Finance neutral potential output: an evaluation on an emerging market monetary policy context

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Abstract

In this paper output gaps that include financial cycle information are evaluated against models used in policy analysis by the Colombian central bank. Employing this dataset is no trivial matter, since policy related models are the only relevant yardstick, and emerging economies (such as Colombia) have been historically more vulnerable to financial imbalances. Unlike previous works, finance neutral gaps were evaluated in a monetary policy context exactly as it is routinely performed by a central bank. The distribution of output gap revisions is analyzed, and a metric to compare real time robustness across models is developed. This metric constitutes a novel way to summarize the distribution of real time uncertainty around output gaps, and policy makers should employ it to compare different methods. Also the real time policy performance of finance neutral gaps is studied, separating suggested *ex-post* from operational *ex-ante* usefulness. Results suggest finance neutral gaps are neither more robust in real time nor more operationally useful than the benchmark estimates. This implies that policy makers should consider uncertainty to the extent that it affects the estimations real time forecasting capabilities.

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1. Introduction

Potential output is defined as the maximum production level an economy can sustainably achieve. In this context, sustainability has been commonly associated with inflation stability. However, economic history reveals that this view might be too narrow, since output can grow at relatively high rates, while accumulating financial imbalances, even in periods of low and stable inflation. Failure to consider this fact may result in misleading policy recommendations (Borio and Lowe 2002, and Borio *et al*. 2003).

Additionally, the usefulness of potential output, and of its corresponding output gap, depends heavily on its ability to inform policy on real time. As it has been widely acknowledged in the literature, there is a large and persistent uncertainty around initial output gap releases, due to subsequent revisions (see for instance Orphanides and van Norden, 2002; Ley and Misch, 2013; Grigoli *et al*., 2015). Therefore, a desirable feature of a potential output models is to vary little as data is revised and new periods enter the sample (*i.e.* real time robustness). However, small revisions are not a sufficient condition for an estimation to be useful, as this is trivially satisfied by an arbitrary constant. Any useful estimation also must provide valuable economic information. Thus, as Orphanides and van Norden (2005) remark, an important distinction emerges between the *suggested* and *operational* usefulness of output gap. Suggested usefulness refers to the historical *ex-post* fit that a given estimate has with observed variables (such as inflation, via the Phillips curve), while operational usefulness deals with out of sample *ex-ante* forecasting accuracy. As economic agents are deemed to be forward-looking, operational usefulness is of the utmost importance in most policy settings.

Recently, some papers have devised ways to imbed financial information into potential output estimations. Borio *et al*. (2013 and 2014) posit a reduced form approach to include financial cycle variables on potential output models for three developed economies. As in this approach the business cycle is determined by a set of financial variables, potential output would be "neutral" to them, so they christen the resulting estimates (and corresponding output gaps) as "finance-neutral". Amador *et al*. (2016) compute similar gaps for three emerging nations. These papers present output gap series that reflect a macroeconomic imbalances build-up prior to financial crises. Also they appear to be more real time robust than benchmarks based on the Hodrick-Prescott (HP) filter and on the Phillips curve.

Yet, up to my knowledge, no rigorous metric has been developed to verify the claim that finance neutral gaps are indeed more real time robust. Also, setting the HP filter and simple Phillips curve-based gaps as benchmarks might be a low hurdle to surpass, since most policy makers employ many and more complex models. As output gap estimates have policy implications, those which are actually used in practice are the only relevant comparison.

In this paper I analyze the real time properties of Colombian finance-neutral output gaps based on Amador *et al*. (2016) against a battery of models employed by Banco de la República (the Colombian central bank) for the period 1994-2015. Using this dataset presents two advantages. First, as it is regularly updated and used by a central bank, it is a relevant yardstick to evaluate models against. Second, as Colombia is an emerging market economy with a history of financial crises, analyzing the links between financial and business cycles in this context is of particular interest.

Results show that finance neutral output gaps are not more real time robust than Banco de la Republica's models. While the suggested usefulness of finance-neutral output gaps is better than some of the benchmarks, their operational usefulness is significantly worse. This is probably due to the difficulties forecasting some of the included financial variables. Interestingly, averaging across different models results in a gap more robust in real time than any individual model. Although financial neutral estimates appear to be informative about core inflation and the monetary policy stance (as evidenced by an historical *ex-post* analysis), their forecasting performance is the worst among all the models considered. As forecasting is the main operational policy use of output gap models, the utility of finance neutral estimations for monetary policy makers in this regard is limited.

One could argue (as do Borio *et al*., 2013 and 2014), that finance neutral estimates are not designed to forecast inflation. However there is evidence that these gaps contain some information about Colombian core inflation. In consequence, there is a justification to evaluate the model on these grounds.

With this paper, I contribute to the output gap literature in three ways. First, to my knowledge this is the only comprehensive evaluation of uncertainty around finance neutral output gap estimates. Second, it's the only paper for the Colombian case that analyzes real time output gap uncertainty, and separates suggested from operational usefulness. Third, an analysis of the distribution of output gap revisions and a metric to compare real time robustness across models is developed and discussed. These contributions represent a comprehensive framework to evaluate uncertainty around potential output estimates and, focusing on its policy implications.

2. Literature review

This paper combines two bodies of literature. The first one concerns the interdependence of financial markets and the real business cycle. A subset of this work seeks to improve output gap estimations by incorporating financial cycle information. The second one addresses the real time uncertainty of output gap estimates and its policy implications. Both areas of study will be briefly summarized in this section.

A. Interdependence of the financial and real business cycles

With the benefit of hindsight after the international financial crisis of 2008-2009, many papers started showing a heightened interest on the interdependence of real and financial variables. Some of this literature has focused on how financial variables interact with monetary aggregates, real activity, and asset prices. For instance, Goodhart and Hoffman (2008) estimate the links between money, credit, house prices and economic activity for 17 advanced economies from 1970 to 2006. Residential property prices are found to have a strong link with monetary variables after 1985. They also find that the economy is more sensitive to monetary and credit shocks when house prices are booming.

Stiglitz (2015) also remarks on the central role of credit in economic activity. He comments on how real business cycles and New Keynesian models fail to explain deep downturns in economic activity. Models that account for financial market imperfections, credit, and real rigidities deliver a more satisfactory interpretation of events, such as the Great Depression and the Great Recession.

Other works have studied these relationships from an historical perspective. Schularick and Taylor (2012) evaluate the behavior of money, credit and macroeconomic indicators for a sample of 14 countries over 1870 to 2008. They find that excessive credit growth frequently predicts financial crises. Analogous results have been obtained by Alessi and Detken (2011), Borio and Drehmann (2009), and by Tenjo and López (2010). Ng (2011) assesses the capacity of financial indicators to forecast business cycles.

Of importance in small open economies, are the links between financial frictions, credit, collateral value, the real exchange rate, and the balance of payments. The interplay of this variables can produce imbalances that explain business cycles fluctuations (see Arteaga *et al*. 2012). First, asset prices affect the perceived wealth of households that in turn influence credit demand (see Kiyotaki and Moore, 1997). Second, several studies have shown that abnormal credit growth is the main predictor of financial crises (Schularick and Taylor, 2012). Finally, the real exchange rate and the terms of trade summarize possible external imbalances of small and open economies. Also, in emerging market economies the literature has underlined the importance of shocks to the global interest rate, terms of trade, and fiscal policy (see for instance Fernandez, 2010). Real exchange rate volatility is a key variable, often associated with external imbalances in small and open economies (Bracke *et al*., 2008). Credit also appears to have an important effect on emerging markets' business cycles. Using a panel of financial institutions, Amador *et al*. (2013) show that in Colombia persistently high credit growth increases banks' riskiness, by a reduction in solvency and in nonperforming loans. Also they show that abnormal credit growth augmented the probability of bank failures during the late 1990s financial crisis in Colombia.

