

Output Gap Estimation Uncertainty: Extracting the TFP Cycle Using an Aggregated PMI Series*

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Abstract: The concepts of potential growth and the output gap are important components in assessing the business cycle and productive capacity of an economy. However, being unobservable, these measures must be estimated. The Fiscal Compact will result in these concepts being used to judge EU Member States adherence to budgetary rules. Therefore, it is vital that the methods applied for their estimation are as accurate as possible. A bivariate Kalman Filter (KF) model using capacity utilisation (CU) as the second series has been proven to produce more reliable estimates of the Total Factor Productivity (TFP) cycle than the Hodrick Prescott (HP) filter methodology formerly used for this task. However, CU data is no longer collected in Ireland. Given the large turning point in the TFP series as a result of the financial crisis, this may no longer be the first-best approach for future TFP cycle estimation. This paper compares the existing method to an approach which uses an aggregated Purchasing Managers' Index (PMI) series as the second series in the bivariate KF model. This approach has the advantage that PMI data is collected on an on-going basis. The results show that PMI shares a common cycle with TFP, and that this new approach leads to a reduction in the total estimation error variance and revisions required to TFP cycle estimates.

I INTRODUCTION

The concepts of potential growth and the output gap are probably the most comprehensive and convincing assessments of the business cycle and productive capacity of an economy (Graff and Sturm, 2012). Potential growth

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constitutes a summary indicator of the economy's capacity to generate sustainable, non-inflationary, growth. The output gap is an indication of the degree of overheating or slack relative to this growth potential. However, being unobservable, potential growth and the output gap must be estimated. A harmonised methodology, developed jointly by the EU Commission and the Member States, measures the output gap through a Cobb-Douglas production function that relates the gap to the cyclical components of labour and total factor productivity (TFP). This paper focuses exclusively on the TFP aspect of this methodology.

As of the Autumn 2010 forecasting exercise, the EU Commission has adopted a bivariate Kalman Filter (KF) model for the decomposition of TFP into its trend and cyclical components. The KF model replaced the Hodrick Prescott (HP) filter methodology, which due to numerous limitations such as a high degree of susceptibility to the endpoint bias, resulted in preliminary estimates of the TFP cycle being frequently and sizeably revised over time. These limitations are particularly apparent close to turning points, of which the recent financial crisis is certainly one. Whilst revisions will never be fully eliminated by any technique due to revisions in the underlying data series, the bivariate KF methodology constitutes an improvement over the HP approach.

The KF does not suffer to the same extent as the HP filter from the well documented (see, for example, Baxter and King, 1999) end-point bias problem for several reasons. First, the capacity utilisation series itself is not revised. Second, the KF uses the valuable economic information on the business cycle which it extracts from the capacity utilisation series to help it produce more accurate forecasts of the cyclical component of TFP. Indeed, Lombardi and Maier (2011) find evidence that suggests survey-based measures may have a particular advantage in responding to changes during volatile periods. The KF model, therefore, aims to exploit the link between the TFP cycle and the degree of capacity utilisation (CU) in the economy. D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012) have both proved that CU has informative content for TFP trend-cycle decomposition in twelve pre-enlargement countries. Graff and Sturm (2012) also show that survey data on capacity utilisation improves real time output gap estimation for a panel of OECD countries.

The TFP series can be extended to the end of the short-term forecast horizon by two additional observations using forecasts for GDP, labour input and the capital stock. However, since there are no forecasts of the degree of capacity utilisation in the economy, the KF model is estimated with two missing values. Nevertheless, these missing values for CU are not problematic, as the operation of the Kalman filter is not dependent on the availability of a forecast extension. The filter can compute linear projections through a recursive procedure which yields the expected value of the TFP

cycle on the basis of only the available observations. The Kalman filter in turn produces trend TFP forecasts by simply running the Kalman filter out of sample, over the required medium-term forecast horizon (D'Auria *et al.*, 2010).

While this is a justifiable approach, the question may be asked as to the length of time for which estimation through linear projections continues to be the first-best approach. In Ireland, data for the capacity utilisation series was last collected in 2008. Therefore, the 2012 TFP cycle estimation process will rely on data from four periods previous, at the risk that such information may not be as relevant to the current situation. This CU series ended before a large decrease in the TFP series in 2009 and thus there is a danger that this missing turning point in the data may manifest itself in increased revisions being required to Irish TFP cycle estimates calculated through the existing format. This is clearly an issue at a time when increased uncertainty in the overall economy, coupled with new legislation to base fiscal policy decisions on the results emanating from such analysis, makes accurate estimation all the more important.

This paper, therefore, examines whether a different series with more up-to-date information would perform better when substituted in for the CU series in the bivariate KF model. Purchasing Managers' Index (PMI) data is chosen for this purpose. The next section describes the motivation behind choosing these data, as well as the construction of the aggregated series to be used in the model. Following this, the methodology employed in the analysis is outlined. The results section begins with an examination of the link between TFP and the PMI data. Following this, the two bivariate KF models are compared in terms of their total estimation error variance and the revisions to TFP cycle estimates. A further comparison of the results is made on the basis of the TFP data vintage and various sample sub-periods examined. Finally, the implications for estimation of potential growth and the output gap of such a change in the methodology are detailed. The final section concludes.

