# An Approach for Assessing Uncertainty and the Balance of Risks: Constructing a Fan Chart for Real GDP Growth Forecasts

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PBO is committed to providing analytical tools for Parliamentarians to enhance their understanding of the state of the nation's finances and trends in the national economy.

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- To better understand the uncertainty and risks surrounding the economic outlook and the fiscal implications, PBO is providing fan charts for real GDP growth forecasts and the Government's budgetary balance.

This note describes the procedure used to construct a fan chart for real GDP growth forecasts. Fan charts can be used to illustrate the uncertainty surrounding forecasts thereby enhancing discussions about risks and helping policymakers to gauge the likelihood of possible economic scenarios.

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# Key Points

Economic forecasts presented in the Government's budgets and fiscal updates provide a single or 'point' forecast, which represents only one possible future outcome.  Different economic outcomes – with varying degrees of probability – are of course possible.  Although it is not possible to know, with certainty, the distribution of these future outcomes, it is nonetheless useful to illustrate the uncertainty surrounding a baseline economic forecast to enhance discussion about risks to the economic outlook and to help policymakers gauge the likelihood of possible economic scenarios.

This note details an approach for constructing a fan chart for real GDP growth forecasts.  This approach is based on the methodology described in Elekdag and Kannan (2009), which has been used to construct the IMF's world GDP growth fan chart.  To illustrate the application of this methodology to Canadian forecasts, PBO uses the forecasts of real GDP growth in 2010 and 2011 presented in Budget 2010.  These forecasts are assumed to be the 'central' forecasts around which a probability distribution of possible outcomes is overlaid, based on the historical forecast accuracy of the Department of Finance's survey of private sector forecasters.  Further, using private sector forecasts made at the time of Budget 2010, this distribution is augmented to reflect the balance of risks for key external factors, which include U.S. economic and financial conditions as well as commodity prices.

At the time of Budget 2010, private sector forecasters anticipated real GDP growth of 2.6 per cent in 2010 and 3.2 per cent in 2011.  Distributions of private sector forecasts of U.S. real GDP growth, U.S. interest rates and oil prices suggested downside risk to the budget forecast of Canadian real GDP growth.  Based on historical forecast errors and downside risk embedded in private sector forecasts at the time of the budget, PBO estimates that there is a 50 per cent chance (or probability) that real GDP growth in 2010 would fall between 1.0 and 3.0 per cent (i.e., a 50 per cent 'confidence' interval).  For 2011, there is a 50 per cent chance that real GDP growth would fall between 1.2 and 3.9 per cent.

**Real GDP Growth Fan Chart (per cent)**
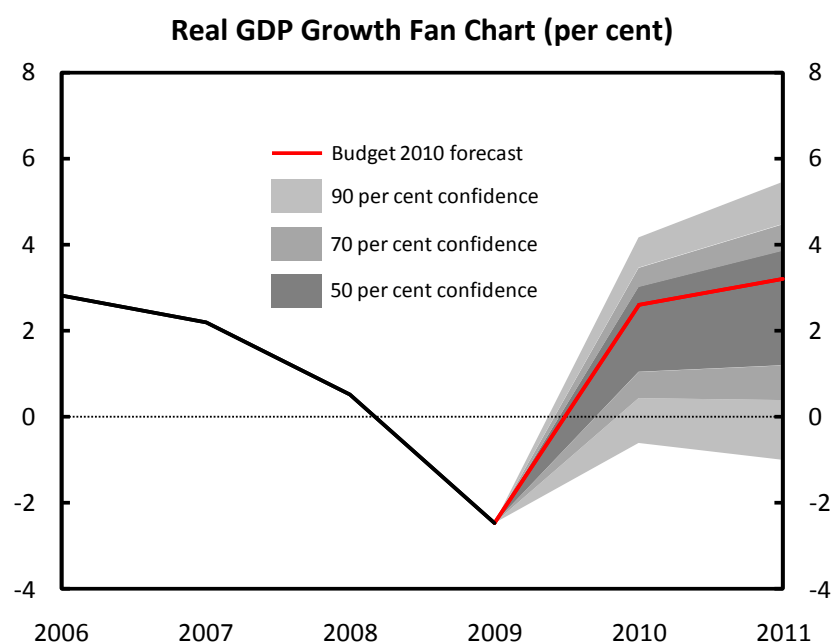
Moreover, based on the probability distribution underlying the confidence intervals shown in the fan chart, the chance that real GDP growth in 2010 and 2011 would be lower than forecast in Budget 2010 is approximately 64 and 62 per cent, respectively.  The recent (June) Department of Finance survey of private sector forecasters, however, indicates real GDP growth of 3.5 and 2.9 per cent, respectively, in 2010 and 2011.  In terms of the above confidence intervals, the recent forecast for 2010 would sit just above the upper bound of the 70 per cent confidence interval and for 2011, the recent forecast would fall roughly in the middle of the 50 per cent confidence interval.

