

Measuring an economy's cyclical position; a review of selected statistical and economic methods

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Executive Summary

Since 2015, the public finances in Ireland have been subject to the preventive arm of the Stability and Growth Pact (SGP). A key requirement of the preventive arm is that Member States meet or progress towards their Medium Term Budgetary Objective (MTO). As the MTO is set in cyclically adjusted terms, an estimate of the economic cycle – the output gap – is needed. However, estimating an economy's potential output and the output gap is not an easy task as neither is directly observable.

Different approaches can be used to estimate the economy's position, however, for the purposes of assessment of compliance with the Stability and Growth Pact (SGP), Member States and the Commission have agreed to the application of a harmonised production function methodology. For methodological and country specific reasons, such as Ireland's high cross border mobility of capital and elastic labour supply the 'harmonised' approach can often provide counter-intuitive estimates of the economy's cyclical position.

It is in this context that the Department over the last number of years has engaged in the development of alternative statistical estimates of the output gap. This has culminated in the publication of two research working papers. First, this paper sets out to review the literature on a selection of statistical and economic approaches used to estimate an economy's potential output and its output gap. This work informs the Department's selection of alternative supply-side models that are estimated in the second paper.

Our review highlights that many approaches can be used to estimate potential output and the output gap. A key concern from a policymaker's perspective is that the estimates produced do vary across each of the methods. Since no single estimation is likely to be reliable at all times, it would appear appropriate to consider a number of alternative estimates to assess the economy's medium term growth potential and cyclical position.

We also review the main approaches applied by Irish and international institutions in recent years. We find that there is a diversity of modelling approaches used across institutions with each tending to use more than one approach. Legal requirements, institutional preferences and model complexity appear to be important factors affecting model selection.

Based on our review, the paper concludes by setting out a three pillar framework under which the Department's approach to measuring the potential growth and output gap are organised. Under the first two pillars, the Department will continue to estimate the harmonised approach while also attempting to address a number of its shortcomings. The third pillar, upon which the second Department working paper (Murphy et al., 2018) is based, will focus on the development of alternative models with the initial focus on statistical filters. This work will be complemented over time with the development of additional models.

Measuring an economy's cyclical position; a review of selected statistical approaches

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Section 1 – Introduction

This paper reviews the literature on a selection of statistical approaches used to estimate an economy's potential output and its output gap. The purpose of which is to inform the Department's development of alternative supply-side estimates to the European Commission-approved production function method (henceforth 'harmonised approach') which heretofore has been used as the Department's primary methodology.

The need for alternative estimates arises from the well documented shortcomings of the harmonised approach which has occasionally provided counter intuitive estimates of Ireland's cyclical position.¹ For example, the most recent estimates of the application of the harmonised approach by the Department² suggest that the economy is producing above its sustainable capacity since 2015. Such a narrative appears to be inconsistent with the lack of inflationary pressures in the economy.

Such estimates call into question the suitability of the model for the purposes of macroeconomic management and fiscal planning. It would appear alternative estimates are required to provide a more robust basis for assessing the compatibility of the public finances with potential output developments over the medium to long term.

In the short term, improved output gap estimates (the percentage difference between actual and potential output) can better determine the appropriate fiscal stance. A more accurate assessment of the level of excess demand or supply in the economy enables the Department to better evaluate and manage the extent to which fiscal policy should be used to move the economy towards its sustainable growth path. In general, the development of alternative measures of potential output should support efforts to avoid the implementation of inappropriate fiscal policies.

In setting out to identify appropriate alternative estimation approaches, the review considers many of the theoretical and empirical challenges that arise when estimating Ireland's potential output. From a theoretical perspective, for instance, it is difficult to conceptualise what potential output should be for a "regional" economy such as Ireland with its relatively elastic labour supply and cross-border mobility of capital (Bergin and Fitzgerald, 2014; Department of Finance, 2017a). From an empirical perspective, estimating an economy's potential output and the output gap is not an easy task as neither is directly observable. The paper considers the extent to which the various methodologies can address these issues as well as outlining the other merits and potential shortcomings of the approaches. Another area where we focus attention is on the selection of output measures that appropriately reflect

¹ McMorrow et al. (2015) show that the Commission's harmonised approach performs well, in terms of its stability, real-time reliability and financial crisis performance, against a number of alternative methodologies including the HP filter and the methodology of OECD and the IMF.

² See Department of Finance (2018).

economic activity in Ireland. This is a particularly relevant issue due to the statistical distortions arising from the activity multinational enterprises in recent years.

In terms of main findings, the review highlights an important finding from the literature that there is no universally agreed methodology on how best to estimate potential output. Moreover, estimates do vary across each of the methods, which can be problematic for policy makers. Since no single estimation method is likely to be reliable at all times, it is considered prudent to adopt a number of alternative estimates to assess the economy's potential growth path and cyclical position. Such an approach can help discard misleading signals about the cyclical position of the economy. Thus, mitigating the possible adoption of policy prescriptions which with hindsight (and additional outturn data) turn out to be inappropriate.

As part of the review we also assess the main approaches that have been applied by Irish and international institutions in recent years. We find that there is a diversity of modelling approaches used across institutions with each tending to use more than one approach. Such divergences in terms of the selection and application of modelling approaches are likely to be driven by institutional preferences as well as legal requirements.

Based on our review, the paper concludes by setting out a three pillar framework under which the Department's approach to measuring the potential growth of the economy is organised. Within this framework, the Department will seek to improve the harmonised approach by addressing various shortcomings. As regards the alternative modelling approaches, work will initially focus on the application of statistical filters. This work will be complemented by the development of additional models over time.

Section 2 – Selected approaches to measuring potential output and the output gap

The methods used to estimate potential output and the output gap range from purely statistical univariate methods to structural models where variable behaviour is governed by economic theory. Multivariate filtering models - often described as hybrid models - represent to some extent a middle ground. Models within this group incorporate economic information into a statistical filtering framework to estimate the trend component of economic output (i.e. GDP) from cyclical fluctuations around the long run trend.³ Before we discuss these models in more detail, we begin with a brief summary of different concepts of potential output that will assist in understanding what the various modelling approaches are seeking to estimate.

2.1: defining potential output

Potential output and the output gap cannot be observed and must be estimated. However, potential output can be defined in a number of ways while there is no standard approach used to estimate it. Over the years the literature has defined potential output in a number of alternative ways. One approach to defining potential output relates it to the level of production consistent with the full utilisation of available factor inputs (Tobin, 1997). This definition of potential output seeks to associate it with the maximum sustainable output (i.e. capacity output). At the firm level, capacity output can be viewed as the level of output where costs per unit are minimised. When each firm or agent is producing at its capacity output, real GDP is considered to be equal to its potential output. This approach is particularly relevant in measuring the scope for improving potential output via market reforms (Kenny, 1995).