II AN AGGREGATE PMI SERIES

The KF model achieves a reduction in the uncertainty surrounding TFP decomposition by applying a bivariate method. This approach exploits the relationship between TFP and another observable economic indicator carrying information about the business cycle which cannot be extracted in real time from the TFP series alone. D'Auria *et al.* (2010) state that for such an indicator to be useful, it must possess two important characteristics. First, it should be measured with acceptable precision and without revisions. This would be helpful in reducing TFP trend estimate revisions due to periodic updates of the

underlying series, which, naturally, ensure that such revisions will never be completely eliminated. Second, the indicator should strongly co-move with the unobserved cyclical component of TFP, hence enabling unbiased extraction of the TFP cycle even at the end of the sample.

D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012) have shown that CU is a good candidate for such an indicator, with a strong correlation between the series as well as evidence that they share a common cycle. Therefore, the usefulness of CU is not in question, rather the level of its effectiveness for Ireland given the missing data observations in recent years and the unavailability of the series going forward. The papers cited above describe in detail how CU allows for the decomposition of TFP into trend and cycle components within the Cobb-Douglas production function framework, thereby firmly establishing the link in economic theory. Originally two competing capacity utilisation series, a direct measure of capacity utilisation in industry and a combination of business sentiment indicators for the services and construction sectors, were examined. These have now been amalgamated into a combined Capacity Utilisation Business Survey (CUBS) indicator.¹

Planas *et al.* (2010) state that PMIs can be considered as an alternative measure of CU. They showed that there was a very high degree of cross-correlation between the PMI and the three CU measures, with a very strong relationship between them in Ireland (>0.80). However, as such data exists for only some countries, it was excluded from consideration for the harmonised approach in order to ensure exhaustive country coverage. Given the concerns stated above regarding the potential for reduced accuracy in the estimation of the TFP cycle as a result of the discontinuation of the CUBS data series, and the apparent substitutability of PMI for CUBS data, the timing is right to conduct an examination of the usefulness of PMI data as the second series in the bivariate KF model.

PMIs are monthly surveys of carefully selected companies which provide an advance indication of what is happening in the private sector economy by tracking variables such as output, new orders, employment and prices across different sectors. Therefore, the indices are themselves composite indicators designed to provide a convenient single-figure summary of overall activity in a given sector. The panel of companies in each survey is stratified geographically and by Standard Industrial Classification (SIC) group, based on the regional and industry contribution to GDP. Therefore, they reflect the

¹ See European Commission (2011) for more details on the aggregation process.

true structure of their relevant sectors. In Ireland PMIs are collected for the manufacturing, services and construction sectors.²

Similar to the CUBS series, the primary advantage of PMI data is that it is not subject to large revisions. The lack of significant revisions is important, as in order to achieve optimal performance from a forecasting model, it is essential that the model be estimated using real time vintage right-hand side data. Using real time vintage data at the estimation stage is critical, as it is almost always these data that are ultimately plugged into the estimated equation to produce a forecast (Koenig *et al.* 2003). PMIs seem to capture output growth trends while filtering out a lot of transitory variation, and therefore deserve the attention they receive in the financial and business press as an indicator of change in real economic activity (Koenig 2002). The data are collected using identical methods in all countries and regions so that accurate comparisons may be made.

In order to ensure the greatest possible comparability with the CUBS indicator, the three sectoral indicators are combined into an aggregated PMI series using the same procedures as applied to the capacity utilisation and business survey series in European Commission (2011). The weights used for combining the three indices into one are taken to be the shares of the corresponding sectors in the total economy, according to the value added series collected by the Irish Central Statistics Office (CSO).³ Before the weighted average is calculated, each individual index is rescaled so that its volatility matches the volatility of the value added series from the given sector. This step is necessary as the volatilities of the sectoral PMIs do not correspond to the volatility of the economic activity in the different sectors they represent. Therefore, failure to rescale the indices would likely bias the resulting aggregate PMI series towards the sector with the most volatile PMI.

One downside of PMIs is that such indices incorporate only information available to corporate executives in the first half of the survey month. If a shock hits a sector in the second half of the month, it will not be reflected in the PMI until the following month's survey is released. However, since the econometric model for detrending TFP is estimated using annual data, the negative effects from this should be minimised. Another potential limitation of PMI series arises from the fact that data are presented as diffusion indices.