The fiscal implications of the distribution of possible outcomes for real GDP growth can be illustrated using the fiscal sensitivity published in Budget 2010.  Given the Government's forecasted budgetary deficits of $49.2 billion and $27.6 billion in 2010-11 and 2011-12 respectively, the confidence intervals for real GDP growth and Budget 2010 fiscal sensitivity imply that there is a 50 per cent chance that the budgetary deficit would be between $47.9 and $53.9 billion in 2010-11.  For 2011-12, the confidence intervals imply that there is a 50 per cent chance that the budgetary deficit would be between $24.0 and $39.2 billion.  The probability distribution of real GDP growth forecasts also implies that there is a 64 and 62 per cent chance, respectively, that the budgetary deficit in 2010-11 and 2011-12 would be higher than forecast in Budget 2010.

**Budgetary Balance Implications given Real GDP Growth Outcomes with Downside Risk ($ billions)\***
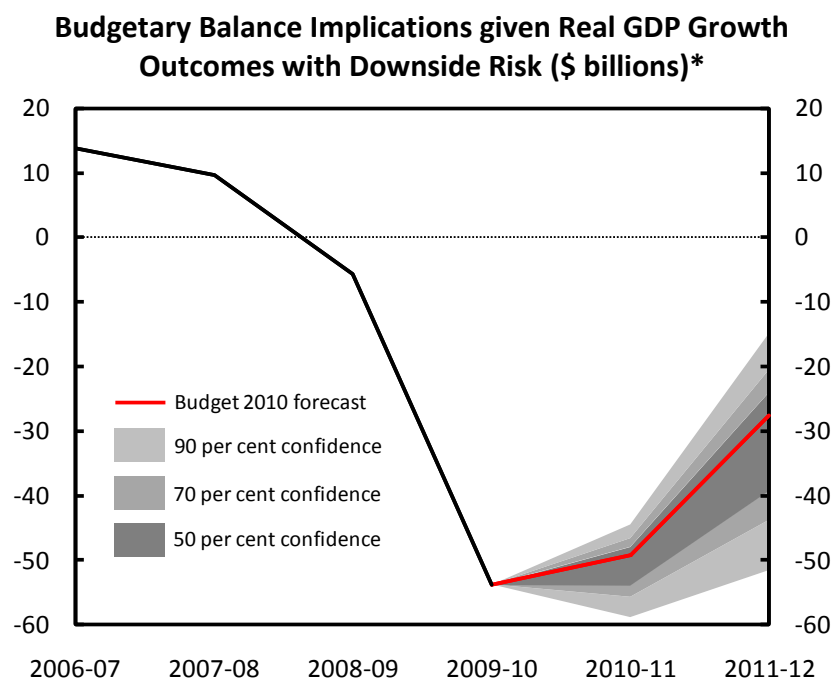


\* This fan chart should not be interpreted as representing the distribution of possible outcomes for the budgetary balance as it does not reflect sources of uncertainty related to other economic forecasts (e.g., for inflation and interest rates) and to the translation of economic forecasts into fiscal forecasts.

## 1. Introduction

Forecasts from the Department of Finance's survey of private sector forecasters form the basis for the economic assumptions that underlie the fiscal projections presented in the Government's budgets and fiscal updates. While the average of the survey's forecasts is used as the economic baseline for fiscal planning, it is nonetheless a single or 'point' forecast around which different outcomes – with varying degrees of probability – are possible. It is not possible, however, to know with certainty the distribution of possible future economic outcomes. Nonetheless, it is useful to illustrate the uncertainty surrounding the baseline economic forecast to enhance discussion about risks to the economic outlook and to help policymakers gauge the likelihood of possible economic scenarios.

Indeed, since 1996 the Bank of England has published its inflation forecast in the form of a probability distribution or 'fan chart' that provides confidence levels associated with its projection. Britton et al. (1998) note that one of the Bank of England's objectives for introducing the fan chart was that it had wanted to focus attention on the whole of the forecast distribution to "promote discussion of the risks to the economic outlook, and thus contribute to a wider debate about economic policy".

