Output Gap Uncertainty and Fiscal Policy Adjustment in Real-Time in Emerging Economies

Giacomo Cattelan* and Boaz Nandwa†

January 2026

Abstract

Real-time estimates of output gap are subject to substantial uncertainty, with important implications for fiscal policy. This paper uses successive vintages of the World Economic Outlook over the period 1998–2022 to study how discretionary fiscal policy responds to the business cycle when this is measured in real time. The findings show that Emerging Markets (EMs) tend to have significantly more unstable real-time output gap estimates compared to advanced economies (AEs), and this contributes to the lower responsiveness to output gap shocks. To interpret these empirical findings, we characterize optimal fiscal policy in a New Keynesian DSGE model calibrated to match the behavior of an average EM. The policy maker is modeled as uncertainty averse, following the robustness literature. The model implies that fiscal policy under uncertainty is less counter-cyclical on impact than in a benchmark environment without uncertainty, but exhibits greater persistence over time. We further show that by adjusting the relative weight placed on output gap stabilization versus debt stabilization in the policy maker's objective function, policy outcomes can be brought closer to those obtained under certainty.

JEL Classification: C3, D8, E1, E6, H3, H6
Keywords: Fiscal policy, real-time output gap estimates, public debt

*University of St Andrews Business School. Contact: gc241@st-andrews.ac.uk.
†International Monetary Fund. Contact: bnandwa@imf.org.

Contents

1 Introduction

Policy makers tend to rely on the real-time estimates of output gap to assess the cyclical position of the economy to guide policy formulation and implementation. However, output gap is not directly observable as it is a function of potential output, a theoretical construct, hence creating the need to use estimates.[1] In turn, these are subject to considerable uncertainty owing to measurement errors, quality of models used to estimate output gap, changes in model parameters over time based on new data releases, and ex post data revisions.

Uncertainty surrounding output gap estimates has important implications for fiscal policy in terms of fiscal planning (e.g., budgetary process) and calibration of the appropriate scope of counter-cyclical fiscal policy to stabilize the economy. Orphanides and van Norden (2002) observed that erroneous assumptions about the timeliness of data availability may lead to incorrect monetary policy choices. In a similar way, policy advice based on underestimated output gap estimates envisaging a negative shock to the economy could prompt fiscal policy advice being too loose and recommending accommodative fiscal policy, while fiscal consolidation or neutral fiscal stance would have been the preferred option (Type I error). This could have the unintended effects of running a pro-cyclical fiscal policy that might contribute to overheating of the economy and excessive accumulation of public debt. On the other hand, overestimating output gap could be interpreted as a positive shock to the economy, signaling to the authorities to pursue fiscal consolidation while looser fiscal policy would have been the preferred option, thus tipping the economy into recession (Type II error).

For fiscal policy, characterized by significant lags associated with policy formulation, implementation and transmission, information available to policy makers at the time a decision is made may differ significantly from the information available ex post. In studies of OECD countries, Beetsma and Giuliodori (2010) and Cimadomo (2012) found that while the fiscal stance appeared counter-cyclical when assessed based on real-time data, the fiscal policy was pro-cyclical when evaluated ex post. This divergence has important implications for optimal fiscal policy formulation and implementation. In budget preparation process, data on deficits and GDP available to policy makers at the time are likely to be preliminary and, therefore, subject to many revisions in subsequent periods as newer and better information becomes available (Golinelli and Momigliano (2006); Ley and Misch (2013) and Kuusi (2018)). In addition, the fiscal implementation lags that are observed when policy makers try to correct for adverse or favorable macroeconomic event also contributes to uncertainty surrounding output gap estimates. In some countries, tax measures depend on when tax laws take effect while for expenditure, it depends on the

[1] The framework for estimating output gap has not radically changed in recent years. For an overview of the various output gap estimation methodologies and their implications see, for example, Cheremukhin (2013); Borio, Disyatat, and Juselius (2017) and Barkema, Gudmundsson, and Mrkaic (2020).

length it takes to disburse funds and fiscal transmission in the economy. Based on a study of OECD countries, Cimadomo (2012) noted that the overall information lag for policy makers can be roughly quantified to be around one and a half year, which implies the possibility of significant forecast errors and sub-optimal fiscal policy decisions. Policy makers are, therefore, left to take decisions under a substantial degree of uncertainty.

This paper studies the implications of output gap and fiscal implementation uncertainty for fiscal adjustment, contributing to both the real-time data literature and the literature on robust policy design. On the empirical side, we find evidence that real-time estimation uncertainty for both output gap and fiscal policy variables is higher in Emerging Markets (EMs) than in Advanced Economies (AEs), based on an analysis of forecast errors across the two income groups. Furthermore, we estimate the fiscal reaction function using real-time data, and find that fiscal policy is found to be counter-cyclical in both AEs and EMs. However, higher uncertainty, proxied by the volatility of forecast errors, is found to dampen fiscal responsiveness to cyclical conditions. This evidence suggests that the lower degree of fiscal counter-cyclicality observed in EMs is, in part, attributable to elevated real-time uncertainty.

To explain these observations, we characterize optimal fiscal policy in a New Keynesian DSGE model in which the policy maker aims to stabilize both output gap and public debt dynamics, but is uncertainty averse and faces both output gap uncertainty and fiscal policy implementation uncertainty. The model is calibrated to match a representative Emerging Market economy, where these issues are particularly pronounced. Uncertainty aversion is modeled as robustness in the sense of Hansen and Sargent (1999). This modeling choice is motivated by two considerations. First, real-time data can be viewed of as generated from a probabilistic model that may differ from the 'true' underlying DGP, due to the presence of measurement errors. Second, potential output (and therefore output gap) is a statistical construct whose estimation depends on the choice of a specific model, which may be misspecified. Hence, the real-time estimates on which policy maker relies are subject to at least two layers of model uncertainty. As a result, concern about uncertainty leads to a fiscal reaction function that is less counter-cyclical than in a benchmark economy without uncertainty. We further show that the attenuated fiscal response can be partially offset by assigning greater weight to output gap stabilization in the policy maker's objective function.

The rest of the paper is organized as follows. Section 2 outlines data methodology and provides real-time summary statistics and stylized facts for both AEs and EMs. Section 3 introduces the New Keynesian DSGE model which is calibrated using real-time data. Section 4 concludes.

1.1 Literature Review

Since the seminal works of Orphanides (2001) and Orphanides and van Norden (2002), which documented large errors in real-time assessment of cyclical conditions in the U.S. on monetary policy, there has been a growing body of literature in the application of real-time data that captures the actual information available to policy makers at the time of decision making. Further studies on the instability of output gap estimates can be found in Marcellino and Musso (2011), Aastveit and Trovik (2014), Borio, Disyatat, and Juselius (2017) and Coibion, Gorodnichenko, and Ulate (2018). Recent studies have expanded the literature to examine reliability of real-time output gap estimates in assessing economic cycle and as a basis of policy formulation and implementation, as for example Cheremukhin (2013), Ley and Misch (2013), Grigoli et al. (2015), Kangur et al. (2019) and Barbarino et al. (2020).

Forni and Momigliano (2004) were among the first to estimate a fiscal policy reaction function for the Euro area using real-time data and found counter-cyclical responses which do not show up when the same estimation is carried out with ex post data. On fiscal monitoring, Jonung and Larch (2006) investigate the effect of the role of errors in potential GDP forecasting, and find that for some Euro area countries, real-time assessments of fiscal position were over optimistic due to a systematic upward bias in government produced forecasts of potential output. Golinelli and Momigliano (2006) surveyed the empirical literature concerning the cyclicality of fiscal policies in the Euro area, and they find that the results are heavily affected by the data vintage used in the analysis of the fiscal policy reactions. Hallet, Kattai, and Lewis (2007) found that real-time estimates of the cyclically-adjusted budget balance are subject to significant revisions ex post, and that this lack of accuracy may explain why some fiscal slippages go unnoticed in real-time.

Most of the empirical studies on fiscal policy in EMs have found overwhelming evidence that these countries pursue pro-cyclical fiscal policies, Gavin and Perotti (1997), Kaminsky, Reinhart, and Végh (2005), Talvi and Vegh (2005), Alesina, Campante, and Tabellini (2008), and Marioli and Vegh (2023). However, these studies are based on ex post data. A few recent studies have emerged applying real-time data analysis to EMs. Ley and Misch (2013) implemented a static theoretical framework to examine the implications of output data revisions on the overall and structural fiscal balances for a group of countries, including EMs. However, the paper does not explicitly model uncertainty inherent in output gap estimation.

The theoretical aspects of policy making under uncertainty have long been at the center of economic debate. Brainard (1967) showed in a very simple static framework that the uncertainty surrounding outcome variables and the sensitivity of such variables to the policy instrument drastically changes the optimal policy. More recently, policy design under uncertainty has been studied in the realm of dynamic models, with particular attention to optimal monetary policy in a New Keynesian framework. Specifically, Hansen and Sargent (1999) and Woodford (2010) introduced the concept of robustness in this class of models. A robust policy maker is uncertain about the probabilistic model that governs the data generating process (DGP), and takes into account all the models in a neighborhood of a reference model in terms of some statistical distance, usually the relative entropy between models. Since the policy maker is uncertainty averse, the policy maker maximizes his/her objective function under the worst-case scenario that the set of models generates.[2]

2 Stylized Facts

2.1 Data and Methodology

We use data from the World Economic Outlook (WEO) Spring and Fall releases for the 1998-2022 period. Each vintage includes estimates of output gap and fiscal variables for the current year (real-time estimates) for 39 Advanced Economies (AEs) and 73 Emerging Markets (EMs), giving a total of 112 countries. Using the WEO database gives the advantage of having the same release dates for a large number of countries. Since the timing of the available information is crucial for real-time analysis, harmonizing the dates at which policy makers have access to information makes our results comparable across the countries.

We focus our analysis on output gap as an indicator of the economic cycle, and the cyclically-adjusted primary balance (CAPB) as a percentage of potential GDP as a measure of fiscal stance, both produced in the WEO. It is common in the literature to interpret the CAPB as the discretionary component of fiscal policy, since it does not contain the automatic stabilizers or the interest expenses on public debt.[3]

We interpret the Spring (S) vintage of a given year as the forecasts for that year, whereas the Fall (F) vintage is considered as the realized values (ex post). Let $x_{i,t|\tau+v}$ be the estimate of a generic variable x of country i for year t: the expression $\tau + v$ refers to the vintage of the data, with τ being the year and $v \in \{S, F\}$ the vintage release. If $\tau = t$ and $v = S$, the estimate is in real-time. Hence, policy makers are assumed to use the figure $x_{i,t|t+S}$ as a forecast of year t to set their fiscal stance.

