Rainy Day Funds for Municipalities Estimated with Value at Risk

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Introduction

The fiscal crises faced by states from 2000-2003 focused attention on the volatility of state revenues, mainly tax revenues, and the size of state rainy day funds. States experienced a larger downturn in tax revenues than might be expected in an economic downturn for two major reasons: tax systems are becoming outdated, that is they no longer match the economic structure, and the stock market bubble had a major impact on revenues from capital gains. An additional factor was that during the preceding growth period, many states had returned tax revenues to citizens rather than adding to their rainy day funds, or states made permanent cuts in taxes, which are difficult to reverse in the short-run.

While state government revenues are recovering, many local governments continue to face fiscal stress. The majority of local governments are much smaller than state governments and face restrictions on the taxes they impose. Because local governments are smaller, it is also likely that their economic base is not as diversified as those of states, possibly increasing reliance on one type of tax. In some states, local governments have customarily received revenue sharing from the state and these revenues were cut (Chernick and Reschovsky; Reschovsky). Whatever the source of variation in revenue streams, it is a continuing problem for local governments to predict revenues to manage their budget planning processes.

This paper reviews the literature on methods of evaluating tax portfolios, focusing on the potential for diversification to assist in risk management in a public finance setting. Measures of fiscal stress are examined, setting the stage for an application of the Value at Risk technique to evaluate the exposure of two small cities to variability in tax revenue. Value at Risk is a risk assessment tool that is frequently used in private lending (Jorion 2001b). The possibilities for using Value at Risk to assist public sector decision-makers in examining the riskiness of their revenue “portfolio” and allocating rainy day funds are examined. The advantage of using Value at Risk from the perspective of local governments is that the distributions are derived from local data. It also allows local decision-makers to set their risk tolerance and from that determine the size of their rainy day fund. The details and possible outcomes of this approach will be explained, and the applications to the cities of Columbia, Missouri, and College Station, Texas, will raise potential benefits and pitfalls of the approach for financial management and for communicating with the public about fiscal stress.

Literature Review on Tax Revenues Risk

Financial management in the private sector is built on the principles of the risk-return tradeoff, first stated in the expected value-variance rule by Markowitz (1952). Higher expected returns are earned from bearing risk, according to the principle. Sharpe (1963)
elaborated on means of measuring the riskiness of individual stocks within a portfolio framework, reaffirming the importance of diversification for reaching risk management goals.

Local governments do not have the full set of opportunities for portfolio diversification available to investors, of course, yet the principles and techniques from finance have been found to be useful in the research in public finance. Several studies have examined the trade-off between the growth and volatility of tax revenue. Tax revenues with high growth rates have been found to be less stable (White, 1983, in a study of Georgia 1970-1981). A related portfolio model was used to develop recommendations for changes in the tax structure that accomplish reduced variances at the same expected growth. The importance of choosing a tax portfolio based on real rates of return was emphasized in a similar study, also of Georgia, covering the 1970s (Misiolek and Perdue, 1987).

Technical refinements in the analysis of volatility followed (Mallick and Harmon, 1994, Harmon and Mallick 1994, applied to New York State for 1970-91), demonstrating the importance of accounting for unit root processes in statistically valid estimation of growth rates and instability measures. Similarly to previous studies, the results form the basis for recommendations of ways to maintain the same growth of revenues with less volatility while accounting for vertical equity as measured by the Suits index.

Several researchers have sought to link tax revenues to broader explanatory factors, to enhance the predictability of future revenue streams or to form the basis of recommendations on tax structure. Business cycle effects on tax revenues have been found to be considerably stronger than wealth effects. In general, corporate income taxes tend to be the most volatile while sales and gross receipts taxes display the most stability (Seyfried and Pantuosco 2003). This result was from an analysis of the 10 largest U.S. states for 1983-1999. The riskiness measure, the elasticity of state revenue by tax type, with respect to changes in state-level income and national level wealth, was used to develop recommendations for the risk-minimizing tax structure, across tax types. The method has similarities to financial portfolio analysis in its focus on growth rates of revenues and the inclusion of various revenue sources. Because the measure of riskiness is an elasticity, it is useful in making comparisons of riskiness across a number of states. Another recent analysis explores the issue of wealth effects further. Capital gains have become a larger component of the state tax base, and the growth in capital gains has added significantly to the fiscal stress of state governments, based on the correlation of deficiency indexes with the 1999 state ranking on per capita capital gains (Sjoquist and Wallace 2003).

