Econometric Modelling for Revenue Projections

1.   An econometric modelling exercise has been undertaken to calibrate the quantitative relationship between the five major items of government revenue (namely profits tax, salaries tax, stamp duties, land premium and other incomes excluding investment income) and a host of economic variables, for the purpose of rendering a set of revenue projections based on the macroeconomic assumptions described in Chapter 2.   This Annex sets out the technical details for the econometric modelling exercises.

Methodology and projection results

2.   As historical experience shows, government revenue bears a close and positive relationship with the boom-bust cycle for the overall economy (for details, please see Chapter 4). The model specifications for the five revenue models are thus based on such priori reasoning, using nominal GDP growth and output gap[1] as the two key explanatory variables to estimate how each revenue item would be affected by macro-economic performance.   For asset-market revenue items which are particularly volatile, namely land premium and stamp duties, dummy variables for the years 1997 and 2007 are included to delineate the exceptional swings because of the asset market exuberance in these two years.

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[1]   Output gap is a measure of the aggregate demand/supply balance, and hence is an indicator of the boom-bust cycle for the overall economy.

3.   The estimation of the parameters is based on the OLS (Ordinary Least Squares) method, using data from the period 1991-92 to 2012-13[2]. In the empirical investigation process, other variables have also been tested to see if individual government revenue items are sensitive to changes in demographic profile, liquidity conditions (i.e. real interest rate) and consumer price inflation.   The possible impact on revenue due to changes in government policy on land sales programme over the period 2002-2009 is also estimated in the form of a dummy variable.   With different combinations of these various explanatory variables, over five hundreds of econometric models have been examined.

4.   The reasonableness and robustness of these econometric models is assessed on a package of standard statistical criteria and tests, including the R-squared, t-test, Godfrey's serial correlation test, the in-sample fitness and out-of-sample forecasting performance, etc. Based on these selection criteria, the Working Group has adopted the following econometric models as the basis for long-term revenue projections (*Table E.1*).

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[2]   The Working Group has also examined the econometric models by using an extended sample period over 1982-83 and 2012-13.   The results indicate that the extension of sample period would not help to improve the out-of-sample forecasting performance of the econometric models.

Table E.1 - Detailed estimation results and model diagnostics of the econometric models

Dependent variable: Ratio of the respective revenue items to NGDP		Profits Tax	Salaries Tax	Stamp Duties	Land Premium	Other Income excluding Investment Income
Estimation results:						
Sample period:		1991-92 - 2012-13				
	Intercept	**0.060 ***	**0.028 *** **	**0.016****	**0.028 *** **	**0.059 *** **
Cyclicality	Nominal GDP growth	**0.053 *** **	**0.015 ** **	**0.023**	**0.117 ** **	**0.019 ***
	Output gap	**0.152 *** **	**0.018 @**	**0.043 @**	**0.099 *** **	
Dummy	Dummy for property market exuberance in 1997				**0.011 *** **	
	Dummy for land sales policy (2002-09)				**-0.010****	
	Dummy for 2007 stock market rally			**0.009****		
	AR(1)	**0.930****	**0.812****	**0.850 *** **		**0.714 *** **
	AR(2)				**0.561 *** **	
Model diagnostics:						
R-Squared		**0.8134**	**0.7320**	**0.8299**	**0.8257**	**0.5858**
Adjusted R-Squared		**0.7822**	**0.6873**	**0.7898**	**0.7713**	**0.5423**
F-statistics (p-value)		**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0002**
AIC		**-7.6766**	**-10.0693**	**-8.4035**	**-7.0361**	**-8.6045**
SIC		**-7.4783**	**-9.8709**	**-8.1555**	**-6.7386**	**-8.4557**
Godfrey's serial corr. test (p-value)		**0.2779**	**0.9269**	**0.2310**	**0.9790**	**0.6486**