We then compute the real-time forecast error ($RTFE$) as the difference between estimates from Fall and Spring releases of a given year, and the final forecast error (FFE) as the difference between the final and the real-time estimate:

[2] See also Maccheroni, Marinacci, and Rustichini (2006) and Hansen and Sargent (2008) for further discussion on the decision theoretical derivation and for the intuition.

[3] By construction, CAPB can be distorted by errors in output gap measurement, potentially making it harder to disentangle whether fiscal policy is cyclical or counter cyclical. This potential measurement error however is addressed by the use of instrumental variable when estimating the policy reaction function.

$$RTFE_{i,t} = x_{i,t|t+F} - x_{i,t|t+S} \tag{1}$$
$$FFE_{i,t} = x_{i,t|2022+F} - x_{i,t|t+S} \tag{2}$$

2.2 Summary Statistics

2.2.1 Output Gap

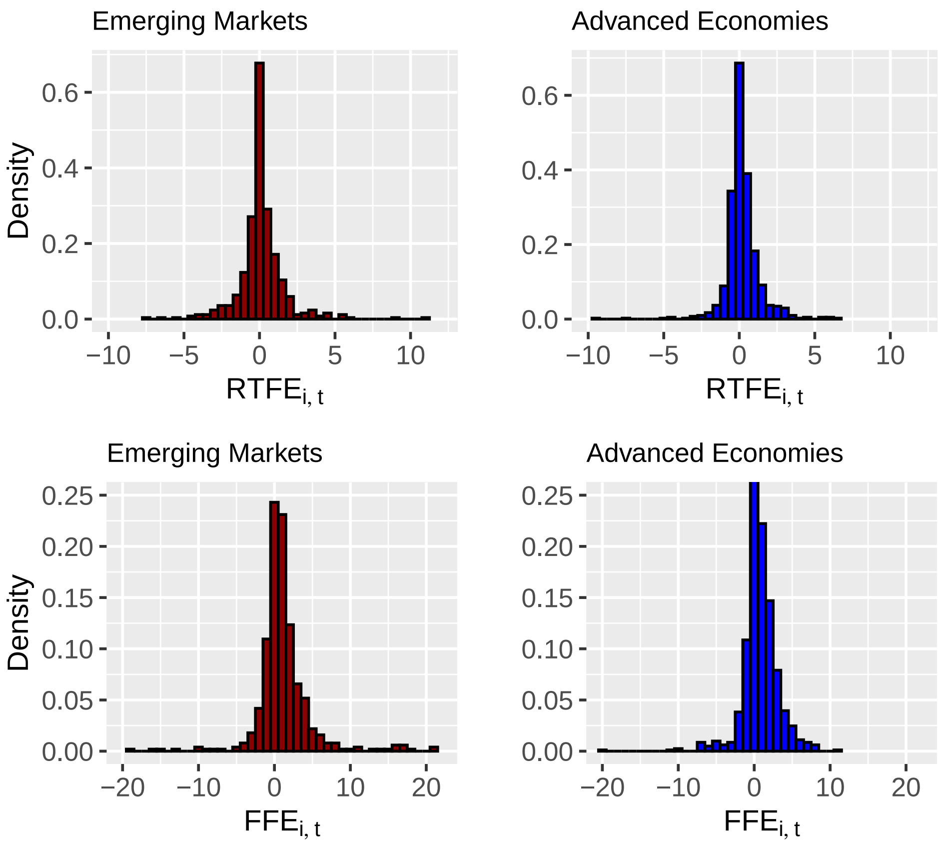
Table 1 summarizes the sample by income group. Real-time forecast errors for AEs are significantly positive, meaning that the WEO persistently under-predicts the actual size of output gap for this group. As for EMs, real-time forecast errors are statistically 0. This, however, does not mean that the estimates for EMs are more accurate, but simply that information takes longer to be updated for this income group, as revealed by the final forecast errors. In fact, revisions using the latest vintage are significantly different from 0 and positive, particularly so for the EMs, with the average magnitude of the final forecast error almost twice compared to AEs.

Table 1: **Summary statistics for output gap estimates and forecast errors by income group.**

	AEs	EMs	Variance ratio test
RTFE			
Mean $RTFE_{i,t}$	0.219	0.117	
SD $RTFE_{i,t}$	1.157	1.558	
p-value H_0: $RTFE_{i,t} = 0$	0.000	0.094	
FFE			
Mean $FFE_{i,t}$	0.803	1.166	
SD $FFE_{i,t}$	2.360	3.747	
p-value H_0: $FFE_{i,t} = 0$	0.000	0.000	
$Var_{EM}/Var_{AE}(RTFE)$			1.815
p-value H_0: $\frac{Var_{EM}(RTFE)}{Var_{AE}(RTFE)} = 1$			0.000
$Var_{EM}/Var_{AE}(FFE)$			2.521
p-value H_0: $\frac{Var_{EM}(FFE)}{Var_{AE}(FFE)} = 1$			0.000

To assess whether forecast errors are more volatile in EMs, the last column of Table 1 compares the variances of revisions for AEs and EMs. In fact, forecast errors variance proxies for the level of uncertainty around the real-time estimation of output gap in the two income groups. As expected, according to the variance ratio test, revisions for EMs are much more volatile than AEs, indicating that output gap estimation in EMs is more uncertain than in AEs. This is evident in Figure 1, which shows the histogram of real-time and final forecast errors of output gap for EMs and AEs. We find that both real-time and final forecast errors for AEs are concentrated around the mean value, with few observations on the tails. On the other hand, forecast errors for EMs have fatter tails and exhibiting extreme values. This confirms that EMs face higher uncertainty in their output gap estimation.

Figure 1: **Histograms of output gap forecast errors by income group.**



Next, we analyze the degree of informational rigidities surrounding real-time estimates by assessing the predictability of forecast errors. According to the framework pioneered by Coibion and Gorodnichenko (2015), if output gaps were estimated under full information, a priori, the forecast errors should be the realization of a pure white noise from a measurement disturbance:

$$GAP_{i,t|t+F} = GAP_{i,t|t+S} + \nu_{i,t} \tag{3}$$

$$RTFE_{i,t} = \nu_{i,t} \sim WN(0, \sigma) \tag{4}$$

If instead the forecast errors were predictable, it would mean that the model used by the forecasters is biased and it would generate some persistence in the forecast errors themselves:

$$GAP_{i,t|t+F} = \alpha + \beta_0 GAP_{i,t|t+S} + \nu_{i,t} \quad (5)$$

$$RTFE_{i,t} = \alpha + \beta_1 GAP_{i,t|t+S} + \nu_{i,t} \quad (6)$$

with $\beta_0 = 1 \iff \beta_1 = 0$ under the hypothesis that output gap is estimated under the correct model. In general, if the forecasting model was correct and there was full information, forecast errors should not be predictable given information available when the forecast was formulated, including other possible predictors. Furthermore, if forecast errors are autocorrelated, the forecaster is putting too much weight on its prior and does not update the predictive model fast enough as new data comes in.

We therefore assess forecast errors predictability by estimating the following regressions:

$$RTFE_{i,t} = \alpha + \beta_1 GAP_{i,t|t+S} + \beta_2 RTFE_{i,t-1} + \nu_{i,t} \quad (7)$$

$$FFE_{i,t} = \alpha + \beta_1 GAP_{i,t|t+S} + \beta_2 FFE_{i,t-1} + \eta_{i,t} \quad (8)$$

The coefficients β_1 and β_2 are jointly 0 under the hypothesis that the forecasters satisfy the Full Information Rational Expectations benchmark (FIRE).

The results are reported in Table 2. The only equation where the coefficients are jointly not significant is the one for $RTFE$ for EMs, indicating that it is not possible, for this group of countries, to predict in advance whether the forecasts are incorrect in real-time. However, since the results for FFE become significant, we conclude that new information is not incorporated in the Fall vintage, pointing at yet another source of informational friction, as already suggested in the descriptive analysis of forecast errors. For all other regressions, the errors made are systematic and not just pure measurement noise, as they can be predicted using information available when the forecasts are released. The lower the output gap estimate in real-time, the bigger the final forecast error. This means that the actual output gap is likely to be larger than the forecast, in particular if the forecast error is positive. This can be easily inferred from the formula $GAP_{i,t|2022+F} = GAP_{i,t|t+S} + FFE_{i,t}$. Hence, a policy maker that reacted strongly to a negative output gap forecast would end up making a Type I error.

Furthermore, final forecast errors are serially autocorrelated, indicating over-reliance on prior information rather than newly acquired data by the forecaster. This is particularly true for EMs, where autocorrelation is stronger. This further hinders the effectiveness of fiscal policy response.

