Better Budget Forecasting
Using Simulation

BY MARC JOFFE
The debate over the fiscal cliff has once again put the spotlight on budget forecasting. The Congressional Budget Office and other forecasters were asked to predict revenues, expenditures, and deficits under various policy scenarios, but these projections have attracted criticism — despite the tremendous effort expended in producing them.

Since we can’t predict the macroeconomic future, what are our options? Abandoning forecasting is not one of them; we need some kind of projections to assess policy alternatives as well as the risks inherent in maintaining the status quo. Instead, forecasters need to change their approach, creating forecasts with a number of possible outcomes instead of just one scenario.

**FORECASTING FAILURES**

Alan Auerbach, director of the Robert D. Burch Center for Tax Policy and Public Finance at the University of California, Berkeley, found large errors in a comparison of federal budget results to Congressional Budget Office and Office of Management and Budget forecasts, but did not find evidence of bias; the forecast errors were sometimes positive and sometimes negative. Richard Boylan, professor of economics at Rice University, found that state general fund revenue forecasts for fiscal years 1982 through 2005 understated actual revenue by 3 percent, on average. He also found that revenue forecasts were significantly more optimistic relative to actual revenue in election years.

The most infamous case of budget forecasting error occurred in 2001. At the time, the CBO anticipated $5.6 trillion in surpluses over the next 10 years. The projection was used to justify $1.6 trillion in tax cuts. While those reductions were supposed to leave the country with $4 trillion in surpluses over the fiscal 2002-2011 period, the actual result was a cumulative deficit of $6.1 trillion.

Some have used this outcome to condemn the CBO, but such criticism is ill-founded. Those familiar with the task of budget forecasting recognize that the CBO strives for quality and objectivity — and succeeds to a remarkable extent.
Unfortunately, CBO analysts can’t do the impossible, which is to accurately forecast economic growth, inflation, interest rates, and policy changes over a 10-year window.

**FORECASTING OPTIONS**

Instead of a single budget projection, forecasters should generate a budget forecast distribution using a large number of randomly selected macroeconomic values chosen from within reasonable ranges. This will produce an array of possible outcomes, as opposed to the traditional “point forecast,” which shows only one scenario. The results will give policymakers and the public a full range of plausible outcomes. This technique is known broadly as simulation. Exhibit 1 shows a fan chart produced by a CBO federal budget simulation in 2007.

The basic premise of simulation is ably described by Sam Savage, author of *The Flaw of Averages* (Wiley, 2012). Savage gives the example of shaking a ladder before climbing on it. When you shake the ladder, you are in effect running a simulation of the ladder’s response to bombardment by a distribution of random forces — information you might like to know before climbing on it. In financial forecasting, simulation can be used to gauge the effects on the future financial position of change in key variables (e.g., economic conditions, policy changes) — information a jurisdiction might like to know before moving forward with a given budgetary plan. Financial simulations, like shaking a ladder, are not perfect models of reality, but they still provide a useful stress test in advance of climbing the first rung or adopting a financial plan.

A powerful simulation technique used widely outside of public finance is Monte Carlo analysis. Monte Carlo simulation uses vast numbers (thousands or millions) of computer-generated scenarios to test the effect of variation in key variables. The level of variation is randomly determined but takes place within certain parameters. These parameters are decided by the analyst, and the model then produces a distribution that shows the likelihood of certain outcomes (e.g., the ladder collapses, large deficits emerge) based on aggregate results from the multitude of scenarios run. Exhibit 2 shows how a variety of simulated interest rate scenarios can be used to produce a distribution of debt/gross domestic product ratios.

Recent advances in technology have made Monte Carlo-style simulations more accessible than before, so they can be employed in a variety of public finance applications. The next section in this article describes how open-source simulation technology has been applied to the problem of assessing municipal and sovereign credits.

**MONTE CARLO SIMULATION IN CREDIT ANALYSIS**

Simulations can be used to yield a distribution of future debt-to-GDP and other fiscal ratios, which could then be used by rating agencies, budget analysts, bond investors, and others to assess the government’s fiscal health. If certain ratio levels are associated with default, a simulation can be used to forecast the probability of a fiscal crisis. For example, if an analyst were to conclude that a given country cannot sustain a debt-to-GDP ratio greater than 180 percent, he or she could run a simulation to generate the probabilities of reaching this unsustainable level, at every point along the maturity curve. Relying on budget distributions might help rating agencies avoid the kind of controversy that accompanied/plagued S&P’s downgrade of U.S. Treasuries in 2011.

Of course, debt/GDP ratios are less applicable to state and local levels of government. Another ratio considered by rating agencies — the quotient of interest expense to total revenue — is a more consistent measure of fiscal burden across levels of government. No U.S. state, Australian state, or Canadian province has defaulted in the last century with an interest to revenue ratio of less than 30 percent. However, Arkansas, Alberta (Canada) and New South Wales (Australia) all defaulted in the 1930s after reaching this threshold.
Simulation could be used to assess the creditworthiness of local governments by determining the proportion of simulation trials that exceed a fiscal breaking point (e.g., interest expense/revenue is more than 30 percent), which would then imply a default probability. The default probability describes creditworthiness. The relationship between default probability and creditworthiness is important: a number of studies have found that municipal bonds with a given rating have lower default rates than corporate or structured bonds with the same rating. Computing and displaying default probabilities could be useful in conversations with credit rating analysts, who might not think in probabilistic terms.

