.4 The institutional separation hypothesis

A major advocate of this view is Wildavsky (1988) who maintains that separate institutions such as the executive and legislative branches of the US government participate in the budgetary process to determine the level of taxation and spending. Budgeting can be incremental and adjustments can be made on the margin if these separate institutions reach a consensus on the fundamentals. The collapse of this consensus may result in an independent determination of the revenue and expenditure sides of the budget as well as the decoupling of the function of raising tax revenues from

the function of allocating them. In this case, taxes and expenditures may be causally independent.[4]

## 2.5 Previous empirical findings

The empirical literature of the tax-spending nexus is voluminous. With few exceptions, previous studies have resorted to aggregate country level data, which have been analyzed using conventional time series methods for either stationary or nonstationary autoregressive models. Support for each of the four competing hypotheses discussed above has been found in at least one country and by at least one study.[5]

A much smaller number of earlier studies have employed data at subnational levels.[6] One example of such a study is von Furstenberg et al. (1985), who found some support for the spend-and-tax hypothesis using aggregate state-local level data from 1954 to 1982. Marlow and Manage (1987) provided evidence consistent with the tax-and-spend hypothesis at aggregate state government level and the institutional separation hypothesis at aggregate local government level during the 1952 to 1982 period based on conventional Granger-causality tests.

Chowdhury (1988) employed the same approach as Marlow and Manage (1987), but with the variables in their first differences to achieve stationarity. His results

---

[4] Hoover and Sheffrin (1992) present evidence of this causal independence at the federal level in the US since the late 1960s. They suggest that this may reflect the fact that "Compared to parliamentary democracies, the United States has many important actors with divergent interests and agendas" (p. 246). Baghestani and McNown (1994) note the existence institutional separation within the legislative branch itself in the form of Appropriations and Ways and Means committees in the House of Representatives.

[5] For a review of major country studies published between 1985 and 2002, see Payne (2003). The US federal government level evidence reviewed by Payne (2003) was consistent with the tax-and-spend hypothesis in twelve studies, the spend-and-tax hypothesis in six studies, the fiscal synchronization hypothesis in four studies, and the institutional separation hypothesis in one study.

[6] Unless otherwise stated, all the subnational data discussed in this section are from the US. Throughout, we use the term "*state-local government*" to refer to cases in which state and local governments' fiscal (and perhaps other) data are lumped together. Furthermore, we use the word *aggregate* to mean that individual observations at the local, state, or state-local level were pooled in each year to yield time series of variables.

confirmed the findings of Marlow and Manage (1987) at the state level, but supported the fiscal synchronization hypothesis at the local level. Ram (1988) employed aggregate state level data covering the years 1929 to 1983 and also found support for the spend-and-tax hypothesis. Unlike von Furstenberg et al. (1985) who added potential GDP and grants as control variables, none of these three latter studies included any control variables.

In a significant departure from the earlier studies, Holtz-Eakin et al. (1989) applied a panel vector autoregressive model to 171 US local (municipal) governments over the period 1972 to 1980. Controlling for federal grants, their results supported the tax-and-spend hypothesis. A later study by Joulfaian and Mookerjee (1990) applied the same panel approach to annual state level data for sixteen countries during the period 1955 to 1986. Their results provided evidence consistent with all but the fiscal synchronization hypothesis, with the US being one of three countries whose data fitted the tax-and-spend pattern. The fiscal synchronization hypothesis was also supported by Miller and Russek (1990) who applied an error correction model to aggregate state-local government data.

Dahlberg and Johansson (1998) employed the panel vector autoregressive model suggested by Holtz-Eakin et al. (1989) to a panel of 265 Swedish municipalities over the period 1974 to 1987. After controlling for grants, they found evidence in favor of the spend-and-tax hypothesis. Payne (1998) analyzed time series for 48 contiguous US states over the period 1954 to 1992. His results supported the tax-and-spend hypothesis in 24 states, the fiscal synchronization hypothesis in 11 states, the spend-and-tax hypothesis in eight states, and the institutional separation hypothesis in three states.

## 3. Data and empirical methodology

### 3.1 Data

Our data set consists of a panel of 50 US state-local government units covering the years 1963 to 1997. The sample period was determined by availability of the data. The variables included are expenditures, tax revenues, non-tax revenues, federal grants, total debt, and state gross product. The data sources are provided in the appendix.

There are several advantages associated with our data set that are worth noting. First, the fact that the data has a panel structure fills a gap that exists in the empirical literature on the US subnational governments between studies that have used time series from individual states and those that have used aggregate state or state-local level data. Second, unlike cross-national data, data from across US states enjoy a relatively high degree of homogeneity in dimensions that range from definition and measurement of variables to fiscal and political institutions, processes, and constraints. The homogeneity along the political dimension is of particular importance here, for the interaction between fiscal decision-makers and the electorate within the framework of a representative democracy seems to be an implicit assumption in each of the four hypotheses discussed earlier.[7]

Third, there is significant degree of variation in the levels of the variables across the state-local government units. This aspect of the data, which may improve the degree of precision in estimating the parameters of the relationship between revenues and

---

[7] Accordingly, results from multi-country samples may be questionable as evidence for or against a particular pattern of tax-spending relationship when the countries studied have restrictive political systems. Cheng (1999, p.186) notes another implication of limited political representation "… if both executive and legislative branches of the government in a country fully participate in the budgetary process, then taxes and expenditures are likely to follow a long-term equilibrium path; otherwise, they may have no co-movement tendency, as the countries in Latin America."

expenditures, will not be exploited if the cross-sectional units are pooled as in Joulfaian and Mookerjee (1990), or when individual time series are used as in Payne (1998). Fourth, the use of panel data addresses the well-known problem of low power of conventional time series unit root and cointegration tests, as it increases the sample size considerably.