Table 2: **Predictability of magnitudes of output gap forecats errors**

	Dependent variable:			
	$RTFE_{i,t}$		$FFE_{i,t}$	
	AEs	EMs	AEs	EMs
	(1)	(2)	(3)	(4)
Output $\text{Gap}_{i,t\|t+S}$	-0.285^{***}	-0.044	-0.397^{***}	-0.212^{***}
	(0.070)	(0.037)	(0.084)	(0.064)
$RTFE_{i,t-1}$	0.132	0.125		
	(0.081)	(0.078)		
$\text{FFE}_{i,t-1}$			0.192^{**}	0.482^{***}
			(0.077)	(0.059)
Constant	-0.230	0.042	-0.051	-0.026
	(0.228)	(0.174)	(0.284)	(0.306)
Observations	175	220	175	220
R^2	0.087	0.015	0.117	0.234
Adjusted R^2	0.077	0.006	0.107	0.227
F Statistic	16.486^{***}	3.328	22.867^{***}	66.206^{***}

*p<0.1; **p<0.05; ***p<0.01

Table 3: **Summary statistics for forecast errors of cyclically adjusted primary balance.**

	AEs	EMs	Variance Ratio test
RTFE			
Mean $RTFE$	-0.304	-0.283	
SD $RTFE$	1.482	1.367	
p-value H_0: $RTFE = 0$	0.000	0.000	
$Var_{EM}/Var_{AE}(RTFE)$			0.851
p-value $\frac{Var_{EM}(RTFE)}{Var_{AE}(RTFE)} = 1$			0.123
FFE			
Mean FFE	0.652	0.006	
SD FFE	1.508	1.637	
p-value H_0: $FFE = 0$	0.000	0.943	
$Var_{EM}/Var_{AE}(FFE)$			1.179
p-value $\frac{Var_{EM}(FFE)}{Var_{AE}(FFE)} = 1$			0.118

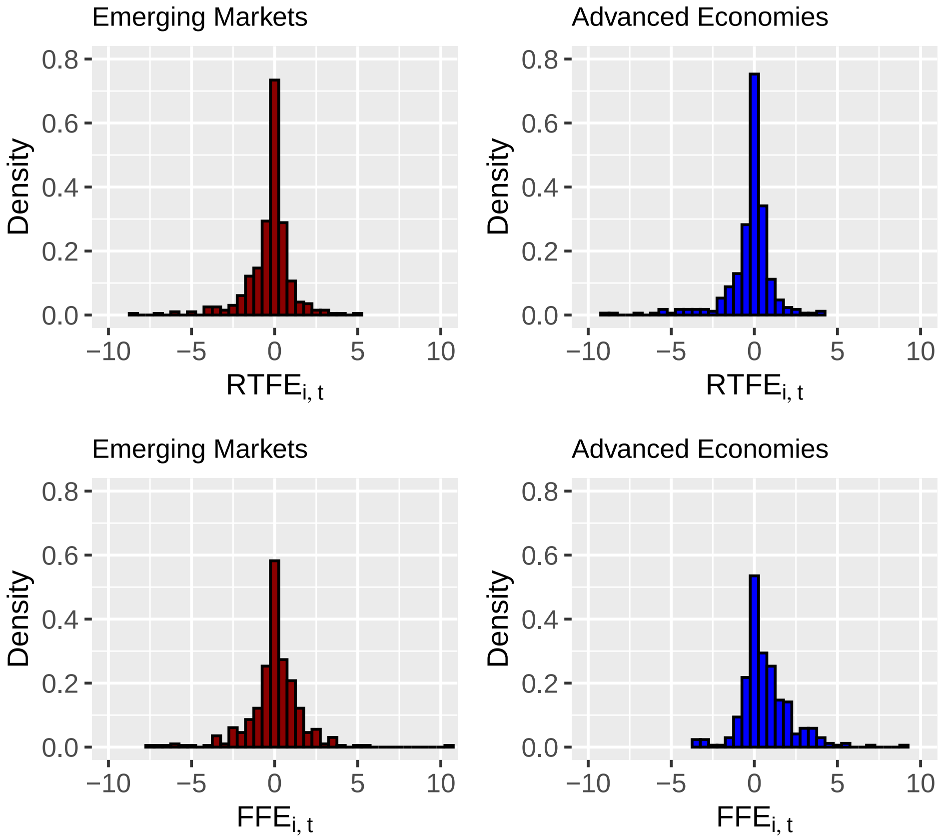
2.2.2 Cyclically Adjusted Primary Balance

We perform similar analysis on the forecast errors and revisions of CAPB-to-GDP ratio. However, it must be noted that, while the errors for output gaps are due to statistical uncertainty and noisy information, errors of fiscal variables arise also due to discrepancies between the planning and the implementation phases of fiscal policy, as observed by Beetsma and Giuliodori (2010), Cimadomo (2012). This leads to significant differences between the original budget plan of the government and what it is actually codified into the budget law. These differences are further amplified when the policies are implemented, due to political or administrative frictions.

Table 3 shows the summary statistics for forecast errors of CAPB. Both real-time and final forecast errors are significantly different from 0 for AEs, whereas EMs forecast errors are biased in real-time but not so in the long run. The last column of Table 3 tests whether the forecast errors are more volatile in one group of the other: we cannot reject the hypothesis that the two are equally uncertain.

Figure 2 shows the histograms for fiscal forecast errors and revisions. For $RTFE$, the two groups are similar in terms of distributions. In particular, range and dispersion are similar, confirming the findings of Table 3: governments in both AEs and EMs face the same uncertainty when planning their fiscal budget. Unlike output gap, whose estimates depend on the precision of the data at hand, CAPB is a policy variable which can be directly measured and its uncertainty stems only from policy implementation. Hence the similarity in the distribution of forecast errors is plausible.

Figure 2: **Histograms of fiscal forecast errors by income group. Units are in percent of GDP**



2.3 Real-time Fiscal Reaction Functions

2.3.1 Methodology

The goal of this section is to estimate a fiscal reaction function in real-time, and use it to gauge whether real-time uncertainty has an impact on the sensitivity of fiscal policy to macroeconomic shocks. The underlying intuition is that the government optimally chooses its fiscal stance based on the *current* estimate of the cyclical position of the economy, which depend on the policy makers' information set at the time of the decision. However, knowing that this information might be inaccurate and subject to revisions in the future can potentially affect the way fiscal policy reacts to macroeconomic shocks. For this purpose, we first compute two indexes for output gap and fiscal implementation uncertainty faced at time t by the policy makers of country i:

$$U_{it}^{GAP} = \left(\frac{RTFE_{it}^{GAP}}{\sigma(RTFE_{it}^{GAP})}\right)^2 \tag{9}$$

$$U_{it}^{CAPB} = \left(\frac{RTFE_{it}^{CAPB}}{\sigma(RTFE_{it}^{CAPB})}\right)^2 \tag{10}$$

where σ indicates the standard deviation. These proxies measure the degree of volatility that the policy makers are currently facing, normalized by the average uncertainty.

The following regression is then estimated:

$$\begin{aligned} CAPB_{it|t+S} =& \alpha + \beta_0 GAP_{it|t+S} + \beta_1 GAP_{it|t+S} \times U_{it|t+S}^{GAP} + \beta_2 GAP_{it|t+S} \times U_{it|t+S}^{CAPB} \\ &+ \beta_3 EM \times GAP_{it|t+S} + X'_{it|t+S}\gamma + \epsilon_{it} \end{aligned} \tag{11}$$

Equation (11) is the fiscal reaction function. Crucially, we allow the sensitivity of fiscal policy to output gap to depend on uncertainty. In fact, Equation (11) implies $\frac{\partial CAPB_{it}}{\partial GAP_{it}} = \beta_0 + \beta_1 U_{it}^{GAP} + \beta_2 U_{it}^{CAPB}$, with β_0 capturing the sensitivity of CAPB to output gap's deviations from its intended theoretical value of 0, whereas β_1 measures how output-gap forecast errors' magnitude relative to their standard deviation changes the strength of the fiscal response to output-gap shocks. Analogously, β_2 captures the impact of fiscal policy implementation uncertainty affects the sensitivity. On top of this we are interested in understanding whether fiscal policy in EMs differs substantially from AEs, and for such purpose we interact the dummy EM, which takes the value of 1 for EMs and 0 for AEs, with output gap.

Since CAPB is computed as revenues minus expenditures, a counter-cyclical stabilization motive would imply $\beta_0 > 0$, since this would imply that when output gap increases, fiscal policy tightens through an increase in revenues and/or a decrease in expenditures.

The degree of counter-cyclicality is determined by the magnitude of the parameter associated with output gap. Therefore if uncertainty reduces counter-cyclicality, we would expect $\beta_1 < 0$ (and $\beta_2 < 0$). Furthermore, if fiscal policy in EMs is on average less counter-cyclical this would mean $\beta_3 < 0$.

The other covariates included in the vector X are designed to capture two other incentives that drives policy makers' decision on fiscal policy. The first one is debt stabilization: the higher the debt, or the cost of debt, the less fiscal policy will be expansionary. The most straightforward way to capture this motive would be to include debt-to-GDP ratio in the list of regressors. However, debt-to GDP is a stock variable that tend to move at a much lower frequency than flow variables that move at the economic cycle frequency, hence it may not be informative. For this reason, we use first difference of debt-to-GDP ratio. On top of this we include interest expenditures from the previous year as a fraction of GDP. These two variables also control for the fiscal capacity that is country-specific: lower increase in debt-to-GDP and lower interest expenditure mean that the country has higher ability to borrow from capital markets. Furthermore, to avoid potential endogeneity, we take the lag of these variables.

The second motive we want to capture is the political incentive. On one hand, politicians may be more prone to raise spending before upcoming elections in order to increase support for the incumbent government or legislature. We then use the lead of this variable in our list of regressors: we assume that politicians start to expand the fiscal budget for electoral reasons 1 year in advance to gather consensus. We collect data from the Varieties of Democracy Research Project ("v-dem.net/") to construct a dummy variable for each country, taking value of 1 if either a presidential or a legislative election took place in a given year. Additionally, the quality of institutions varies greatly across countries, and in particular it varies across income groups, making policy response more inefficient. We proxy for this factor using the Corruption Perception Index computed by Transparency International ("transparency.org"): the higher the index, the less corrupt the country. To get a better understanding of the results, we use the negative of the index, so that the higher the number we obtain, the lower the quality of institutions.

2.3.2 Instrumental variables

Equation (11) suffers from endogeneity issues, arising mainly from the fact that output gap is affected by the fiscal stance in the first place. In fact, an expansionary fiscal stance could imply a higher output gap. For this reason, we need to find a suitable instrument for the output gap. A large body of literature (see, e.g. Galí et al. (2003) and Alesina, Campante, and Tabellini (2008)) uses the output gap of an external economy considered to be a source of output gap shocks that is not affected by fiscal policy in the countries of interest. In particular, they use the output gap of the US to instrument for the output gap of every country in the Eurozone, arguing that European countries' fiscal policy does not affect output gap in the US, but shocks to US output gap is a meaningful source of shocks to European output gaps.

Building on this, we use a weighted average of output gaps from other countries in the same regional grouping of the WEO[4]. The key assumption is that shocks to output gaps of neighboring countries are an external source of shocks for the output gap of the country itself, but fiscal policy in any given country is not enough to impact this weighted average:

$$G\bar{A}P^{IV}_{g,t|t+S} = \frac{\sum_{i\in g} GDP_{i,t|t+S} GAP_{i,t|t+S}}{\sum_{i\in g} GDP_{i,t|t+S}} \tag{12}$$

where $g \in \{AFR, APD, EUR, MCD, WHD\}$ is the geographical department of the WEO. This methodology echoes the instrument introduced by Jaimovich and Panizza (2007), who used the share of exports from i to j as weights to construct an instrument specific to country i.

