PF2 Securities Evaluations

Public Sector Credit Framework
An Open Source Tool for Rating Sovereign and Sub-Sovereign Bond Issuers

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Introduction

Recent years have seen substantial criticism of ratings assigned to sovereign and sub-sovereign issuers – including states, provinces, counties, cities and special taxing districts. Government ratings are vulnerable to attack, in part, because of the lack of transparency in rating processes. To reduce the risk of bias, rating agencies and other credit adjudicators should adopt transparent, quantitative processes for assessing government bonds.

In an effort to stimulate the development of transparent, quantitative government bond analytics, PF2 is releasing a free, open source Public Sector Credit Framework (PSCF). The framework enables an Excel user to create a multi-year budget simulation, to specify a default threshold in terms of a fiscal ratio and to calculate default probabilities and implied ratings.

In this research note, we discuss how PSCF operates and how it may be applied to specific government bond issuers. The discussion mixes technical details with rationales for some of the parameter choices we made in creating the sample US (Federal) and California models being released with the framework.

In the spirit of open source, we welcome community criticism of the framework and the sample models. Further, we urge readers to move beyond criticism and embrace collaboration by making and publishing improvements to the samples and enhancements to the framework.

To use the software and get involved, please visit the following web pages:

PSCF Download Page: http://www.publicsectorcredit.org/pscf.html
Source Code Repository: http://www.github.com/joffemd/pscf
User Forum: http://groups.google.com/group/pcsf-support
Developer Forum: http://groups.google.com/group/pscf-developers

Core Concepts

We have worked to make PSCF as flexible as possible, but the approach requires the user to embrace two core assumptions:

(1) It is possible to build a multi-year budget simulation that produces a range of annual fiscal outcomes in which a government's actual "results" will fall. This approach needs to be distinguished from multi-year budget forecasts offered by government agencies such as the US Congressional Budget Office. The CBO's point estimates rely on specific inflation, interest rate and growth forecasts. A simulation approach, however, allows the user to specify a wide variety of macroeconomic scenarios, leveraging the framework's random number generation capabilities.

(2) A default point can be specified in the form of a fiscal ratio – such as the ratio of debt to GDP or the ratio of interest expense to revenues. Different ratios and different default thresholds can be applied to different issuers. For users who do not believe certain sovereigns can default (perhaps because of their ability to monetize debt), the default threshold can be relabeled as a fiscal crisis threshold.

The choices of default ratio, default threshold and simulation approach are all left to the user's discretion.

PSCF's simulation approach enables the analyst to push beyond various government accounting dilemmas. For example, there has been significant debate over the appropriate discount rate to apply when calculating unfunded pension liabilities. In PSCF, such discounting is unnecessary. Future pension fund asset levels can be simulated based on a range and distribution of possible returns. In certain simulation trials, pension fund assets may remain available to be contributed to retiree benefits, while in other trials the fund may be exhausted, requiring a shift to a "pay as you go" system.

Appropriate default points can be determined through a combination of research and theory as we discuss in the next section.

Establishing a Default Threshold

Modeling advanced economy government defaults is challenging because of the scarcity of recent default data. To determine a reasonable default point, one needs to research government defaults over a much longer time period than one might use for corporate or structured models. Carmen Reinhart and Kenneth Rogoff have recently set the standard for investigating sovereign defaults over a longer time frame. Their research data has been published at http://www.reinhartandrogoff.com/data/.

For general obligation US municipal bonds, significant numbers of defaults occurred in the 1920s and 1930s. Some information about these defaults is reported in the 1971 Hempel Study published by NBER at http://www.nber.org/books/hemp71-1 and the 2011 Kroll Bond Rating Agency Municipal Bond Default Study available at http://www.krollbondratings.com/show_report/44.[1]

Considering the history of US states, we are aware of only one case after 1900 in which an issuer failed to service bonds held by the general public, on a timely basis, due to insolvency. This is the case of Arkansas in 1933.[2]

[1] The author of this piece was a co-author of the referenced study.
[2] As reported in the Kroll study, there were three other state bond defaults during the Depression. Louisiana made some interest payments two months late due to the failure of Hibernia Bank. Texas failed to service bonds held by certain state funds. South Carolina compulsorily refunded maturing bonds – giving some bondholders new bonds instead of cash, while still paying a market rate of interest.

Surviving records indicate that the state continued to service its bonds until its ratio of interest expense to total revenue exceeded 30%. Looking at comparable nations, we find that the Canadian province of Alberta and the Australian State of New South Wales also defaulted during the Depression. Both of these sub-sovereigns also had interest expense to revenue ratios in excess of 30%. No American or Australian state, or Canadian province, appears to have defaulted at levels below 30% over the last century.