Fifth, our data may provide prior information regarding the kind of spending-tax nexus that is more or less likely to emerge from empirical analysis. Specifically, many states and local governments in the US operate under fiscal constraints in the form of budget requirements and debt limits. These constraints, while not strictly binding, may be effective enough to result in revenue-constrained spending decisions. If so, we would expect to obtain results that are consistent with the tax-and-spend hypothesis. Similarly, to the extent that such constraints also tend to create causal dependence between revenues and expenditures in any direction, we do not expect to find empirical support for the institutional separation hypothesis. This expectation is reinforced by the fact that the divergence of interests, agendas, and decision-making institutions that tend to decouple spending and tax decisions at the federal level is likely to be less at the state and local levels.

**3.2 Empirical methodology**

To investigate the relationship between spending and taxes, we begin by specifying the following model for state-local government $i = 1, 2...., N$ in year $t = 1, 2,...., T$

$$y_{it} = \theta_i' d_t + \beta_i' x_{it} + \varepsilon_{it} \tag{1}$$

where $y_{it}$ is a measure of government spending and $d_t$ is a vector of deterministic components, typically comprised of only an intercept but could also include other

elements such as time trends and break dummies. The vector $x_{it}$ contains the regressors which include a measure of tax revenues, federal government grants, non-tax revenues, the debt level, and state gross product. Provided that the variables are integrated of order one, equation (1) may be viewed as representing a long-term, or cointegrating, relationship.[8]

It is worth noting that the number of variables included in $x_{it}$ is much larger than what is typically employed in the literature. In what follows, we present a brief justification for each of these variables.

Grants from a higher level of government have been hypothesized to affect expenditure and revenue decisions of the recipient governments. A large body of empirical literature has found that grants not only boost the level of spending but do so by an amount which is larger than equal increases in private income.[9] This phenomenon has come to be known as the "flypaper effect" to suggest that "money sticks where it hits." On the tax side, grants may create a substitution effect when they replace tax revenues. Accordingly, omission of grants can cause misleading results, as an increase in spending due to an increase in grants may be incorrectly attributed to a change in tax revenues. Non-tax revenues, such as charges and fees, are other sources of funds to state-local governments that have been curiously ignored in much of the empirical literature. One would expect higher non-tax revenues to produce similar qualitative effects on expenditures and tax revenues as intergovernmental grants. In this connection, data

---

[8] Banerjee et al. (1993) point out that the choice of the left-hand side conditioning variable in a multivariate cointegrating equation is arbitrary. We followed Holtz-Eakin et al. (1989) and Dahlberg and Johansson (1998), and chose expenditures as the left-hand side variable in our baseline model. However, for the purpose of our analysis, expenditures and tax revenues may be interchanged. As regards to the control variables, none can be considered as strictly exogenous. As in much of the literature, we do not estimate separate equations for them.
[9] See, for example, Hines and Thaler (1995) for a review of the literature.

suggest a heavier reliance by state governments on non-tax revenues to finance spending in the past several years. This reflects, among other things, a substitution away from tax revenues, which are constrained by statutory and constitutional limits, and towards non-tax revenues which are not bound by these limitations (Skidmore, 1999).

A measure of total state-local government debt is also included in equation (1) to control for the ability of the government to resort to deficit financing associated with tax cuts and/or spending increases. Controlling for the debt level is important for several reasons. For one, a reduction in the supply of tax revenues to limit government spending, as supported by advocates of the "starve the beast approach" to shrinking the deficits, may not be effective if the government can raise the level of its debt by issuing new debts. In addition, within the tax-and-spend pattern of causality, both a decrease and an increase in spending can be the outcome of a tax cut, depending on whether the Friedman (1978) or the Buchannan and Wagner (1977, 1978) version of the hypothesis holds true. When the level of outstanding debt is controlled for, the sign and magnitude of the coefficient of tax revenues capture of the effect of tax changes on spending that are not accompanied by new government borrowing. Finally, within an intertemporal approach to balancing the budget (Barro, 1979) raising taxes to pay for current spending increases can be shifted into the future if the current debt level is allowed to go up. Thus, tax and spending decisions may be decoupled over an extended time period not necessarily due to institutional separation, but because the government can accumulate debt without much effective restrictions.[10] Accordingly, by including the level of debt, we can more accurately test the validity of the institutional separation hypothesis.

---

[10] Many state and local government have also constitutional and legislative limitations that are intended to constrain the ability of government units to resort to debt-issuance. However, as Marlow and Mange (1987)

11

Finally, we include a measure of total state output to control for changes in those components of government spending and taxes that are sensitive to variation in the level of economic activity. As noted by Holtz-Eakin et al. (1989), government expenditures and revenues at the state and local levels are largely free of discretionary changes that are made at the federal level as a part of countercyclical policies. However, changes in these variables due to presence of automatic stabilizers cannot be ruled out. In this connection, note that deterioration in the state of the economy can reduce tax revenues and increase some expenditures, at the same time. If output, as the factor that derives both tax revenues and expenditures, is omitted from the estimating equation, the observed inverse relationship between the two variables may be incorrectly interpreted as support for the Buchannan and Wagner (1977, 1978) hypothesis.