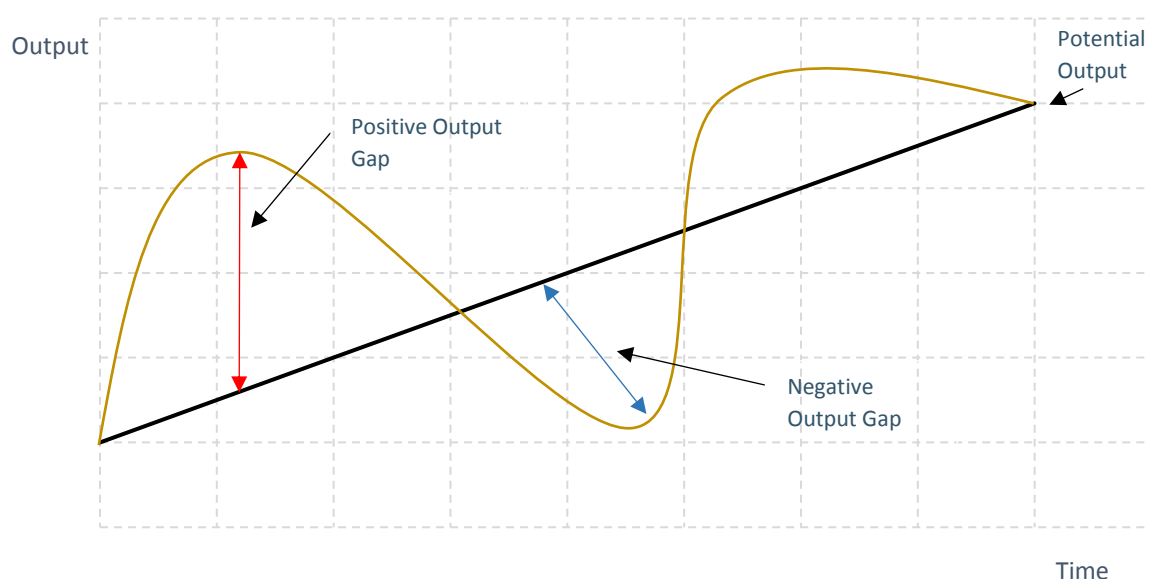
³ The reader is referred to the literature for more detailed discussions. See Borio et al. (2013, 2014), Cuerpo et al. (2018), Aramendia and Raciborski (2015), Blagrove et al. (2015) and Casey (2018) for example.

A second definition focuses on the relationship between potential output and stable inflation. Okun's (1962) paper identifies potential output as the highest level of output an economy can produce while maintaining inflation at a stable rate. This view has remained particularly popular amongst fiscal and monetary policy makers. A number of papers have attempted to extend Okun's traditional definition of potential output to include additional information to better explain the current economic cycle than more limited definitions. For example, Alberoa et al., (2013) consider the role of additional macroeconomic imbalances while Borio et al., (2013) emphasise the role of financial imbalances. However, it is argued that these models can be seen as 'gauging the path of sustainable future output rather than current potential output in the output-inflation trade-off sense' (Blagrove et al., 2015).

By contrast, another measure which differs markedly is one that has been developed within the New Keynesian Dynamic Stochastic General Equilibrium literature, where potential output is defined as the equilibrium level of output arising, or associated with, flexible wages and prices (see Galí, 2002). Finally, from a statistical perspective, within filtering methods the trend component of the actual output series is interpreted as a measure of potential output.

In the medium to longer term, actual economic output is expected to grow in line with potential output. However, in the shorter term, actual economic output may not exactly match potential output. This gives rise to the need to estimate the output gap. The output gap represents the deviation of the actual output of an economy around its potential level. Therefore developments in the output gap are not only technical in nature and should be viewed as a measure of the business cycle (Figure 1). A positive or increasing output gap can be viewed as an upswing in the business cycle while a negative output gap implies that an economy is producing below its capacity. Accurate estimation of the output gap allows policymakers to develop a better understanding of the business cycle and to develop economic policy that is consistent with the position of the economy in the business cycle.

Figure 1: The Business Cycle and the Output Gap



Source: Department of Finance

2.2: univariate statistical filters⁴

Univariate techniques decompose observed output into its trend and cyclical components. Statistical filters by their nature are atheoretical and rely on mechanical processes, driven by statistical assumptions around how the components evolve over time. Therefore, the resulting trend and cycle estimates can only be interpreted as proxy estimates of the potential level of output and the output gap. This means that the researcher must draw on their own knowledge when judging how changes in the trend component relate to the underlying determinants of the economy's potential level of output. A number of univariate approaches have been developed which differ according to assumptions on the components' behaviour. These approaches tend to be relatively simple to implement, with limited constraints imposed on the data. Popular univariate filtering approaches that are used in the literature include Hodrick-Prescott filter (Hodrick & Prescott, 1997), Band Pass filter (Baxter & King 1999), Kalman filter (Kalman 1960, 1963; Kalman & Bucy, 1961), and the Beveridge-Nelson decomposition (Beveridge & Nelson, 1981).

One of the most widely used approaches is the Hodrick-Prescott (HP) filter. This filter calculates the trend component as a weighted moving average of lags and leads of the series. The estimation process centres on addressing the trade-off between minimising the variance of the trend component and that of the cycle component. The degree of smoothness of the trend series depends on the span of the moving average. Whilst the filter is simple to apply, one significant criticism of this approach is that it requires judgement around the average duration of the business cycle as captured in the smoothing parameter (denoted by λ). Various values have been proposed for this parameter, although unanimous consensus has not been reached (Ravn and Uhlig, 2001; Backus and Kehoe, 1992; Cooley and Ohanian, 1991; Baxter and King, 1999). The need for judgement remains problematic as the selection of an incorrect smoothing parameter can lead to the generation of spurious cycle estimates (Stock and Watson, 1996; Kaiser and Maraval, 1999; and Schenk-Hoppe, 2001).

Another widely used technique is the Kalman filter. This filter is highly applicable since it enables the estimation of state space systems containing unobserved components (i.e. trend and cycle).⁵ Therefore, it can provide greater flexibility with regards to the specification of the components of a series. For example, Harvey (1989) shows that a series can be decomposed into a trend, cycle, and seasonal component. The trend could take several forms, with the local level model and the random walk being the standard specifications applied. Similarly, a range of different processes could be chosen to model the cyclical component, such as autoregressive or trigonometric functions. Seasonal components are generally modelled using dummies. However, it is rare that all components are included. For example, it would be appropriate to exclude a seasonal term if seasonally adjusted or annual data were used (Hindrayanto et al., 2010). To produce estimates of these unobserved components, the filter uses a recursive process, whereby the forecast of the unobserved components are updated with each additional observation, and the estimation of the parameters relies on the maximum likelihood method.

⁴ This discussion focuses on linear filters.

⁵ The reader is referred to Murphy et al. (2018) for an overview of the Kalman filter as specified in a state space format and its application to the estimation of the output gap for the Irish economy.