The International Monetary Fund (IMF) has also published (since 2006) its world GDP growth forecast in the form of a fan chart. IMF (2009) notes that the fan chart "serves primarily as a visual communications device" and addresses the questions:

- What is the baseline forecast for the current and future years?
- What level of uncertainty surrounds the forecast?
- Where does the balance of risks lie?

More recently, the United Kingdom's Office for Budget Responsibility (OBR) has published fan charts for its forecasts of real GDP growth and public sector net borrowing to:

> help to promote transparency and illustrate the uncertainty that the Government faces in planning fiscal policy, and in meeting any numerical target. Explicit recognition of uncertainty can help commentators assess the Government's fiscal plans.

The following details an approach for constructing a fan chart for real GDP growth forecasts based on the Department of Finance Canada's survey of private sector forecasters. The approach follows the procedure described in Elekdag and Kannan (2009) on which the IMF fan chart is based. The focus of this note is cast on the outlook for real GDP growth, however, this approach could be extended to other indicators.

## 2. The Distribution of Possible Outcomes and the Balance of Risks

Britton et al. (1998) discuss the choice of the distribution of possible outcomes used in constructing the Bank of England's inflation fan chart. Extending this discussion to real GDP growth, one might expect future real GDP growth to be distributed (roughly) symmetrically around the most probable or 'central' value, with values closer to the centre more likely to be realized than those further away, suggesting the familiar normal 'bell-shaped' distribution.[1]

The dispersion of possible outcomes for future real GDP growth (measured by the standard deviation) reflects the degree of uncertainty. That is, a wide dispersion and large standard deviation indicates a high degree of uncertainty. The symmetry of the distribution of possible outcomes indicates that outcomes greater than or less than the central value are equally likely. It could be the case, however, that the distribution of possible outcomes is asymmetric, or skewed, and the expected outcome (the mean forecast) differs from

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[1] This framework assumes that the distribution of possible outcomes is unimodal.

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the single most likely outcome (the 'mode' forecast).

Figure 1 provides an illustration of symmetric and skewed distributions with the same central forecast (i.e., the same mode). In the case of the symmetric distribution, the single most likely outcome (the mode) is equal to the expected outcome (the mean) and there is an equal chance that outcomes could exceed or fall short of the central forecast. This would suggest that the risks to the central forecast are balanced. In the case of a (negatively) skewed distribution the expected outcome is less than the central forecast, which suggests that the balance of risks to the central forecast is to the downside. Thus the skewness value (positive or negative) of the distribution of possible outcomes reflects the balance of risks (upside or downside) to the central forecast.

**Figure 1**

**Symmetric and Skewed Distributions**

(Probability distribution)
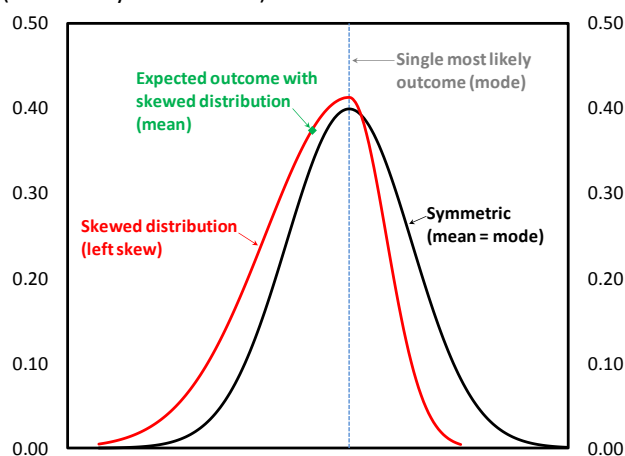


Source:    Office of the Parliamentary Budget Officer.

Note:    The area under each distribution is equal to 1.0. The skewed distribution is constructed using a two-piece normal distribution.

The 'two-piece' normal distribution provides a convenient framework to illustrate the uncertainty surrounding a forecast and the balance of risks.[2]

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[2] This distribution can be thought of as the combination of two halves of two separate normal distributions with the same mode but with different standard deviations. The degree to which the standard

This distribution underlies the construction of the Bank of England's inflation fan charts, the IMF's world GDP growth fan chart and the OBR fan charts of real GDP growth and public sector net borrowing.