2.3.3 Results

Table 4 shows the results for the estimated fiscal reaction functions using country-specific fixed effect models. Under linear fiscal reaction function (Column (1)), fiscal policy is counter-cyclical when variables are measured in real-time, confirming the results from Cimadomo (2012), with CAPB-to-GDP ratio significantly increasing by 0.572 percentage points for a 1 percentage point increase in output gap. We find evidence, however, that uncertainty in output gap significantly decreases the counter-cyclicality of fiscal policy. In fact, 1 standard deviation increase in the squared forecast error of output gap decreases the sensitivity of fiscal policy by 0.131. In practical terms, this means that when output gap decreases by 1%, the government would decrease CAPB-to-GDP ratio by 0.680% to stabilize the economy in the absence of uncertainty, but with an output gap forecast error of 1 standard deviation, CAPB-to-GDP actually decreases by 0.680-0.131= 0.549%. Fiscal policy implementation uncertainty, on the other hand, seems to have a positive effect on fiscal policy sensitivity to output gap shocks, although the results are not robustly significant across specifications.

We also find evidence of counter-cyclicality in EMs, although the magnitude is lower: the coefficient for interaction term $GAP_t \times EM$ is significantly negative, meaning that for EMs CAPB-to-GDP increases on impact by 0.514 percentage points in response to a 1 percentage point increase in output gap. Furthermore, EMs face a significantly higher magnitude of forecast errors, as we documented in Section 2.2.1. In particular, the output gap uncertainty index for AEs is 0.306, whereas it is 2.024 for EMs. This implies that,

[4]The IMF has five regional area departments: African (AFR), Asia Pacific (APD) European (EUR), Middle East and Central Asia (MCD), and Western Hemisphere (WHD).

on average, the counter-cyclicality of fiscal policy in EMs is further reduced compared to the AEs benchmark.

In conclusion, the magnitude of the coefficient associated with output gap varies significantly and substantially depending on the output gap uncertainty faced by policy makers, and across income groups. This result yields an important behavioral implication: as output gap measurement is much more uncertain, policy makers may want to be more cautious in their response to shocks.

Table 4: **Real-time fiscal reaction functions, Fixed Effects models.**

	Dependent variable:			
	Cyclically adjusted primary balance-to-GDP$_t$			
	(1)	(2)	(3)	(4)
GAP	0.572***	0.680***	0.872***	0.723**
	(0.055)	(0.079)	(0.102)	(0.304)
GAP$\times U^{GAP}$		−0.131**	−0.151***	−0.132**
		(0.057)	(0.059)	(0.062)
GAP$\times U^{CAPB}$		0.027	0.031*	0.048***
		(0.017)	(0.017)	(0.016)
GAP×EM			−0.358***	−0.416***
			(0.132)	(0.129)
Time FE	No	No	No	Yes
Observations	423	423	423	423
R^2	0.362	0.366	0.366	0.060
Adjusted R^2	0.244	0.240	0.236	−0.156
F Statistic	228.477***	232.575***	241.247***	43.853***

*p<0.1; **p<0.05; ***p<0.01

3 Model

We adapt the standard closed economy New Keynesian model to accommodate for active fiscal policy, in a similar way to Vitek (2023). The following subsections present the main building blocks of the model, and all the derivations can be found in the Appendix.

3.1 Households

A fraction ϕ^C of households is financially constrained: they cannot save or borrow, so they have to consume all their income in the current period. Hence they can only choose the amount of hours worked, N_t^C, and consume the totality of their income:

$$\max_{C_t^C, N_t^C} \frac{(C_t^C)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{(N_t^C)^{1+\varphi}}{1+\varphi} \tag{13}$$

subject to

$$P_t C_t^C = (1-\tau)(W_t N_t^C + \Theta_t^C) \tag{14}$$

Θ_t^C represents the profits of firms rebated lump sum to the constrained households. Both labor income and profits are subject to proportional taxation with tax rate τ.

The remaining $1-\phi^C$ fraction of households are instead unconstrained, and maximizes the lifetime expected utility by choosing consumption, amount of nominal bonds to hold and hours worked:

$$\max_{(C_t^U, B_t^n, N_t^U)_{t\geq 0}} \mathbb{E}_0 \sum_{t\geq 0} \beta^t \left[\frac{(C_t^U)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{(N_t^U)^{1+\varphi}}{1+\varphi} \right] \tag{15}$$

subject to

$$B_t^n = (1+i_t)B_{t-1}^n + (1-\tau)(W_t N_t^U + \Theta_t^U) - P_t C_t^U \tag{16}$$

B_t^n represents the demand for nominal government bonds.

3.2 Firms

There is a continuum of intermediate goods producers which use labor as input, and a final good producer which aggregates the intermediate goods. The final good producer is perfectly competitive, featuring a CES production function with elasticity ε, and chooses the quantity of each intermediate goods to minimize the cost.

The producer of each variety i is a monopolist facing an isoelastic demand $Y_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t$ and production function: $Y_t(i) = A_t N_t(i)$. All such firms are subject to staggered price setting *á la* Calvo: at any time t they can adjust their price with probability $1-\vartheta$. If they can adjust, they will chose a reset price $P_t^*(i)$ that maximizes the future stream of real profits.

3.3 Government

The fiscal authority chooses the amount of government spending G_t, and the amount of real public debt B_t to issue. The government budget constraint is:

$$P_t B_t = (1 + i_{t-1}) P_{t-1} B_{t-1} + P_t G_t - \tau P_t Y_t \tag{17}$$

The monetary authority, on the other hand, sets the nominal interest rate according to a Taylor rule:

$$(1 + i_t) = \beta^{-1} (\Pi_t)^{\phi_\pi} \left(\frac{Y_t}{Y_t^p} \right)^{\phi_y} \tag{18}$$

with $\Pi_t = \frac{P_t}{P_{t-1}}$ being the gross inflation rate and Y_t^p being potential output.

3.4 Equilibrium and Log-linear Economy

Goods market, labor market and bond market clearing conditions are:

$$C_t^C + C_t^U + G_t = Y_t \tag{19}$$

$$N_t = N_t^U + N_t^C \tag{20}$$

$$B_t^n = P_t B_t \tag{21}$$

where $N_t = \frac{Y_t}{A_t}$.

We will now present the relevant equilibrium equations of the model log-linearized around the non-inflationary steady state, that is $\Pi_{ss} = 1$, and the output level is at potential. It is crucial to stress the distinction between what we label potential output, Y_t^p, and the natural level of output, which we label as Y_t^n. Natural output is the flexible price equilibrium output, which can be proved (see Appendix) to be

$$y_t^n = \psi_g g_t + \psi_a a_t \tag{22}$$

Potential output, on the other hand, is the purely exogenous component of natural output which depends on productivity, and indicates the resources available given the current level of technology. These two concepts differ because government spending is not a nominal friction, and therefore affects the flexible price equilibrium, even if is a demand-side policy. However, given the endogenous nature of government spending in the optimal policy exercise of later Sections, it is useful to keep these two quantities clearly distinct. This distinction leads us to redefine output gap as the log-deviation of output from its *potential* level: $\hat{y}_t = y_t - y_t^p$.

The Dynamic IS curve, given by the combination of the intertemporal optimality condition of the unconstrained household and the goods market clearing condition, is given by :

$$y_t = \mathbb{E}_t y_{t+1} + \mu^g (g_t - \mathbb{E}_t g_{t+1}) - \chi (i_t - \mathbb{E}_t \pi_{t+1} - \rho) \tag{23}$$

where $\rho = -\log \beta$ is the steady state level of the interest rate, γ is the government spending ratio in steady state, $\mu^g = \frac{\gamma}{1-(1-\tau)\phi^C}$ is the fiscal multiplier, and $\chi = \sigma \frac{(1-\phi^C)(1-\gamma)}{1-(1-\tau)\phi^C}$. Since we are interested in the role of fiscal policy for output gap stabilization, we recast the IS curve in terms of this variable:

$$\hat{y}_t = \mathbb{E}_t \hat{y}_{t+1} + \mu^g (\hat{g}_t - \mathbb{E}_t \hat{g}_{t+1}) - \chi (i_t - \mathbb{E}_t \pi_{t+1} - \rho) + (1 - \mu^g) \mathbb{E}_t \Delta y_{t+1}^p \tag{24}$$

where $\hat{y}_t$ represents the output gap and $\hat{g}_t = g_t - y_t^p$.

Inflation dynamics can be derived from the supply-side block, which yields the standard New Keynesian Phillips curve augmented to account for fiscal policy:

$$\pi_t = \kappa \hat{y}_t - \kappa_g \hat{g}_t + \beta \mathbb{E}_t \pi_{t+1} \tag{25}$$

The log-linearized Taylor rule (18) is:

$$i_t = \rho + \phi_y \hat{y}_t + \phi_\pi \pi_t \tag{26}$$

Government debt dynamics is characterized in terms of log-deviations of debt-to-potential GDP ratio, and it derives from equation (17), the fiscal authority budget constraint:

$$\beta \hat{b}_t = \hat{b}_{t-1} + (i_{t-1} - \pi_t - \rho) + \beta \delta (\gamma \hat{g}_t - \tau \hat{y}_t) - \Delta y_t^p \tag{27}$$

where $\delta = \frac{Y}{B}$ is the inverse of debt-to-GDP ratio in steady state and τ is the income tax rate.

3.5 Benchmark Optimal Fiscal Policy

We will now discuss the policy maker's optimal choice of government spending in a benchmark case with rational expectations and perfect foresight. We do not formally derive the social welfare function as in Woodford (2003) and Benigno and Woodford (2003). Instead, we assume that the government aims at stabilizing the output gap at 0 taking into account the effect of excess spending on future debt-to-potential GDP ratio $\hat{b}_t$, which should not deviate from a target level $\bar{b}$.