Notes: @, *, ** and *** indicate statistical significance at 15%, 10%, 5% and 1% respectively.
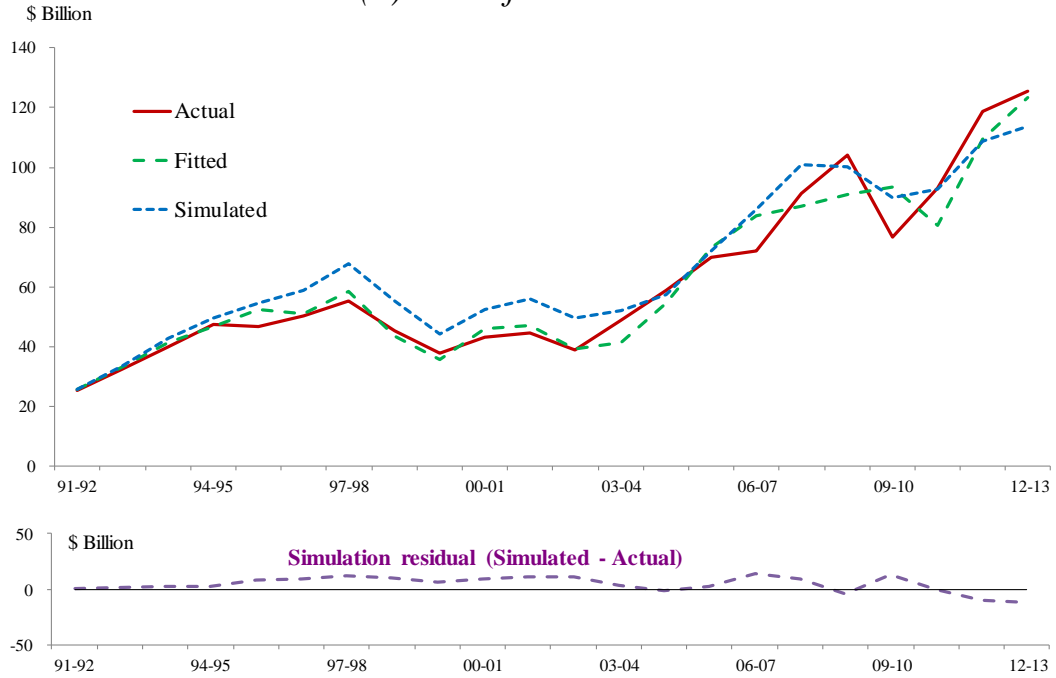
Auto-regressive terms are included in the estimation to deal with the auto-correlation issues of the error terms, if needed.

5.   All the five adopted econometric models are found to explain the revenue items reasonably well with the signs of the explanatory variables all conforming with a priori reasoning. Specifically, the empirical estimates indicate that when nominal GDP growth accelerates and aggregate demand/supply balance tightens up during economic upswings, government revenue as ratio of nominal GDP would tend to increase; and vice versa.   The estimated coefficients for the property market exuberance in 1997; the exceptionally buoyant stock market conditions in 2007; and the changes in land sales policy in 2002-09 are likewise consistent with priori reasoning.