Following the IMF, constructing the fan chart for Canadian real GDP growth requires an estimate of the uncertainty surrounding the central forecast and an estimate of the degree of skewness. For the purposes of this note, PBO takes the private sector forecast of real GDP growth presented in Budget 2010 as the central forecast and uses the private sector survey's historical forecast errors to determine the degree of uncertainty surrounding this forecast. Using the approach developed by Elekdag and Krannan (2009), the skewness value of the distribution of possible outcomes is based on the skewness of private sector forecasts of proxies for external economic and financial conditions as well as commodity prices.

## 3.   Uncertainty Surrounding the Private Sector Forecast of Real GDP Growth

The forecast of real GDP growth presented in Budget 2010 represents the average of the individual forecasts in the Department of Finance's survey of private sector forecasters. Although the individual forecasts in the survey provide a distribution of possible outcomes, PBO believes that the dispersion of these forecasts is not a robust measure of the uncertainty surrounding the survey's average forecast.[3] PBO (2010) noted that research examining the dispersion of private sector

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deviations differ determines the skewness of the overall distribution. Elekdag and Kannan (2009) provide a summary of the key features of this distribution, based primarily on John (1982).

[3] For example, there may be a tendency for herding among forecasters such that no forecaster wishes to deviate too far from the consensus forecast, leading to forecast clustering. As a result, the degree of uncertainty surrounding the average forecast may be understated. The 2005 research report on the Department of Finance's forecasting processes and performance conducted by the Policy and Economic Analysis Program (PEAP) and Centre Interuniversitaire de Recherche en Analyse des Organisations (CIRANO) speculated that, based on a sub-sample of forecasters, the domination (with respect to forecast accuracy) of the average private sector forecast was "a signal that the forecasters in truth look very much alike" and that further investigation of this issue was warranted.

forecasts as a measure of uncertainty for Canada and other countries is not conclusive.

Therefore PBO, following Elekdag and Kannan (2009) and the OBR, uses the historical forecast errors of the Department of Finance's surveys of private sector forecasters to provide an estimate of the standard deviation of the distribution of possible outcomes for future real GDP growth. As noted by the OBR, this approach has its limitations in that the past forecast performance "is only an imperfect guide to the future" nevertheless, it does provide a "clear, transparent and objective method for quantifying the degree of uncertainty".[4]

Forecast errors for one- and two-year ahead forecasts of real GDP growth are calculated for the period 1994-2009 using the Department of Finance's surveys from December, which are typically used for budget projections.[5] Using the current vintage of real GDP growth as the 'actual' against which the forecast is compared, PBO calculates the standard deviation to be 1.5 and 2.0 percentage points for the one- and two-year ahead forecast errors, respectively.[6] The standard deviation is larger for the two-year ahead forecast error, which suggests that the uncertainty surrounding the forecast in year two is greater than the uncertainty in year one.

Under the assumption that current forecasts are not biased[7] (i.e., there is no tendency to over- or under-predict) and based on the normal distribution, this means that there is a 68 per cent chance – or level of 'confidence' – that the one-year (two-year) ahead forecast error for real GDP growth will lie within plus or minus one standard deviation, or between -1.5 and +1.5 (-2.0 and +2.0) percentage points.[8] Plus or minus two standard deviations (i.e., ±3 percentage points and ±4 percentage points, respectively, for one- and two-year ahead forecasts) would result in a 95 per cent level of confidence.[9]

Using the private sector forecast of real GDP growth in 2010 and 2011 from Budget 2010[10] (2.6 and 3.2 per cent respectively) as the central forecast (and under the assumption that the risks to the forecast are balanced), the distribution of possible outcomes can be generated using the density function of the normal distribution and the above standard deviations. Figure 2 presents distributions of real GDP growth in 2010 and 2011 respectively based on historical forecast errors of Finance Canada's private sector survey.

Figure 2 indicates that assuming balanced risks, there is a 50 per cent chance that real GDP growth in 2010 would be between 1.6 and 3.6 per cent. The increased uncertainty surrounding two-year ahead forecasts implies that the 50 per cent confidence interval for real GDP growth in 2011 would be between 1.9 and 4.5 per cent.

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[4] Robbins et al. (2007) use the historical forecast errors of the Department of Finance survey of private sector forecasters as a check of the reasonableness of the dispersion of their stochastic model-based distributions.

[5] Forecast errors for the period 1994-2006 are based on Robbins et al. (2007). For 2007 and 2008, respectively, forecast errors are calculated using the private sector forecasts presented in Budget 2007 (March 2007 survey) and Budget 2008 (December 2007 survey updated in January 2008). The forecast error for 2009 is calculated from the December 2008 survey of private sector forecasters (see http://www.fin.gc.ca/n08/data/08-106-eng.asp). On June 12 2010, PBO requested from Finance Canada the summaries of its survey of private sector forecasters since 1994 in order to expand and complete its analysis (see http://www2.parl.gc.ca/sites/pbo-dpb/documents/Info_Request_030_R.pdf). To date, this information has not been provided to PBO.