Having described the variables of interest, we now take a moment to discuss the model that relates them. As is well-known, if the variables in (1) are cointegrated, then they also have an error correction representation. The particular panel error correction model employed here is due to Westerlund (2007a), and can be written in the following way

$$\Delta y_{it} = \delta_i' d_t + \alpha_i (y_{it-1} - \beta_i' x_{it-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \quad (2)$$

where $d_t$ now absorbs the deterministic components of both the level and first differenced relationships, and where $\alpha_i$ is the error correction coefficient. Note that

---

noted, these limitations have been circumvented through a number of "creative financing procedures" invented by politicians and bureaucrats. These include earmarking revenues to service the debt, heavier reliance on "nonguaranteed debt" and establishment of "Off-Budget Enterprises" or "quasi"-governmental units whose debts do not require voter approvals and are not subject to debt-issuance limitations. As a consequence, the level of state debt has been rising over time; sometimes at a rate faster than the federal government's debt.

equation (2) can be interpreted as a conditional error correction model for $y_{it}$. As such, it is nothing but a restricted version of the full panel vector error correction model considered by Larsson et al. (2001). The idea here is to avoid estimating all the parameters of full model and to make inference based on the conditional model only (see Harbo et al., 1998).

In so doing, we assume that $\Delta x_{it}$ is independent of $e_{it}$ at all lags and leads. This assumption is not restrictive in the sense that it holds as long as the error correction model in (2) is well-specified. If the model is correct, so that all short-run dynamics have been accounted for, then $e_{it}$ is independent of $\Delta x_{it}$ by construction. We also assume that these errors are independent across both $i$ and $t$. Again, there is nothing restrictive about assuming independence across $t$ as long as the model is correctly specified. However, the same cannot be said about the assumption of independence across $i$.[11] Later on we therefore relax this assumption to allow for quite general forms of cross-state dependencies.

The key parameter in equation (2) is $\alpha_i$, which determines the speed at which the system corrects back to the equilibrium relationship $(y_{it-1} - \beta_i' x_{it-1})$ after a sudden shock. If $\alpha_i < 0$, then there is error correction, which implies that $y_{it}$ and $x_{it}$ are cointegrated, whereas if $\alpha_i = 0$, then there is no error correction and thus no cointegration. Note that this interpretation of $\alpha_i$ rests on two key assumptions. The first one is that there can be at most one cointegrating relationship, suggesting that the elements of $x_{it}$ cannot be

---

[11] Cross-sectional dependence may arise, for example, due to tax and spending competition among states. Accordingly, a state may adjust its tax and spending decisions in response to those of its neighboring states' to prevent erosion of its mobile tax base and influence the flows of capital and population. See, for example, Case et al. (1993) and Rork (2003) for evidence on the response of various expenditure and tax revenue categories, respectively.

cointegrated among themselves. Although clearly an important assumption, being testable, it is not very restrictive. The second assumption is that the extent of the cointegration can be inferred by looking at $\alpha_i$ alone, which means that $x_{it}$ cannot be error correcting. In other words, the regressors contained in $x_{it}$ must be weakly exogenous with respect to $\alpha_i$. Fortunately, this assumption is also quite innocent in the sense that it can be tested by simply performing a reverse test for error correction (see Zivot, 2000). For example, in order to test if tax revenues can be regarded as weakly exogenous, one simply estimates equation (2) with taxes as the dependent variable. The test for weak exogeneity can then be implemented as a test for the absence of error correction in the resulting reverse regression.

Finally, note that weak exogeneity of a variable does not preclude the possibility of dependence between that variable and other variables in the system. Indeed, in order to test if a particular variable is strictly exogenous with respect to the other variables in the system we also need to test if the lags and leads of the first differences of the other variables are zero in the regression corresponding to the variable we want to test. For example, for $x_{it}$ to be regarded as strictly exogenous, neither the error correction term nor the lags and leads of $\Delta y_{it}$ must enter the equation for $\Delta x_{it}$.

## 4. Empirical results

In the main part of our empirical analysis all variables as expressed in log real per capita terms. This obviates the need for adding population as an additional variable to our model to control for changes in taxes and spending that are due to changes in the size of state population.

**4.1 Unit root tests**

We begin the empirical analysis by testing the variables for unit roots, employing the recently developed bootstrap tests of Smith et al. (2004). The tests use a sieve sampling scheme to account for error dependence across both the time series and cross-section dimensions of the panel. We consider four tests denoted as $\bar{t}$, $\overline{LM}$, $\overline{\max}$ and $\overline{\min}$. All four tests are constructed with a unit root under the null hypothesis and heterogeneous autoregressive roots under the alternative, suggesting that a rejection should be taken as evidence in favor of stationarity for at least one state.[12] The order of the sieve is permitted to increase with the number of time series observations at the rate $4(T/100)^{2/9}$ and so is the lag length of the individual unit root test regressions.[13] As the series do not appear to be trending, each test regression is fitted with an intercept only. The bootstrapped *p*-values are based on 1,000 replications.