We can supplement this evidence with political economic theory. For an elected official, the political cost of defaulting is quite high. It not only represents a serious embarrassment, but it also restricts his or her ability to finance future deficits through bond issuance. On the other hand, high levels of interest service crowd out programs demanded by powerful constituencies. This dilemma was captured by New South Wales Premiere Jack Lang when announcing the state's 1931 default:

> *Parliament in New South Wales was faced with an extremely awkward problem. It was committed to pay to oversea [sic] bondholders £700,000. The Government itself had not the money. It was informed, however, that this amount would be made available for shipment overseas if the Government needed it. Having in mind the reiterated statement that every £ of credit consumed by the Government meant a £ less for circulation among the primary and secondary industries, the Government was faced with a most difficult problem. If we took the £700,000 which the bank offered us, it meant that £700,000 worth of credit would have to be withdrawn from the primary and secondary industries of New South Wales. Default faced us on either hand. We could default, if we chose, to the farming community by withdrawing £700,000 from it, or we could default to our oversea creditors. Having to choose between our own people and those beyond our shores, we decided that the default should not be to our own citizens.*[3]

Consequently, the default decision was a political calculation, balancing the interests of bondholders and voters.

A number of analysts argue with us that the 30% ratio is no longer applicable, and that states could be expected to default at much lower levels. This opinion has a strong counter, however. Available evidence suggests that the vast majority of Arkansas, Alberta and New South Wales debt was held externally – usually by investors in financial centers like New York, Montreal or London. Today, state bonds are commonly held by high net worth residents, who could be expected to vote against politicians choosing default, and to make campaign contributions to opposing candidates.

That argument notwithstanding, our sample model for California does make one concession to those advocating a lower default point. While we still prefer the 30% level, we add pension expenses to interest costs in the numerator of the default ratio. California courts have held that the state may not defer pension contributions, and these costs do have the effect of crowding out program expenditures.

Two final notes are in order. Our sample model applies 30% to *total* state revenues – not just those in the general fund. The historical default ratios applied to total revenue, and it should be noted that the three defaulting governments cited above were receiving substantial central government subsidies. Second, readers who disagree with our choice of default point can still use PSCF, since the ratio and level are model inputs that can be easily changed in the Excel workbook interface. In this, and many other cases, it is important to distinguish between the framework itself (which is quite flexible) and modeling choices we have made in our samples (which are quite specific).

We also use 30% as a threshold for a US Treasury default or fiscal crisis. As discussed in our blog post "Correction: The US Has Defaulted Before and It Can Default Again" the US abrogated the gold clause in Treasury bonds in 1933. The gold clause entitled treasury bondholders to receive payment in gold or currency. As detailed

[3] The Sydney Morning Herald, 2 April 1931, page 11.

in the post, the abrogation was driven by fiscal considerations, the importance of which has been forgotten with time. 1933 was also the only year in which the US interest expense to revenue ratio surpassed 30% since Reconstruction. Australia imposed an interest reduction on bondholders in 1931, just after its interest expense to revenue ratio exceeded 30%.[4]

Other Basic PSCF Model Parameters

The default ratio and threshold are among the parameters entered on the PSCF *model* sheet. The sheet also allows the user to specify the number of simulation trials to run and whether to output projection details. Since these details can be voluminous, this option should not be selected when running over 100 trials. Given the power of new computers and the fact that PSCF simulations are executed by compiled C-language code, users should expect to run 10,000 or more trials in a couple of minutes, as long as projection detail output is turned off.

The *model* sheet also allows the user to specify the initial year of the analysis and the number of years over which the simulation should be run. Our example models typically start with the prior fiscal year – the last for which actuals are available – and project the current fiscal year as well as 30 future fiscal years, i.e. 31 years of projection in all. These parameter choices allow one to see results for the longest dated bonds issued by most governments. Some analysts may reasonably question the value of long term projections; they can choose a smaller number of projection years. On the other hand, since demographic trends are fairly well established in some areas, longer term projections can provide useful insight into a government's long term fiscal balance.

Aside from the default ratio, the user may also specify up to four additional ratios which will be calculated and displayed in the projection detail if the option to generate that detail is enabled.

PSCF Series

Because PSCF relies on Monte Carlo simulation, random number generation is an important part of the framework. In a typical PSCF model, random numbers affect macroeconomic variables, which, in turn, affect revenue and expenditure items.