The external shocks that the government has to counter in order to stabilize output gap and debt are demand-side shocks that that have not been explicitly modeled, but that it will be assumed affect the dynamic IS equation and whose law of motion follows an AR(1) process:

$$\hat{y}_t = \mathbb{E}_t\hat{y}_{t+1} + \mu^g(\hat{g}_t - \mathbb{E}_t\hat{g}_{t+1}) - \chi(i_t - \mathbb{E}_t\pi_{t+1} - \rho) + (1-\mu^g)\mathbb{E}_t\Delta y^p_{t+1} + x_t \tag{28}$$

$$x_t = \rho_x x_{t-1} + \epsilon_t \qquad \epsilon_t \sim N(0,1) \tag{29}$$

The policy maker's objective function is thus a quadratic loss with relative weight of debt λ_b

$$\max -\frac{1}{2}\mathbb{E}_0\sum_{t\geq 0}\beta^t[\hat{y}_t^2 + \lambda_b(\hat{b}_t - \bar{b})^2] \tag{30}$$

subject to

$$\begin{aligned}
\hat{y}_t &= \mathbb{E}_t\hat{y}_{t+1} + \mu^g(\hat{g}_t - \mathbb{E}_t\hat{g}_{t+1}) - \chi(i_t - \mathbb{E}_t\pi_{t+1} - \rho) + (1-\mu^g)\mathbb{E}_t\Delta y^p_{t+1} + x_t && IS\\
\beta\hat{b}_t &= \hat{b}_{t-1} + (i_{t-1} - \pi_t - \rho) + \beta\delta(\gamma\hat{g}_t - \tau\hat{y}_t) - \Delta y^p_t && BC\\
\pi_t &= \kappa\hat{y}_t - \kappa_g\hat{g}_t + \beta\mathbb{E}_t\pi_{t+1} && PC\\
i_t &= \rho + \phi_y\hat{y}_t + \phi_\pi\pi_t && MP\\
x_t &= \rho_x x_{t-1} + \epsilon_t
\end{aligned}$$

This can be assumed without loss of generality, as Problem (30) closely resembles the problem of the social planner in Vines and Stehn (2007) and Leith and Wren-Lewis (2013).

We adopt the Lagrangian solution method as in Currie and Levine (1993). In particular, we recast the problem as follows:

$$\max -\frac{1}{2}\mathbb{E}_0 \sum_{t\geq 0} \beta^t [\mathbf{x}_t' R \mathbf{x}_t + \mathbf{u}_t' Q \mathbf{u}_t] \tag{31}$$

subject to

$$A\mathbf{x}_t = B\mathbb{E}_t\mathbf{x}_{t+1} + C\mathbf{x}_{t-1} + D\mathbf{u}_t + \boldsymbol{\epsilon}_t$$

where $\mathbf{x_t}$ is a vector containing all the endogenous variables of the model and $\mathbf{u}_t$ is the vector of controls (in our case $\mathbf{u}_t = g_t$). In Lagrangian form, the problem can be rewritten as:

$$\max \mathbb{E}_0 \sum_{t\geq 0} \beta^t \mathbf{L}_t \tag{32}$$

$$\mathbf{L}_t = -\frac{1}{2}[\mathbf{x}_t' R \mathbf{x}_t + \mathbf{u}_t' Q \mathbf{u}_t] + \boldsymbol{\mu}_t'(B\mathbb{E}_t\mathbf{x}_{t+1} + C\mathbf{x}_{t-1} + D\mathbf{u}_t + \boldsymbol{\epsilon}_t - A\mathbf{x}_t) \tag{33}$$

where $\boldsymbol{\mu}_t$ is a vector of multipliers associated with each constraint. The first order conditions imply:

$$\mathbf{0} = - R\mathbf{x}_t + \beta^{-1}\boldsymbol{\mu}_{t-1}' B + \beta\mathbb{E}_t\boldsymbol{\mu}_{t+1}' C - \boldsymbol{\mu}_t' A \qquad (\mathbf{x}_t) \tag{34}$$

$$\mathbf{0} = - Q\mathbf{u}_t + \boldsymbol{\mu}_t' D \qquad (\mathbf{u}_t) \tag{35}$$

The system of equations consisting of the first order conditions, together with the laws of motion represented by the constraints, form a dynamic linear system that pins down the dynamics of all the endogenous variables, the multipliers and the controls.

The dynamics of our economy is represented by the 4 constraints of the government problem together with the following system of first order conditions

$$\begin{aligned}
0 =& - \hat{y}_t - \mu_t^{IS} + \beta^{-1}\mu_{t-1}^{IS} - \beta\delta\tau\mu_t^{BC} + \kappa\mu_t^{PC} + \phi_y\mu_t^{MP} && (\hat{y}_t)\\
0 =& - \lambda_b(\hat{b}_t - \bar{b}) - \beta\mu_t^{BC} + \beta\mathbb{E}_t\mu_{t+1}^{BC} && (\hat{b}_t)\\
0 =& \mu^g\mu_t^{IS} - \beta^{-1}\mu^g\mu_{t-1}^{IS} - \kappa_g\mu_t^{PC} + \beta\delta\gamma\mu_t^{BC} && (\hat{g}_t)\\
0 =& \chi\beta^{-1}\mu_{t-1}^{IS} - \mu_t^{BC} - \mu_t^{PC} + \mu_{t-1}^{PC} + \phi_\pi\mu_t^{MP} && (\pi_t)\\
0 =& - \chi\mu_t^{IS} + \beta\mathbb{E}_t\mu_{t+1}^{BC} - \mu_t^{MP} && (i_t)
\end{aligned}$$

where we labeled each multiplier with the name of the corresponding constraint.

3.6 Optimal Fiscal Policy under Uncertainty

To capture the idea of output gap and fiscal implementation uncertainty, we will add a slight modification to the robustness literature pioneered by Hansen and Sargent (2008). In particular, we assume that the government observes output gap and government spending with some measurement error when estimated in real-time:

$$\hat{y}_{t|t} = \hat{y}_t + \sigma_w w_t \tag{36}$$

$$\hat{g}_{t|t} = \hat{g}_t + \sigma_v v_t \tag{37}$$

with $(w_t, v_t)_{t\geq 0}$ being random errors.

As outlined in Section 2, output gap estimates are unstable due to uncertainty surrounding the data generating process (i.e. the probabilistic model adopted by the statistician). This can be captured assuming that output gap (and government spending) is a linear combination of latent variables in the economy, $\hat{y}_t = a'\boldsymbol{\xi}_t$. When the government estimates it, it takes into account that the model used can be misspecified, and in particular the observed output gap can be expressed as $\hat{y}_{t|t} = a'\boldsymbol{\xi}_t + w_t = \hat{y}_t + w_t$, which is exactly what we have in Equations (36).

Then, an uncertainty averse (robust) decision maker in the sense of Hansen and Sargent (2008) solves for the optimal fiscal policy rule considering a worst-case scenario among a set of possible disturbances. The set of feasible disturbances is such that the relative entropy between the disturbances and the reference model with no misspecification is bounded:

$$\frac{1}{2}\sum_{t\geq 0}\beta^t(w_t^2 + v_t^2) \leq \frac{\eta}{1-\beta} \tag{38}$$

Additionally, we assume that the policy maker uses the observed value of the output gap in the objective function. The reason behind this choice is twofold: on one hand, it is mathematically necessary to generate a meaningful impact of observational uncertainty; on the other hand, it captures the possibility that policy makers have political incentives to prioritize current estimates of the output gap, as they are more relevant fro electoral purposes. Writing down the Lagrangian for the entropy constraint given by Equation (38) allows us to restate the problem for the robust government in real-time:

$$\max \min_{(w_t,v_t)_{t\geq 0}} -\frac{1}{2}\sum_{t\geq 0}\beta^t\left\{\hat{y}_{t|t}^2 + \lambda_b(\hat{b}_t - \bar{b})^2 + \theta^{-1}\left[\eta - w_t^2 - v_t^2\right]\right\} \tag{39}$$

Table 5: **Calibrated parameters of the model.**

Variable	Parameter	Value	Source
Discount factor (annual)	β	0.8235	Average long term real rate
Target/SS Debt-to-GDP	$\bar{b}$ (δ^{-1})	0.4892	Average debt-to-GDP ratio
SS tax-to-GDP	τ	0.28	Average revenues-to-GDP ratio
SS government spending-to-GDP	γ	0.285	$\tau+$ average CAPB-to-GDP ratio
CRRA	σ	1	Standard
Relative weight on debt	λ_b	0.05	Calibrated (details in the text)
Persistence of output gap shock	ρ	0.5	Bhattacharya and Patnaik (2013)
Fraction of constrained HH	ϕ^C	0.786	Bhattacharya and Patnaik (2013)
Slope of the Phillips curve	κ	0.2	Standard
SD of the error in the IS equation	σ_w	1.558	S.D. of output gap FFE
SD of the error in the debt equation	σ_v	1.352	S.D. of CAPB FFE
Taylor rule output gap coefficient	ϕ_y	0.7	Standard
Taylor rule inflation coefficient	ϕ_π	1.3	Standard
Uncertainty aversion	θ	0.292	Calibrated (details in the text)

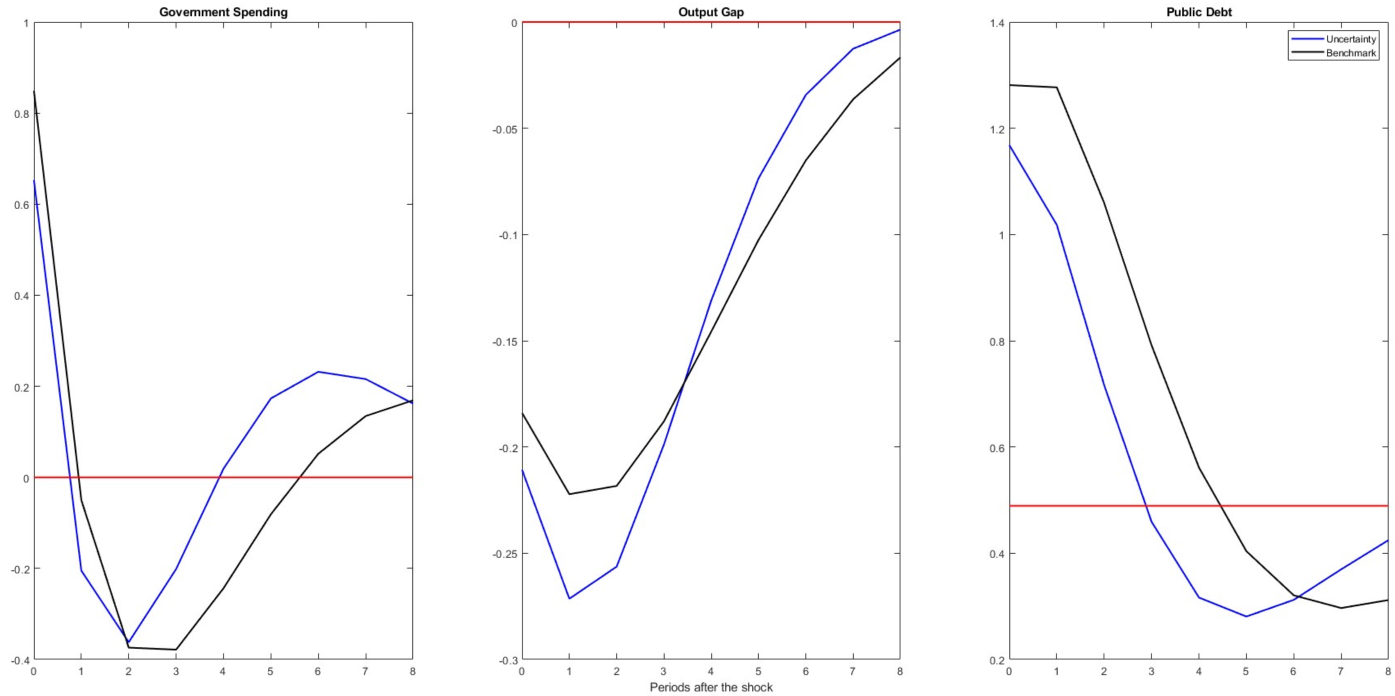
subject to the laws of motion IS-BC-PC-MP, the measurement Equations (36) and (37).