The results reported in Table 1 suggest that the unit root null cannot be rejected at any conventional significance level for any of the variables. The only exception is federal grants, for which the null must be rejected at the 1% level when using the $\bar{t}$ and $\overline{LM}$ tests. However, since the rejections are quite marginal, we chose to proceed as if all six variables are indeed nonstationary. This conclusion is reinforced by the fact that if we permit for the possibility of a linear trend, the null cannot be rejected for any of the variables.[14]

---

[12] The $\bar{t}$ test can be regarded as a bootstrap version of the well-known panel unit root test of Im et al. (2003). The other tests are basically modifications of this test.

[13] The idea is that the serial correlation of the data can be approximated arbitrarily well by an autoregressive model of increasing order. To also preserve the cross-sectional dependence, the bootstrap innovations are drawn from the joint cross-sectional distribution on the estimated residuals.

[14] The unit root tests applied to the first difference of the variables confirm that they are all integrated of order one.

**4.2 Cointegration tests**

Given that the variables appear to be nonstationary, we now proceed to test for cointegration. The approach used for this purpose is taken from Westerlund (2007a), who develops four new panel tests based on the error correction model in equation (2). All four tests take no error correction as the null hypothesis but differ in the way the alternative is formulated. Two of the tests, $P_\alpha$ and $P_\tau$, assume that the error correction coefficient $\alpha_i$ is equal for all $i$, in which case the alternative is formulated as that $\alpha_i = \alpha < 0$ for all $i$. The second pair, $G_\alpha$ and $G_\tau$, do not require $\alpha_i$ to be equal, which means that the alternative is formulated as that $\alpha_i < 0$ for at least some $i$. Thus, while a rejection by the first two tests provides evidence in favor of cointegration for all $N$ states, this is not the case for the other two. Similar to the Smith et al. (2004) unit root tests, the error correction tests use a sieve type sampling scheme that accounts for both the time series and cross-sectional dependencies of the regression error.[15]

The computed values of the test statistics are presented in Table 2 along with two sets of $p$-values, one is based on the asymptotic normal distribution, while the other is based on the bootstrapped distribution using 1,000 replications. We begin by examining the results associated with the baseline specification with expenditures as the dependent variable. As can be seen, the no cointegration null is strongly rejected by all four tests when using the asymptotic $p$-values, which we take as evidence in favor of cointegration. There is no difference depending on whether $\alpha_i$ is restricted to be equal for all $i$ or not,

---

[15] As with the Smith et al. (2004) tests, we set the order of the sieve approximation equal to $4(T/100)^{2/9}$. The same rule is used for selecting $p_i$ and $q_i$, the number of lags and leads used in the estimation of the model in equation (2). For the estimation of the various long-run variances needed to compute the error correction tests, we follow the recommendation of Westerlund (2007a) and use the Newey and West (1994) estimator.

suggesting that the whole panel is cointegrated. We also see that, although the evidence

against the null is not as strong, the bootstrapped $p$-values still lead to the same

conclusion, at least at the 10% level. The fact that $G_\alpha$ has such a large $p$-value is strange

but consistent with its relatively poor power properties in small samples, as documented

by Westerlund (2007a). We therefore choose to interpret these results as evidence in

favor of cointegration.

As pointed out by Westerlund (2007a), violations of the assumption of weakly

exogenous regressors are only problematic to the extent that the tests are unable to reject

the null of no cointegration, in which case we do not know whether there is no

cointegration at all, or if there is cointegration, but it is only $x_{it}$ that is error correcting.  In

other words, our finding of cointegration is not going to be altered even if some of the

regressors happen to be non-weakly exogenous. Nonetheless, in order to shed at least

some light on the appropriateness of this assumption, we performed a series of reverse

regression tests.  As explained in Section 3, if regressors contained in $x_{it}$ are indeed

weakly exogenous in the baseline model, then they should not be error correcting. The

results obtained from the model with taxes as the dependent variable are reported in the

rightmost panel of Table 2. Note that, consistent with the notion of weak exogeneity, the

null of no error correction cannot be rejected based on the bootstrapped $p$-values. Similar

results were found for the other variables of the model.[16] Thus, there seem to be no

serious violations of the weak exogeneity assumption.

Finally, to test the validity of the assumption that the regressors cannot be

cointegrated amongst themselves, we tested the rank of $x_{it}$ using the trace test of

---

[16] As the relationship between taxes and spending is the focus of our analysis, we do not report these
results.  However, they are available from the authors upon request.

Johansen (1988). The results indicate that in only six out of the 50 cases do we end up

rejecting the null hypothesis of full rank at the 1% significance level, which means that

the regressors can be considered as roughly non-cointegrated.[17]

**4.3 Cointegration estimation**

It is well known that the pooled least squares estimator of Kao and Chiang (2001) is

consistent under fairly general conditions when applied to cointegrated regressions such

as ours. Unfortunately, the presence of endogeneity and cross-sectional dependence

means that the least squares estimator will generally be inefficient and biased, which

makes it a poor candidate for inference. A common approach to alleviate this problem is

to use seemingly unrelated regressions techniques. However, this approach is not feasible

in our case where $N$ is only moderately larger than $T$. To circumvent this problem, we

apply the newly developed panel estimator of Westerlund (2007b), which is based on

modeling the cross-sectional dependence by means of a small number of common

factors. This makes the estimator applicable even in cases such as ours where $N$ and $T$ are

about equal.