[6] The standard deviation of forecast errors based on Statistics Canada's initial estimates of real GDP growth is slightly smaller at 1.3 and 1.8 percentage points, respectively, for one- and two-year ahead forecasts.

[7] Statistical tests indicate that the hypothesis that the real GDP growth forecast errors are zero on average cannot be rejected. These test results, however, should be treated with some caution given the small sample size.

[8] Statistical tests indicate that the hypothesis that the distribution of real GDP growth forecast errors is normal cannot be rejected. These test results, however, should be treated with some caution given the small sample size.

[9] Elekdag and Kannan (2009) refer to the uncertainty based on historical forecast errors as a 'baseline' measure of uncertainty. Further, they augment this uncertainty to take into consideration the current assessment of forecast uncertainty relative to its historical level.

[10] The average private sector forecast of real GDP growth presented in Budget 2010 is based on the December 2009 Department of Finance survey of private sector forecasters.

**Figure 2**

**Real GDP Growth Outcomes in 2010 and 2011**

(Probability distribution)



Budget 2010:
2.6 per cent

Real GDP growth in 2010 (%)



Budget 2010:
3.2 per cent

Real GDP growth in 2011 (%)
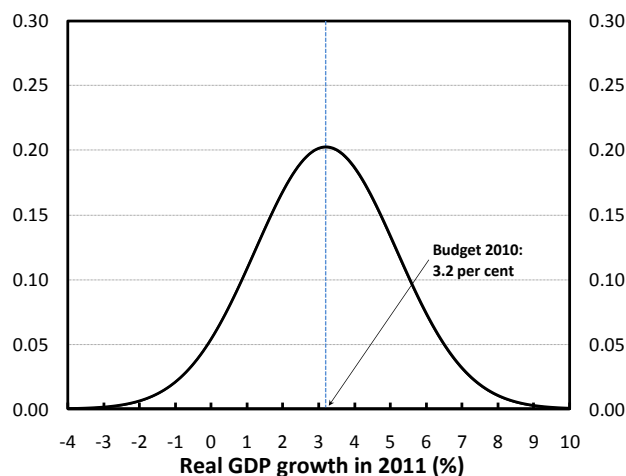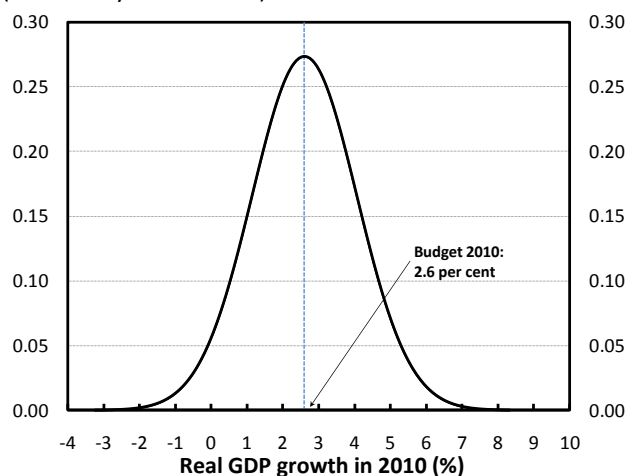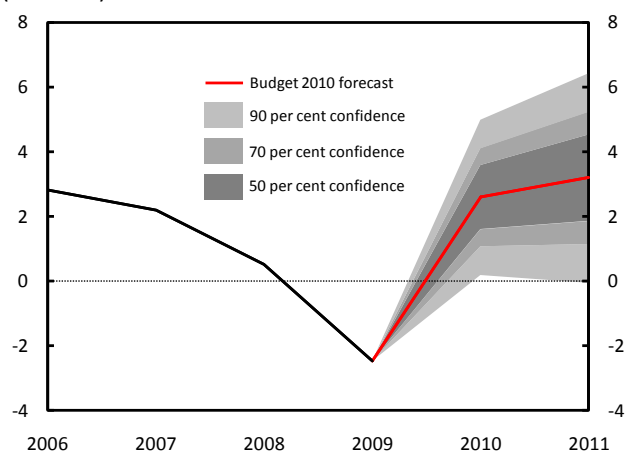
Source: Office of the Parliamentary Budget Officer.