All random number series must be specified at the top of the *series* sheet. The users can create as many random number series as they wish. Random numbers are denoted both by their position at the top of the *series* sheet and through the use of an appropriate prefix in the series name. Random number series must begin with one of the following three prefixes:

unirandom	Uniformly distributed random numbers
normrandom	Normally distributed random numbers
cauchyrandom	Cauchy-Lorenz distributed random numbers

As the table suggests, PSCF currently supports three types of random number distributions. While the uniform and random distributions are familiar, the Cauchy Lorenz option is worth noting. This is a bell-shaped distribution that, depending on the sigma parameter provided, can have much fatter tails and a much smaller hump than the normal distribution. Its inclusion was inspired by widespread criticism of reliance on normal distributions in pre-crisis financial models.

[4] Moody's 1934 Municipal and Government Manual, P. 2152

After random number series, the user typically specifies macroeconomic series and then fiscal (revenue and expenditure) series. Since series are processed by the simulation routine in descending order, any series referenced by other series must be specified first. For example, if one wants to assume that income taxes are 8% of GDP, then GDP must be listed in the *series* sheet above income taxes.

A detailed description of each column of the *series* sheet is available in the documentation tab of the sample.xlsm workbook. We will briefly attend to a few concepts here. Column K contains "year zero" values which are typically known inputs from the prior fiscal year, although it is also possible to start with current fiscal year estimates. Columns L and higher contain projected values or equations for each year of the projection. Values can be used for a fiscal series if budget office estimates are available and expected to be accurate or nearly accurate regardless of future economic conditions. Otherwise, the fiscal series should be functions of macroeconomic variables.

At the national and state level, GDP, inflation and personal income are the most frequently referenced macroeconomic drivers. For a city primarily dependent on property taxes, one might use home price appreciation forecasts to capture growth in the tax base. In some cases, it may also be appropriate to project and partially randomize property tax collection rates, since low collection rates were a major factor in many Depression-era municipal defaults.

Series should also be created to capture total revenue, total expenditures, the resulting surplus or deficit and the total stock of debt. The example workbooks have these variables, so it may be easier to copy and edit one of the samples than to start from scratch.

Finally, a review of the samples will show many expressions that contain *[y]* or *[y-1]*. These specify current and prior year data respectively. Each series in PSCF is implemented as an array, with *[y]* evaluating to the array member associated with the year represented by the current column.

Key Series in the US and California Samples

Both the US and California workbooks contain a demographic process based on the Lee Carter mortality model (see http://lcfit.demog.berkeley.edu/). We show estimated population by age buckets of one year, which are then simulated through the analysis period with the addition of new births, migrations and age-specific death rates. In the examples, births and deaths include a random factor and thus vary with each trial. Net migration – a smaller component – is not randomized.

We simulate real GDP changes as a function of productivity growth and changes in labor force size. Labor force size, in turn, is assumed to be a function of working age population and labor force participation. Productivity growth and labor force participation rates both contain random components, so GDP growth shows substantial year-to-year and trial-by-trial variance. We could have made GDP growth even more volatile by additionally assuming variations in the unemployment rate, but a review of the projection output should convince the reader that that was not necessary in these samples (given the amount of variance already present).

Most near-term revenue and expenditure series are based on US Congressional Budget Office and California Legislative Analyst Office estimates. Since these estimates assume specific rates of real GDP growth and inflation, any revenue and expenditure items that are sensitive to these macroeconomic factors need to be adjusted to take into account differences between the budget office forecast and the results of each trial. For example, if CBO personal income tax revenue estimates assume 5% nominal GDP growth in a given year, but the simulation generates 8% nominal GDP growth for that year in a particular trial, revenue growth must be adjusted upward for that trial. The amount of the adjustment should be based on an estimate of sensitivity of personal income tax revenues to changes in nominal GDP.

Budget office forecasts usually assume that specific policies will be implemented or maintained. For example, CBO's baseline forecast assumes that the Bush tax cuts will expire at the end of 2012 - in conformance with current law. However, it is likely that Congress will extend at least some of these reductions. If Republicans gain the upper hand in the November elections, we can reasonably expect all the tax cuts to be extended. If Democrats dominate, the most likely scenario is that the reductions will be extended to all but those in the top two tax brackets. In the US sample, we assign probabilities to these outcomes. For example, we assume a 35% probability that tax cuts for the top two brackets will be extended, based on Mitt Romney's probability of being elected according to a recent check of Intrade – a political market. During each trial, we generate a uniformly distributed random number between 0 and 1, and compare this value to 0.35; we assume an extension of the top two bracket reductions if the random number is below 0.35. When a large number of trials are executed, approximately 35% will include the extension.