As stated by Hansen and Sargent (2008), the inverse of the multiplier θ^{-1} represents the sensitivity of the policy maker to the measurement errors of output gap and debt respectively. The higher the parameter, the more pessimistic the worst-case scenario will be and hence the decision maker will be more cautious.

3.7 Calibration

We use the real-time data set from the first section to calibrate all the parameters deriving from steady state objects, focusing on EMs. In particular, for the discount factor β, we compute the average of the gross long term real interest rate across the EMs sample we have available over the selected time period, and we compute the inverse. As for public debt-to-GDP ratio $\bar{b}$ and tax rate τ we simply compute the average of debt-to-GDP ratio and revenues-to-GDP ratio. We then compute the share of government spending γ by adding the average CAPB-to-GDP ratio to the calibrated value of τ. The share of financially constrained households ϕ^C is taken from Bhattacharya and Patnaik (2013), who computed the share of Indian households with no access to banking before the financial sector liberalization reform in 1991. We also compute the standard deviations of final forecast errors for output gap and CAPB to calibrate σ_w and σ_v respectively. Lastly, λ_b, the relative weight the policy maker attaches to debt in the maximization problem, is set to generate a response of fiscal spending to an output gap shock that is consistent with the coefficients estimated in the fiscal rule in Section 2. In particular, we set λ_b so that the coefficient on the shock ϵ_t of the policy function of g_t in the benchmark case with no

Figure 3: **Response to a 1% shock to output gap: benchmark case vs different degrees of uncertainty aversion**



uncertainty matches the coefficient β_0 estimated in Equation (11). Taylor rule coefficients ϕ_y and ϕ_π and the slope of the Phillips curve κ are standard in New Keynesian literature. Although these parameters are usually calibrated for the US economy, they also ensure the stability of the system. We summarize our calibration in Table 5.

3.8 Results

We will now study how the government optimally responds to a 1% negative shock to output gap under different degrees of uncertainty aversion. We are first interested in describing the behavior of the economy when there is no uncertainty, i.e. what we call the benchmark case. Second, we analyze the situation in which the policy maker is concerned about output gap and fiscal policy implementation uncertainty. The multiplier θ which captures risk aversion is set to 0.292, as this figure is obtained by matching the coefficient on the shock ϵ_t of the policy function of g_t to $\beta_0 + \beta_1$ from Equation (11).

Figure 3 plots the impulse responses of debt, output gap and the implied dynamics of government spending to a 1% shock to output gap under different degrees of uncertainty aversion. The black line represents the benchmark case without uncertainty; the blue line shows the case when the policy maker is uncertainty averse. Government spending increases by 0.8% on impact and sharply falls in subsequent periods, as the policy maker tries to counteract the effects of Ricardian equivalence, which would significantly reduce consumption of the financially unconstrained households. An uncertainty averse fiscal policy maker, however, increases spending slightly less on impact and decreases it much faster in subsequent periods in order to avoid debt overaccumulation. As a result, output gap decreases more sharply in the short run, i.e. in the first 4 periods, but it recovers faster thanks to the effects of Ricardian equivalence. Debt, on the other hand, remains steadily below the benchmark scenario, pointing at the more cautious stance of the robust policy maker.

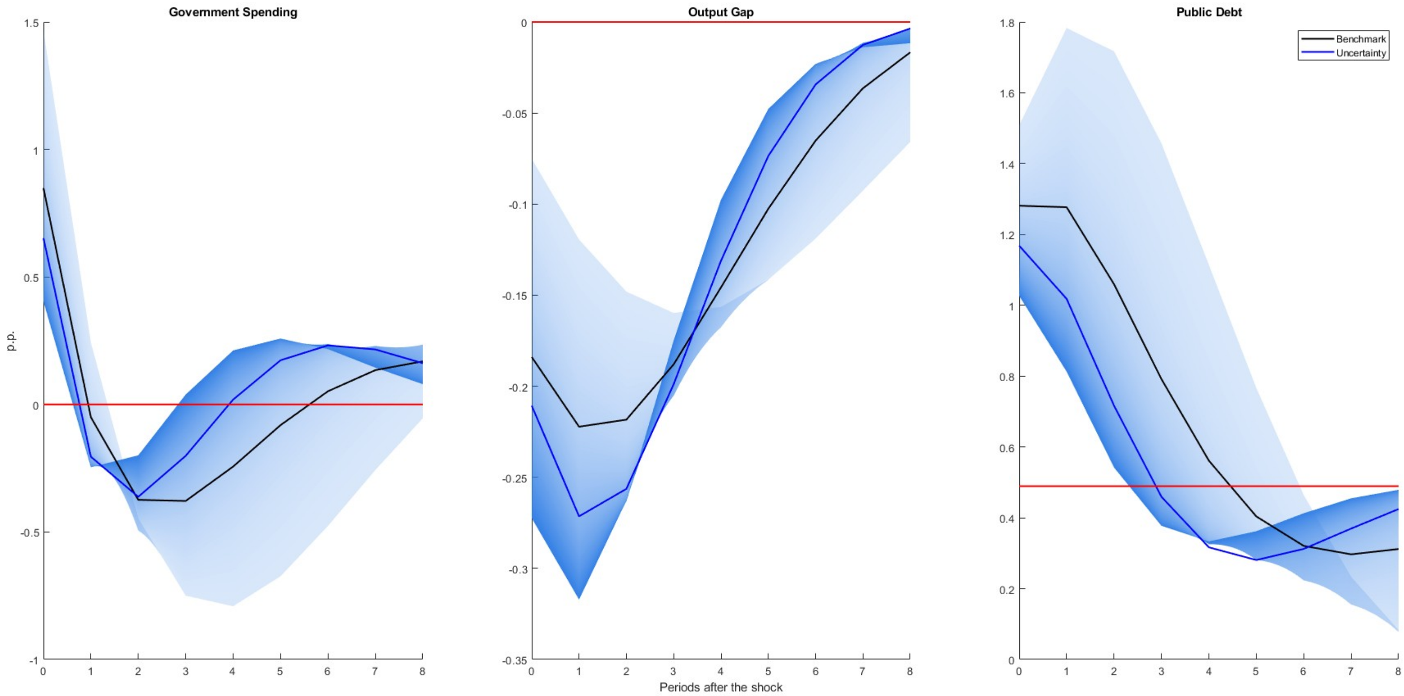
These findings can be rationalized as follows. If the policy maker is uncertainty averse, the worst-case scenario they entertain when optimizing the fiscal response entails a larger negative output gap shock and an excessive accumulation of public debt. However, under the current calibration, the policy maker is more worried about this latter effect, and the government reaction becomes more timid on impact as a result. The resulting effect is an under-reaction to the output gap shock compared to the benchmark, consistent with observations in Section 2. The improved outlook on debt, however, means that the government has additional fiscal capacity in the medium run to maintain higher levels of spending for longer, making thus output gap converge back to 0 to a faster rate.

The previous discussion highlights the dependence of our result on the calibration of the relative weight on debt stabilization in the policy maker's objective function, λ_b. Hence, the effects of uncertainty aversion can be mitigated by fine-tuning this parameter. Figure 4 shows the range of impulse responses of government spending, output gap, and public debt as λ_b varies between 0.005 and 0.1. This shows that the policy maker can replicate the benchmark case of no uncertainty by adjusting the relative preference for debt stabilization, hence triggering a higher and more persistent fiscal response compared to what would otherwise be the case. It is important to note that this does not necessarily mean that this would result in an explosive public debt dynamics because a faster recovery of output leads to a faster increase of tax revenues, implying that public debt stabilizes in the long run.

4 Conclusions

This paper contends that policy makers try to stabilize output, while also attempting to minimize debt accumulation, using output gap estimates as an indicator of the cyclical position of the economy. However, uncertainty surrounding these estimates owing to measurement errors, model specifications, and ex post data revisions could give rise to Type I and II errors, leading to excessive debt accumulation or tipping an economy into recession, respectively. Using data from past WEO vintages, we find a significant dispersion in the forecast errors of real-time estimates for both output gap and fiscal stance. Furthermore, output gap dispersion is significantly higher for EMs than for AEs. Despite this, we find that fiscal policy is counter-cyclical when estimated in real-time,

Figure 4: **Responses to a 1% shock to output gap for $\lambda_b \in [0.005, 0.1]$. Darker blue indicates higher λ_b**



although the responsiveness to output gap shocks is affected by the presence of real-time uncertainty. In particular, such uncertainty reduces the degree of counter-cyclicality of the fiscal reaction function for both income groups.

We rationalize these two facts by building a model of optimal fiscal policy within a New Keynesian general equilibrium framework. When there is uncertainty around output gap estimates and fiscal policy implementation, the model produces less counter-cyclical fiscal responses to output gap shocks compared to the benchmark with no uncertainty. In particular, this means that policy makers tend to undershoot the fiscal response when compared to the benchmark. This suggests that, as output gap uncertainty is a major issue in EMs, fiscal response should be more counter-cyclical than what is observed for these countries. In fact, we show that the benchmark optimal fiscal response to an output gap shock can be replicated by significantly lowering the relative weight that policy makers assign to public debt targeting in favor of output gap stabilization in their objective function. Notably, this does not necessarily imply an explosion of public debt, as public debt tends to stabilize over the long run thanks to a faster recovery of the economy.