As a natural consequence of these works, some authors began to consider the effect of financial-real links on policy. In particular some make the case to incorporate financial considerations in output gap estimates. The seminal contribution on this regard is Borio *et al* (2013). They argue that financial variables can improve output gap measurements. The key issue here is sustainability. Since potential output is defined as the maximum production level an economy can sustainably achieve (Okun, 1962; Mishkin, 2007), the choice of a sustainability criterion can affect the results significantly. In the context of monetary policy, this criterion has been commonly associated with inflation stability. This is captured by the Phillips curve, as inflation tends (*ceteris paribus*) to rise (fall) when output is above (below) potential. However, economic history reveals that this view might be too narrow, since output can grow at unsustainable rates while accumulating imbalances, even in periods of low and stable inflation (Borio and Lowe, 2002).

Borio *et al*. (2013) sustain that ignoring the interdependence between business cycles and financial variables leaves out valuable information. To illustrate the point, the authors compute potential output estimations from simple reduced form models for three advanced economies. The computed gaps are found to be significantly higher before crises that their HP filter benchmarks. Also, they present some results that suggest that finance neutral gaps are estimated more precisely, and are more robust in real time (this is asserted via a visual comparison in Borio *et al*., 2013, pp. 19).

Borio *et al*. (2014) explain in a more detailed fashion the concepts presented on their previous paper. They critique the popular strategy of including structural economic relationships to inform output gap estimations (for example, including a reduced-form Phillips curve equation). According to their analysis, this approach has important weaknesses that have not been addressed adequately. The main contention is that this type of estimations is highly susceptible to specification errors, and that the interaction of many structural relationships may yield unpredictable outcomes. They present estimates similar to those of the preceding paper for the United States. Results suggest that financial variables contain important information. Additionally, the finance-neutral gaps appear to be more robust in real time than both the HP filter and a Phillips curve based estimation using (this claim is supported by a visual comparison and using the average of absolute revisions in Borio *et al*., 2014, pp 20).

Amador *et al*. (2016) compute output gaps that are informed by the behavior of some financial and external variables, in the spirit of Borio *et al*. (2013 and 2014), for Chile, Colombia and México. As in Borio *et al*. (2013) and (2014), output gaps also appear to show an accumulation of macroeconomic imbalances prior to financial crises.

B. Real time uncertainty and the output gap

Business cycle fluctuations analysis often involves assessing observed output relative to its potential level; that is the output gap. Since neither the potential nor the gap are observed, there is a great deal of uncertainty around these concepts. This arises not only from statistical and modeling errors, but also from real time uncertainty. Real time data stands for information that is provided immediately after collection and/or estimation. For example, some official statistics such as gross domestic product (GDP), often are published initially based on preliminary estimates and are adjusted as new information becomes available.

The impact of data revision has been explored extensively in the literature[1]. Diebold and Rudebusch (1991) were the first to explore "real time analysis". Rudebusch (2002) designates the term as "the sequential use of information sets that were actually available as history unfolded". Crushore (2011) somewhat expands this definition as "[…] research for which data revisions matter[s] or for which the timing of the data releases is important in some way."

In the context of the output gap uncertainty, the works of Kuttner (1994) and St-Amant and van Norden (1997) show how mid and end of sample output gap estimates can differ significantly. A number of papers examined the policy implications of such discrepancies (see McCallum and Nelson, 1999; Orphanides, 2001 and 2003, among others). Julio and Gómez (1998) consider the monetary policy implications of output gap uncertainty for Colombia. They evaluate Taylor rules' performance under certainty and estimation uncertainty about the output gap. Results suggest that accounting for this uncertainty means smaller monetary policy reactions to gap fluctuations.

Orphanides and van Norden (2002) are the first to study the reliability of alternative output gap models in real time. They find that revisions are substantial and persistent[2] and it appears to be due to poor real time robustness of end of sample estimates. This is called the optimal filtering end of sample problem. Julio (2011a) proposes a remedy for this issue. He computes an output gap using Colombian GDP data in which the effect of revisions was corrected, following Julio (2011b). To ameliorate the end of sample problem, GDP forecast

1 For a comprehensive review, see Crushore (2011).

2 As measured by the first order serial correlation of the revision series.

are included in the estimation. The gap obtained by the method is found to be more robust in real time than the standard HP filter.

Monetary policy makers are often interested in the output gap as an indicator of demand-side inflationary pressures. This is especially true in inflation targeting regimes (such as Colombia since 1999). Orphanides and van Norden (2005) evaluate the usefulness of output gap estimates in this sense by evaluating their ability to predict inflation. They present an important discussion on *suggested* versus *operational* usefulness.

A given output gap estimation is commonly evaluated on the basis of its historical *ex-post* fit to inflation, using revised data. That would be its *suggested* usefulness. However, as monetary policy is forward looking in nature, output gap performance should be measured by its ability to forecast inflation *ex-ante* using initial estimates; that is *operational* usefulness. For a range of output gap estimation methods, Orphanides and van Norden (2005) show that suggested usefulness does not necessarily imply operational usefulness. Results also reveal that simple inflation and GDP forecasting models outperform forecast based on real time output gaps.

Grigoli *et al*. (2015) present an excellent taxonomy about output gap uncertainty sources. Besides uncertainty owing to the fact that it is unobservable, they cite data revisions, forecast errors and policy reactions as causes of output gap revisions. In the paper they focus on uncertainty that arises from data revisions and from changing trend-cycle decompositions. They analyze revisions behavior of the International Monetary Fund (IMF) output gap estimates presented in the *World Economic Outlook*, for 176 countries and the period 1990-2007. Results suggest that initial publications overestimate the output gap, and that their corresponding revisions are persistent. Also revisions cannot be predicted using information available at the time of the first release. While data quality is not a significant determinant of revision size, countries with inflation targeting regimes tend to have smaller revisions. These authors also analyze the monetary policy implications of output gap revisions, for a set of Latin American countries including Colombia. In all but Colombia, initial gap estimates are not correlated with observed inflation. Also monetary policy mistakes due to output gap uncertainty are likely to be large. Both facts are evidence that uncertainty is not accounted for in the real time monetary policy stance.

3. Models and data

In this section, each of the benchmark models and the finance-neutral one, based on Amador *et al*. (2016), will be briefly described. In addition to these, their average will also be included in the analysis as a different model. As well, the data employed will be discussed.

A. Models

i) Hodrick-Prescott

The Hodrick–Prescott filter (Hodrick and Prescott, 1997) decomposes a time series into its trend and cyclical components. It is common in business cycle and output gap applications. The estimated trend is a smoothed representation of the series that is only affected by longer term (lower frequency) fluctuations. The relative sensitivity of the smoothed series to short vs. long term fluctuations depends by the parameter λ. The specification employed by Banco de la República sets λ at 1600, as is standard practice for quarterly series. A five year GDP forecast is included to address the optimal filtering end of sample issue.

ii) Principal Components

Indicators from business and sectorial surveys are an important source of business cycle information. Rodríguez *et al*. (2006) propose a principal components analysis method to aggregate this data into an output gap measure. They obtain it as the unobserved factor driving all the chosen indicators. Among them are capacity utilization, overtime hours worked in manufacturing, retail sales, construction licenses, the trade balance, expected demand, among others. The authors find that the resulting gap can contribute to improve core inflation forecasts.

iii) New Keynesian

Following González *et al* (2013), two New Keynesian semi-structural models are estimated for the *Inflation Report.* These reflect the idea that, although potential output is unobservable, there are ways to relate the output gap to observable variables other than GDP using structural economic relationships. The two versions of the model portrait a small open economy, and include a Taylor rule, an investment-savings curve, a Phillips curve, and equations that describe the behavior of the real interest rate and the real exchange rate. The only difference between the two is the inflation expectations formation, as in one these are adaptive and in the other rational. The estimated gaps appear to be strongly correlated with historical inflation and they behave according to the business cycle's chronology posited by Alfonso *et al* (2011).

iv) Finance Neutral

Amador *et al*. (2016) compute output gaps that are informed by the behavior of some financial and external variables, in the spirit of Borio *et al*. (2013 and 2014), for three Latin-American countries. As the selected variables only determine cyclical dynamics, potential output is deemed to be neutral to them.