6.   The adjusted R-squared for the models of profits tax, salaries tax, stamp duties and land premium ranges (all expressed as ratio of nominal GDP) between high levels of around 0.7 and 0.8.   The model for other incomes excluding investment income (as ratio of nominal GDP), being a summation of revenue items with diverse nature, also gives a relatively high adjusted R-squared of around 0.54. These suggest statistically high level of explanatory power for the five revenue models, as also graphically illustrated in the in-sample fitness in *Chart E.1*[3].
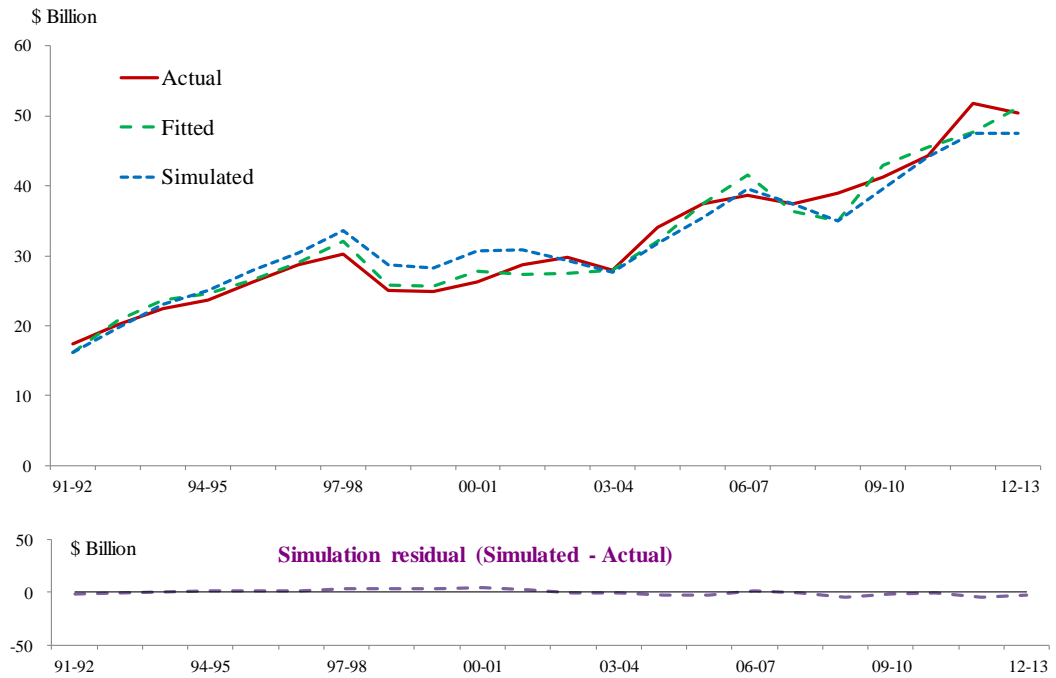
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[3]   The Working Group has also examined an aggregate approach of estimating the parameters for total revenue instead of estimating based on five separate equations pertaining to the major revenue items.   The estimation results indicate that the out-of-sample forecasting performance under the aggregate approach is significantly worse as compared to the component approach based on five separate revenue models.