Overall, the main advantage of univariate filters is that they are simple to apply. By definition, they can be run using just a single variable, and although this can be seen as an advantage, it also gives rise to their main limitation – the end-point bias of the produced results (Runstler, 2002). This is the main criticism of the HP filter. End-point bias entails that, given the nature of the HP filter, the final data point in a series has an exaggerated impact on the trend at the end of the series. This also refers to the tendency of the trend estimates to exhibit a procyclical bias at the end of the sample (i.e. the filtered trend observations are likely to closely match the actual series). The HP filter has been widely criticised on these grounds (Baxter and King, 1999). In the context of formulating fiscal policy this is particularly problematic as the end of sample estimates are the most relevant. Though the Kalman Filter represents an improvement on the HP filter in terms of end-point bias, it may not entirely purge the bias that may be present in the observations at the end of the series.

One approach to mitigate this bias has been to extend the observed series with forecasts.⁶ Another approach in the context of the HP filter is to increase the smoothing parameter lambda value at the end of the sample (Bruchez, 2003). Another criticism of statistical filters may be the inappropriate smoothing of structural breaks in time series (Hamilton, 2017; Ódor and Jurašeková Kucserová, 2014). For example, if there has been structural breaks or an unexpected shift in the economic time series in the economy, for example the unprecedented increase in Irish GDP growth in 2015, then the use of this type of statistical filter may not be appropriate as the process of filtering the data may result in the structural breaks being regarded as cyclical rather than structural.

With the intention of addressing some of these shortcomings, Hamilton (2017) has developed an alternative regression-based filter. However, Schüller (2018) argues that his filter is also based on *ad hoc* assumptions and induces a certain cyclical structure in economic time series. She suggests the Hamilton filter is more suited to filtering time series with cycles that exceed eight years (i.e. longer than the average business cycle) such as the credit-to-GDP ratio. She also finds that the filter can provide end of sample estimates that are more robust relative to HP estimates.

It is also well acknowledged in the literature that statistical filters may fail to detect cyclical turning points. Supply shocks can impact on the level of potential output, while leaving the headline growth rate of potential unchanged, while demand shocks can be regarded as cyclical and as a consequence should have no impact on potential output (Cronin and McCoy, 1999). Statistical filters cannot differentiate between demand and supply shocks. This means that caution needs to be exercised when analysing trend output data produced by statistical filters, as the effects of the business-cycle fluctuations may not be completely removed.

However, as Blanchard (2018) recently emphasised, the interpretation of shocks can be quite difficult; demand shocks can have temporary effects on supply, while supply shocks can affect demand. This is an issue which even more sophisticated models can struggle to deal with. We

⁶ Kaiser and Maraval (2001) derive an ARIMA model to produce forecast observations intended to reduce the end point problem. See Mohr (2005) for a detailed discussion on end-point bias and the development of model to alleviate it. The Kalman filter is often used as an alternative to the HP filter to overcome the end-point bias in the HP filter. Though the Kalman alleviates some of this bias it does not remove all of it.

will return to this issue later in the section in the context of our discussion of structural vector auto regression models.

2.3: multivariate models

As discussed above one of the key problems with univariate models is that they can struggle to distinguish between the permanent (trend) and temporary (cycle) components of the economic output series, i.e. structural shocks being interpreted as cyclical. Multivariate filtering models can help address this issue by including additional information to better identify the output series' cycle component (Runstler, 2002). Some examples of these type of models include the multivariate Beveridge-Nelson decomposition model, the extended HP filter and the multivariate unobserved components method, which can be estimated using the Kalman filter algorithm.

In the context of estimating potential output, the extended HP filter was popularised by Borio et al. (2013). This approach entails the inclusion of cyclically relevant economic variables (e.g. credit growth) which inform the decomposition process and assist in identifying the cyclical component of GDP. They find the extended HP filter performs better in real time relative to the univariate HP filter and other models more firmly anchored to structural economic relationships, such as the Phillips curve. Among the advantages of this approach is that it is more parsimonious and transparent in comparison with several other approaches. However, some concerns have been raised regarding the model's capacity for real time identification of financial cycles (Blagrove et al., 2015).

Whilst the work of Borio et al. (2013) focuses predominantly on the US, this approach has been applied to Ireland by others. Aramendia and Raciborski (2015) produce financial-neutral estimates of potential output, controlling for real interest rates and house price growth. The results imply stronger overheating during the early and mid-2000s, and a deeper recession between 2009 and 2013 than implied by both the univariate HP filter and the harmonised approach. The model also appears to perform better in real time than the alternatives, with estimates for 2007 showing a positive output gap of approximately 5 per cent. However, the authors also caution that the results for earlier periods (late 1980s and early 1990s) appear less plausible when compared with conventional business cycle estimates.

Berger et al. (2015) also replicate this approach for a stylized two-region group of European economies: one region of peripheral economies, including Ireland, and the second including core economies.⁷ They apply a multivariate filter, controlling for house prices and credit growth. They also control for long-frequency financial trends by pre-filtering the input data. For the group of peripheral countries, the results show that the output gap became positive at the start of the last decade, peaked at in 2005 to 2007 at around 4 per cent, and troughed in 2013 at around -4 per cent. However, the real time estimates for 2007 is at around 1 per cent, implying a non-trivial revision ex-post. Overall, the authors conclude that the evidence suggests that financial variables can inform estimates of sustainable or potential output, but note that the multivariate approach requires numerous practical decisions which influence the findings and deserve further scrutiny.

⁷ Peripheral economies include Ireland, Portugal, Italy, Spain and Greece. Core economies include Germany and France.

Perhaps the most widely applied technique in the space of multivariate filters is the Kalman filter, owing to its applicability to state space systems, as previously noted. The approaches can easily facilitate the incorporation of economic relationships such as, for example, in Blagrove et al. (2015) where Okun's law and the Phillips Curve are included.⁸ The model maintains a relatively simple model structure and requires limited data i.e. output, inflation and unemployment rate data. Allichi et al. (2015) extends this model further by incorporating information on capacity utilisation and the labour force participation rate in an attempt to capture the impact of population ageing. Both studies find that the model produces more robust real-time estimates relative to the univariate filter, and in that regard is more resilient to the end-point bias.

Darvas et al. (2015), on the other hand, develop a model embedded in the Phillips curve and incorporate the current account in order to account for openness to trade. The model is estimated for 45 countries and the findings indicate that the current account equation is more important in determining the sustainable level of output than the Phillips curve. The real-time estimates of potential output are found to be superior to the univariate HP filter, as well as those of the European Commission, OECD and IMF.

It is important to point out that in previous work, the Department of Finance has worked on the design of a multivariate Kalman filter to incorporate financial cycle impacts including house price, private sector credit and adjusted current account dynamics, Weymes (2016). The paper highlights the need to look beyond aggregate capacity constraints and to focus on the misallocation of resources and the potential build-up of sectoral imbalances as captured in the suite of variables listed for example, when measuring the economy's stance.