1 (Jones, Stallmann, and Tanyeri-Abur, 1997) “Equity or fairness: The tax system is fair in its relative treatment of different individuals. That is, the tax system bears equally on people in similar circumstances (horizontal equity) and differentially on people in dissimilar circumstances (vertical equity). Vertical equity: compares the percentage of income paid in taxes by persons of varying incomes (regressive or progressive tax).”

2 The Center on Budget and Policy Priorities categorized state tax collection changes between fiscal 2001 and fiscal 2002 into categories based on the magnitude of decline, and the authors use this data to build collections deficiency indexes.
While the literature shows many useful approaches for considering long-term structural recommendations for tax systems, there is still a gap in our understanding of how small, undiversified communities, many of which are in rural areas, might most effectively measure risks and improve upon their risk management programs. The limited available research on municipal-level portfolios has focused on large cities and followed similar approaches to the state-level analyses. Berg, Marlin, and Heydarpour used a Markowitz-type portfolio model to examine whether New York City’s tax structure is mix-efficient – minimizing volatility for a given level of revenue growth, for the period 1984-1998. Business and personal income taxes are income-sensitive taxes, and are very volatile and progressive. The New York City sales tax is affected by recessions, is regressive, but is not as volatile as the income-sensitive taxes; and the property tax is regressive and structured to limit volatility, because the tax revenue is determined by averaging the previous five years’ assessments. They suggest changes in the tax structure that can improve vertical equity and reduce volatility while maintaining the same growth in revenues.

Another study of a large municipal public finance situation provides a case study of a risk management failure, in Orange County, California (Jorion 2001a). Managers of a portion of the county’s investment portfolio took on risks to earn higher rates of return and unexpected market outcomes led to a large loss. An alternative means of measuring risk exposure using Value at Risk would have provided an easily understood measure of exposure, and perhaps led to reconsideration of the investment strategy.

Most analyses of risk issues in public finance take a retrospective inquiry, aimed at making prescriptions for tax structure based on long-run historical data. Risk management in private finance is much more short-term in nature. The goal is to identify exposure and make short-run adjustments, even overnight, to match exposures with risk tolerances. The local government budgeting process, typically conducted annually, is more long-run than an overnight portfolio re-balancing, but the ability to estimate shortfalls and adjust without resorting to legislative changes is important for public finance managers. The rainy day fund, or other reserve funds, are possible means for public authorities to cushion budgets against unexpected shortfalls.

Among the studies that specifically address rainy day funds, Wolkoff provides a detailed analysis and rationale for such funds at the municipal level. Three major revenue sources: income tax, property tax, sales tax, were ranked by the extent of cyclicality, with the result that city income taxes were most linked to business cycles, followed by sales taxes and property taxes. The “percent of own source revenue from income and sales tax,” (p. 55), or % cyclic revenue is the measure of risk exposure used in Wolkoff’s study. The risk rankings for the responding cities in 1983 were compared with the existence of formal rainy day funds (in 6 of the 27 responding cities) or other reserve funds for these large cities.

Estimates of the optimal level of rainy day funds have been completed for several states. Based on the experience of the State of Ohio, 1969-1995, the optimal sized rainy day fund amounts to 13% of general fund revenue (Navin and Navin 1997). This balance
could be obtained by contributions averaging 4% of general fund revenue in a non-contractionary year. Variations in real personal income in the state were the source of the cyclical movements underlying the estimate. The most comprehensive study on state-level rainy day funds (Sobel and Holcombe) highlighted the measurement issues involved in public finance risk management. The authors measure fiscal stress as the reduction of expenditure from long-run trend. Building from a benchmark concept of “neutrality,” which takes into account discretionary tax increases in the stress indicator, they showed that a rainy day fund balance of 30% of general expenditures would have been needed to weather the recession of 1991-92. This balance is much larger than the 5% of the state's budget recommended by the National Conference of State Legislatures Fiscal Affairs and Oversight committee (page 39).