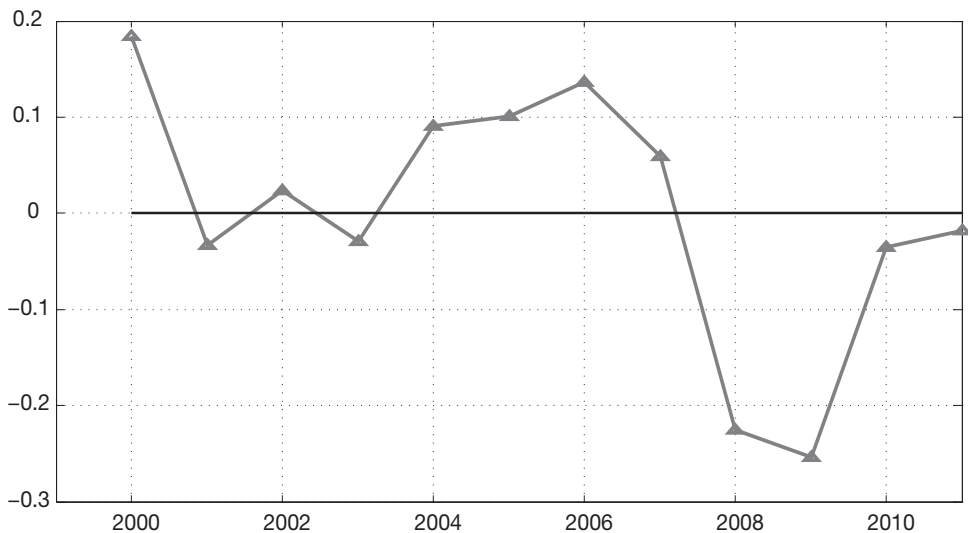
² PMI and Purchasing Managers' Index are both registered trademarks owned by the Markit Group. In Ireland, the manufacturing and services sector PMIs are collected by NCB Stockbrokers, with the construction sector PMI collected by Ulster Bank.

³ It should be noted that the value added series may potentially need to be revised and extended, thus leading to a revision in the aggregated PMI indicator. This, however, would also be an issue for the CUBS series.

These are a weighted sum of the positive, negative and no change replies and form a convenient single-figure summary of the data. Diffusion indices vary between 0 and 100, with a level of 50.0 signalling no change on the previous month. Readings above 50.0 signal an increase on the previous month, with readings below signalling a decrease. The greater the divergence from 50.0, the greater the rate of change signalled (expansion or contraction).

Therefore, a high PMI reading simply means that more executives are reporting improving business conditions than are reporting deteriorating business conditions. As noted by Koenig (2002), there is no attempt to capture differences across firms or over time in the intensity with which conditions are changing. However, for the purposes of this exercise, the aggregate PMI variable is just being used to proxy the degree of capacity utilisation in the economy at a time when data specifically measuring this is no longer collected. Historically, the PMI data has been shown by Planas *et al.* (2010) to have a high degree of correlation with the previously collected CU data and, therefore, it is felt to be fit for purpose. The aggregated PMI series is detailed in Figure 1, in terms of deviations from the sample mean. From a brief visual inspection it appears that the series proxies the business cycle of the last decade quite well, with a fall-off from the peak from the dot-com bubble in the year 2000 through to the housing boom and subsequent bust in the latter part of the examined period. A more formal examination of the link between the PMI data and the cyclical component of TFP is conducted in later sections.

Figure 1: *Aggregated PMI Series*



III METHODOLOGY

The modelling framework used is entirely consistent with that of D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012). This consistency is essential to ensure comparability between these earlier analyses, on the basis of which the current harmonised EU methodology was adopted, and that presented in this paper. The following contains only a brief overview of the intuition behind the model, with the reader referred to the source documents for a detailed treatment.

The bivariate KF method exploits the link between the TFP cycle and capacity utilisation that arises in the Cobb-Douglas production function framework. This approach relates TFP to labour and capital efficiency levels of the available technology, and to labour and capital capacity utilisation. A TFP decomposition into a trend P and a cycle C , such that $\text{TFP} = P \times C$, is proposed on the basis that efficiency is a more persistent process than capacity utilisation, which is thought to depend more on current economic conditions. Thus, accurate estimation of capacity utilisation is vital for the extraction of the unobserved cyclical components of TFP. Survey data is used for this purpose. However, only aggregate capacity utilisation measures, U , which fail to distinguish between the different production factors, are available. Therefore, it is implicitly assumed that the TFP cycle is correlated with the percentage deviation of this aggregate series around its mean

$$u = \beta c + \varepsilon \quad (1)$$

where the small-case letters indicate log-levels of their large-case letter counterparts, ε is measurement error and β can be considered a formal quantitative measure of the link between capacity utilisation and TFP. The strength of this relationship is determined by firms participating in the survey's measurement of the productivity gap. As $\beta = 0$ only in the case that capacity utilisation is not correlated with the productivity gap, β is expected a priori to be positive. This link is exploited to detrend TFP through the following bivariate model:

$$tfp_t = p_t + c_t \quad (2)$$

$$u_t = \mu_U + \beta c_t + \varepsilon_t \quad (3)$$

where the index $t = 1, \dots, T$ introduces time. The cyclical component c_t is thus a stationary factor which is common to TFP and CU series. The long-run

component is modelled as a damped trend model,⁴ which specifically accounts for the series average growth rate. The (short-run) cyclical movements are captured using an AR(2) process with complex roots that are parameterised in terms of cycle amplitude and periodicity.

The analysis is performed using Bayesian inference, in which all parameters are considered as random variables with an initial distribution that reflects prior knowledge. This is a major advantage of the Bayesian approach, in that any additional information brought by macroeconomic knowledge can be incorporated into the analysis. The estimation procedure aims at delivering posterior distributions of all unobserved quantities given both prior assumptions and observations. For the purposes of this exercise, the priors assumed for the model parameters are those used by D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012) when examining the usefulness of capacity utilisation for estimating the TFP cycle of EU Member States.⁵ These contain some information that is available about the inertia of the potential growth of productivity and the periodicity and amplitude of the business cycle. This consistency in Bayesian priors, as with the overall modelling framework, ensures comparability between these previous studies and this analysis. All computations are made using Program Bayesian GAP, which has been developed in the EU Commission's Joint Research Centre. Details about the procedures implemented are contained in Planas *et al.* (2008).