These probability distributions can be used to construct intervals for any level of confidence and provide the cross-sections of the values used in constructing the fan chart of real GDP growth forecasts.

Figure 3 presents PBO's fan chart of real GDP growth forecasts, based on Budget 2010, for 50, 70 and 90 per cent confidence intervals. These intervals are computed under the assumption that the risks to the Budget 2010 forecast of real GDP growth are balanced (i.e., the probability distributions are symmetric about the budget forecast).

**Figure 3**

**Real GDP Growth Fan Chart (balanced risks)**

(Per cent)



Budget 2010 forecast
90 per cent confidence
70 per cent confidence
50 per cent confidence

Sources: Office of the Parliamentary Budget Officer; Statistics Canada; Finance Canada.

Note: Real GDP growth over 2006-2009 is Statistics Canada's estimate as of May 31, 2010.

## 4. Determining the Balance of Risks

Typically, determining where the balance of risks to a forecast lies is based on a forecaster's subjective judgement. Elekdag and Kannan (2009), however, develop a procedure to gauge the balance of risks based on a more objective approach. Essentially, the authors employ survey- and market-based data, which they argue are inherently forward-looking and could therefore inform policymakers on the evolution of risks as perceived by markets, to determine where the balance of risks lies.

That said, Elekdag and Kannan (2009) suggest that a 'layer' of judgement could – and perhaps should – be added to incorporate other risk factors that are not easily quantified. Indeed, the use of survey-based forecasts to inform one's judgement on the balance of risks should be regarded as a first step toward a more objective risk assessment. Further work on this issue is warranted.

In the case of survey-based data, this procedure involves first identifying relevant quantifiable risk

factors.[11] The next step involves determining the skewness (if any) among the individual forecasts of each risk factor. Lastly, the skewness values of the individual risk factors are aggregated to form an overall measure of skewness, which is then used – based on the two-piece normal distribution – to augment the distribution of possible outcomes generated from the historical forecast errors. The weights used to aggregate the individual risk factors are based on estimated sensitivities of the forecasted variable to the risk factors.

To illustrate this procedure, PBO identifies a subset of (external) risk factors to the Budget 2010 outlook for real GDP growth in 2010 and 2011 and uses the skewness observed in distributions of private sector forecasts of these risk factors made at the time of Budget 2010.[12] The skewness values of the risk factors are then aggregated using estimation and model-based sensitivities.

*Risk Factors and the Balance of Risks*

In general, external factors play a key role in developing a forecast of Canadian real GDP growth given that Canada is a relatively small open economy and net exporter of commodities. This illustration therefore focuses on risks related to external economic and financial conditions as well as commodity prices. Figure 4 presents the balance of risks to Canadian real GDP growth associated with selected external risk factors: U.S. real GDP growth, U.S. interest rate term spread[13] and West Texas Intermediate (WTI) oil prices.

Distributions of private sector forecasts of the identified risk factors in 2010 and 2011 (made at the time of Budget 2010) appear to be negatively skewed.[14] Based on Elekdag and Kannan's procedure, this would suggest that the balance of risks to Canadian real GDP growth in 2010 and 2011 from U.S. growth, U.S. financial conditions and oil prices is to the downside.

**Figure 4**

**Balance of Risks to Canadian Real GDP Growth Associated with Selected External Risk Factors**



(Coefficient of skewness)
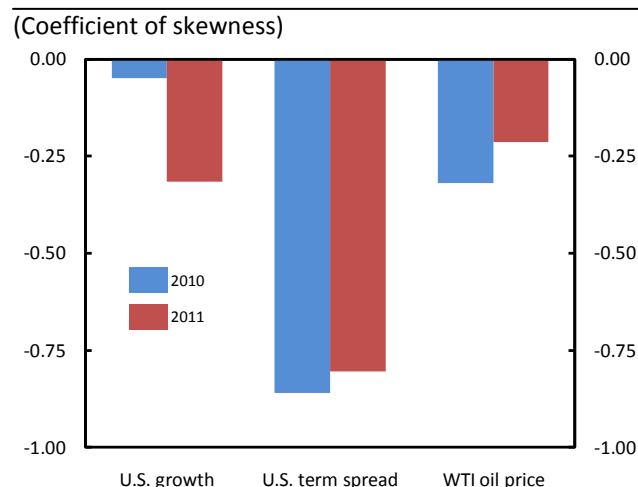
Sources: Office of the Parliamentary Budget Officer; Consensus Economics.