Overall, the evidence suggests that multivariate filters perform better in real time relative to univariate filters, and in that sense are more resilient to end-point bias. However, it is important to consider that the estimation of multivariate models are more sophisticated, and those incorporating economic relationships, such as the Phillips Curve, could be subject to misspecification.

2.4: production function approach⁹

The production function approach, which is grounded in economic theory, links the level of output in the economy to its factor inputs e.g. labour, capital, materials and energy. The level of technology together with the degree to which the factors are used (forming what is known as total factor productivity (TFP)) ultimately determine the level of output. One prominent application of the production function methodology to estimate potential output is the European Commission's harmonised approach (Havik et al., 2014). Other international

⁸ Okun's law states that there is a negative relationship between the unemployment rate and economic growth. The Phillips curve suggests that there is a negative relationship between the inflation rate and unemployment rate.

⁹ A number of papers have used the production function approach to estimate the supply-side of the Irish economy. The generic Cobb-Douglas production function (Cobb and Douglas, 1928) was applied to Ireland by Slevin (2001). In this paper Slevin presents a suite of models to estimate potential output for Ireland. McQuinn (2003) uses a number of different specifications including the Cobb Douglas model with associated factor demands, and two fully flexible functional form specifications – a dual cost function and a production function. He also works to expand on Allen and Mestre (1997) to allow for the possibility of a structural break in the Irish economy over the sample period as well as the specification of a more flexible productivity measure.

organisations which use a production function approach include the IMF¹⁰ and OECD (e.g. Andrle, 2013; Beffy et al., 2006; Giorno et al., 1995).

This approach can be used to link potential output growth to growth in TFP, and factor inputs which themselves can be further decomposed into sub components. This allows for a deeper analysis of fluctuations in potential output, its growth rate and the output gap. However, a certain degree of judgement is required when developing this approach including the selection of the appropriate functional form, the level of aggregation (i.e. number of sectors, type of factor inputs), assumptions on the role of technological progress and returns to scale, and addressing data requirements. A common criticism of this approach relates to the measurement TFP which is calculated as a residual. The accuracy with which it is measured depends entirely on how well the factor inputs are measured.

There are a number of approaches to using the production function framework to calculate potential output. Potential factor inputs, for instance, can be determined exogenously using univariate or multivariate filters before being inserted into the production function. While this approach can be relatively straightforward, Cerra and Saxena (2000) contend that potential output estimates derived from the detrended factor inputs can share a similar end of sample bias to that which is present when actual output is detrended.

Another method is to estimate the production function as part of a structural model where the factor inputs are estimated endogenously. Within multivariate structural time series models factor inputs are decomposed into unobserved components (e.g. a trend, cycle and an irregular component) and the relationships between variables and their cycles are then modelled. To calculate the unobserved components a Kalman filter can be used with the system being estimated by maximum likelihood for example. Examples of this type of model based production function approach include Proietti et al. (2002) and Moës (2006).

Finally, the European Commission's harmonised approach is estimated within a Cobb Douglas production function framework (Cobb and Douglas, 1928) with two factor inputs - labour and capital, along with TFP. As discussed above, this is the approach that is used by the Commission when assessing Member State compliance with the Stability and Growth Pact. However, there are a number of shortcomings regarding its application to Ireland which have contributed to implausible output gap estimates on occasion. Casey (2018) summarises some of weaknesses of the approach which include its inability to account for openness of the economy as reflected in movements in trade balance, measurement issues regarding the capital stock and issues with the assumption of its full utilisation in the context of asset bubbles, procyclicality of the NAWRU estimate, and the models' failure to take account of migration which for small open economies like Ireland can add to difficulties in distinguishing between trend and cyclical developments.

2.5: macroeconomic structural models

At present, one of the main macroeconomic structural models of the Irish economy is COSMO which was initially developed by the Economic and Social Research Institute (ESRI) and the

¹⁰ The IMF do not have a 'common' method to estimate potential output across countries. Each country desk chooses the method that fits the country situation best.

Central Bank of Ireland (Bergin et al., 2017). This model is underpinned by a theoretical structure with econometrically estimated parameters and dynamics. It is a multi-sector model including a traded, non-traded and government sector.

The model defines potential output in terms of the capacity output of each sector and is consistent with the first definition of potential output discussed earlier. A production function is used to drive medium-term growth, where the productive capacity of each sector is modelled as a 3 factor nested Constant Elasticity of Substitution (CES) production function with constant returns to scale and labour augmenting technical progress.

One important basis for estimating potential output based on the capacity output approach is that Ireland has a very open labour market where relative wages and unemployment play a key role in wage formation. In this regard, Irish wage formation models which estimate a non-accelerating wage rate of unemployment (NAWRU) based on the Phillips curve are viewed by many researchers as being inappropriate (Bergin and Fitzgerald, 2014).

In terms of understanding potential output and also output gap fluctuations, this structural model approach can provide a relatively more in-depth account of the key drivers. This is particularly beneficial as it can provide greater insight and a clearer narrative to policy makers (Mestre and McAdam, 2008; Hjelm and Jönson, 2010).

More generally, while the underlying reliance on theory is an advantage, the estimation of structural models can require a large amount of data, some of which are not always available and may need to be imputed. Moreover, model parameters may need to be estimated before being included in the structural model. Finally, structural models, by their nature, tend to be less flexible than astructural¹¹ models given their origination in economic theory and the various constraints that should be imposed.

2.6: principal component analysis

Principal components analysis (PCA) is another approach used to estimate the output gap (Casey, 2018; Murray, 2014; Pybus, 2011; Altissimo et al., 2001; French Finance Ministry, 2018). The approach makes use of a set of correlated variables to extract the information into a set of linearly uncorrelated (orthogonal) variables, so called principal components. Weights are assigned to each of the cyclical indicators so that the derived common determinant explains as much of the variability of the data as possible. When using PCA to estimate the business cycle or output gap, the first principal component extracted is the linear combination of the indicators of the cycle that accounts for the greatest variance of these indicators. The main common determinant extracted by the PCA is taken to represent the output gap (Pybus, 2011).

One of the main limitations of using PCA is that it does not directly estimate potential output. In using a common factor of a range of cyclical variables as a proxy for the output gap, potential output is measured as a residual. This implies that it cannot necessarily be used for forecasting the medium-term growth potential of an economy. As PCA incorporates data that

¹¹ Astructural or reduced form estimation focuses on the statistical relationship between observed variables.

is correlated with the output gap, PCA could be used as a robustness check of alternative estimates of the output gap and to improve short-term economic analysis.