The Westerlund (2007b) estimator, which can be seen as a factor augmented

version of the more conventional panel bias-adjusted least squares estimator of Kao and

Chiang (2001), is implemented in two steps. The first step involves estimating the

common factors using the method of principal components. In the second step, the

cointegration vector is estimated by least squares conditional upon the resulting first-step

factor estimates. The number of common factors used in the first step is determined using

the $IC_1$ information criterion recommended by Bai and Ng (2004), while the second-step

---

[17] Note that with 50 states, we expect the full rank null to be rejected a certain number of times just by chance.

estimation of the cointegration vector is carried out using the Newey and West (1994) long-run variance estimator.

For comparison, the bias-adjusted estimation results are reported along with their unadjusted least squares counterparts in Table 3.[18] It is seen that both estimators produce very similar results, and that all five right-hand side variables are highly significant. Note also the positive sign of the estimated slope coefficients of the first four variables, which corroborates the notion that expenditures at the state level are resource constrained. The positive sign of the per capita tax revenue variable is of particular interest as it provides support in favor of the tax-and-spend hypothesis. The estimated slope of real per capita tax revenues is by far the largest, and suggests that a 10% increase in per capita tax revenues raises the level of expenditures by about 5%, controlling for other funding sources.

**4.4 Short-run exogeneity tests**

We have already established that the variables in $x_{it}$ appear to be weakly exogenous. To determine whether they are also strictly exogenous, we now proceed to test the significance of the first differenced variables. Since these variables are stationary, the exogeneity test is implemented as an ordinary *F*-test of the null hypothesis that the lags and leads of each element in $x_{it}$ are jointly zero.

The problem is that there is not just one, but *N* regressions to consider for each choice of dependent variable. Therefore, in order to facilitate inference at the overall

---

[18] The regressions are fitted with an unreported state specific intercept.

panel level, we propose combining the *p*-values of the individual *F*-tests, henceforth

denoted $P_i$, in the following way

$$P_m = -\frac{1}{\sqrt{N}} \sum_{i=1}^{N} [\ln(P_i) + 1]. \qquad (3)$$

As shown by Choi (2001), given that the individual tests are independent across *i*, then

$P_m$ converges to the standard normal distribution as *N* grows large. As already noted,

however, the assumption of cross-sectional independence is not likely to hold in our data.

Therefore, in order to permit for violations of this assumption, we further propose

bootstrapping the individual *F*-tests under the null hypothesis of short-run exogeneity.

The resulting bootstrapped *p*-values can then be used in place of their asymptotic

counterparts, and $P_m$ should again converge to the standard normal distribution.

The results from both sets of *p*-values are reported in Table 4. These may be

summarized in the following way.

Firstly, it is quite clear that in several cases whether the first differences of a

variable significantly enter expenditures and/or tax revenue equations depend on the type

*p*-value used. The difference in the two sets of results is particularly pronounced in the

tax revenues equation. This illustrates the importance of adjusting for cross-sectional

dependence in drawing inferences when there are reasons to expect it to be present.

Secondly, focusing now on the bootstrapped *p*-values only, then we see that the

first differences of all five explanatory variables enter the expenditures equation

significantly, at least at the 10% level. Thus, expenditures react not only to deviations

from the long-run relationship, but also to short-run movements in the rest of the system,

including tax revenues. At the 1% level, however, only tax revenues, non-tax revenues, and output pass the short-term exogeneity test.

Thirdly, if we look at the tax revenue equation, and keep focusing on the bootstrapped $p$-values, then there are only two significant variables at the 10% level, expenditures and output. At the 1% level only output remain significant. Thus, since tax revenues did not error-correct either, they may be considered as roughly strictly exogeneous at the 1% level.

Finally, based on the combined results of the effects of the short-run dynamics, we cannot reject the hypothesis that there is a bidirectional relationship between expenditures and tax revenues at the more conventional 5% level of significance. These results are broadly consistent with the findings in favor of the tax-and-spend hypothesis at the subnational level reported by Holtz-Eakin et al. (1989), Marlow and Manage (1987), Chowdhury (1988), and Payne (1998), as well as those favoring the fiscal synchronization hypothesis reported by Chowdhury (1988) and Miller and Russek (1990).

**4.5 Robustness checks**

To check the robustness of our initial results, we first dropped Alaska and Hawaii from the original sample and repeated our tests for the remaining 48 contiguous states.[19] Since there is no consensus about the measures of taxes and spending variables in the empirical literature (see for example Baghestani and McNown, 1994), we also repeated our analysis using the full sample and replacing the real per capita variables with real total variables and nominal total variables scaled by state output.

---

[19] In a number of studies, Alaska and Hawaii have been excluded because they are not continental states and/or have an atypical fiscal structure making them outliers.

Our original findings seem to be quite robust to the change in the composition of the sample and to the use of alternative variable definitions. In particular, based on the bootstrapped *p*-values, the evidence of error-correction was consistently stronger for expenditures than for tax revenues. In fact, the coefficient of the error-correction term in the tax revenue equation was not even statistically significant in the sample of the 48 contiguous states. The evidence consistent with bidirectional causality was also confirmed by the new results.[20]

## 5. Summary and concluding remarks

In this paper, we re-examined the tax-spending nexus using for the first time a panel of 50 US states-local government units over a period of roughly three and a half decades.