In this paper the procedure proposed by Amador *et al*. (2016) is modified to incorporate forecasts, to address the optimal filtering end of sample problem. A general to specific approach is employed. First a general specification was estimated. Only the statistically significant coefficients are preserved on the specific specification. The state space representation of the general model is described by:

$$y_t = y_t^* + \beta(y_{t-1} - y_{t-1}^*) + \sum_{i=0}^{8} \gamma_i \Delta x_{1,t-i} + \sum_{i=0}^{8} \sigma_i \Delta x_{2,t-i} + \sum_{i=0}^{8} \delta_i \Delta x_{3,t-i} + \sum_{i=0}^{8} \alpha_i \Delta x_{4,t-i} + \varepsilon_t \qquad (1)$$

$$y_t^* = y_t^* + \zeta_t \qquad (2)$$

Where y_t stands for the natural logarithm of real GDP and y_t^* for its corresponding potential output. The terms ε_t and ζ_t are assumed to be a Gaussian independently distributed error terms with zero mean and variances ${\sigma_\varepsilon}^2$ and ${\sigma_\zeta}^2$. $\Delta x_{j,t-i}$ for (j = 1,2,3,4) represents the yearly growth rate of real credit, real used housing prices, the real multilateral exchange rate, and the level of the current account (as a percentage of GDP).

The four included variables are currently employed by Banco de la República in its Macroeconomic Imbalances Indicator (MII), an early warning crisis indicator (see Arteaga *et al*, 2012). In the model the output gap is explained by these variables, which have been identified as imbalances indicators. Thus, when the economy grows at is potential and the output gap is zero, there would be no build-up (or reduction) in imbalances. Therefore potential output estimated by this method represents a level that is "neutral" to macroeconomic imbalances accumulation. In this context, neutrality is used referring to the fact that if the gap is closed, imbalances neither increase nor decrease. While it is possible to include others, in this document I only consider variables related to the financial cycle, in order to evaluate models as presented in the literature.

All variables were mean-adjusted by the Cesaro's procedure. That is the sequence of means obtained by successively increasing the sample by one observation starting from the initial date is subtracted sequentially from each data point. According to Borio *et al*., (2013) this procedure results in much faster convergence and reduces pro-cyclicality in the mean adjustment[3]. Potential output is assumed to follow a random walk.

The signal to noise ratio, $\lambda = \frac{\varepsilon_t}{\zeta_t}$, determines the relative variability of the estimated potential output series. As in Borio *et al*. (2013), λ is set to preserve the same business cycle duration of the standard HP filter. The details of the calibration are provided on Appendix A.

Equations 1 and 2 are estimated following a Bayesian approach, due to the relatively high number of parameters involved. All parameters in equation 1 follow gamma distributed priors. The variance of error terms prior distribution is an inverse gamma. The the Kalman filter was used and initial values for both the level and variance of the potential output were chosen using the HP estimation. Prior and posterior means and standard deviations for the estimated parameters are shown in Appendix A.

Initial estimations included all lags presented in equations (1) and (2). However, using a general to specific approach (see Amador *et al*., 2016), a model for which only statistically significant coefficients were included is employed in following the analysis. This excludes variables and lags that don't add important information and reduces computational time. This procedure is described in detail in Appendix A. As in Amador *et al*. (2016) only credit, housing prices, and the exchange rate were included in the final estimation[4].

B. Data

[3] The resulting mean adjusted series were suggested to be stationary, by a Dickey-Fuller GLS test, at at least the 10% significance level.

[4] For a discussion of the economic significance of this results see Amador *et al*. (2016).

To compare the finance-neutral output gap estimation, I employ data and forecasts used to prepare Banco de la República's quarterly Inflation *Report*. This report is published to lend transparency and credibility to the monetary policy decisions and to help the market understand them.

As every report is prepared, five different output gap models are updated and presented to the central bank's Board of Governors. These estimated gaps also inform forecasting and policy analysis models. Only the four of them that yield quarterly data, and the finance-neutral model, are considered in this paper. In addition, the simple average of these five models is included as a separate one. As the bank summarizes all gaps by computing their average, including the five model average is also of interest.

This paper focuses on the real time performance of output gap models, so their revisions are of particular importance. Revisions are defined as $r_{j,t} = g_{j+i,t} - g_{i,t}$ where $g_{i,t}$ is the initial output gap *vintage*, and $g_{j+i,t}$ the same series of a *vintage j* quarters ahead. The term *vintage* is used to describe information and estimation as available at a particular point in time. Each *Inflation Report*, (released quarterly) represents a vintage, for which the output gap series is updated and estimated. As is common practice in the real time analysis literature, for this paper I use 2015Q4 as the "final" vintage, granting that calling it that way is only temporary, since new "final" calculations are performed each quarter. In a similar fashion, the first vintage is also a relative concept.

To ensure comparability, for each model 14 vintages are used, corresponding to every *Inflation Report* from 2012Q2 to 2015Q4. These vintages are imposed on the analysis, as regular estimation for some models started in 2012Q2. Using real time data and forecasts from the *Inflation Report*, 14 vintages are simulated for the finance neutral gap. All time series start from 1994Q1 and end from one to five quarters after the corresponding *Inflation Report* date, due to a changing forecasting horizon.

Using this data set is no trivial matter. As output gap assessments have policy implications, those which are actually used in practice are the only relevant yardstick. Unlike usual academic benchmarks, *Inflation Report* output gaps were subject to improvements over time. Also, substantial expert knowledge contributed in their design, selection and calibration. As a result, even the simplest models have features to address practical issues. For instance, all estimates that involve trend extraction incorporate forecasts of all exogenous variables. This is done not only to obtain out of sample predictions, but to ameliorate the optimal filtering end of sample problem, described by Kuttner (1994) and St-Amant and van Norden (1997).

Additionally, as Colombia has a history of financial crises, assessing financial imbalances and their impact on the business cycle gains special relevance. The sample considered includes at least three business cycles (following Alonso *et al*. (2011) business cycle chronology), and importantly the 1998-1999 financial crisis.

4. Results

A. Output gap, revisions and a corresponding uncertainty metric

Figure 1 shows a panel for each of the considered gaps initial (2012Q2) and final (2015Q4) vintages. The shaded area is the range between the maximum and minimum values across all vintages for each quarter, and represents variability across time. Initial and final releases in some cases differ substantially. However, even if they are similar, estimates were substantially revised across vintages, as evidenced by the shaded areas. Some models show important historical revisions, while others show more important changes on the forecast period (from 2012Q4 onwards).

Table 1 shows the median and the standard deviation of the initial (2012Q2) and final (2015Q4) vintages for each of the six output gaps. Only the time period covered by the first vintage is considered in this analysis (1994Q1 to 2012Q4). Table 2 shows the same values only for the business cycles peak periods, as identified in the business cycles chronology presented in Alonso *et al*. (2011). In addition to the peak quarters, those immediately after and before are also included to increase robustness to possible misdating. Both tables show as well the percentage of quarters for which the gap switched its signs between any of the 14 vintages. Both tables show that real time uncertainty persists over several years, and can be of significant magnitude. Although the typical revision appears to be small in most cases, a sizable portion of the revisions are noteworthy. Evidence of it is the size of some standard deviations, and the fact that sign changes are frequent. This is also true for turning points, as shown by peak periods data.