A few studies apply the measurement procedure of Value at Risk to public finance. Value at Risk is a technique for estimating the risk exposure of investment portfolios. One difficulty in utilizing private-sector risk management tools in public decision-making is that governments have more diverse missions than private sector institutions and financial risk management in the public sector should have the goal to "maximize the probability of the agency accomplishing its primary mission" (Buttimer 2001, page 4). Buttimer proposes redefining Value at Risk as “Mission at Risk,” an important concept for an application to public sector decision-making, yet to date, there is no applied research utilizing Mission at Risk in the published literature.

The Value at Risk technique was the framework for statistical analysis of a state’s exposure to budget shortfalls (Nelson and Cornia 2003). Using a Monte Carlo approach, Nelson and Cornia developed a probability distribution for the state of Utah’s budget surplus/deficit, for fiscal year 2003 based on the previous 10 years experience. Their results indicate a 5% risk of a potential budget deficit of $147 million. This tail loss probability is a worst-case outlook, as required with the Value at Risk measure. The most likely outcome under the distribution estimated by Nelson and Cornia is for budget balance.

The literature clearly establishes that Value at Risk is may be a part of the risk management activities undertaken by public authorities. To the extent that municipalities use capital markets to raise funds or invest funds, their risk exposure can be estimated with Value at Risk in the same manner that would be used by a private investor. For most smaller communities, however, the investment portfolio is small as a share of the budget and its exposure is limited by law to low-risk securities. The more significant risk that affects communities is the uncertain revenue stream, as has been documented in the earlier studies on portfolios of revenue. Therefore we propose an application of Value at Risk for estimating the size of a rainy day fund aimed at managing the risk of tax revenue shortfalls at the municipal level. The procedures reported in this paper rely on a non-parametric method and readily available data. The methods and results are reported below, following formal definitions of Value at Risk.
Value at Risk Methodology

After the October 1987 stock market crash, market turbulence and innovations in financial instruments led to higher use of derivative securities among private investors. Several publicized major incidents, including Orange County’s 1994 bankruptcy, drew attention to the potential for huge losses from derivatives trading. Since that time, the regulators of financial institutions have required risk-based capital adequacy measures. Value at Risk is one of those measures.

Definition of Value at Risk

“Value at Risk is the maximum loss over a target horizon such that there is a low, pre-specified probability that the actual loss will be larger” (Jorion 2001a). Value at Risk has become accepted in investment and banking practice because it collapses the distribution of portfolio returns into a single number, in dollar value, and therefore is suitable for decision makers to use, regardless of whether they have a high level of knowledge of statistics. The underlying concept in the calculation of Value at Risk is a probability distribution of rates of return (figure 1). Taking the generic distribution of wealth (W) shown here as an example, consider the choice of a confidence level $c$ to represent a risk tolerance on a loss, or a pre-specified probability of the rare lower tail outcome. Thus the analyst or decision maker can specify the risk associated with the lower quantile of bad outcomes. Using the features of the distribution, the confidence level $c$ is linked with a percentage loss, or negative rate of return. The negative rate of return is multiplied by the value in the portfolio to obtain the dollar estimate of Value at Risk.
Either an empirical distribution, a simulation-based approach, or a parametric model of a statistical distribution can be used to generate estimates of Value at Risk. In this paper, a regression model is used as the basis of an empirical distribution of year-to-year municipal revenue shortfalls. These shortfalls are within the portfolio context, to the extent that we aggregate types of taxes within a time period and include the instances in which one tax’s shortfall may be partly compensated by the stability of another tax type. We specify shortfalls with respect to underlying trends, to rule out the predictable growth tax revenue and obtain an estimate of the unpredictable component, or the percentage shortfalls from trend. The estimated shortfalls from trend in each year are used as the empirical distribution underlying the Value at Risk estimate.

Our case examples are two small cities that, as the homes of Texas A&M University and the University of Missouri, have a high dependence on education and professional services. These cities have been chosen for illustrative purposes and are not intended to be representative of the larger national experience. Tax revenues collected in both College Station and Columbia have grown at a steady pace in absolute terms during the 1990s and early 2000s, in nominal values (figure 2). As a share of total general revenue, taxes have increased, from 46% (1992) to 66% (2002) of general revenue in College Station and from 46% (1992) to 70% (2002 and 2003) of general revenue in Columbia. These upward trends led to annual rates of growth in tax revenue that were positive in all years examined except one (1997 for College Station, and 1999 for Columbia).