Both bivariate KF systems, in which CUBS and the aggregate PMI are the second equation series, are run with the 2011 and real-time TFP data vintages. In order to empirically test whether the aggregate PMI series contains information useful for extracting the cyclical component from TFP, a test of whether the 90 per cent interval lower bound was above zero and if $\beta > 0$ was conducted. The 90 per cent confidence interval is the smallest region of the β posterior distribution that contains 90 per cent of the distribution. A positive outcome to this test would indicate that there is a common cycle shared by the two series.

The bivariate estimators are then compared in terms of their total estimation error variance. Such a comparison focuses on the accuracy of the models concurrent estimates, which is of key interest to policymakers (Maravall and Planas, 1999). The subsequent revisions in TFP cycle estimates are also examined. Planas *et al.* (2012) describe the two sources of revisions in real time TFP gap estimates. The first are forecast errors and parameter updates, i.e. the signal extraction error or statistical uncertainty, with the

⁴ While this is consistent with D'Auria *et al.* (2010), Planas *et al.* (2012) consider additional specifications for the trend component of TFP.

⁵ It should be noted that these priors are country specific.

second being the use of real time data sets that are corrected every year, i.e. data vintages. In order to ascertain the relative contribution of these two sources of revisions, results obtained using both the 2011 data vintage and real time data sets are reported. With a view to maintaining consistency with previous studies in this area, the theoretical analysis of revisions developed by Pierce (1980) are implemented.

Let x_t denote the set of observations available at time t , i.e. $x_t = (x_1, \dots, x_t)$. The cycle estimates for period t , based on observations until period $t + k$, are obtained as the expectation of c_t given observations $x_t + k$. Hence, the cycle estimates for a given point in time depend on the information available. A revision can thus be defined as the correction of preliminary estimates due to incoming observations. The results show the path taken by cycle estimates for the years 2000 to 2010 when observations are ending in 2000, 2001, ..., until 2011. Averaging the squared values of the revisions obtained with one more observation from $t = 2000$ to $t = 2011$ approximates the variance of the first revision in concurrent estimates:

$$V(\hat{C}_{t|t+1} - \hat{c}_{t|t}) \approx (1/11) \sum_{t=2000}^{2011} (\hat{c}_{t|t+1} - \hat{c}_{t|t})^2 \quad (4)$$

The same computations can be completed for empirical evaluation of the variance in the second revision of concurrent estimates. As revisions are independent, they can be cumulated in order to obtain the variance of the revisions with k more observations. The model parameters are re-estimated every time the data set is updated. When the data that have previously been observed are not updated, revisions on the trend and on the cycle sum to zero and as such are equivalent in absolute value. However, this equivalence breaks down when past data are revised. Due to the fact that most TFP vintages show level shifts, real time trend estimates do not converge over the different vintages (Planas *et al.*, 2010).

In their analysis of competing models of TFP trend-cycle decomposition, D'Auria *et al.* (2010) also assessed the impact of including the European Commission Directorate General of Economic and Financial Affairs (ECFIN) short-term forecasts in each vintage. This was conducted by extending the TFP vintages used at each estimation period with the ECFIN country desk forecasts for the following two years. These two points are handled as actual observations in the bivariate approach. D'Auria *et al.* (2010) found that the inclusion of these forecasts improved the reliability of the TFP cycle estimates as the level of revisions required were lower than when the forecasts were omitted. Therefore, such an analysis was replicated here in order to assess if

the aggregate PMI bivariate model is improved through the incorporation of the ECFIN forecasts. However, since there are no forecasts available for the second equation variable in the bivariate approach, be it CUBS or aggregate PMI, these are treated as missing.

IV RESULTS

4.1 *Common Cycle Hypothesis*

The β coefficient measures the strength of the relationship between capacity utilisation and the TFP cycle. The test $\beta > 0$ is computed as the frequency of $\beta > 0$ in posterior samples.⁵ Table 1 reports the posterior mean and 90 per cent confidence intervals obtained with the 2011, real time and real time with ECFIN forecasts TFP vintages. Similar to the results found by D'Auria *et al.* (2010) and Planas *et al.* (2010) for CUBS data, there is strong evidence that β is significantly different from 0 for all data vintages examined.⁶ In each data vintage β is greater than 0. For all years in all data vintages the 90 per cent confidence interval excludes zero, and so the hypothesis of a common cycle between the TFP and PMI series seems to be supported by the data. This suggests that the information contained in the aggregate PMI series is very useful for extracting the cyclical component of TFP. However, of concern is that there are some years in which the 90 per cent interval of each data vintage is extremely close to zero. It is quite clear from the tables that the real time, in particular those with ECFIN forecasts, perform better than the 2011 vintage in terms of a greater lower bound on the 90 per cent interval, thereby being further away from zero.