Exhibit 2: Simulated Interest Rate Scenarios Produce a Distribution of Debt/GDP Ratios
PUTTING IT INTO PRACTICE

Historically, creating simulations that could run in a reasonable amount of time required an advanced programming background. Improvements in computer processing speed and software, however, now make simulation a feasible option for budget professionals who are experienced with spreadsheet software.

The Public Sector Framework, a free, open source resource (available at www.publicsectorcredit.org/pscf.html), includes a basic sample workbook (see Exhibit 3), a spreadsheet software add-in, and a processing engine that runs without user intervention. Sample spreadsheets are also available, containing simulation inputs and results for the federal government and State of California. More recently, PSCF was used to assess the long-term credit risk for the ten Canadian provinces, in a study published by Ottawa’s Macdonald-Laurier Institute for Public Policy.

Simulation tools use random numbers to differentiate each trial (i.e., each simulation run). PSCF allows users to generate uniformly distributed or normally distributed numbers that can then be used to “shock” macro-economic components, including interest rates, inflation, and economic growth. Financial models relying on normal distributions received substantial criticism in Nassim Taleb’s *The Black Swan: The Impact of the Highly Improbable* (Penguin, 2008) because they inadequately represent the likelihood of unusual events of the sort that caused the 2007-08 financial crisis. In response, PSCF includes a “fat tail” distribution (a probability distribution that is heavily asymmetrical) that should be applied to highly variable series like the revenue base for capital gains taxes.

In the sample models, most revenue series are driven by changes in GDP (at the national level) or personal income (at the state level). The simulation can directly generate economic growth rates. For example, it can be assumed that growth is normally distributed around 2 percent. The model will generate a large proportion of growth scenarios around 2 percent, but — depending on how the random numbers are applied — it can also generate a few negative outcomes (to simulate recessions) and some realizations reflecting rapid growth of more than 4 percent.

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Instead of random GDP numbers,
the samples use a more sophisticated method of simulating economic growth rates, developed by Ronald Lee, professor of economics and demography at University of California, Berkeley, and his colleagues. Under this methodology, economic growth is assumed to be determined by working age population size, labor force participation, and productivity. Each of these components is simulated individually, and then they are combined to derive growth projections.

This might seem irrelevant to the municipal government forecaster, who may be primarily concerned with property tax revenues. For this revenue source, it is best to simulate home price appreciation and collection rates.

Simulation techniques can also be used in modeling pension expenses. In the California model, the state’s future pension contributions are based on simulated returns earned by the California Employee Retirement System. By basing the CalPERS return projections on a Cauchy-Lorenz (fat-tailed) distribution, we ensure that future returns show substantial volatility — as they have in the recent past. Our simple pension model also includes estimates of future contributions and benefits, which, along with returns, affect the system’s future asset balances. These projected asset balances, in turn, are assumed to determine the ability of CalPERS to contribute to the cost of state retiree pensions. Remaining costs are assumed to be the responsibility of the state (or local agency members of the CalPERS system). If CalPERS assets are exhausted, pension obligations are assumed to be funded on a pay-as-you-go basis.

**ABOUT OPEN SOURCE**

PSCF provides a free platform on which to build multi-year simulation models and gauge default risk for government bond issuers. On the other hand, open source software like PSCF has a couple of disadvantages. Lacking subscription revenue, open source tools can be rough around the edges. It can also be harder to get support for open source software than for commercial packages (although the author welcomes inquiries from *Government Finance Review* readers and commits to responding to them).
Generating distributions for input variables is a major challenge, as discussed earlier. The PSCF sample relies on regressions of historical data with random shocks derived from the random number generator (see Exhibit 4). Eventually, users may have the option of obtaining standard distributions. Sam Savage’s ProbabilityManagement.org is developing standardized distributions that are applicable to various industries and can be represented in a compact format, making it easy for analysts to share sets of assumptions with each other and the general public.

**CONCLUSIONS**

Simulation techniques have revolutionized many industries in recent decades. Supply chain management, oil exploration, and financial portfolio management have all benefited by moving away from flawed thinking based on averages to an enlightened understanding of risks and opportunities provided by distributions. Now it is time for the systemically important task of budget forecasting to benefit from this technology. I

**Notes**

3. Unfortunately, the CBO simulation was improperly parameterized. A discussion of the CBO simulation technique is beyond the scope of this article, but readers are encouraged to contact the author for his analysis of the now-discontinued CBO simulation effort.
4. To be more precise, no unit defaulted on interest and principal payments to investors due to fiscal conditions. Louisiana temporarily defaulted in 1933 due to the failure of a bank in which the state’s cash was deposited, while Texas was reported to have missed debt service payments to certain state-controlled funds.

**MARC JOFFE**, a former senior director at Moody’s Analytics, is the founder of Public Sector Credit Solutions. In 2011, Joffe researched and co-wrote Kroll Bond Rating Agency’s inaugural municipal bond default study. Earlier in 2012, he introduced a free open source budget simulation tool, the Public Sector Credit Framework. Joffe has a BA in Economics and an MBA in finance from New York University, and an MPA from San Francisco State University.