When budget office forecasts are not available for expenditure and revenue series, forecasts must be derived directly from the underlying macroeconomic series. We believe that best practice is to estimate revenue and expenditure series for a given year as the previous year's realization plus or minus some change, typically based on the change in one or more macroeconomic drivers during that year.

As mentioned earlier, we condition future California pension expenditures on simulated returns for the California Public Employees' Retirement System (CalPERS). Our return function relies on a Cauchy-Lorenz distributed random variable to introduce substantial volatility into the projected returns. 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 CalPERS ability to contribute to the cost of state retiree pensions. If CalPERS' assets are exhausted, pension obligations are assumed to be funded on a "pay as you go" basis. Since total CalPERS benefits paid to state retirees currently account for only 3% of the state's total revenue, and since the number of retirees is projected to grow slowly, the exhaustion of CalPERS assets does not necessarily trigger a default in the sample model. Near term CalPERS cost estimates are taken from state's Legislative Analyst's Office (LAO) rather than by using this method. LAO forecasts very slow near term growth in CalPERS benefits over the next five years, partially because strong returns in 2010 and 2011 will gradually filter through the actuarial process used to determine state contribution rates.

At the federal level, Social Security and Medicare benefits are assumed to increase with the number of retirees, as well as inflation. These expense items are thus projected to grow quite rapidly due to baby boomer retirements, which continue through 2031.

In the US sample, current year debt is the sum of prior year debt, the current year's deficit and forecast increases in government lending balances. This last component may require explanation. When the federal government issues a student loan, the deficit is not increased, but the government still must borrow money to advance the funds. Since balances in government loan programs tend to rise over time, the national debt increases by more than the deficit in most years.

It is also worth noting that the US sample uses debt held by the public rather than the more widely reported "national debt." Since the national debt includes special Treasury bonds held by the Social Security Trust fund and other government entities, it is not an appropriate indicator of US government solvency. Similarly, the IMF's General Government debt statistics -- used by one or more of the major credit rating agencies -- are also inappropriate in the US context. The IMF data combines central government debt with state and local debt. Since the federal government has no obligation to bail out defaulting states or cities (it has allowed cities to default in the recent past) we believe that only central government debt should be considered. Finally, publicly held debt includes government bonds held by the Federal Reserve. It is reasonable to argue that this debt should be excluded from the analysis. We did not do so since the Federal Reserve may sell these holdings in the future to combat inflation.

Consistent with our exclusion of public debts held by government entities, our analysis excludes any consideration of the Social Security or other trust funds. While current law requires that Social Security benefits be reduced once the trust fund is emptied, we see no meaningful chance of this reduction actually occurring given the voting power and political influence of senior citizens. We implicitly assume that full benefits will continue to be paid from general funds.

In the California sample, debt may be accumulated from both operations (although this is bounded, as discussed below) and from the issuance of voter approved bonds, usually to finance capital investments. Bond issuance amounts in the sample model are based on the most aggressive issuance scenario outlined in the State Treasurer's 2011 Debt Affordability Report.

In our samples, interest expense forecasts are not taken from budget office estimates since they are based on static deficit and interest rate estimates. Our method is to multiply the previous year's debt by an average coupon rate paid by the issuer. The average coupon for each year is influenced by changes in interest rates – another random process which we have biased upward on the expectation of a gradual return to longer term averages. When computing the average coupon, it is important not only to simulate changes in interest rates but also to estimate the proportion of an issuer's debt subject to the new rate. Since the vast majority of government debt is fixed rate and carries multiple year terms, most debt will not be affected by interest rate changes in the current fiscal year. The weights we applied to newly issued debt were based on term structures gathered from the US Treasury's Monthly Statement of Public Debt (http://www.treasurydirect.gov/govt/reports/pd/mspd/2012/2012.htm) and the California Treasurer's Debt Affordability Report (http://www.treasurer.ca.gov/publications/2011dar.pdf). As our samples show, a much higher proportion of federal debt than California debt turns over in a given year, leaving the US Treasury much more vulnerable to unwelcome interest rate movements.

Optional Input Sheets

A PSCF simulation can run as long as the model and *series* sheets are properly completed. Additional functionality may be leveraged by populating one or both of the optional sheets: *adjustments* and *ratingmap*.

The *ratingmap* sheet allows the user to specify a relationship between ranges of cumulative default probabilities calculated by PSCF and letter ratings. While we have provided sample values, users are welcome to substitute their own mappings. Rating agencies publish default rates by letter grade on a regular basis; these rates can be used as inputs for the *ratingmap* table.