Figure 2 analyzes the whole distribution of revisions across vintages for each model. This time all 14 vintages are considered, all of them covering the period from 1994Q1 to 2012Q4. Every vintage is revised a number of times, the first one thirteen times, the second one twelve, and so on. Thus, for all the fourteen vintages the whole time series is revised one quarter ahead thirteen times, two quarters ahead twelve times, and so on. As vintages are limited, sample size decreases as revision number increases. In figure 2, the horizontal axis shows the number of steps ahead of revisions, and the vertical axis its corresponding size. Each panel shows shaded areas that represent the inter-percentile ranges between revision size percentiles 95, 90, 75, 25, 10 and 5 of revisions for all models. Darker blue tones denote higher distributional concentration of revisions. The average and the median for each vintage are also included. As in Tables 1 and 2, the average and the median show no large systematic biases across time in any of the models. Note that, excluding some small variation due to statistical noise, uncertainty measured by the variance of revisions increases with time. This happens up to a certain point, as the distribution of revisions is pretty stable after some revisions in all models, except the finance neutral, for which it grows monotonically.

It is relevant to remark that this suggests that when accounting for uncertainty, central tendency might not be as informative as dispersion. Most of the existing literature focuses on the mean or mean absolute revision, ignoring the other moments of the revisions' distribution. The data presented here illustrates a case on which even as the median of revisions remains close to zero, there is considerable real time uncertainty.

Thus, for comparisons across models summarizing dispersion is a key issue. However developing a measure to do so presents some issues. Two natural candidates, the variance and standard deviation of revisions may not be ideal, as sample size decreases for latter revisions. Also these measures are vulnerable to outliers. For example, the thirteenth revision of the initial 2012Q3 vintage can only be performed once, and has only 76 individual revisions, while the first revision can be performed 13 times and has 988 data points. This issue can be seen as some shaded areas decrease with time in Figure 2.

Thus, to address this problem, real time robustness is summarized succinctly by the maximum distance across revisions between percentiles 5 and 95[5]. This is represented by the distance between the dashed lines in Figure 2 panels. As distance is measured by the absolute value it can be shown easily that it satisfies the condition to be a metric[6]. The maximum distance presents the advantage of being less sensitive to sample issues, as it contains all other ranges with larger samples. This is a novel contribution of this paper.

Table 3 shows the maximum distance between percentiles 5 and 95 across all revisions. The model with the least uncertainty is the average, and the one with the most is the finance neutral. Note that this conclusion is quite strong, as the proposed metric considers the whole distribution of revisions across time.

B. Forecasting efficiency and determinants of output gap revisions size

This section considers empirically the forecast efficiency of potential output estimates. My approach is similar to Grigoli *et al*. (2015). For each model, the following regression is computed:

$$\left|g_{2015Q4,t} - g_{2012Q3,t}\right| = \alpha \quad + \beta \quad X_{2012Q3,t} + \varepsilon_t^m \tag{3}$$

Where $\left|g_{2015Q4,t} - g_{2012Q3,t}\right|$ is the absolute value of the accumulated gap revision between 2012Q3 and 2015Q4 (the thirteenth revision). The intercept is α. $X_{2012Q3,t}$ is a set of variables available at the time of preparing the 2012Q3 vintage, and its corresponding coefficients would be in β. The zero-mean error term is ε_t^m. Equation 2 is estimated by OLS, using Newey-West standard error to address heteroskedasticity and autocorrelation.

This model tests if the 2012Q3 vintage was an efficient forecast of the one of 2015Q4. Forecast efficiency implies that estimations include all relevant information available at release date, and thus cannot be improved upon. If first estimates are not efficient, revisions (and its size, as measured the left side of equation 2) will be correlated with data in $X_{2012Q3,t}$. The selected variables for the test are the output gap first vintage, inflation

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[5] Results don't change when considering the 1 and 99 percentiles or the variance.

[6] This conditions are: Non negativity $d(x, y) \geq 0$, identity of indiscernibles, $\mathrm{d(x, y) = 0 \Leftrightarrow x = y}$, symmetry; $\mathrm{d(x, y) = d(y, x)}$ and triangle inequality: $\mathrm{d(x, z) \leq d(x, y) + d(y, z)}$

deviations from target, dummy variables for the inflation targeting period (2001Q1 to 2012Q4)[7] and for economic downturns (as identified in Alfonso *et al*., 2011).

Forecast efficiency can be verified by an F-test of the null hypothesis that all slope coefficients (excluding the intercept) are equal to zero. Rejection of H_0 would suggest that the initial output gap publication is not an efficient forecast of the revised series.

Results of the estimation of equation 3 and the corresponding F-tests are presented in Table 4. H_0 is rejected for the HP, the finance neutral, and the 5 model average. However for the last two explanatory power, measured by the adjusted and unadjusted R^2, is low.

An important conclusion is that more complex models, in terms of more exogenous variables included, are more efficient. Finance neutral gaps appear to be no better than the central bank models in this regard. However, as the explanatory power of these regressions measured by the R^2 is low, the improvement in efficiency that can be gained is probably small.

C. Policy usefulness of the output gap

This subsection examines the policy utility of the output gap, separating *suggested* from *operational* usefulness. Output gap estimations are commonly evaluated on the basis of their historical *ex-post* fit to observed variables using the revised series. An example of this would be comparing the historical behavior of inflation and the output gap. A high correlation would suggest that the gap contains valuable information, and that the model should be useful for policy. That would be its suggested usefulness. However, as monetary policy is forward looking in nature, performance should be measured by its ability to forecast observed variables *ex-ante* using the initial estimate; that is operational usefulness.

I employ two observed variables of policy relevance to evaluate both types of usefulness; core inflation (measured by non-tradable CPI excluding foods and regulated items) and the real inter-bank interest rate. The first variable is frequently associated with demand-side

[7] As there was no official communication announcing the implementation of inflation targeting in Colombia, The start of the inflation targeting is frequently dated at some point of the year 2000, after the exchange rate was allowed to float. To avoid a possible misdating, I prefer to date start of the inflation targeting period at 2001Q1.

inflationary pressures and thus should be correlated with the output gap. Colombian inflation is frequently subject to weather related shocks that dramatically affect the supply of several products. As the behavior of the foods component is mainly driven by supply factors, it is reasonable to exclude it in the following exercises. The second one is the main instrument of monetary policy, and reflects its stance over time.

Two structural theoretical relationships are used to obtain fitted values and forecasts of these variables. The Phillips curve of the Colombian central bank main forecasting and policy analysis model, the Monetary Transmission Mechanisms Model (or MMT for its acronym in Spanish), is used to obtain core inflation fitted values and forecasts for each individual gap (see Gómez *et al*, 2002). The Taylor rule from the same model is used to obtain interbank rate fitted values, and to assess policy deviations associated to gap revisions.

The model equations are used instead of estimating new ones for two reasons. The first is to use the same uniform benchmark to evaluate all gaps. The second is that, the output gap is also included as an exogenous variable in the MMT model. Output gap forecasts for a few quarters are conditioned, while the following ones are determined by the model's structure, and include policy reactions. The model's interbank rate simulated path is part of the information set considered by the Board of Governors on its monetary policy decisions. This implies that output gap estimates inform policy via the MMT, and thus the relevant structural relationships are those contained in the model. Both equations are presented and described in Appendix B[8].

One could argue (as do Borio *et al.*, 2013 and 2014), that finance neutral estimates are not designed to forecast inflation. However as I will show ahead, there is evidence that these gaps contain historical information on the Colombian core inflation. In consequence, there is a justification to evaluate the model on these grounds.

i) Suggested usefulness of the output gap

[8] While other models also provide a simulated interest rate path, the MMT model is the only one that includes the output gap.