The findings in this paper contribute to the debate on the scope and pace of fiscal spending and their impact on output amid rising public debt accumulation, especially with constrained fiscal space. Overall, the results suggest the need for continued caution in relying on the real-time output gap estimate in EMs for policy formulation and implementation, especially where fiscal policy is the main instrument against asymmetric output gap shocks to the economy.

References

Aastveit, K. A., and T. Trovik. 2014. "Estimating the Output Gap in Real Time: A Factor Model Approach." *The Quarterly Review of Economics and Finance* 54 (2): 180–93.

Alesina, A., F. R. Campante, and G. Tabellini. 2008. "Why Is Fiscal Policy Often Procyclical?" *Journal of the European Economic Association* 6 (5): 1006–36.

Barbarino, A., J. T. Berge, H. Chen, and A. Stella. 2020. "Which Output Gap Estimates Are Stable in Real Time and Why?" *Finance and Economics Discussion Series 2020-102.*

Barkema, J., T. Gudmundsson, and M. Mrkaic. 2020. "What Do We Talk about When We Talk about Output Gaps?" *IMF Working Paper WP/20/259.*

Beetsma, R., and M. Giuliodori. 2010. "Fiscal Adjustment to Cyclical Developments in the OECD: An Empirical Analysis Based on Real-Time Data." *Oxford Economic Papers* 62: 419–41.

Benigno, P., and M. Woodford. 2003. "Optimal Monetary and Fiscal Policy: A Linear Quadratic Approach." *NBER Macroeconomics Annual* 18: 271–333.

Bhattacharya, R., and I. Patnaik. 2013. "Credit Constraints, Productivity Shocks and Consumption Volatility in Emerging Economies." *IMF Working Paper No. 2013/120.*

Borio, C., P. Disyatat, and M. Juselius. 2017. "Rethinking Potential Output: Embedding Information about the Financial Cycle." *Oxford Economic Papers* 69 (3).

Brainard, William C. 1967. "Uncertainty and the Effectiveness of Policy." *The American Economic Review* 57: 411–25.

Cheremukhin, A. 2013. "Estimating the Output Gap in Real Time." *Federal Reserve Bank of Dallas Staff Discussion Paper No. 22.*

Cimadomo, J. 2012. "Fiscal Policy in Real Time." *The Scandinavian Journal of Economics* 114 (2): 440–65.

Coibion, O., and Y. Gorodnichenko. 2015. "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts." *American Economic Review* 105 (8): 2644–78.

Coibion, O., Y. Gorodnichenko, and M. Ulate. 2018. "The Cyclical Sensitivity in Estimates of Potential Output." *Brookings Papers on Economic Activity* 49: 343–441.

Currie, D. A., and P. Levine. 1993. *Rules, Reputation and Macroeconomic Policy Coordination.* Cambridge University Press.

Forni, L., and S. Momigliano. 2004. "Cyclical Sensitivity of Fiscal Policies Based on Real-Time Data." *Bank of Italy, Economic Research and International Relations Area* Temi di discussione (Economic working papers) No540.

Galí, J., R. Perotti, P. R. Lane, and W. F. Richter. 2003. "Fiscal Policy and Monetary Integration in Europe." *Economic Policy* 18: 533–72.

Gavin, M., and R. Perotti. 1997. "Fiscal Policy in Latin America." *NBER Chapters, in: NBER Macroeconomics Annual 1997* 12.

Golinelli, R., and S. Momigliano. 2006. "Real-Time Determinants of Fiscal Policies in the Euro Area." *Journal of Policy Modeling* 28: 943–64.

Grigoli, F., A. Herman, A. Swiston, and G. Di Bella. 2015. "Output Gap Uncertainty and Real-Time Monetary Policy." *Russian Journal of Economics* 1: 329–58.

Hallet, H., R. Kattai, and J. Lewis. 2007. "Early Warning or Just Wise After the Event? The Problem of Using Cyclically Adjusted Budget Deficits for Fiscal Surveillance." *CEPR Discussion Paper No. DP6213.*

Hansen, L. P., and T. J. Sargent. 1999. "Robustness and Commitment: A Monetary Policy Example." *Manuscript.*

———. 2008. *Robustness.* Princeton University Press.

Jaimovich, D., and U. Panizza. 2007. "Procyclicality or Reverse Causality?"

Jonung, L., and M. Larch. 2006. "Improving Fiscal Policy in the EU: The Case for Independent Forecasts." *Economic Policy* 21: 491–534.

Kaminsky, G. L., C. M. Reinhart, and C. A. Végh. 2005. "When It Rains, It Pours: Procyclical Capital Flows and Macroeconomic Policies." *NBER Chapters, in: NBER Macroeconomics Annual 2004* 19: 11–82.

Kangur, A., K. Kirabaeva, J-M. Natal, and S. Voigts. 2019. "How Informative Are Real Time Output Gap Estimates in Europe?" *IMF Working Paper No. 19/200.*

Kuusi, T. 2018. "Output Gap Uncertainty and the Optimal Fiscal Policy in the EU." *Review of Economics* 69: 111–46.

Leith, C., and S. Wren-Lewis. 2013. "Fiscal Sustainability in a New Keynesian Model." *Journal of Money, Credit and Banking* 45: 1477–1516.

Ley, E., and F. Misch. 2013. "Real-Time Macro Monitoring and Fiscal Policy." *Policy Research Working Paper No. 6303, World Bank.*

Maccheroni, F., M. Marinacci, and A. Rustichini. 2006. "Ambiguity Aversion, Robustness, and the Variational Representation of Preferences." *Econometrica* 74: 1447–98.

Marcellino, M., and A. Musso. 2011. "The Reliability of Real-Time Estimates of the Euro-Area Output Gap." *Economic Modelling* 28: 1842–56.

Marioli, F. A., and C. A. Vegh. 2023. "Fiscal Procyclicality in Commodity Exporting Countries: How Much Does It Pour and Why?" *NBER Working Paper Series No. 31431.*

Orphanides, A. 2001. "Monetary Policy Rules Based on Real-Time Data." *American Economic Review* 91: 964–85.

Orphanides, A., and S. van Norden. 2002. "The Unreliability of Output Gap Estimates in Real Time." *The Review of Economics and Statistics* 84: 569–83.

Talvi, E., and C. A. Vegh. 2005. "Tax Base Variability and Procyclical Fiscal Policy in Developing Countries." *Journal of Development Economics* 78: 156–90.

Vines, D. A., and S. J. Stehn. 2007. "Debt Stabilization Bias and the Taylor Principle: Optimal Policy in a New Keynesian Model with Government Debt and Inflation Persistence." *IMF Working Paper No. 2007/206*.

Vitek, F. 2023. "Measuring the Stances of Monetary and Fiscl Policy." *IMF Working Paper No. 2023/106*.

Woodford, M. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press.

———. 2010. "Robustly Optimal Monetary Policy with Near-Rational Expectations." *The American Economic Review* 100: 274–303.

Appendix

Fiscal Reaction Function Robustness Checks

Table 6 shows the full results of the estimation of Equation (11) using a country fixed effects model, whereas Table 7 shows the results from random effects models. Columns (1) and (2) show strong counter-cyclical behavior of fiscal policy on impact for both AEs and EMs, with the former group being more counter-cyclical than the latter. However, contrary to the fixed effect models estimated in Section 2.3, we find that fiscal policy is much more persistent, with a very high autoregressive coefficient. Furthermore, we also find that EMs are prone to consolidating their balance once they are hit by an output gap shock: their cyclically adjusted primary balance moves in the opposite direction of the lagged output gap.

The Hausman test statistic rejects the use of random effect models for the two symmetric specifications of Equations (11), although it does not for the specification including potential asymmetries, as shown in Table 8. However, we think it is important to capture country-specific differences even in the case that would deliver a statistically inefficient result. Hence we prefer fixed effects models reported in Table 4.

An alternative way to account for the impact of initial conditions on fiscal reactions is given by Golinelli and Momigliano (2006), who estimate the Equation (40)

$$\Delta CAPB_{i,t|t+S} = \alpha + \rho CAPB_{i,t-1|t+S} + \beta GAP_{i,t-1|t+S} + X'_{i,t|t+S}\gamma + \epsilon_{i,t} \tag{40}$$

where we collected the proxy for the fiscal space in the vector X.

Table 9 shows the results of the estimation. Fiscal policy appears to be more history-dependent for EMs, as the coefficient on lagged CAPB-to-GDP is twice the one for AEs in both specifications.

Table 6: **Real-time fiscal reaction functions, Fixed Effects models.**

	Dependent variable:			
	Cyclically adjusted primary balance-to-GDP			
	(1)	(2)	(3)	(4)
$CAPB_{t-1}$	0.340***	0.332***	0.327***	0.179***
	(0.052)	(0.054)	(0.055)	(0.059)
GAP	0.572***	0.680***	0.872***	0.723**
	(0.055)	(0.079)	(0.102)	(0.304)
U^{GAP}		−0.644*	−0.665*	−0.598*
		(0.372)	(0.365)	(0.362)
U^{CAPB}		0.157*	0.187**	0.261***
		(0.091)	(0.093)	(0.089)
INT/GDP_{t-1}	0.949***	1.044***	0.999***	0.649***
	(0.195)	(0.201)	(0.204)	(0.247)
Election Year_{t+1}	−0.074	0.087	0.117	0.184
	(0.214)	(0.229)	(0.230)	(0.220)
Corruption Perception	−0.138***	−0.151***	−0.138***	−0.098*
	(0.050)	(0.051)	(0.052)	(0.051)
EM			−0.655	−0.168
			(1.987)	(1.925)
$GAP \times U^{GAP}$		−0.131**	−0.151***	−0.132**
		(0.057)	(0.059)	(0.062)
$GAP \times U^{CAPB}$		0.027	0.031*	0.048***
		(0.017)	(0.017)	(0.016)
$EM \times GAP$			−0.358***	−0.416***
			(0.132)	(0.129)
Observations	423	423	423	423
R^2	0.362	0.366	0.366	0.060
Adjusted R^2	0.244	0.240	0.236	−0.156
F Statistic	228.477***	232.575***	241.247***	43.853***