4.2 *Concurrent Estimation*

The results in Table 1 provide evidence that the aggregate PMI series shares a common cycle with TFP. However, there is no indication as to whether the information content of this series is more useful for the detrending of TFP than that of capacity utilisation. Maravall and Planas (1999) note that if error-induced actions are to be avoided, the accuracy of concurrent estimates is of most interest to policymaking institutions. Therefore, a comparison is made between the concurrent estimates from the two models in terms of the total estimation error variance, computed as the posterior variance of the cycle at a

⁵ The prior distribution, as in D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012), is $f(\beta) \propto N(1.4, 1)$ $1(\beta \in (0, 5.4))$, where $1(\cdot)$ represents the indicator function.

⁶ An examination of the posterior odds by Planas *et al.* (2012) finds only weak support for a synchronised common cycle between CUBS and TFP in Ireland.

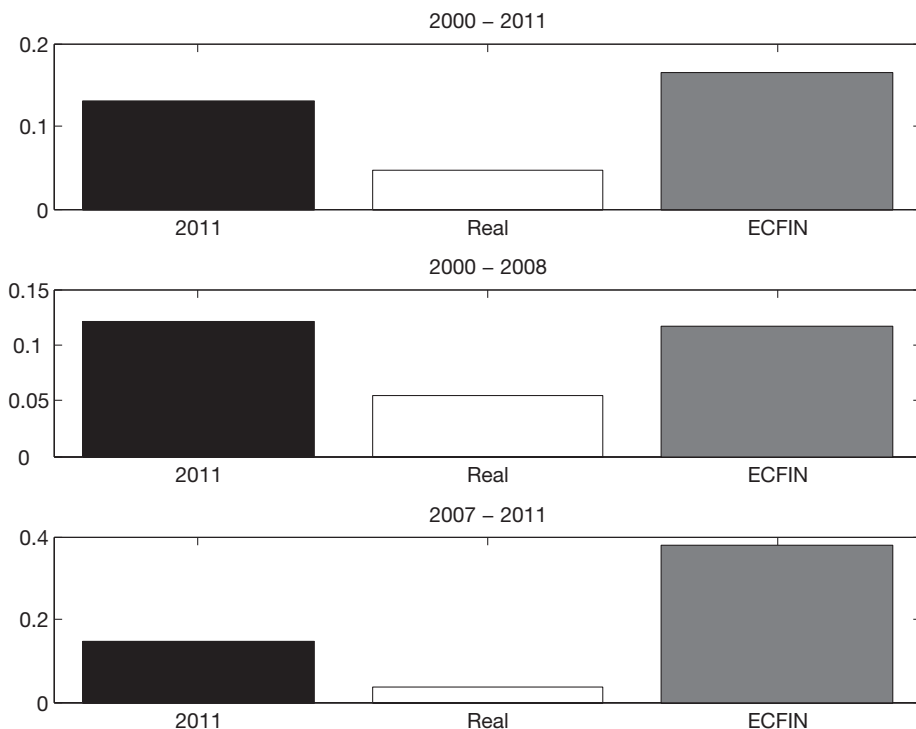
Table 1: *Posterior Mean ($E\hat{\theta}_{i|y}$) and 90 Per cent Confidence Band for β Coefficients*

Year	2011 Vintage		Real Time Vintage		ECFIN Vintage	
	$E\hat{\theta}_{i y}$	90% Interval	$E\hat{\theta}_{i y}$	90% Interval	$E\hat{\theta}_{i y}$	90% Interval
2000	1.282	[0.268, 2.148]	1.173	[0.226, 2.116]	1.210	[0.288, 2.172]
2001	1.639	[0.288, 2.620]	1.286	[0.111, 2.490]	1.130	[0.074, 2.367]
2002	1.497	[0.389, 2.604]	1.369	[0.231, 2.494]	1.345	[0.221, 2.471]
2003	1.608	[0.503, 2.692]	1.597	[0.283, 2.548]	1.423	[0.242, 2.516]
2004	1.235	[0.125, 2.292]	1.150	[1.043, 2.318]	1.364	[0.122, 2.349]
2005	0.734	[0.003, 2.051]	0.652	[0.001, 1.942]	0.862	[0.001, 1.994]
2006	0.502	[0.001, 2.182]	0.375	[0.001, 2.062]	0.507	[0.001, 2.104]
2007	0.626	[0.002, 2.091]	1.053	[0.017, 2.169]	1.276	[0.082, 2.292]
2008	1.791	[0.405, 3.260]	1.680	[0.364, 3.162]	1.523	[0.217, 2.996]
2009	2.473	[1.057, 3.930]	2.411	[1.051, 3.727]	2.442	[1.015, 3.826]
2010	2.510	[0.949, 3.855]	2.098	[0.739, 3.566]	2.402	[0.872, 3.750]
2011	2.311	[0.978, 3.811]	2.311	[0.978, 3.811]	2.494	[1.080, 3.846]

given time period. The results, detailed in Figure 2, show the percentage decrease in total estimation error variance from using PMI rather than CUBS as the second variable in the bivariate KF model.