The complexity of this approach can also present another significant challenge. For instance, the individual cyclical indicators need to be combined and weighted to create the output gap. Casey (2018) acknowledges that this can be an arbitrary process as it is not clear what data transformations are required while the estimation of weights may not be obvious.¹²

A number of data selection issues arise in the application of this methodology. Data highly correlated with the economic cycle and not necessarily with GDP growth should be included. To be effective at capturing cyclical developments in real time, data should be published at a relatively short lag and should adequately capture cyclical developments in the economy (Giannone et al., 2005). A trade-off emerges between ‘hard’ data (e.g. GDP growth) and ‘soft’ data (e.g. Business sentiment indicators). In general, the former will provide better information about the economy but are produced at a considerable lag (quarterly or annual) while the latter tends to have a lower predictive power but are released at a shorter lag (monthly). The use of ‘soft’ data for this type of analysis is not necessarily a limitation as this data tends to be unrevised which implies that the estimates in real time are unlikely to change from those estimates which might be estimated at another point in time (Giannone et al., 2005; Murray, 2014). This point has particular relevance for Ireland as Irish GDP data have among the largest revisions in the OECD (Casey and Smyth, 2016) while the European Commission’s estimates of the Irish output gap, as estimated under the harmonised approach and HP filter, have the highest real time revisions in the EU15 (Daly and Murphy, forthcoming).

However, more recently, there has been debate about whether business sentiment survey indicators are state dependent in the sense that, after a deep recession, a normal level of economic activity is viewed more positively by firms (OECD, 2017). This would imply that developments in business sentiment indicators have started to move away from GDP growth in a number of countries. The economic crisis may have led to a ‘level shift’ in sentiment indicators implying that the average position of the level of sentiment has increased as the economic crisis resulted in the demise of firms with low levels of capacity utilisation, with a consequent increase in the average level. This ‘soft’ data may now appear to be excessively positive and provide an indication of overheating when it is not actually the case from looking at ‘hard’ data.

The Irish Fiscal Advisory Council (IFAC) have recently applied the PCA approach to estimate the Irish output gap (Casey, 2018). This is a novel approach to estimating Ireland’s output gap.

While the survey indicators of economic sentiment such as construction and manufacturing sector PMI’s¹³ are included it could be argued that the analysis is hampered by the absence

¹² Data are typically standardised and weighted prior to estimation. Weights can be estimated using statistical or econometric procedures.

¹³ Purchasing Managers’ Index. PMI’s are monthly surveys of a number of companies which provide an insight into economic activity in the private sector by tracking variables such as output, employment and prices. In Ireland, PMI’s are collected in the manufacturing, services and construction sector.

of other 'soft' indicators of the Irish cycle.¹⁴ To put this into context the Office of Budget Responsibility (OBR) in the U.K. use a much broader array of survey data on the economic cycle in their PCA¹⁵. This is not a criticism of the IFAC approach but rather a criticism of the dearth of survey data (business sentiment and capacity utilisation indicators) on the Irish economic cycle at a time when it is becoming increasingly challenging to measure aggregate Irish economic performance.¹⁶

In terms of the estimated output gap series, the PCA approach appears to provide a sensible representation of the output gap's evolution in the past. As regards the recovery period, although the output gap begins to recover from 2015, the magnitude of the negative gap is implausibly large compared with that suggested by other approaches. As noted in the paper, the PCA analysis places significant weight on housing completions - around 80 per cent - which, given its slow recovery, would appear to be having a negative effect on the estimates. To the extent that housing markets are significantly entwined with the business cycle such a weighting may be appropriate (Learner, 2007).

2.7: structural vector autoregression models

Structural vector autoregressions (SVAR) were proposed by Sims (1980), and have evolved into one of the most widely used models in macroeconomic research. Within the SVAR framework, all variables are treated as endogenous and are expressed as linear functions of the other variables in the model.

Blanchard and Quah (1989) use this framework to decompose output into demand and supply components, which could be interpreted as measures of the cycle and trend. They specify a bivariate VAR including output and unemployment. The model assumes the existence of two types of disturbances generating output dynamics: the first having only a transitory effect, and the second having a permanent effect. These could be interpreted as demand and supply shocks respectively. With regard to unemployment, it is assumed that both the supply and demand components are subject only to transitory shocks. Estimates of the supply and demand components of output can be produced by setting the shocks of the counterpart elements to zero. In other words, the supply (demand) component is derived by setting demand (supply) innovations to zero. Therefore, the path of trend output is derived as the sum of past supply distortions. The estimated demand component of output is found to closely coincide with business cycle trends.

More recently, Coibion et al (2017) apply this framework to estimate potential output for the US. In contrast to estimates of other institutions, their results indicate that substantial slack remains in the economy. They argue that the alternative modelling approaches adopted by other institutions are inadequate, since they do not have the capacity to distinguish between different sources of economic shocks. They demonstrate that potential output estimates based on these models under-respond to supply shocks and over-respond to demand shocks. The SVAR framework, on the other hand, successfully differentiates between the different

¹⁴ Planas et al. (2010) show that PMIs can be used as measure of capacity utilisation (CU). In fact, Clancy (2013) replaces CU with PMI data to help extract the TFP cycle using a Kalman Filter in the harmonised approach.

¹⁵ OBR base their analysis on firm-level survey measures of spare capacity and recruitment difficulties which are then complemented by other indicators of potential overheating such as average weekly earnings growth and the unemployment gap (Pybus, 2011; Murray, 2014).

¹⁶ The Irish capacity utilisation (CUBS) series was discontinued in 2008.

types of shocks and can therefore produce estimates of potential output which are driven exclusively by long-term supply factors, as opposed to transient demand shocks.

Compared to other modelling approaches used to estimate potential output, SVAR models have several advantages. For example, they do not require assumptions around the duration of the business cycle, nor are they subject to the end-point bias inherent in filtering techniques. Additionally, they allow the model to be grounded in economic theory, in contrast to, for example, the unobserved component models or filtering techniques, which are more reliant on stochastic processes. Furthermore, judgement in the form of priors is not required (Dupasquier et al., 1999). However, as Cooley and Dwyer (1998) highlight, SVARs are sensitive to misspecification in the identifying assumptions, but since these assumptions are necessary in the estimation process, they cannot be tested. Mazzi et al (2008) compare the performance of a range of models used to estimate the output gap for the euro-area. These include a production function model, an unobserved components model and a structural VAR.

A key finding from their analysis would appear to be that the preferred approach depends on the objective of the research exercise. For example, the production function approach provides greater insight into the drivers of potential growth, and could therefore be more useful in the context of policy. On the other hand, unobserved components and SVAR models perform better in forecasting inflation. However, in the context of business cycle analysis, the unobserved components model appears to outperform the other methods.

2.8: aggregate measures of Irish output

For all the discussion of the various approaches that can be used to estimate potential output, the results are ultimately only as good as the data that are used. In this regard, recent statistical distortions in Ireland's national accounts (e.g. GDP, GNP) associated with the activities of multinational enterprises (MNE's) such as contract manufacturing, aircraft leasing, asset relocations distorting the capital stock, royalty exports and balance sheet relocations have little to do with Irish economic fundamentals. As a consequence, models which fail to account for these distortions can provide inaccurate or even implausible potential output estimates. At present, it appears that this issue is particularly important for Ireland reflecting the size and structure of the economy and the behaviour of MNE's.