The major findings of our analysis, based on recently developed panel tests and estimation techniques, may be summarized as follows. Firstly, in our baseline specification with expenditures as the dependent variable, we found that real per capita expenditures, taxes, federal grants, non-tax revenues, debt level, and state output were cointegrated. Further analysis, however, revealed that taxes as well as other variables of the model were weakly exogeneous, suggesting that they did not error correct. Secondly, panel estimates of the parameters of the cointegrating relationship indicated that expenditures were positively and significantly affected by all the variables of the model with one exception. The exception was the output variable whose coefficient was negative and significant. Thirdly, the analysis of the effects of the short-run dynamics indicated that while taxes affected expenditures, expenditures did not seem to affect taxes, at least not at the 1% level of significance. At the more conventional 5% level of significance, however, the relationship between taxes and spending was found to be

---

[20]All results discussed in this section are available from the authors upon request.

bidirectional. Finally, our results did not appreciably change when we used a sample of 48 contiguous states, or alternative variable measures.

The statistical evidence presented in this paper seem to suggest that while taxes are rather exogenously set, expenditures adjust not only to deviations from the long-term equilibrium relationship but also to the short-run changes in taxes, other funding sources and output. Stated differently, expenditures seem to bear the adjustment burden in response to budgetary disequilibria. An implication of this finding is that the size of the government at the state-local level is not determined by expenditure demand, but rather by resource supply, such as taxes and grants. It is hard not to conclude that these results, at least in part, reflect the constitutional or legislative limitations that seek to constrain deficits under which many state and local governments operate in the US. These include submission of balanced budgets, limiting appropriations to estimated revenues, and/or requiring revenue shortfalls to be matched by spending cuts.

The fact that expenditures seem to depend on taxes both in the long- and short-terms, underscores the important role of taxes in controlling government deficits at the state-local level. In this connection, reductions in the federal commitment to existing entitlement and mandatory programs and/or introduction of new unfunded mandates will result in fiscal imbalances through cost shifts to state and local governments. To avoid confronting these governments with the unpleasant choices of raising taxes or cutting other expenditures, stricter adherence to provisions of the Federal Unfunded Mandates Reform Act of 1995 is necessary.

## References

Baghestani,, H., and R. McNown. (1994). "Do Revenue or Expenditures Respond to Budgetary Disequilibria?" *Southern Economic Journal* 61, pp. 311-322.

Bai, J., and S. Ng (2004). "A Panic Attack on Unit Roots and Cointegration." *Econometrica* 72, pp. 1127-1177.

Banerjee, A., J. J. Dolado, J. W. Galbraith, and D. F. Hendry. (1993). Cointegration, error-correction, and the econometric analysis of non-stationary data. London: Oxford University Press.

Barro, Robert J. (1974). "Are Government Bonds Not Wealth?" *Journal of Political Economy*, Nov.-Dec., pp. 1095-1118.

Barro, Robert J. (1979). "On the Determination o the Public Debt." *Journal of Political Economy*, 81, 940-971.

Barro, Robert J. (1989). "The Ricardian Approach to Budget Deficits." *Journal of Economic Perspectives* 3, 37-54.

Buchanan, James M. and Richard W. Wegner. (1977). Democracy in Deficit, Academic Press, New York.

Buchanan, James M. and R. Wagner. (1978). "Dialogues Concerning Fiscal Religion." *Journal of Monetary economics*, 4, 627-636.

Case, Anne C, Rosen, Harvey S, Hines, James R Jr. (1993). "Budget spillovers and fiscal policy interdependence: Evidence from the states." *Journal of Public Economics*. Vol. 52, Iss. 3; p. 285-308.

Cheng, Benjamin S. (1999). "Causality between Taxes and Expenditures: Evidence from Latin American Countries", *Journal of Economics and Finance*, Vol. 23, No. 2, pp. 184-192.

Choi, I. (2001). "Unit Root Tests for Panel Data," *Journal of International Money and Finance*, 20: 249-272.

Chowdhury, A. R. (1988). "Expenditures and Receipts in State and Local Government Finance: Comment." *Public Choice*, 59: 277-85.

Dahlberg, Matz and Eva Johansson. (1998). "The Revenues-Expenditures Nexus: Panel Data Evidence from Swedish Municipalities." *Applied Economics*, 30, 1379-1386.

Friedman, M. (1978). "The Limitations of Tax Limitation," *Policy Review*: pp. 7-14.

von Furstenberg, G.M.R., J. Green, and J.H. Jeong. (1986). "Tax and Spend, or Spend and Tax?" *Review of Economics and Statistics* 68, 179-188.

Harbo, I., S. Johansen, B. Nielsen and A. Rahbek (1998). "Asymptotic Inference on Cointegrating Rank in Partial Systems. *Journal of Business & Economic Statistics*, Vol. 16, No. 4 (Oct., 1998), pp. 388-399.

Hines, Jr., James R., and Richard H. Thaler. (1995). "The Flaypaper Effect." *Journal of Economic Perspectives* 9, No. 4, pp. 217-26.