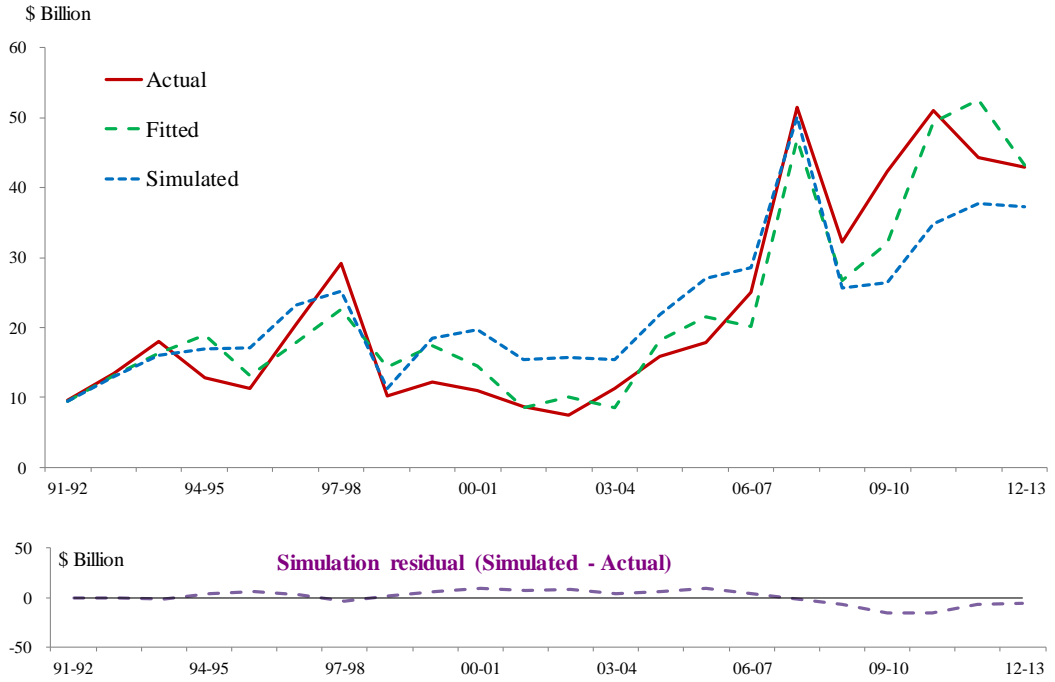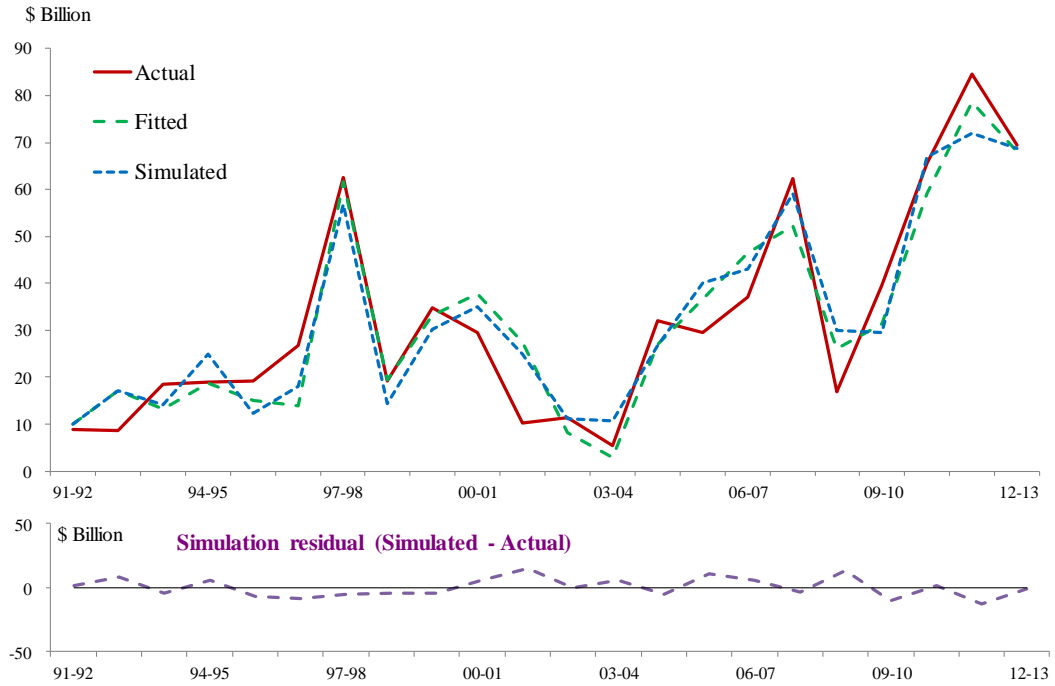## Chart E.1 - In-sample simulation of the selected models
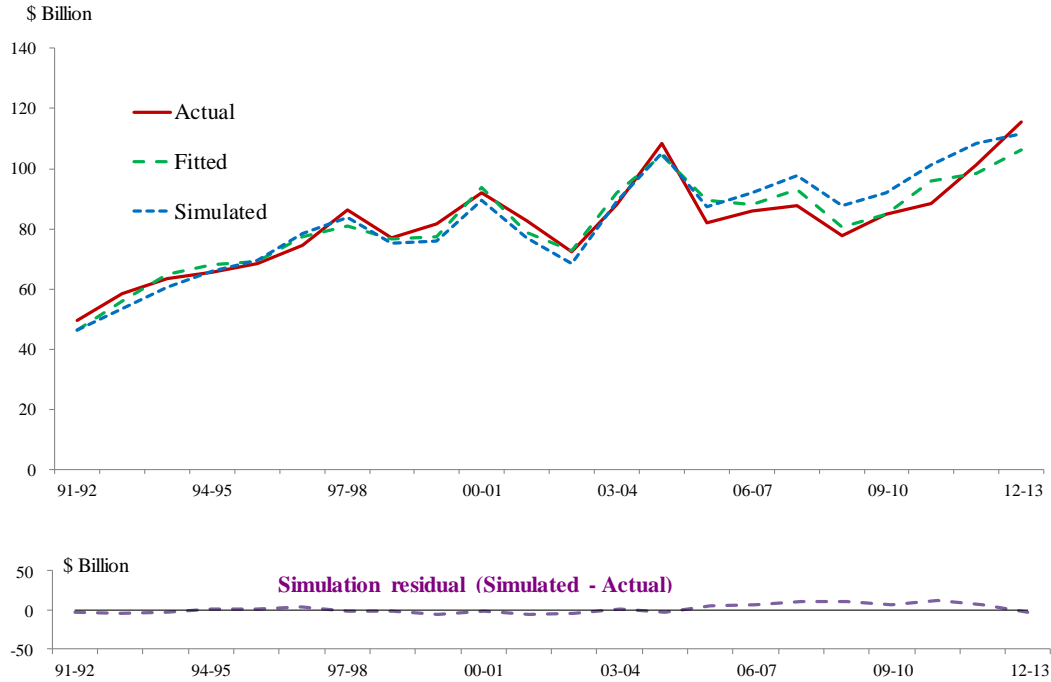
(a)   Profits tax