Approaches to correct for these distortions include within model adjustments to GDP using dummy variables or the use of alternative output data series that exclude multinational activity. The IMF (2015b) have found that the change in gross value added (GVA) of the multinational dominated sectors does not have a statistically significant impact on tax revenue growth while they tend to have a low impact on employment. Given this evidence, the IMF (2015a and 2015b) and Casey (2018) have used a measure of actual Irish or 'domestic' economic output, domestic GDP and domestic GVA respectively, which exclude the volatile multinational sectors.¹⁷ They argue that filtering these domestic output series can provide more appropriate estimates of the Irish economic cycle. Also, findings in Casey (2018) suggest that developments in domestic GVA are more relevant for explaining changes in Irish tax

¹⁷ A relevant issue to note of is that Irish GDP data have been shown to have among the largest revisions in the OECD (Casey and Smyth, 2016).

receipts. More recently, IMF (2018) have developed a quarterly GNI* series which they use to estimate Ireland's potential output.

2.9: summary of estimation techniques

Based on the above discussion, the table below briefly summarises the important attributes of each of the techniques. The level of complexity of a methodology is positively related to the data requirements. For example, highly complex methodologies such as production function approaches or macro structural models generally require a wide ranging set of input data, whereas simpler frameworks can be implemented with fewer or even a single variable.

There is a trade-off between the level of complexity of a model and the depth of the narrative it can provide. Relatively complex models which are embedded in economic relationships are better placed to identify the drivers of potential growth and the channels through which their impacts occur. Similarly, more complex models can be used to distinguish between demand and supply shocks, which facilitates the narrative.

An additional observation is that statistical filters in general are subject to an end-point bias, although to varying degrees. Multivariate filters generally perform better in real time than univariate filters. The remaining approaches considered are generally robust to the end-point bias, with the production function approach being a potential exception. Although in principle, this framework should not be subject to an end-point bias, in practice it could occur if its implementation involves the use of statistical filters, for example in the estimation of a structural unemployment rate. All frameworks with the exception of principal components produce estimates of both the output gap and the potential growth rate. Principal components can only be used to extract a cyclical estimate as a proxy of the output gap, which is an important limiting factor for the purposes of informing fiscal policy formation.

Table 1: Overview of models for estimating potential output

	Data Requirements	Level of Complexity	Provides Narrative	Separates Supply and Demand Shocks?	End-point bias	Provides Estimates of Potential Growth
HP Filter	Low	Low	No	No	Yes	Yes
Beveridge Nelson Filter	Low	Low	No	No	Yes	Yes
Extended HP Filter	Low	Medium	Limited	No	Yes	Yes
Kalman Filter	Low	Medium	Limited	No	Yes	Yes
Production Function	High	High	Yes	Yes	Yes	Yes
Macro Structural Models (e.g. COSMO)	High	High	Yes	Yes	Possibly	Yes
SVARS	Low	Medium	Yes	Yes	No	Yes
Principal Components	High	Medium	Limited	No	No	No

Source: Department of Finance.

Section 3 – Summary of methodologies used by Irish and international institutions

This section briefly describes the main approaches that have been applied by Irish and international institutions in recent years to estimate Ireland's potential output growth and output gap. By way of background, a number of studies have highlighted that there are many factors that are likely to influence the choice of modelling approaches applied by each institution (Hjelm and Jonsson, 2010). For example, central banks may favour methods which perform better at forecasting inflation. On the other hand, international institutions such as the OECD and the European Commission may place greater weight on factors such as model transparency and replication.

3.1: Central Bank of Ireland

The Central Bank use a range of multivariate models when estimating the Irish economic cycle (O'Grady, 2018). The first makes use of a multivariate filter set in state space form which takes information about the financial cycle into account in the spirit of Borio et al (2013, 2014). Secondly, they make use of a Cobb-Douglas production function in two different models for estimating potential output and the output gap. Firstly, they estimate the harmonised approach. The second sets the production function framework in state space form and includes other key economic relationships such as Okun's Law to estimate output gaps and unemployment rate gaps. Finally, they also apply a Bayesian model averaging method which relies on a flexible model specification to estimate output, unemployment and inflation gaps. This type of model is typically used when a variety of models exist which may all be statistically reasonable but can often lead to different conclusions for the research question of interest.

Bayesian model averaging allows researchers to deal with model uncertainty which given the intricacies present in the Irish economy allows additional flexibility across specifications which can be useful for estimating unobservable variables such as the output gap. These types of models enable researchers to quickly determine which models and/or explanatory variables which have high likelihoods (i.e. more suitable relative to others). By averaging across a large set of models the researcher can determine the specification and variables which are most relevant to the data generating process for a given set of initial priors. In their model, in particular, the Central Bank again make use of Okun's Law, a Phillips curve and unemployment gap as part of their specification. As far as we are aware, the Central Bank has not published any methodology paper on the application of these approaches.

3.2: ESRI

The ESRI use COSMO - which is discussed in detail above - to forecast potential output growth. Their most recent estimates forecast potential output to grow by 4.9% in 2018 and 4.4% in 2019 (Bergin and Garcia-Rodriguez, 2018). It is our understanding that the model is currently being re-estimated and a new version will be finalised during 2019.

3.3: IFAC

IFAC adopt a suite of models approach which consists of univariate and multivariate filters and a principal component analysis that are applied to measures of domestic activity such as domestic gross value added (Casey, 2018). In their approach, IFAC summarise the various estimates into one measure by taking the mid-point of the range of estimates. While such an approach potentially limits the reliance on one particular methodology - when multiple variants of the same methodology are considered – it does mean the summary output gap

estimate is determined by the two border observations. However, given that all selected models are individually assessed this supports the robustness of this summary estimate. To the extent that models may be discarded or amended within the range, comparability issues may arise over time.

IFAC also estimate the European Commission's harmonised approach as part of the endorsement process of the Department of Finance's macroeconomic forecasts. IFAC have often outlined their criticisms of the approach.

3.4: European Commission

The European Commission estimate potential output and the output gap using a production function and a HP filter of real GDP. Although estimates from both methodologies are published by the Commission, the production function method or 'harmonised approach' (Havik et al., 2014) is the reference method used by the Commission for assessment of Member State's compliance with the Stability & Growth Pact.

3.5: IMF

The IMF do not have a 'common' methodology for estimating potential output and the output gap that is used across countries (Cotis et al., 2004). Discretion is provided to individual country desks to use a methodology which best characterises the country. In the past the IMF have used multivariate filters based on economic relationships such as the Phillips Curve and Okun's Law, which relate the output gap to inflation and the unemployment gap (Blagrove et al., 2015), univariate HP filters, multivariate filtering models (Benes et al., 2010; Berger et al., 2015) and production functions (De Masi, 1997; IMF, 2018).