Notes: The coefficient of skewness is calculated based on the mean and variance of the distribution of forecasts (see footnote 14) and is expressed in units of the underlying variables.

A negative (positive) skewness coefficient indicates that there is downside (upside) risk to the forecast of Canadian real GDP growth.

The term spread is calculated as the U.S. 10-year Treasury bond yield minus the U.S. 3-month Treasury Bill rate.

To arrive at an overall measure of skewness, the skewness coefficients for the individual risk factors are weighted by their elasticities (i.e., the sensitivity of Canadian real GDP growth to the risk factor in question). Based on regression and

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[11] Alternatively, the skewness of current survey-based forecasts of real GDP growth itself could be used to determine an overall measure of skewness.

[12] Individual private sector forecasts of the external risk factors are taken from January 2010 Consensus Economics surveys to coincide with the December 2009 Department of Finance survey of private sector forecasters. These forecasts were used in place of Finance Canada's since PBO does not have access to the individual private sector forecasts in the Department's survey. That said, the average forecasts of U.S. and Canadian real GDP growth in 2010 and 2011 in the two surveys are almost identical.

[13] Elekdag and Kannan (2009) proxy financial conditions by the interest rate term spread (i.e., the long-term minus the short-term interest rate) as well as by the Standard and Poor's 500 index.

[14] There are several measures of skewness. The coefficient of skewness shown in Figure 4 is calculated based on the mean and variance of the distribution of forecasts. For additional detail, see EViews 6 User Guide I (p. 307). Elekdag and Kannan (2009) use a variant of Pearson's skewness coefficient.

model-based weights[15] the overall measure of skewness is estimated at -0.6 for 2010 and -0.7 for 2011.  This suggests that, based on private sector forecasts of key external factors made at the time of Budget 2010, the overall balance of external risks to the real GDP growth forecast in Budget 2010 is tilted to the downside.[16]

*Adjusting the Distribution of Possible Outcomes for the Balance of Risks*

The fan chart shown in Figure 3 can be augmented to incorporate the downside balance of risks.[17]  Following Elekdag and Kannan (2009), the symmetric distribution of possible outcomes for real GDP growth is adjusted such that the difference between its mean and mode (which is also a measure of skewness) matches the aggregate skewness value of the risk factors and its dispersion matches the standard deviation of the historical forecast errors.  This adjustment effectively shifts the confidence intervals while the central forecast remains at its mode – the private sector forecast from Budget 2010.  For example, in the case of 'balanced' risks, there is a 50 per cent chance that the real GDP growth would fall between 1.6 and 3.6 per cent in 2010, and between 1.9 and 4.5 per cent in 2011.  In the case where the balance of risks is to the downside (Figure 5), there is a 50 per cent chance that real GDP growth would fall between 1.0 and 3.0 per

cent in 2010, and between 1.2 and 3.9 per cent in 2011.

Further, based on the probability distribution underlying the confidence intervals presented in Figure 5, there is approximately a 64 (62) per cent chance that real GDP growth in 2010 (2011) would be lower than forecast in Budget 2010.

**Figure 5**

**Real GDP Growth Fan Chart (downside balance of risks)**
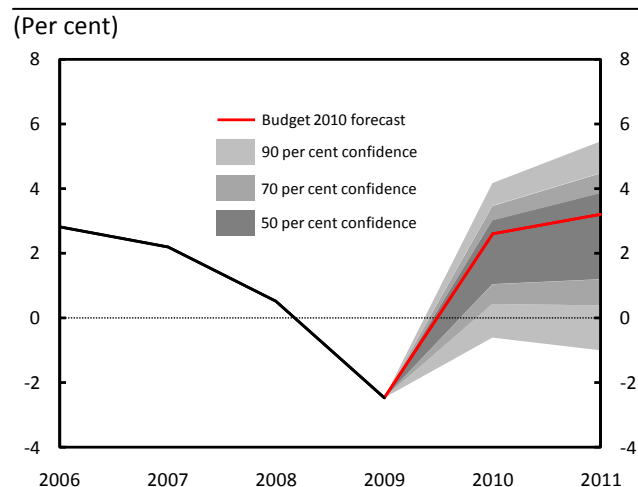


(Per cent)

Sources:  Office of the Parliamentary Budget Officer; Statistics Canada; Finance Canada.

Note:  Real GDP growth over 2006-2009 are Statistics Canada's estimates as of May 31, 2010.