Table 5 presents, for each output gap model, mean squared errors of observed data against Phillips curve and Taylor Rule based fitted values, for inflation and the interbank rate, respectively. These values were computed for the revised final vintage of the six gaps, so they reflect suggested usefulness. After accounting for lags in the Phillips curve (see Appendix B), two periods are considered, the whole sample (1994Q2 to 2015Q3) and the inflation targeting period (2001Q to 2015Q3). For the Taylor rule both samples end in 2014Q2, as it has some inflation expectations leads.

For both core inflation and the interbank rate, errors are smaller for the inflation targeting period. Interbank rate errors are particularly large in the whole sample: This is due to the fact that the interest rate was not the main policy instrument in the previous monetary policy regime, and it was thus highly volatile. The best model for each sample-variable pair is highlighted in grey. The top performers for inflation are the adaptative and rational expectations models, for the full sample and for the inflation targeting period, respectively. For the real interbank rate the best model over all is the HP filter, while for the inflation targeting period the five model average has the better fit. For both variables, the finance neutral gap is at least as good as the worse of the central bank's models, and in some cases its performance is close to the best.

These results suggest that the finance neutral gap contains useful information on the historical behavior of core inflation, and that the central bank implicitly has considered financial variables in the determination of its policy stance. In particular, the good fit of the financial neutral gap to historical inflation data is partly due its high negative levels during the 1998-1999 Colombian financial crisis. This behavior fits better the drop in inflation experienced during those years. Trend extraction models such as the HP filter, accommodate part of the crisis output drop as a lower potential output they present less negative gaps, and thus their fit to inflation in that period is worse.

ii) Operational usefulness of the output gap

To evaluate their operational usefulness, core inflation forecasts based on the output gap estimates are computed. As the central bank's output gaps are not designed as policy analysis tools (most models do not include policy reactions), the real interbank interest rate is not considered in the forecasting analysis. However, the effect of revisions on the monetary policy stance, as expressed by the Taylor rule, is assessed.

Table 6 shows mean squared errors for core inflation forecasts based on each output gap model. Forecast horizons are defined as the number of periods ahead of observed data the prediction is calculated. The best model for each horizon is highlighted in grey. The simple HP filter outperforms all models in the short term; up to three quarters ahead of observed inflation. For the longer term (four and five quarters ahead) and across all horizons, the best performing is the New Keynesian adaptative expectations model. The worst model overall is the finance neutral.

This is probably due to poor forecast performance of the finance neutral model´s exogenous variables. For instance, exchange rates are difficult to predict (Wang, 2008). Also credit, housing prices and the current account are difficult variables to forecast. Given this issue, central bank's forecasts of these variables are frequently naïve. This problem is further compounded when considering the publication lags associated with these series. It remains to be seen if the finance neutral gap's performance would be better if forecasts improve.

To gauge the effect that output gap revisions may have on monetary policy, the policy rate suggested by the first vintage is compare to that of the last one, using the Taylor rule. Table 7 shows the mean absolute deviation of policy initially recommended in the 2012Q3 vintage from the revised 2015Q4 recommendation. Values are calculated for the whole sample (1994Q2 to 2014Q4) and for the period initially forecasted (2012Q3 to 2013Q3). As expected the model with the smallest deviations is the 5 model average, as it is the more real-time robust.

5. Conclusions

In this paper I evaluated output gaps augmented by financial variables in the spirit of Borio *et al* (2013 and 2014) and Amador *et al* (2016) for the Colombian economy. This evaluation represents a contribution to the literature in three key ways, which add up to a comprehensive approach to evaluate output gap uncertainty and its relevance for monetary policy. First, since assessments of the output gap have policy implications, the methods which are used in practice are the only relevant yardstick, and are therefore employed in this paper. Unlike previous works, finance neutral gaps were evaluated in a monetary policy context exactly as it is routinely performed by a central bank. Second, an analysis of the distribution of output gap revisions and a metric to compare real time robustness across models is developed. This metric constitutes a novel way to summarize the distribution of real time uncertainty around output gaps, and policy makers should employ it to compare different methods. Third, the real time policy performance of finance neutral gaps is studied, separating its suggested *ex-post* and operational *ex-ante* usefulness. As monetary policy makers are forward looking in nature, they should focus mainly on operational forecasting performance. However, uncertainty should be accounted for in policy recommendations.

Results suggest that models employed as an input for real time monetary policy by the Colombian central bank outperform finance neutral gaps in real time robustness, as its uncertainty is the most persistent and the largest among the considered models. An analysis of the output gap revisions determinants rejects the null hypothesis that finance neutral initial releases are efficient forecasts of future releases. However, as the explanatory power of available data is low, the space for improvement in this regard might be small.

When analyzing the suggested *ex-post* usefulness of finance neutral estimates, it appears that they contain important information, on both core inflation and the monetary policy stance. However the operational *ex-ante* utility of finance neutral gaps is worse than the Colombian central bank's models; as measured by its ability to predict core inflation. As these finance neutral computations present larger revisions, policy recommendations derived from them are subject to significant uncertainty.

An interesting result for policy is that the average of the five models considered is the best performing in terms of real time robustness, as it presents the least revisions variability. Frequently, analysts are interested on summarizing several output gap measures on one. For this purpose, the Colombian central bank of computes the simple average of its output gap models. Results indicate that aggregating several methods in this fashion might yield important gains in real time robustness. However, this did not result in better core inflation forecasts. Therefore there is room to improve the forecasting performance combining different output gap measures, weighting more heavily the models that yield better predictions. An example of this approach for the Colombian case can be found in Melo and Sánchez (2013)

A fact that must be highlighted is that the order from best to worse varies across models. This implies that, although real time uncertainty should be considered, it should only be done to the extent that it affects the model operational usefulness. This is reflected by the fact that the model that has the smallest uncertainty profile is not the best one forecasting core inflation. To illustrate this point, consider the trivial case of a constant output gap over which you have absolute real time certainty, but that is not good for forecasting. Such model would not be useful for policy makers. Thus, evaluating models on their real time forecast capabilities it's a must (as remarked in Orphanides and van Norden, 2005).

However, one could argue (as do Borio *et al*., 2013 and 2014), that finance neutral estimates are not designed to forecast inflation. As per core inflation predicted by these gaps fits historical data, there is a justification to evaluate the model on these grounds. Besides, even if one dismisses the core inflation forecasting exercise, finance neutral gaps are still the least robust in real time. In conclusion, the results presented here suggest that finance neutral output gap estimations do not necessarily represent an improvement in real time uncertainty or in forecasting accuracy for monetary policy makers.

Nonetheless, finance neutral gaps still show promise. It remains to be seen if they successfully predict financial crises, as a clever reader might anticipate. Thus, their usefulness might be in the literature on early warning indicators, commonly used by policy makers and international financial institutions (see for example Berg *et al*., 2005). Additionally, output gaps that account for other alternative variables (besides financial imbalances) might be estimated and evaluated using the framework presented in this paper. Two examples are fiscal position indicators and commodity cycle variables.