More recently, the IMF have sought to refine their approach to modelling Ireland's potential output by taking account of both the distortions in national accounts data caused by the presence of large multinational enterprises, and the openness of the labour market where migration plays an important role. The IMF have estimated the Irish output gap using GVA which excludes the GVA of multinational firms (IMF, 2015a) and more recently have made use of modified GNI or GNI*.¹⁸ They have used various modelling approaches including a HP filter, multivariate Kalman filter and a production function (IMF, 2018). In the latter two models, the IMF also attempt to estimate a NAWRU or natural rate of unemployment while explicitly accounting for the role of migration. Making use of the model proposed by Watson (1986), stochastic trends and cycles of employment and the labour force are incorporated into a multivariate Kalman filter by assuming that the cycle of both factors (employment and the labour force) are co-determined by a common factor – net migration. Their results suggest that the output gap became positive in 2015 (IMF, 2018). Making use of the production function, they find that changes in the output gap have been mainly driven by cyclical employment and capacity utilisation.

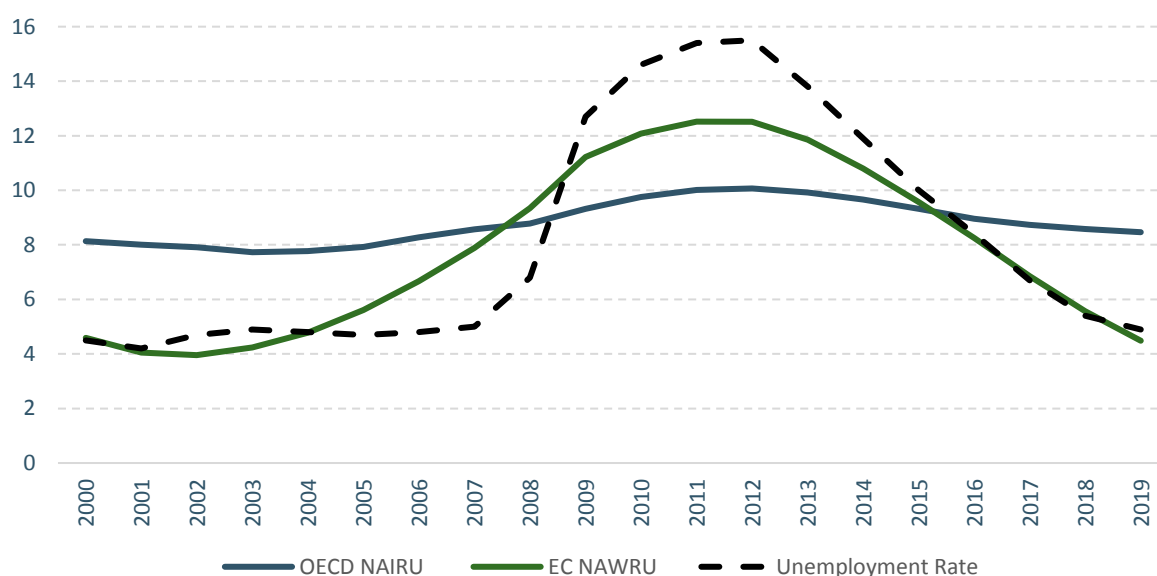
¹⁸ Modified GNI (or GNI*) is defined as GNI less the effects of the profits of re-domiciled companies and the depreciation of intellectual property products and aircraft leasing companies. See Department of Finance (2017b).

3.6: OECD

The OECD estimate potential output and the output gap using a production function (Turner et al., 2016; Giorno et al., 1995). A constant returns to scale Cobb-Douglas production function is used (Cobb and Douglas, 1928). The production function consists of a labour component and a capital component with labour augmenting technological progress. The labour component consists of total employment while the capital component represents the whole economy measure of the productive capital stock. Finally, as labour efficiency cannot be observed it is calculated as a residual while the labour share of income is kept constant for all countries.

The main difference with the Commission's approach is with regard to the estimation of the trend or natural rate of unemployment. The natural level of unemployment (NAIRU) is derived using a Phillips curve equation with anchored inflation expectations which is estimated using a Kalman Filter (Richardson et al., 2000; Rusticelli et al., 2015, 2016). The OECD estimate a NAIRU using price inflation while the Commission estimate a NAWRU and use wage inflation. In the EU methodology (NAWRU), equilibrium unemployment tracks actual unemployment for Ireland quite closely, and even rises ahead of the crisis. In contrast as shown in Figure 2, the OECD measure (NAIRU) appears to be more stable, over the period 2000-2019 the current OECD NAIRU ranges from just below 8 per cent in 2004 to 10 per cent in 2011.

Figure 2: Estimates of the natural rate of unemployment, % of labour force



Source: CSO and Department of Finance (2018), European Commission Autumn 2018 Economic Forecasts November 2018, OECD EO 103 May 2018

Another difference with the Commission's approach is that the OECD excludes hours worked from its formulation of potential labour as the potential labour force is estimated solely on the basis of de-trended participation rates, and the unemployment gap (via the NAIRU). A further difference is that the OECD output gap model models TFP in levels rather than rates of growth.

3.7: summary of approaches

A summary of the approaches taken by the each of the institutions is presented in Table 2. The majority of institutions use more than one modelling approach to assess the potential growth of the economy. The preferred approaches used within each institution differs across the sample. The frequency with which estimates are published is also found to vary. The Department of Finance and the European Commission, for instance, publish real time potential output estimates twice a year which reflects the need to assess compliance with the fiscal rules within the Stability and Growth Pact. By contrast, while the Central Bank of Ireland and ESRI regularly comment on the economy's cyclical position they do not appear to have published output gap estimates in their main economic commentaries over the last number of years for which we checked.

Table 2: Models for estimating potential output used by Irish and international institutions

	Univariate filters		Multivariate filters		Principal components	Production function	Structural model	Bayesian model	Latest publication, (frequency per annum)
	HP	Kalman Filter	Extended HP	Kalman Filter					
IFAC	Y	Y		Y	Y				November 2018, (2)
ESRI							Y		
C.B.			Y			Y	Y	Y	
D.o.F	Y	Y	Y	Y		Y			October 2018, (2)
IMF	Y			Y		Y	Y		October 2018, (2)
OECD	Y					Y			November 2018, (2)
EC	Y					Y			November 2018, (2)

Source: IFAC – Fiscal Assessment Report (FAR) published in June and November; ESRI preliminary estimates are found in the (Bergin and Garcia-Rodriguez, 2018) presentation to IFAC Annual Conference 2018; Central Bank (C.B.) models are presented in (O’Grady, 2018) presentation to IFAC Annual Conference 2018; Department of Finance estimates are published twice annually during the Budget and Stability Programme Update (SPU) forecast rounds (October and April); the IMF publish their output gap estimates in the World Economic Outlook (WEO) published twice a year (May and October); the OECD publish estimates of the output gap in their Economic Outlook which is published twice annually (May and November); the European Commission publish estimates of the output gap twice annually in their Spring and Autumn forecast rounds (May and November).