The results show that over the full PMI sample period of 2000-2011, the use of the bivariate PMI model reduces the total estimation error variance. This is the case for all data vintages. Figure 2 also displays the results for the period 2000-2008, as this was the period that both CUBS and PMI series were available and should, therefore, provide the most balanced comparison of the relative merits of the two approaches. The results from the full sample are robust to this sub-period, with the total estimation error variance from the bivariate PMI model lower than those from the CUBS model.

The reason for exploring an alternative series to replace CUBS is that this survey is no longer conducted in Ireland and, therefore, its position as the first-best modelling option may be in question over the coming years. As such, a potentially more telling assessment of the relative merits of the alternative models would be an examination limited to the recent past. The period since 2007 coincides with the financial crisis and a recessionary period for Ireland after the bursting of the housing bubble. This period represents a turning point in the TFP series and so precision of the cycle estimates is at a premium. The results again show that the total estimation error variance is reduced by using the PMI model, with the improvement particularly pronounced in the data vintage containing ECFIN forecasts.

Figure 2: *Reduction in Total Estimation Error Variance from PMI model*

This improvement in the estimation accuracy is at least in part due to the fact that the CUBS series was discontinued from 2008, and therefore is missing from the model during the majority of this period. While it is possible that this may only have a limited effect in comparatively normal periods, the large turning point in TFP as a result of the downturn was not captured as accurately as in the case where the aggregate PMI was used to proxy the cyclical element of TFP.

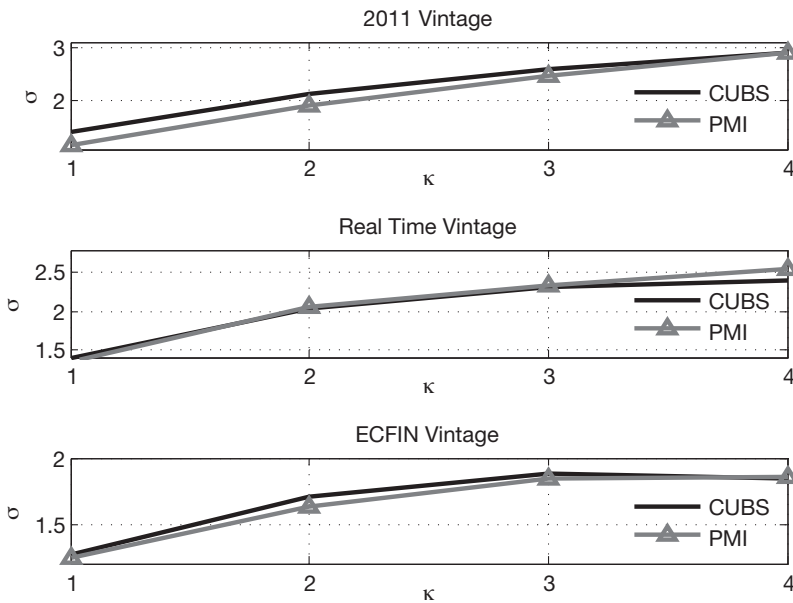
4.3 Revisions in Estimates of the TFP Cycle

Another important assessment of the comparative accuracy of the bivariate estimators is in terms of their revision error. In this context, a revision is the correction of the preliminary estimate due to the arrival of new information (Planas *et al.*, 2012). Here this corresponds to an additional years observation becoming available. Figure 3 details the standard deviations ($\times 100$) of the one-to-four-step revisions recorded for the 2011, real time and real time with ECFIN forecasts data vintages cycle estimates calculated over the period 2000-2011. The numbers on the x-axis correspond to the number, k ,

of additional observations. Both bivariate models are considered, with the models being judged according to the lowest revision standard error, as this indicates a greater reliability in the TFP cycle estimates. The bivariate model with the aggregated PMI data as the second equation series performs better on the whole than the CUBS model currently used to generate the official TFP cycle estimates.

There appears to be a clear gain in estimation accuracy from using the ECFIN country desk forecasts, regardless of the bivariate method applied. This suggests that these forecasts do bring additional information that is useful in the process of TFP cycle extraction. Kaiser and Maravall (1999) also found that the extension of a series with forecasts improved the accuracy of trend-cycle decompositions.⁷ The magnitude of the revisions in concurrent cycle estimates due to the incoming of additional observations rises from approximately 0.012 after one to approximately 0.031 after four. The uncertainty is thus substantial regardless of the estimation technique applied to the decomposition. However, regardless of the estimation method applied, these revisions will never be completely eliminated due to revisions in the underlying TFP data series. Figure 4 focuses on the period 2000-2008, with the results from the full sample once again robust to this sub-period.

Figure 3: 2000-2011 Revision Standard Deviations ($\times 100$)



⁷ However, this analysis examined the improvement in decomposition from a HP, rather than Kalman, filter.