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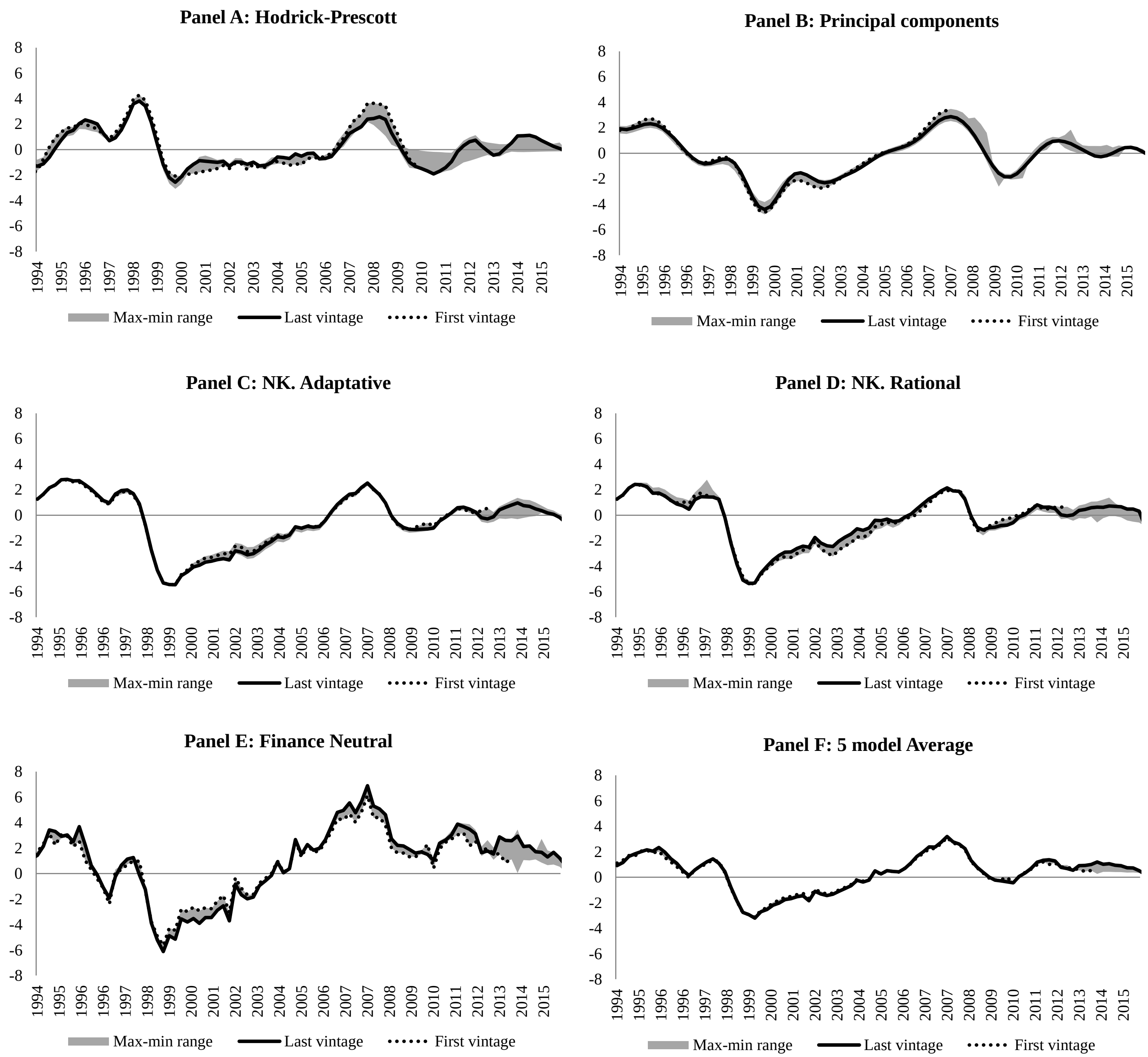
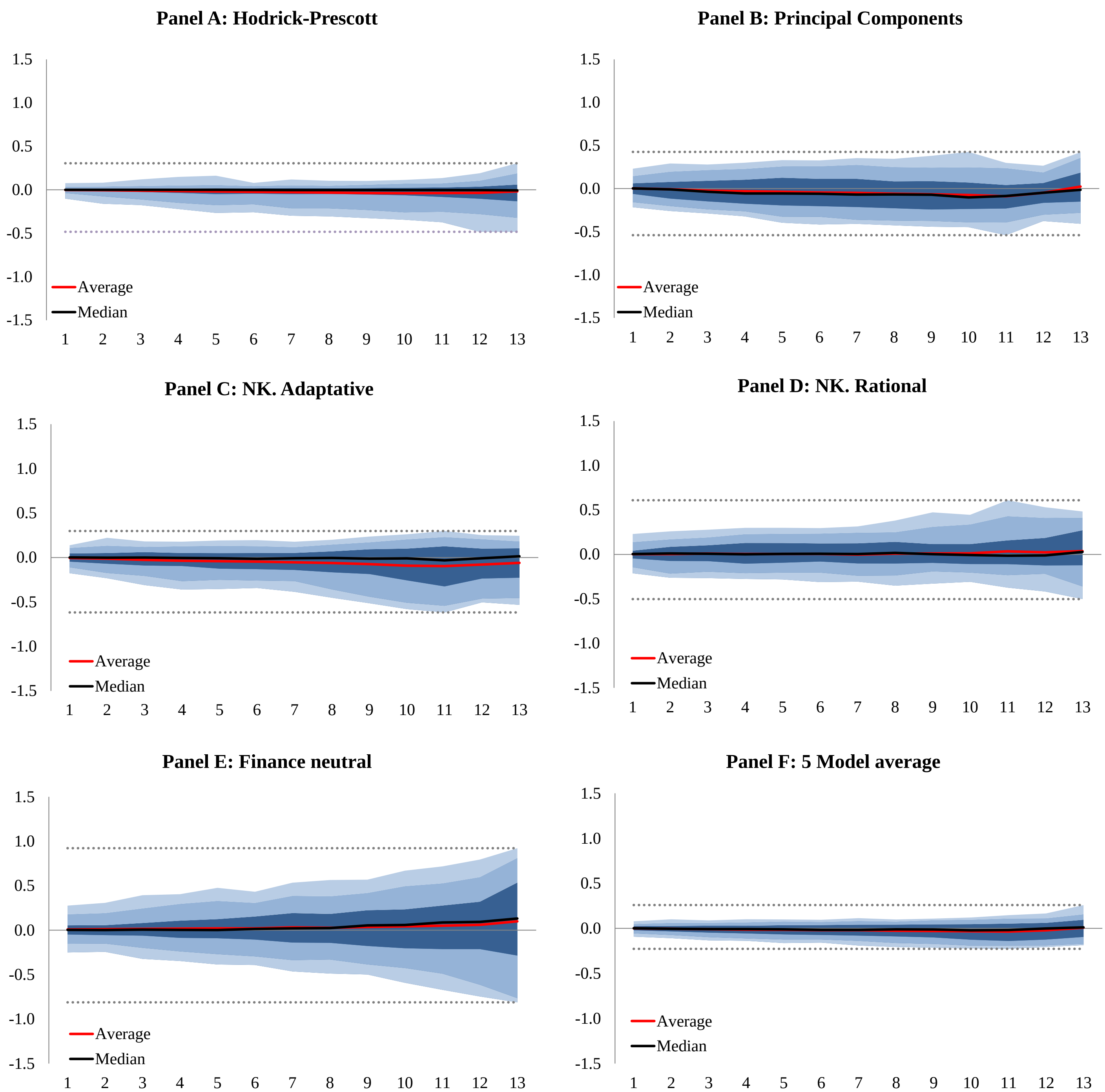
Figure 1: Output gap: first and last estimations and range



Source: Banco de la República and author’s calculations

Figure 2: Evolution of the distribution of output gap revisions



Source: Banco de la República and author’s calculations

Table 1: Output Gap: Estimations and Revisions for the Full Sample

(Vintages from 2012Q3 to 2015Q4, data from 1994Q1 to 2012Q4)