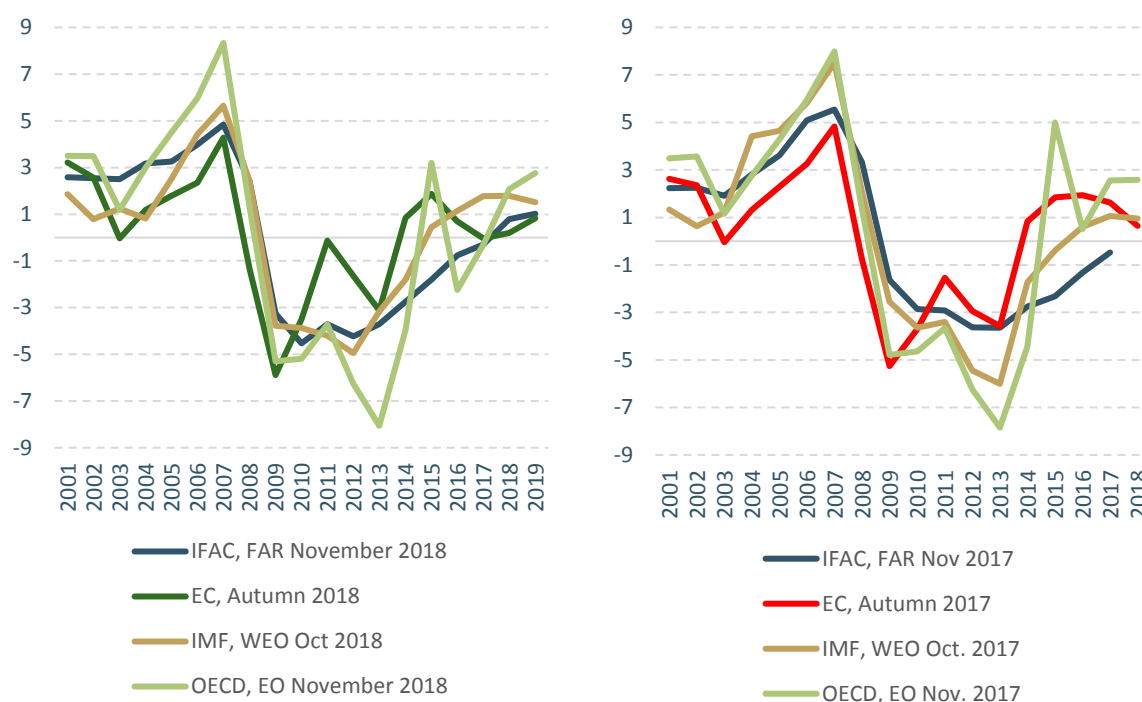
The most recent estimates of the Irish output gap as produced by the European Commission, IMF, OECD and IFAC follow a similar historical trend – a positive output gap in the years prior to the crisis - which is consistent with views on the economy overheating - followed by a large negative output gap during the recessionary period (Figure 3). From the most recent output gap vintages (chart in left hand panel), it appears that there are some differences in terms of the estimates of the rate with which the output gap has closed and the subsequent cyclical position of the economy across institutions. In this chart all institutions estimate a positive output gap in 2018/2019. The Commission’s estimate turned positive in 2014 but has fluctuated around zero since. By contrast, IMF estimates turned positive in 2015 and are forecast to be strongly positive from 2017-2019. The OECD estimate in particular displays a large degree of uncertainty. The OECD output gap turns positive in 2015, then negative in

2016 and positive from 2017 onwards. The IFAC estimate demonstrates a more intuitive estimate of the output gap – one that is closing from below and is consistent with other indicators of the cyclical position of the Irish economy. This usefully demonstrates that different methodologies often produce different estimates (i.e. model uncertainty); the magnitude of these differences can be large on occasion and even differ in terms of the sign of the estimate.¹⁹

There is a large degree of uncertainty surrounding the Commission's estimate of the Irish output gap from one year to the next. The Commission's output gap estimates, in particular, based on its forecasts from the two vintages previous suggested a different output gap series (red line in chart in right hand panel). In the autumn 2017 vintage the Commission estimate a positive output gap from 2014 onwards, which increases to approximately two percent in 2015-2017 and 'closes from above' over the next two or three years. These positive output gap estimates would appear to be implausible given the lack of inflationary pressures and the apparent slack in the labour market in the economy at the time. To the extent that no single estimation method is likely to be consistently reliable, it is prudent to consider a number of alternative estimates.

¹⁹ A further complicating factor relates to estimate uncertainty that arises when the model is re-estimated with new or revised data. This can be particularly problematic as revisions to real time output gap estimates can often be substantial. For a detailed analysis of this issue the reader is directed to Marcellino and Musso (2011).

Figure 3: Output gap estimates by institution, % of potential output



Note:

(1) The chart in the left hand panel examines the most recent Irish output gap estimates of the European Commission (EC), IFAC, IMF and OECD.

Source: European Commission Autumn 2018 Forecasts, OECD Economic Outlook (EO) November 2018, IMF World Economic Outlook (WEO) October 2018, IFAC Fiscal Assessment Report (FAR) November 2018.

(2) The chart in the right hand panel examines Irish output gap estimates of the European Commission (EC), IFAC, IMF and OECD from the second half of 2017.

Source: European Commission Autumn 2017 Forecasts, OECD Economic Outlook (EO) November 2017, IMF World Economic Outlook (WEO) October 2017, IFAC Fiscal Assessment Report (FAR) November 2017.

Section 4 – Conclusions and next steps

Estimating an economy's potential output and in turn the output gap is not an easy task. There are many approaches that can be applied but it can be difficult to distinguish model estimates across methodologies given that potential output is not directly observed. From a policymaker's perspective, a key concern is that the estimates produced vary across each of the methods. Since no single estimation method is likely to be reliable at all times, it is appropriate to consider a number of alternative estimates to assess the economy's potential growth path and cyclical position.

Building on this review and taking into account the key attributes of each of the techniques, including their resource and operational requirements, model complexity, and statistical measurement issues such as end-point bias, the Department has set out a three pillar framework under which its selected approaches to estimating the economy's potential output and output gap are organised.

Under the first pillar, the Department will continue to estimate potential output using the EU harmonised approach which remains definitive for the purposes of assessing compliance with the fiscal rules. Under the second pillar, the Department continues to develop an alternative production function which addresses the main shortcomings of the harmonised approach as they relate to Ireland. It is envisaged that this work will form the basis of future submissions and engagement with the European Council's Economic Policy Committee's evaluation framework through participation at the Output Gap Working Group (OGWG) which considers the inclusion of economically justified country specificities into the harmonised approach.

The third pillar involves the estimation of other statistical methodologies including univariate and multivariate filtering methods to produce potential output and output gap estimates (Murphy, Nacheva and Daly, 2018). These alternative estimates of the output gap were first published in the Stability Programme Update 2018 and subsequently in Budget 2019.

In addition, it is intended that these alternative estimates will be complemented by additional estimates based on more detailed structural models in the future.

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