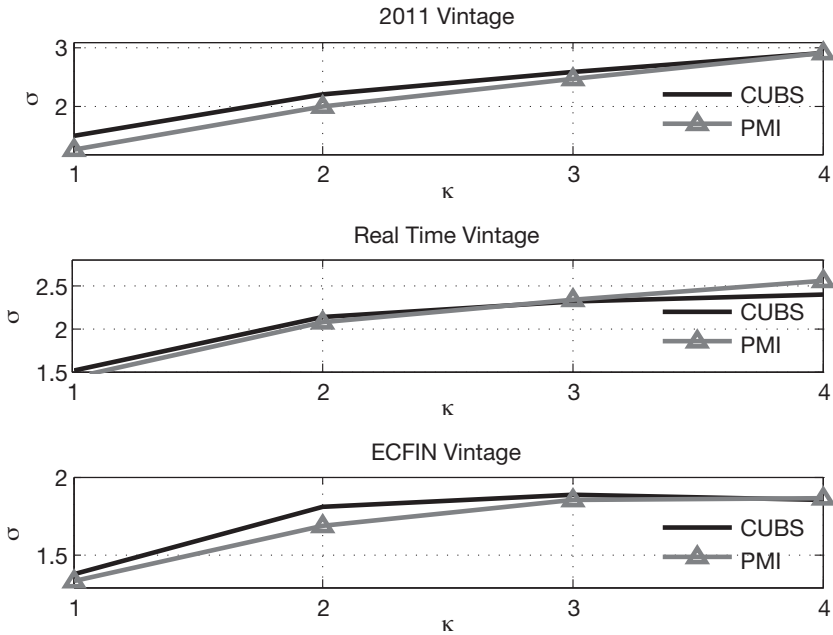
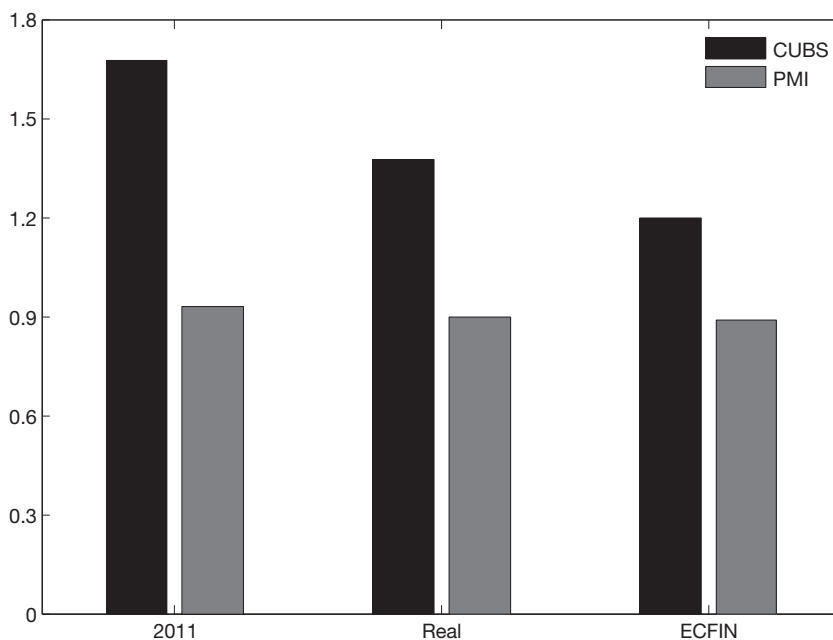
Figure 4: 2000-2008 Revision Standard Deviations ($\times 100$)

Figure 5 shows the degree of one-step revisions from the different TFP cycle estimates for the period 2007-2011. In this sample period, the KF model with aggregate PMI as the second equation series is by far the most preferred option. This is true for all data vintages, with the vintage containing two years of ECFIN forecasts again performing the best in terms of reducing the amount of revisions. As with the results from the concurrent estimation, the missing data from the CUBS series after 2008 undoubtedly has an effect. While the 'fairest' comparison between the two models is between the 2000-2008 period for which both series were available, this analysis focuses on the best option for TFP decomposition going forward. In that context, the assessment should be based on the relative accuracy of the estimators as they are at the current time, which this test for the 2007-2011 period best represents.

4.4 Implications for Output Gap Estimation

The previous sections provide evidence that the aggregated PMI series shares a common cycle with TFP, and that its use in a bivariate KF model leads to a reduction in TFP cycle total estimation error variance and subsequent revisions when compared with the official estimates. However, what is not clear is the effect that this change in methodology would have on

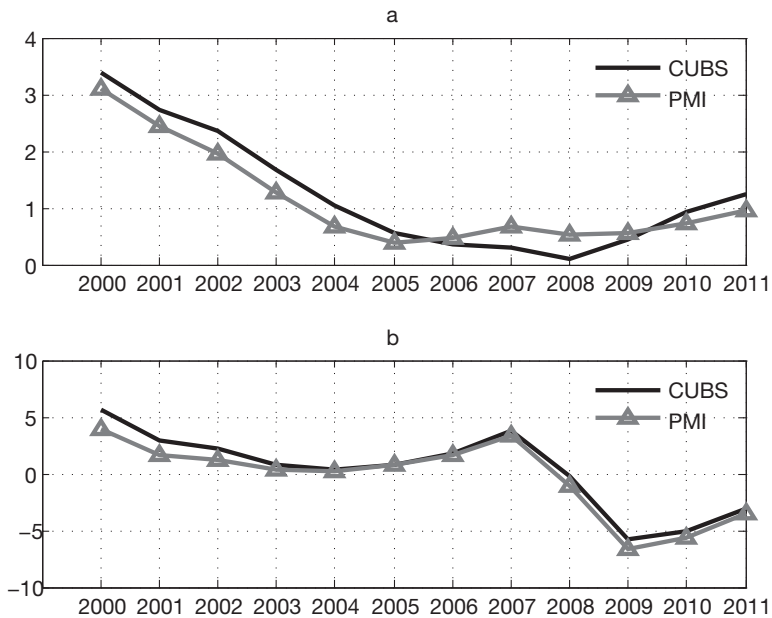
Figure 5: 2007-2011 Revision Standard Deviations ($\times 100$)