(b)   Salaries tax

(c)   *Stamp duties*

$ Billion

Simulation residual (Simulated - Actual)

(d)   *Land premium*

$ Billion

Simulation residual (Simulated - Actual)
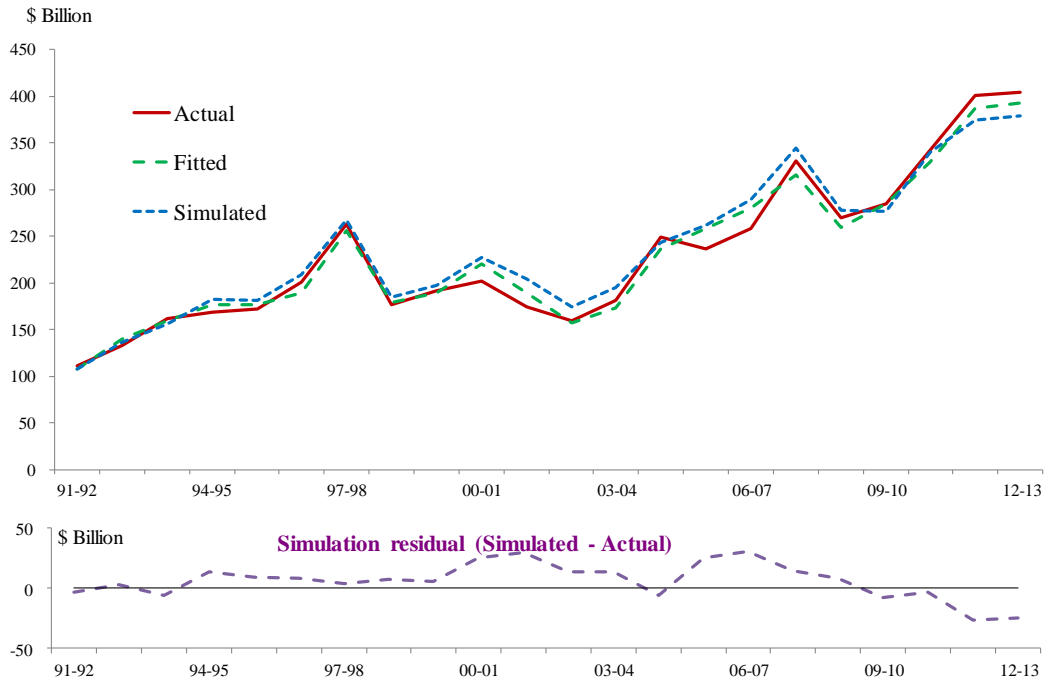
(e)   Other incomes excluding investment income

(f)   Total revenue (ex. Investment income) upon aggregating up

7.   In addition to in-sample performance, the Working Group has also looked at the out-of-sample forecasting performance, this being an even more stringent test for model adequacy and forecasting ability. The results likewise suggest a satisfactory performance.   In particular, upon aggregating up the simulated figures from the five models (*Chart E.2*), the five-step-ahead out-of-sample forecast is projected to increase by 7.7% per annum for the period from 2009-10 to 2013-14, versus the actual trend growth of 8.8% per annum, indicating a reasonably good forecasting power even amidst the extra-ordinary shocks to the macro economy and hence revenue collection in the aftermath of the Global Financial Crisis in late 2008.

Chart E.2 –   Out-of-sample simulation upon aggregating up the five models

Total revenue (ex. Investment income)

$ Billion

— Out-of-sample forecast

— Actual outturn

Trend growth rate (2009-10 - 2013-14)：

Actual outturn: 8.8% p.a.
Out-of-sample forecast: 7.7% p.a.

Out-of-sample forecast

91-92 93-94 95-96 97-98 99-00 01-02 03-04 05-06 07-08 09-10 11-12 13-14
(Estimate)