	Hodrick-Prescott		Principal Components		NK. Adaptative		NK. Rational		Finance Neutral		Average	
	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.
Initial estimate	-0.33	1.47	-0.31	2.00	-0.38	2.18	-0.16	2.13	1.32	2.59	0.47	1.47
Final estimate	-0.33	1.49	-0.28	1.74	-0.49	2.22	-0.19	2.10	1.53	2.89	0.50	1.49
Revision	-0.01	0.23	-0.01	0.24	0.01	0.24	0.03	0.31	0.13	0.58	0.01	0.14
Percent switching signs	3.95		5.26		3.95		7.89		2.63		3.95	

Source: Author's calculations

Table 2: Output Gap: Estimations and Revisions for the Peak Periods

(Vintages from 2012Q3 to 2015Q4, data from 1994Q1 to 2012Q4

	Hodrick-Prescott		Principal Components		NK. Adaptative		NK. Rational		Finance Neutral		Average	
	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.	Median	Std. Dev.
Initial estimate	2.49	0.92	1.98	1.75	2.00	0.66	2.01	0.35	2.10	1.95	1.91	0.71
Final estimate	2.43	0.72	1.98	1.52	2.05	0.59	1.73	0.28	2.50	2.29	2.04	0.73
Revision	-0.06	0.28	0.00	0.27	0.12	0.10	-0.27	0.36	0.67	0.68	0.09	0.16
Percent switching signs	0.00		0.00		0.00		0.00		11.11		0.00	

Source: Author's calculations

Table 3: Maximum distance between percentiles 5 and 95 of the output gap revisions across all vintages

Vintages from 2012Q3 to 2015Q4, data from 1994Q1 to 2012Q4, in percentage points

Model	Hodrick-Prescott	Principal Components	NK. Adaptative	NK. Rational	Finance Neutral	Average
Distance	0.80	0.88	0.92	0.98	1.73	0.44

Best model for each percentile-revision pair highlighted in grey

Source: Author's calculations

Table 4: Determinants of Absolute Output Gap Revisions

(Dependent variable is revision no. 13 of output gap data initially published on 2012Q4)

	Constant		First vintage		Inflation deviations from target		Inflation targeting period		Economic Downturns[1]		R^2	Adjusted R^2	F-statistic robust p-value
Hodrick- Prescott	0.22	***	-0.04	*	0.01		-0.15	***	0.15		0.26	0.22	0.01
Principal Components	0.20	***	0.01		-0.02		0.00		0.11	*	0.10	0.05	0.32
NK. Adaptative	0.09		-0.05	**	0.04	**	0.07		-0.06		0.25	0.21	0.14
NK. Rational	0.27	***	-0.02		0.02		-0.04		-0.13	*	0.07	0.01	0.42
Finance Neutral	0.40	***	0.01		-0.02		0.08		0.23	*	0.06	0.01	0.03
Average	0.11	***	-0.01		0.01		-0.01		0.02		0.08	0.03	0.05

1: Downturns chosen according to Alfonso *et al* (2013) business cycles chronology. *, ** and ** denote significance at the 10, 5 and 1 percent, respectively.

OLS estimates with heteroskedasticity and autocorrelation standard errors. Note: in this exercise the sample size is 76 periods.

Source: Author's calculations

Table 5: Historical output gap goodness of fit

Mean squared errors of Phillip's curve and Taylor Rule fitted values for last available estimate

	Inflation (excluding foods and regulated items)		Real interbank interest Rate	
Data range	1994Q2 - 2015Q3	2000Q1-2015Q3	1994Q2 - 2014Q2	2000Q1-2014Q2
Hodrick- Prescott	0.42	0.25	35.45	1.45
Principal Components	0.37	0.19	36.54	1.55
NK. Adaptative	0.34	0.20	36.37	1.86
NK. Rational	0.35	0.19	36.21	1.72
Finance Neutral	0.42	0.21	36.23	1.46
Average	0.35	0.19	35.97	1.40

Best model for horizon highlighted in grey

Source: Author's calculations

Table 6: Forecast accuracy of non-tradables inflation based on output gap estimates

Mean squared error of Phillip's curve non-tradables inflation forecasts

Horizon	Data Observed up to: GDP	Data Observed up to: Non-Tradables Inflation	Hodrick-Prescott	Principal Components	NK. Adaptative	NK. Rational	Finance Neutral	Average
0	- 1 Quarter	Contemporaneous	0.029	0.036	0.035	0.049	0.252	0.060
1	- 2 Quarters	- 1 Quarter	0.027	0.027	0.033	0.048	0.269	0.057
2	- 3 Quarters	- 2 Quarters	0.074	0.089	0.090	0.152	1.014	0.192
3	- 4 Quarters	- 3 Quarters	0.159	0.182	0.165	0.304	2.088	0.384
4	- 5 Quarters	- 4 Quarters	0.235	0.271	0.205	0.424	3.420	0.595
5	- 6 Quarters	- 5 Quarters	0.226	0.410	0.150	0.283	4.532	0.816
Across all forecast horizons (1 to 5)			0.110	0.138	0.109	0.199	1.595	0.291

Best model for horizon highlighted in grey

Source: Author's calculations

Table 7: Policy rate deviations owing to output gap revisions

Mean absolute deviations of Taylor rule real interbank rate for the 13th revision

	Hodrick-Prescott	Principal Components	NK. Adaptative	NK. Rational	Finance Neutral	Average
Whole sample (1994Q2 to 2014Q2)	0.044	0.048	0.053	0.063	0.151	0.041
Forecast period (2012Q3 to 2014Q2)	0.089	0.088	0.094	0.092	0.230	0.068

Best model for data range highlighted in grey

Source: Author's calculations

Appendix A: Finance neutral model specification and estimation

The Hodrick and Prescott filter can be represented in a state-space form by the following transition and measurement equations, respectively:

$$\Delta y^{*}_{0t} = \Delta y^{*}_{0t-1} + \varepsilon_{0,t} \qquad (A.1)$$

$$y_t \;= y^{*}_{0t} + \varepsilon_{1,t} \qquad (A.2)$$

Where $y_t = \ln(y_t)$ stands for real GDP and $\varepsilon_{i,t}$ (for $i = 0{,}1$) is assumed to be a Gaussian independently distributed error term with zero mean and ${\sigma_{i,t}}^2$ variance. For any given state equation such as A.1, $\lambda = \frac{{\sigma_{0,t}}^2}{{\sigma_{1,t}}^2}$ is the signal-to-noise ratio, which determines the relative variability of the estimated potential output series. If λ is large, potential output would follow approximately a linear trend, while if it is small, potential output would duplicate actual output. Borio *et al*. (2013 and 2014) re-write the measurement equation A.2 to include additional economic information:

$$y_t \;= y^{*}_{2t} + \beta\left(y_{t-1} - y^{*}_{2t-1}\right) + \gamma' x_t + \varepsilon_{2,t} \qquad (A.3)$$

Where x_t is a vector of economic and financial variables and $\varepsilon_{2,t}$ is a Gaussian error term. The scaling factor, λ, is set such that:

$$\frac{var\left(y_t \;- y^{*}_{0t}\right)}{var\left(\Delta y^{*}_{0t}\right)} = \frac{var\left(y_t \;- y^{*}_{2t}\right)}{var\left(\Delta y^{*}_{2t}\right)} \qquad (A.4)$$

Where y^{*}_{0t} and y^{*}_{2t} correspond to potential output series from equation A.1 and A.3 respectively. This implies that the standard HP filter business cycle duration of A.1 and A.2 are preserved when extending the model using A.3.