Riskiness of these revenue streams, based on the standard deviations of the raw data, has been significant (table 1). Over the 1991-2003 period, the City of College Station had a standard deviation of annual revenue of over $8.3 million, almost 19% of its budget. The
riskiness of tax revenue is lower in dollar terms, but almost as high in percentage of budget, at $6.7 million in standard deviation and 15% of the College Station budget. Columbia’s recent experience suggests higher risk, because its budget is higher than College Station. The standard deviation of annual general revenue was $11 million, just below 14% of the 2003 budget. Columbia had a standard deviation of tax revenue of $10.1 million, or approximately 13% of the budget. It should be noted that using the standard deviation as a measure of riskiness imposes a penalty for positive deviations from the mean as well as shortfalls. The consistent growth trend can lead to misleadingly high measures of risk when the standard deviation is used.

We estimate Value at Risk using the revenue streams only. Given balanced-budget constraints, an approach that examines total revenues less expenditures obscures the importance of “mission risk” (Buttimer 2001). Government officials who are forced to drastically cut expenditures in response to impending tax revenue shortfalls manage to meet budgetary requirements, yet they have had to leave certain obligations unmet. Hence we will not use historical data on the surplus/deficit, which would have built these adjustments into the data set underlying the risk measure. Other researchers recognized this problem and developed procedures to accommodate it in their studies. For example, Sobel and Holcombe (1996) measured fiscal stress as the reduction of expenditures from trend, excluding discretionary tax increases. Our approach to avoid measurement of budget cuts made under duress will be to look at revenue only.

Table 1. Measures of Revenue Risk for College Station, Texas, and Columbia, Missouri.

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<tr>
<td></td>
<td>(in $)</td>
<td>% of 2003 budget</td>
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<td>General Revenue</td>
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<td>std dev from mean</td>
<td>8,376,481</td>
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<td>std dev from trend</td>
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<td>Value at Risk</td>
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<td>Tax Revenue</td>
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<td>std dev from mean</td>
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<td>std dev from trend</td>
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<tr>
<td>Value at Risk</td>
<td>2,332,595</td>
<td>-</td>
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</table>
Because downside risk is important for the conceptual framework of this study, the Value at Risk estimation procedure used focuses on the negative deviations and includes an adjustment for trends in tax revenue, to link exposure to the unpredictable outcomes. Consistent growth in revenue for the two cities can be observed from figure 2. In spite of a slowdown in the general economy, these cities’ tax revenues have tracked well with the long run baseline trend (figures 3 and 4). A simple time trend regression was used as the underlying model for this initial research. (See appendix table 1 for estimated parameters of the trend model.)
Empirical Distribution Procedure to Estimate Value at Risk

Value at Risk computed under a maintained hypothesis that budget shortfalls were normally distributed would be more precise, in statistical terms, than an empirical distribution. The precision would result from the continuous nature of the parametric distribution that had been chosen. Upon defining the relevant confidence level, one can use the normal probability tables to obtain an exact value associated with the point on the lower tail of the distribution. The use of the normal distribution presupposes symmetry and a relatively low chance of high loss or gain (in expected shortfalls).

With the observed historical data for our two small municipalities, the distributions over the last several years do not resemble a symmetric normal distribution. In part, this may be the result of working with so few data points, but it is also a phenomenon of the growth in tax revenues experienced in the 1990s and early 2000s. The empirical
distributions that form the basis for the Value at Risk estimates are not bell-shaped. The
distributions resemble a uniform density with fairly high dispersion at the lower tails
(figures 5 and 6). For Columbia, the lower tail at 8% or larger annual tax revenue
deviation from trend is associated with a confidence level of 13.3%. Because we have
few discrete observations, it is not possible to choose one of the usual statistical p values,
like 5% or 10%, without serious effort at interpolation. By letting the actual observations
guide the confidence level, we are not able to take advantage of one of the features that
makes Value at Risk useful for risk managers—namely the choice of confidence level.
Nevertheless, we can provide an intuitive measure of exposure in dollars, as follows:
There is a 13.3% probability that Columbia will have a tax shortfall of at least $4.5
million. Interestingly, this $4.5 million Value at Risk estimate is somewhat larger than
the $4.02 million benchmark of 5% of general revenue that some public budget
administrators use for estimating the state-level rainy day fund (Strayhorn, 2004).
Columbia’s reserves are in the form of a requirement that 16% of the budget be
“undesignated,” which amounts to $35.5 million in FY03. This level of reserves is
substantially higher than the estimated Value at Risk.