Some time ago, Moody's published an idealized default rate table which adjusts for idiosyncrasies in observed default rates, such as the lack of a monotonic relationship between ratings and rates. Our sample table is based on the Moody's rates, but we have used more familiar S&P/Fitch rating symbols. However one devises the map, default probabilities should increase as one looks downward and to the right within the table. Default probabilities should increase with both riskier ratings and over time within any rating category.

The *adjustments* tab enables the user to impose limits on the size of annual deficits or surpluses. This is particularly relevant in a jurisdiction with a balanced budget requirement, since the legislature is likely to be compelled to take action if deficits are forecast. Also, political pressure for tax reductions and spending increases tends to mount when large surpluses are in the offing; limiting those, therefore, also appears warranted. Imposing these adjustments reduces the incidence of extreme outcomes, such as large negative interest to revenue ratios, in the later years of some simulation trials.

The adjustment functionality in version 1 of PSCF is admittedly both fairly limited and hard to use. We look forward to building and enhancing it with the collaboration of an open source community of users and developers.

For now, the user must first specify a ratio for the system to evaluate each year during each trial. The recommended ratio is total revenues over total expenses, which can be used to limit surpluses or deficits as a proportion of the government's size. In the California example, we trigger adjustments when revenues fall below 80% of expenditures - recognizing that the state's balanced budget requirement can be partially circumvented but still imposes relatively strict limits on the size of possible deficits. In reviewing 20 years of previous Comprehensive Annual Financial Report (CAFR) data, we found that the state's total revenues ranged from 84% to 107% of total expenditures.[5]

PSCF calculates a fiscal adjustment needed to return the government's budget to the minimum or maximum ratio specified by the user. The system can then distribute these cuts or increases *pro rata* across a list of revenue and expenditure items also specified by the user.

The user can also constrain the impact of the adjustment on any given revenue and expenditure item. When a constraint is triggered, the total amount of the adjustment will be less than originally calculated, so the total revenue to total expenditure ratio will surpass the limit specified – but probably by less than it would have had the adjustment not been entered. Again, constraints are necessary to control unreasonable values.

Finally, the user must provide a list of series that should be recalculated by the system once adjustments have been made. Since adjustments are performed each year after all series have been computed, all series that depend on adjusted values must be recalculated. For example, if total revenues or total expenditures change, the annual surplus (or deficit) must be recalculated along with total debt.

Interpreting the Output

Summary output is provided in the *results* sheet. This shows default counts and probabilities for each year. The probability is simply the number of defaults (i.e., the number of trials that surpass the default threshold) divided by the total number of simulation trials.

The *results* sheet also includes cumulative default count and cumulative default probability columns. While the default count shows the number of defaults in any given year, the cumulative default count reflects the number of trials that have had at least one default in any year to date. This concept is best understood with a simple example. The following table considers one trial in a simulation that has a 30% default threshold.

Year	Ratio	Default?	Cumulative Default?
1	24%	No	No
2	28%	No	No
3	31%	Yes	Yes
4	29%	No	Yes

[5] Most CAFR data is reported according to the modified accrual method. Since defaults are often triggered by a lack of cash, we believe that the cash basis is more appropriate for modeling purposes. The revenue and expense ratios reported here would probably not have varied substantially if they had been reported on a cash basis.

In the first two years of the simulation trial, the default threshold is not reached. In Year 3, the threshold is exceeded and we have a default. In Year 4, the ratio falls below the default level, but since a default has occurred previously, the cumulative default flag remains on. This cumulative default counter is more consequential, since we are more concerned with whether a government will become insolvent *by* a given year rather than *in* a given year.

If projection details were requested, they will appear in the *projection* tab. One row is provided for each year and each trial, so this sheet can become very large and very slow if projections are requested for a large number of trials. The *projection* tab includes one column for each series whose output was requested, i.e. all series for which the user entered a "Y" in the "*Include in Output File?*" column of the *series* tab (Column J). At the extreme right end of the projection, each metric listed in the *model* tab is calculated for each year and the default and cumulative default flags are displayed.

Conclusion

PSCF provides analysts with a way to measure future government solvency based on ranges of macroeconomic and policy outcomes. While the approach is quantitative, it does not negate fundamental analysis. Instead, it encourages the analyst to consider how revenue and expenditure items will evolve over time. By rapidly performing large numbers of computations, the system makes it easy to determine the implications of these tax and spending paths on various solvency metrics. The system also disciplines the analysis by requiring the user to provide a default condition stated in terms of one of these metrics.

Since PSCF models make all of an analyst's assumptions plainly visible, the approach combats bias. If PSCF models are published, others can review and debate the assumptions provided in the model. The result, we believe, will be a more *structured* analysis of government debt.

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Please contact PF2 Securities Evaluations if you have questions you would like to discuss about this research piece.

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