The June Department of Finance survey of private sector forecasters, however, indicates real GDP growth of 3.5 and 2.9 per cent, respectively, in 2010 and 2011.  In terms of the confidence intervals shown in Figure 5, the recent forecast for 2010 would sit just above the upper bound of the 70 per cent confidence interval and for 2011, the recent forecast would fall roughly in the middle of the 50 per cent confidence interval.

## 5.   Fiscal Implications of Possible Outcomes for Real GDP Growth

The fiscal implications of the distribution of possible outcomes for real GDP growth can be illustrated using the fiscal sensitivity published in

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[15] Regression results are based on the approach used by Elekdag and Kannan (2009), which involves regressing Canadian real GDP growth against the risk factor and lagged growth.  Model-based estimates are taken from Murchison and Rennison (2006).  The weight for U.S. real GDP growth is 0.62; 0.61 for the U.S. term spread; and, 0.20 for oil prices.  These weights, however, should be regarded as preliminary as further work is required to ensure their robustness.

[16] Budget 2010 provides a limited discussion of the risks to the private sector economic forecast and does not explicitly state the Government's judgement as to where the balance of risks lies.  This stands in contrast to the economic risk assessment provided in Budget 2009 in which the Government judged that downside risks to the global economic outlook and commodity prices were significant and prompted the Government to adjust downward the private sector forecast of nominal GDP.

[17] This augmentation uses the two-piece normal distribution. Calculations required to generate the desired skewness and overall dispersion of the distribution are based on Elekdag and Kannan (2009). The corresponding confidence intervals, however, are computed by generating the probability density function.  This guarantees that the central forecast remains the mode of the distribution.

Budget 2010. Table 4.2.7 in Budget 2010 shows the impact on the Government's budgetary balance of a 1 per cent reduction in real GDP over the forecast horizon: a 1 per cent reduction would lower the budgetary balance by $3.1 billion in the first year and by $3.4 billion in the second year.

Figure 6 shows a fan chart of the Government's budgetary balance constructed using the confidence intervals for real GDP growth[18] in which the balance of risks is to the downside (Figure 5) and using the fiscal sensitivity provided in Budget 2010.[19] The central forecast of a $49.2 billion deficit in 2010-11 and a $27.6 billion deficit in 2011-12 is the Government's forecast presented in Budget 2010.

The confidence intervals for real GDP growth (adjusted for the downside balance of risks) and the Budget 2010 fiscal sensitivity imply that there is a 50 per cent chance that the budgetary deficit would be between $47.9 and $53.9 billion in 2010-11; and, between $24.0 and $39.2 billion in 2011-12.

**Figure 6**

**Budgetary Balance Implications given Real GDP Growth Outcomes with Downside Risk**



($ billions)
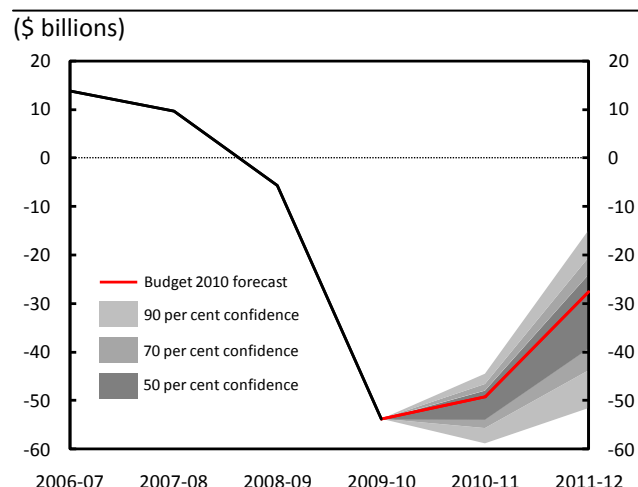
Sources: Office of the Parliamentary Budget Officer; Budget 2010.

The probability distribution of real GDP growth underlying the confidence intervals in Figure 5 also implies that there is a 64 and 62 per cent chance, respectively, that the budgetary deficit in 2010-11 and 2011-12 would be higher than forecast in Budget 2010.

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[18] Since these fiscal sensitivities are expressed in terms of (per cent) deviations of the level of real GDP from its baseline, the distributions of possible real GDP growth outcomes must be first translated into real GDP (level) deviations from the central forecast.

[19] There are of course additional sources of uncertainty related to other economic forecasts (e.g., for inflation and interest rates) and to the translation of economic forecasts into fiscal forecasts (e.g., see Robbins et al. (2007)). Thus the fan chart presented in Figure 6 should not be interpreted as representing the distribution of possible outcomes for the budgetary balance.

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