It should be noted that this version of the empirical distribution was developed with the
lower tail aggregated into shortfalls of 8% or higher; there were two such occurrences in
our period of observation. Columbia experienced a drastic 21% shortfall from trend in
1999. The Value at Risk measure as reported previously is not affected by how dispersed
that outlier observation is from the mean, it is simply a part of the 13.3% of area in the
distribution that is encompassed by the lower tail. If we had wanted to highlight that
lower tail loss, the Value at Risk would have been a 7% probability of a shortfall of at
least $12 million. It is a lower chance of a bad event, but the bad news is considerably
worse than in the other Value at Risk estimate.

Figure 5. Value at Risk empirical distribution for Columbia, Missouri, 1989-2003.
College Station similarly has a Value at Risk that naturally is associated with two lower tail data points, but because of smaller sample size the confidence level is 15.4%. Its tax revenue exposure is expressed as: *There is a 15.4% probability that College Station will have a tax shortfall of at least $2.3 million.* Compared with Columbia, the Value at Risk is lower, and like Columbia, College Station’s estimated Value at Risk is close to the suggested benchmark of 5% of general revenue, which would be $2.23 million. College Station’s actual reserves as of September 30, 2003, were $42.8 million, substantially higher than the estimated Value at Risk. This reserve balance includes encumbered funds for operations (around $1 million) and several large reserves for anticipated capital projects, and is not explicitly designated as a rainy day fund.

These lower-tail outcomes for College Station occurred in the early 1990s, an earlier recession, and it is possible that changes to the tax structure accommodated the more recent business cycle and enabled the financial managers to avoid tax shortfalls in the late 1990s-2000s. Our data collection effort to date has not examined the institutional differences across the cities or policy changes that may have occurred. Moreover, the empirical distribution procedure does not account for duration of shortfalls associated with cycles or timing of the various outcomes used to form the distribution. These issues, and other factors that explain the shortfall in addition to the simple time trend, are the subject of further research planned on this topic.

**Figure 6.** Value at Risk empirical distribution for College Station, Texas, 1991-2003.
Conclusions

Rainy day funds remain a hot topic as state governments recover from recent economic downturns. Just last month, the Comptroller of the State of Texas, Carole Keeton Strayhorn, noted:

…our state's Rainy Day Fund has grown to $878.5 million due to a surge in tax collections that Texas natural gas producers pay to the state. I believe, however, that the Rainy Day Fund balance remains well below where it needs to be. We should build it to at least $3 billion, which would be just 5 percent of our state's general revenue budget. The money in the Rainy Day Fund should only be used for a true emergency. Texas government needs to budget like any hard-working Texas family--spend wisely, invest wisely and save for a rainy day.

What are the criteria by which local government financial managers can best implement these laudable goals? A consideration of the risk management tools used in the private sector suggests the potential for Value at Risk to be applied. This preliminary investigation of two small cities indicates that Value at Risk associated with unexpected tax shortfalls can be estimated without undue difficulty. Columbia, Missouri would have a rainy day fund of $4.5 million and College Station would have a rainy day fund of $2.3 million if the Value at Risk estimate were used to set the fund balance. These estimates of Value at Risk are a bit more than 5% of each city’s general revenue.

The empirical distribution approach used to isolate deviations from trend is an important feature of the procedure and especially necessary when cities are experiencing consistent growth. The Value at Risk measure, which focuses on shortfalls from easily estimated trends, provides a better risk assessment device than does standard deviation. The extremely simple trend model used here was a good fit for these two growing cities in the time frame examined, but may not be well suited for municipalities that have more cyclical tax revenue sources. A more extensive and systematic selection of municipalities would shed more light on the usefulness of Value at Risk for municipal exposure to tax shortfalls.
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<th>College Station</th>
<th></th>
<th>Columbia</th>
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<tr>
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<tr>
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<td>Coefficient on Time</td>
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<td>11.572</td>
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Reference List