Holtz-Eakin, D., W. Newey, and H. S. Rosen. (1989). "The Revenues-Expenditures Nexus: Evidence from Local Government Data." *International Economic Review*, 30 (2) 415-429.

Hoover, Kevin D. and Steven M. Sheffrin. (1992). "Causation, Spending, and Taxes: Sand in the Sandbox or Tax Collector for the Welfare State?" *The American Economic Review*, Vol. 82, No.1, pp. 225-248.

Joulfaian, D., and R. Mookerjee. (1990). "The Intertemporal Relationship Between State and Local Government Revenues and Expenditures: Evidence from OECD Countries." *Public Finance*, Vol. 45, pp. 109-117.

Kao, C. and M.-H. Chiang. (2001). "On Estimation and Inference of a Cointegrated Regression in Panel Data," Advances in Econometrics, 15, 179-222.

Larsson, R., J. Lyhagen and M. Lötgren (2001). "Likelihood-Based Cointegration Test in Heterogeneous Panels." *Econometrics Journal* 4, pp. 109-142.

Lee, D. R. and R. K. Vedder. (1992). "Friedman Tax Cuts vs. Buchanan Deficit Reduction as the Best Way of Constraining Government." *Economic Inquiry*, 3, 722-732.

Marlow, Michael L and Neela Manage. (1987). "Expenditures and Receipts: Testing for Causality in State and Local Government Finances", *Public Choice*, Vol. 53, pp. 243-55.

Meltzer, A. H. and S.P. Richard. (1981). "A Rational Theory of the Size of Government." *Journal of Political Economy* 89: 914-927.

Miller, Stephen M. and Frank S. (1990). "Co-Integration and Error-Correction Models: The Temporal Causality between Government Taxes and Spending" *Southern Economic Journal*, Vol. 57, No.1, pp. 221-229.

Musgrave, R. (1966). "Principles of Budget Determination." In Public Finance: Selected Readings, edited by H. Cameron and W. Henderson. New York: Random House.

Newey, W., and K. West (1994). "Autocovariance Lag Selection in Covariance Matrix Estimation." *Review of Economic Studies* 61, pp. 631-653.

Niskanen, William A. (1988). Reaganomics: An Insider's Account of Politics and the People. New York: Oxford University Press.

Payne, James E. (1998). "The Tax-Spend Debate: Time Series Evidence from State Budgets" *Public Choice* 95: 307-320.

Payne, J. E. (2003). "A Survey of the International Evidence on the Tax-Spend Debate." *Public Finance Review*, 31, 302-324.

Peacock, S.M., and J. Wiseman. 1979. "Approaches to the Analysis of Government Expenditures Growth." *Public Finance Quarterly*, Vol. 7, pp. 3-23.

Ram. R. (1988). "Additional Evidence on Causality between Government Revenue and Government Expenditure." *Southern Economic Journal,* 54(3), pp. 763-69.

Roberts, P.C. (1978). "Idealism in Public Choice Theory." *Journal of Monetary Economics*, 603-616.

Romer, Christina D. and David H. Romer. (2007). "Do tax Cuts Starve the Beast? The Effect of Tax Changes on Government Spending." NBER Working paper 13548.

Rork, Johnathan. (2003). "Coveting Thy Neighbors' Taxation." *National Tax Journal*, 56, 4, pp. 775-787.

Skidmore, Mark. (1999). "Tax and Expenditure Limitations and Fiscal Relationships between State and Local Governments." *Public Choice* 99, 77-102.

Smith, V. L., S. Leybourne, T-H. Kim and P. Newbold (2004). More Powerful Panel Unit Root Tests with an Application to the Mean Reversion in Real Exchange Rates. *Journal of Applied Econometrics* 19, pp. 147-170.

Wildavsky, A. (1988). The New Politics of Budgetary Process. Glenview, IL: Scott Foresman.

Westerlund, J. (2007a). "Testing for Error Correction in Panel Data." *Oxford Bulletin of Economics and Statistics*, Vol. 69, Issue 6, pp. 709-748.

Westerlund, J. (2007b). "Unbiased Estimation of Cointegrated Panel Regressions with Cross-Section Dependence." *Journal of Financial Econometrics* 5, pp. 491-522.

Zivot, E. (2000). "Cointegration and Forward and Spot Exchange Rate Regressions." *Journal of International Money and Finance* 19, pp. 785–812.

# Appendix A: Data Sources

- The data for state-local expenditures, tax revenues, non-tax revenues, total debt outstanding, and federal intergovernmental revenues (grants-in-aid to state and local governments) were extracted from the computer files provided by the US Census Bureau (http://www.census.gov/).

- The data for state gross product were obtained from the US Department of Commerce:
  Bureau of Economic Analysis, BEA, (http://www.bea.gov/regional/gsp/). The series used were computed based on the *Standard Industrial Classification (SIC)* industry definitions which covered the years 1963 to 1997. The BEA switched to the *North American Industrial Classification System (NAICS)* industry definitions after 1997 and renamed the series as gross domestic product. This change created discontinuity in the data due to differences in source data and different estimation methodologies. Since the BEA explicitly cautioned against appending the two series, the end year of our sample was 1997.

- In the absence of an appropriate state-specific deflator we used a price index for aggregate state-local government consumption expenditures and gross investment to convert nominal values into real values. The source of the data for this series is the US Bureau of Economic Analysis (Table 3.9.4. http://www.bea.gov/national/nipaweb).