In this paper A.3 is replaced for:

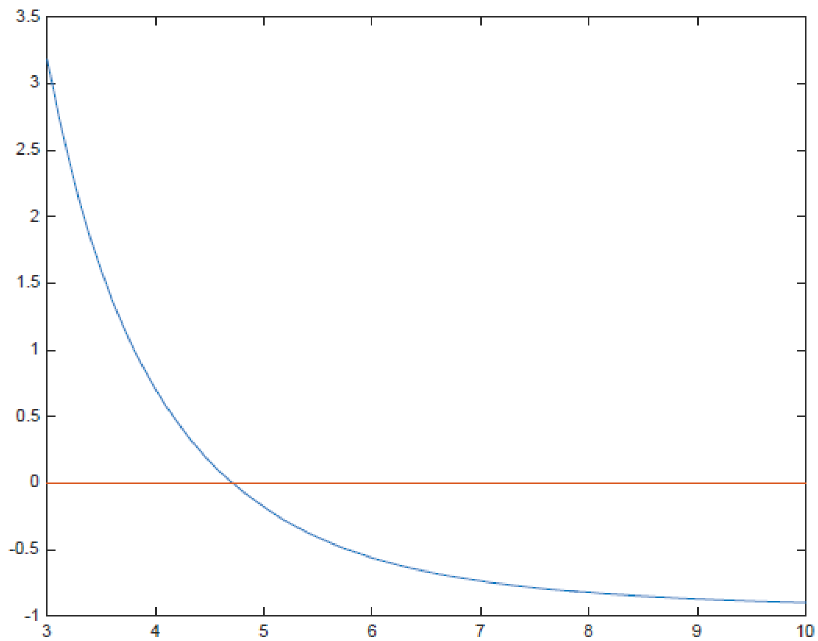
$$y_t \;= y^{*}_{t} + \beta\left(y_{t-1} - y^{*}_{t-1}\right) \;+ \sum_{i=0}^{8}\gamma_i \Delta x_{1,t-i} + \sum_{i=0}^{8}\sigma_i \Delta x_{2,t-i} + \sum_{i=0}^{8}\delta_i \Delta x_{3,t-i} + \sum_{i=0}^{8}\delta_i \Delta x_{4,t-i} + \varepsilon_{3,t} \qquad (A.5)$$

Where y_t stands for the natural logarithm of real GDP and $\varepsilon_{i,t}$ (for $i = 1,2$) are assumed to be a Gaussian independently distributed error terms with zero mean and ${\sigma_i}^2$ variance. $\Delta x_{j,t-i}$ for j = 1,2,3,4 represents the yearly growth rate of real credit, real used housing prices, the real multilateral exchange rate, and the level of the current account (as a percentage of GDP).

All variables were mean-adjusted by the Cesàro's procedure. That is the sequence of means obtained by successively increasing the sample by one observation starting from the initial date is subtracted sequentially from each data point. According to Borio *et al*., (2013) this procedure results in much faster convergence and reduces pro-cyclicality in the mean adjustment[9].

As in A.4, the business cycle duration of the standard HP cycle is preserved. Figure A.1 shows calibration values. A scale parameter of approximately 4.7 makes A.4 hold for equation A.5.

Figure A.1: Scale parameter calibration for equation A1.5



Source: Author's calculation

[9] The resulting mean adjusted series were suggested to be stationary, by a Dickey-Fuller GLS test, at at least the 10% significance level.

Equations A.1 and A.5 were estimated following a Bayesian approach. All parameters in equation 1 follow gamma distributed priors. The variance of error terms prior distribution is an inverse gamma. All lagged variables had decreasing prior coefficients with time, akin to the Minnesota prior. The model was estimated by the Kalman filter and the initial values for both the level and variance of the potential output were chosen using the HP estimation. Prior and posterior means and standard deviations for all parameters are shown in Table A.1. All parameters had the expected sign. To reduce computational time, all variables whose corresponding coefficient was statistically insignificant at the 5% level were not included in the simulations.

Table A.1: Finance Neutral Estimation Results

	Prior		Posterior	
Parameter	Mean	SD	Mean	SD
Output gap persistence	0.700	0.700	0.368	0.080
Contemporaneous credit	0.900	0.900	0.091	0.019
First credit lag	0.800	0.800	0.000	0.019
Second credit lag	0.700	0.700	0.000	0.019
Third credit lag	0.600	0.600	0.000	0.019
Fourth credit lag	0.500	0.500	0.000	0.018
Fifth credit lag	0.400	0.400	0.000	0.018
Sixth credit lag	0.300	0.300	0.000	0.018
Seventh credit lag	0.200	0.200	0.000	0.019
Eight credit lag	0.100	0.100	0.023	0.019
Contemporaneous housing prices	0.900	0.900	0.109	0.022
First housing prices lag	0.800	0.800	0.000	0.022
Second housing prices lag	0.700	0.700	0.020	0.021
Third housing prices lag	0.600	0.600	0.000	0.021
Fourth housing prices lag	0.500	0.500	0.029	0.021
Fifth housing prices lag	0.400	0.400	0.000	0.021
Sixth housing prices lag	0.300	0.300	0.000	0.021
Seventh housing prices lag	0.200	0.200	0.000	0.021
Eight housing prices lag	0.100	0.100	0.063	0.021
Contemporaneous real exchange rate	-0.900	0.900	-0.000	0.011
First real exchange rate lag	-0.800	0.800	-0.020	0.011
Second real exchange rate lag	-0.700	0.700	-0.000	0.011
Third real exchange rate lag	-0.600	0.600	-0.000	0.011
Fourth real exchange rate lag	-0.500	0.500	-0.005	0.011
Fifth real exchange rate lag	-0.400	0.400	-0.010	0.011
Sixth real exchange rate lag	-0.300	0.300	-0.000	0.011
Seventh real exchange rate lag	-0.200	0.200	-0.000	0.011
Eight real exchange rate lag	-0.100	0.100	-0.000	0.011
Contemporaneous credit	-0.900	0.900	-0.000	0.070
First current account lag	-0.800	0.800	-0.000	0.058
Second current account lag	-0.700	0.700	-0.000	0.081
Third current account lag	-0.600	0.600	-0.000	0.052
Fourth current account lag	-0.500	0.500	-0.000	0.064
Fifth current account lag	-0.400	0.400	-0.000	0.051
Sixth current account lag	-0.300	0.300	-0.000	0.072
Seventh current account lag	-0.200	0.200	-0.000	0.075
Eight current account lag	-0.100	0.100	-0.000	0.077

Coefficients statistically different from zero (5%) highlighted in grey

Source: Author's calculations

Appendix B: Monetary Transmission Mechanisms Model Equations

In section 4.C. of this paper two structural theoretical relationships from a policy analysis model are employed. The Phillips curve of the Colombian central bank main forecasting and policy analysis model, the Monetary Transmission Mechanisms Model (or MMT for its acronym in Spanish), is used to obtain core inflation fitted values and forecasts for each individual gap (see Gómez *et al*, 2002). The Taylor rule from the same model is used to obtain interbank rate fitted values, and to assess policy deviations associated to gap revisions.

The core inflation component of the Philips curve in Gómez *et al.* (2002) can be rewritten as the following equation:

$$\pi_t^C = 0.65\pi_{t-1}^C + 0.35E[\pi_{t+4}^C] + 0.29g_t$$

Where π_t^C is core inflation deviations from target (as measured by the yearly growth in non tradable CPI excluding foods and regulated items), $E[\pi_{t+4}^C]$ denotes one year ahead inflation expectations and g_t is the output gap.

The Taylor rule from the model is described by:

$$r_t = 0.7r_{t-1} + 0.3r_t^* + 0.75E[\pi_{t+6}^C] - 0.75\bar{\pi}_{t+6} + 0.24g_t$$

Where r_t is the real interbank interest rate, r_t^* is the real natural interest rate, $E[\pi_{t+6}^C]$ are core inflation expectations six quarters ahead, and $\bar{\pi}_t$ is the inflation target.

In this paper core inflation forecasts are computed from each output gap. For the Taylor rule, core inflation forecasts from each output gap Phillips curve calculation are used as expectations.