the estimation of potential growth and the output gap in Ireland. Given the budgetary rule changes on the horizon, accurate estimation of potential output and the output gap is more essential than ever. Within the production function framework, potential output refers to the level of output which can be produced with a ‘normal’ level of efficiency of factor inputs (D’Auria *et al.* 2010). Potential output estimation, therefore, amounts to removing the cyclical component of labour and TFP. In the case of TFP, trend efficiency is estimated using the bivariate Kalman filter model, and thus using an alternative series in the second equation should result in different values despite an identical underlying TFP series being used. Figure 6a details the results provided by both models, using the most up-to-date (2011) TFP Vintage.

Both models follow the trend of most EU12 countries, as described by Planas *et al.* (2012), which show a steadily decreasing contribution of TFP to potential output due to increased labour force participation, hours worked and capital investment levels. However, since the financial crisis this trend has been sharply reversed as the usage of the other factor inputs has declined. Of particular note is the fact that the CUBS model estimates a lower contribution to potential growth from TFP than the PMI model during the worst of the

crisis. This is likely a direct result of the missing data for the capacity utilisation series from 2008 onwards. In the absence of such data, the model runs out of sample based only on the observations it has to that point. However, in this case, the last observation occurred before the full scale of the downturn was known. This omission of the financial crisis in the CUBS data results in the reduction in the TFP level being attributed to the trend rather than the cycle. This underestimation of the cyclical effect then leads to a sharp upwards revision in the contribution of TFP to growth in order to match the upturn in the level. Thus, the recovery of TFP growth is likely to be over-estimated relative to the bivariate model with PMI data. Figure 6b shows the effect that this has on the output gap.

Figure 6: *TFP Contribution to Potential Growth (a); the Output Gap (b)*



Although the figure indicates that both models result in a very similar path for the output gap, there are important differences in magnitude. This divergence becomes even more noticeable during the financial crisis period, exactly when accurate assessment of the economy's stage in the business cycle is most required. The model applying the aggregate PMI series suggests that the recession resulted in a more negative output gap than that calculated by the CUBS model. This is due to the fact that potential output is calculated as being higher under the PMI model, and thus the difference between actual and potential output is greater. Again this is the consequence of the lack of

CUBS data regarding the downturn, and thus a greater attribution of the subsequent lowering of the TFP level to the trend rather than the cycle.

V CONCLUSION

Given the recent developments at the European Heads of State level, the cyclically adjusted budget balance is set to become a key component of fiscal policy decisions. Therefore, it is of the utmost importance that the key components of such analysis, potential growth and the output gap, are estimated as accurately as possible. The KF model with a capacity utilisation series has been proven to surpass a HP filter in terms of reducing the amount of revisions required to the TFP cycle estimates for Ireland. However, this series has been discontinued, with the last observation collected in 2008. As a result, the KF model is now estimated with this second series missing for recent years. Therefore, this paper seeks to establish whether or not an alternative series may be better positioned to proxy the current level of capacity utilisation, and so lead to greater accuracy in the estimation of the TFP trend-cycle decomposition over the upcoming period.

In order to ensure comparability with earlier work in this area, the same modelling framework and method of empirical evaluation as that detailed by D'Auria *et al.* (2010) and Planas *et al.* (2010; 2012) was applied. The results provide evidence of a common cycle between TFP and the aggregate PMI series. The KF model with the aggregate PMI variable as the second equation series also results in a coefficient significantly different from zero in the majority of cases, suggesting that the information contained in this PMI series is relevant for extracting the cyclical component from TFP.

The PMI model was shown to be the most favoured model in terms of minimising the total estimation error variance and subsequent revisions to the preliminary estimates over the full sample (2000-2011) and the period in which they were both available (2000-2008). This is also the case when the focus is on the more recent (2007-2011) past, which captures a turning point in the TFP series and upheaval in the Irish economy. As this period most closely resembles the playing field going forward, in light of a discontinued CUBS series, there is an argument for the estimation of the TFP trend-cycle decomposition for Ireland to be made using the aggregate PMI series. Naturally, were collection of the CUBS data to be recommenced, further analysis would be required to ascertain the relative merits of both approaches with post-financial crisis data.

This analysis found that the official estimates appear to under-estimate the potential output of the Irish economy during the midst of the financial

crisis. This has the knock-on effect of underestimating the output gap by a full percentage point, relative to the alternative measure proposed here. This process is seemingly reversed during the subsequent upturn, with the contribution of TFP to potential growth being over-estimated. Such divergence between the official estimates calculated by the European Commission and those obtained through the PMI bivariate model proposed in this paper, could have significant ramifications for Irish fiscal policy decisions.

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