Table 1. Unit root test results (log real per capita variables, 1963-1997)

| Variable | Test-statistic values | | | | $p$-values | | | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{t}$ | $\overline{LM}$ | $\overline{\max}$ | $\overline{\min}$ | $\bar{t}$ | $\overline{LM}$ | $\overline{\max}$ | $\overline{\min}$ |
| Expenditures | 4.89 | -4.68 | 9.77 | -5.18 | 1.00 | 1.00 | 1.00 | 1.00 |
| Tax revenues | 6.81 | -5.75 | 8.25 | -5.65 | 1.00 | 1.00 | 1.00 | 1.00 |
| Federal grants | -10.50 | 8.68 | 20.35 | 1.20 | 0.00 | 0.00 | 1.00 | 0.05 |
| Nontax revenues | 5.52 | -5.04 | 14.78 | -4.14 | 1.00 | 1.00 | 1.00 | 1.00 |
| Debt | -2.25 | -0.20 | 9.17 | -4.95 | 0.76 | 0.85 | 1.00 | 1.00 |
| Output | 10.30 | -6.77 | 9.56 | -5.65 | 1.00 | 1.00 | 1.00 | 1.00 |

*Notes*: The tests of Smith *et al*. (2004) take a unit root as the null hypothesis. The test regression is fitted with an intercept and 4 $(T/100)^{2/9}$ lags. The *p*-values are based on 1,000 bootstrap replications.


Table 2.  Cointegration test results (log real per capita variables, 1963-1997)

| Test statistic | Expenditure equation | | | Tax revenue equation | | |
|---|---|---|---|---|---|---|
| | Value | $p$-value$^a$ | $p$-value$^b$ | Value | $p$-value$^a$ | $p$-value$^b$ |
| $G_\tau$ | -19.96 | 0.00 | 0.00 | -10.19 | 0.00 | 0.41 |
| $G_\alpha$ | -1.84 | 0.03 | 0.37 | 0.33 | 0.63 | 0.99 |
| $P_\tau$ | -10.31 | 0.00 | 0.03 | -8.79 | 0.00 | 0.24 |
| $P_\alpha$ | -4.81 | 0.00 | 0.06 | -3.47 | 0.00 | 0.53 |

*Notes*: The tests of Westerlund (2007a) take no cointegration as the null hypothesis. The test regression is fitted with 4 $(T/100)^{2/9}$ lags and leads. The tests are based on Newey and West (1994) variance estimator.
*a.*    The *p*-values are for one-tailed test based on the normal distribution.
*b.*    The *p*-values are bootstrapped using 1,000 replications.

Table 3. Cointegration estimation results (log real per capita variables, 1963-1997)

| Variable | LS | | | Bias-adjusted LS | | |
|---|---|---|---|---|---|---|
| | β | SE | *p*-value | β | SE | *p*-value |
| Tax revenues | 0.50 | 1.38 | 0.00 | 0.52 | 4.55 | 0.00 |
| Federal grants | 0.08 | 0.58 | 0.00 | 0.06 | 1.74 | 0.00 |
| Nontax revenues | 0.03 | 1.03 | 0.00 | 0.04 | 3.60 | 0.01 |
| Debt | 0.02 | 0.53 | 0.00 | 0.03 | 1.40 | 0.00 |
| Output | -0.03 | 1.78 | 0.00 | -0.08 | 4.89 | 0.00 |

*Notes*: The value of β is the estimated cointegration slope, SE refers to the Newey and West (1994) robust standard errors, and LS refers to the least squares estimator of Kao and Chiang (2001). The bias-adjusted LS estimator can be found in Westerlund (2007b). The results are based on an intercept and the *p*-values are for two-tailed zero slope test based on the normal distribution.

Table 4. Short-run exogeneity (causality) test results (log real per capita variables, 1963-1997)

| Variable | Expenditure equation | | | | Tax revenue equation | | | |
|---|---|---|---|---|---|---|---|---|
| | $P_m$ | *p*-value[a] | $P_m$ | *p*-value[b] | $P_m$ | *p*-value[a] | $P_m$ | *p*-value[b] |
| Tax revenues | 19.28 | 0.00 | 2.99 | 0.00 | 15.84 | 0.00 | 2.05 | 0.02 |
| Federal grants | 14.45 | 0.00 | 1.60 | 0.06 | 11.85 | 0.00 | 0.68 | 0.25 |
| Nontax revenues | 20.51 | 0.00 | 3.70 | 0.00 | 9.16 | 0.00 | -0.34 | 0.63 |
| Debt | 15.52 | 0.00 | 1.95 | 0.03 | 13.13 | 0.00 | 1.26 | 0.11 |
| Output | 17.89 | 0.00 | 2.69 | 0.00 | 27.08 | 0.00 | 5.62 | 0.00 |

Notes: $P_m$ is the test statistic constructed using the *p*-values from the individual *F*-test for the short-run exogeneity. The test regression is fitted with an intercept and 4 $(T/100)^{2/9}$ lags and leads. The *p*-values are based on the normal distribution.
*a.* The *p*-values are based on asymptotic *F*-distribution.
b. The *p*-values are based on bootstrapping the *F*-test using 1,000 bootstrap replications.