*p<0.1; **p<0.05; ***p<0.01

Table 7: **Real-time fiscal reaction functions, Random Effects models.**

	Dependent variable:		
	Cyclically adjusted primary balance-to-GDP		
	(1)	(2)	(3)
$CAPB_{t-1}$	0.752***	0.742***	0.728***
	(0.039)	(0.039)	(0.041)
GAP	0.507***	0.465***	0.722***
	(0.059)	(0.078)	(0.103)
U^{GAP}		−0.206	−0.106
		(0.378)	(0.384)
U^{CAPB}		−0.047	0.014
		(0.074)	(0.079)
INT/GDP_{t-1}	0.440***	0.432***	0.411***
	(0.085)	(0.086)	(0.088)
Election Year_{t+1}	−0.006	0.042	0.029
	(0.230)	(0.235)	(0.240)
Corruption Perception	0.002	0.003	0.013
	(0.006)	(0.006)	(0.010)
EM			−0.978**
			(0.429)
$GAP \times U^{GAP}$		−0.027	−0.033
		(0.056)	(0.058)
$GAP \times U^{CAPB}$		−0.001	0.009
		(0.014)	(0.015)
$EM \times GAP$			−0.453***
			(0.133)
Constant	−0.716	−0.652	0.429
	(0.450)	(0.467)	(0.807)
Observations	423	423	423
R^2	0.527	0.545	0.539
Adjusted R^2	0.521	0.535	0.526
F Statistic	513.365***	535.376***	537.642***

*p<0.1; **p<0.05; ***p<0.01

Table 8: **Hausman test: Fixed vs Random Effect models for Equation (11).**

	(1)	(2)	(3)
Statistic	122.878	162.98	159.146
p-value	0.000	0.00	0.000

Table 9: **Real-time fiscal reaction functions according to Equation (40).**

	Dependent variable:		
	Δ Cyclically adjusted primary balance-to-GDP		
	(1)	(2)	(3)
$CAPB_{t-1}$	−0.663***	−0.668***	−0.673***
	(0.052)	(0.054)	(0.055)
GAP	0.612***	0.680***	0.872***
	(0.057)	(0.079)	(0.102)
U^{GAP}		−0.644*	−0.665*
		(0.372)	(0.365)
U^{CAPB}		0.157*	0.187**
		(0.091)	(0.093)
INT/GDP_{t-1}	0.933***	1.044***	0.999***
	(0.198)	(0.201)	(0.204)
Election Year_{t+1}	−0.082	0.087	0.117
	(0.216)	(0.229)	(0.230)
Corruption Perception	−0.137***	−0.151***	−0.138***
	(0.051)	(0.051)	(0.052)
EM			−0.655
			(1.987)
$GAP \times U^{GAP}$		−0.131**	−0.151***
		(0.057)	(0.059)
$GAP \times U^{CAPB}$		0.027	0.031*
		(0.017)	(0.017)
$EM \times GAP$			−0.358***
			(0.132)
Observations	423	423	423
R^2	0.411	0.419	0.418
Adjusted R^2	0.302	0.304	0.299
F Statistic	282.859***	284.401***	292.032***

*p<0.1; **p<0.05; ***p<0.01

Model Solution

Household Problem

The Lagrangian for the unconstrained household is:

$$\max_{\{(C^U)_t, B_t^n, (N^U)_t\}_t} \mathbb{E}_0 \sum_{t\geq 0} \beta^t \{ \frac{(C_t^U)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{(N_t^U)^{1+\varphi}}{1+\varphi} \tag{41}$$

$$+ \Lambda_t^U [-P_t C_t^U - B_t^n + (1+i_{t-1})B_{t-1}^n + (1-\tau)(W_t N_t^U + \Theta_t)]\} \tag{42}$$

Then, the FOC are

$$\begin{aligned} &(C_t^U)^{-\frac{1}{\sigma}} - P_t \Lambda_t^U = 0 && (C_t^U) \\ &-\Lambda_t^U + \beta(1+i_t)\Lambda_{t+1}^U = 0 && (B_t^n) \\ &-(N_t^U)^{\varphi} + \Lambda_t^U (1-\tau) W_t = 0 && (N_t^U) \end{aligned}$$

Combining the three equations yields the Euler equation and the labor supply:

$$\beta \mathbb{E}_t \left[\left(\frac{C_{t+1}^U}{C_t^U} \right)^{-\frac{1}{\sigma}} \frac{(1+i_t)}{\Pi_{t+1}} \right] = 1 \tag{43}$$

$$(C_t^U)^{\frac{1}{\sigma}} (N_t^U)^{\varphi} = (1-\tau) \frac{W_t}{P_t} \tag{44}$$

As for the constrained household, his Lagrangian is:

$$\max_{\{C_t^C, N_t^C\}_t} \frac{(C^C)_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{(N^C)_t^{1+\varphi}}{1+\varphi} + \Lambda_t^C [-P_t C_t^C + (1-\tau)(W_t N_t^C + \Theta_t)] \tag{45}$$

The FOC

$$\begin{aligned} &(C_t^C)^{-\frac{1}{\sigma}} - P_t \Lambda_t^C = 0 && (C_t^C) \\ &-(N_t^C)^{\varphi} + \Lambda_t^C (1-\tau) W_t = 0 && (N_t^C) \end{aligned}$$

yielding the labor supply curve:

$$(C_t^C)^{\frac{1}{\sigma}} (N_t^C)^{\varphi} = (1-\tau) \frac{W_t}{P_t} \tag{46}$$

Final Good Producer

The problem of the final good producer is:

$$\min_{(Y_t(i))_i} \int P_t(i)Y_t(i)di \tag{47}$$

subject to

$$\left(\int Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}di\right)^{\frac{\varepsilon}{\varepsilon-1}} = Y_t \tag{48}$$

Hence, the Lagrangian is:

$$\min_{\{Y_t(i)\}_i} \int P_t(i)Y_t(i)di + \Lambda_t^f \left[Y_t - \left(\int Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}di\right)^{\frac{\varepsilon}{\varepsilon-1}}\right] \tag{49}$$

Taking the FOC:

$$\begin{aligned}
P_t(i) - \Lambda_t^f Y_t(i)^{-\frac{1}{\varepsilon}} Y_t^{\frac{1}{\varepsilon}} &= 0 \qquad \forall i \\
\frac{P_t(i)}{P_t(j)} &= \left(\frac{Y_t(i)}{Y_t(j)}\right)^{-\frac{1}{\varepsilon}} \\
Y_t(i) &= \left(\frac{P_t(i)}{P_t(j)}\right)^{-\varepsilon} Y_t(j) \\
Y_t(i)P_t(j)^{-\varepsilon} &= P_t(i)^{-\varepsilon}Y_t(j) \\
Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} P_t(j)^{-(\varepsilon-1)} &= P_t(i)^{-(\varepsilon-1)} Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}}
\end{aligned}$$

Integrating both sides in dj yields:

$$\begin{aligned}
Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} \int P_t(j)^{-(\varepsilon-1)}dj &= P_t(i)^{-(\varepsilon-1)} Y_t^{\frac{\varepsilon-1}{\varepsilon}} \\
Y_t(i) &= \left(\frac{P_t(i)}{(\int P_t(j)^{1-\varepsilon}dj)^{\frac{1}{1-\varepsilon}}}\right)^{-\varepsilon} Y_t
\end{aligned}$$

Since the final good producer is perfectly competitive, she makes 0 profits. Hence, the no-profit condition pins down the price index P_t:

$$P_tY_t = \int P_t(i)Y_t(i)di = \int P_t(i)\left(\frac{P_t(i)}{(\int P_t(j)^{1-\varepsilon}dj)^{\frac{1}{1-\varepsilon}}}\right)^{-\varepsilon} diY_t$$

$$P_t = \frac{\int P_t(i)^{1-\varepsilon}di}{(\int P_t(j)^{1-\varepsilon}dj)^{\frac{\varepsilon}{1-\varepsilon}}} = \left(\int P_t(i)^{1-\varepsilon}di\right)^{1-\frac{\varepsilon}{1-\varepsilon}} = \left(\int P_t(i)^{1-\varepsilon}di\right)^{\frac{1}{1-\varepsilon}} \tag{50}$$

The individual demand for input i is thus:

$$Y_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t \tag{51}$$

Intermediate Goods Producers

The reset price problem of the intermediate good producers is

$$\max_{\{P_t^*(i)\}} \sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} \left[\frac{P_t^*(i) Y_{t+s}(i)}{P_{t+s}} - \frac{TC_{t+s}(i)}{P_{t+s}}\right] \tag{52}$$

subject to

$$Y_{t+s}(i) = \left(\frac{P_t^*(i)}{P_{t+s}}\right)^{-\varepsilon} Y_{t+s} \tag{53}$$

where $TC_{t+s}(i) = \frac{W_{t+s} Y_{t+s}(i)}{A_{t+s}}$, and hence $MC_{t+s}(i) = MC_{t+s} = \frac{W_{t+s}}{A_{t+s}}$ and $\Lambda_{t,t+s}$ is the stochastic discount factor of the unconstrained household, that is the ratio between marginal utility of consumption at time $t+s$ and t. This is because the ownership of the firms is held by the households, and the unconstrained type is the only one concerned with dynamics.

The solution is then given by:

$$\sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} \left[\frac{Y_{t+s}(i)}{P_{t+s}} + \frac{P_t^*(i)}{P_{t+s}} \frac{\partial Y_{t+s}(i)}{\partial P_t^*(i)} - \frac{MC_{t+s}}{P_{t+s}} \frac{\partial Y_{t+s}(i)}{\partial P_t^*(i)}\right] = 0$$

$$\frac{\partial Y_{t+s}(i)}{\partial P_t^*(i)} = -\varepsilon \frac{P_t^*(i)^{-\varepsilon-1}}{P_{t+s}^{-\varepsilon}} Y_{t+s}$$

$$\sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} \left[\left(\frac{P_t^*(i)}{P_{t+s}}\right)^{-\varepsilon} \frac{Y_{t+s}(i)}{P_{t+s}} - \varepsilon \frac{P_t^*(i)^{-\varepsilon}}{P_{t+s}^{-\varepsilon}} \frac{Y_{t+s}}{P_{t+s}} + MC_{t+s} \varepsilon \frac{P_t^*(i)^{-\varepsilon-1}}{P_{t+s}^{-\varepsilon}} \frac{Y_{t+s}}{P_{t+s}}\right] = 0$$

$$\sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} \left[(1-\varepsilon) P_{t+s}^{\varepsilon-1} Y_{t+s} + \varepsilon MC_{t+s} P_t^*(i)^{-1} P_{t+s}^{\varepsilon-1} Y_{t+s}\right] = 0$$

$$P_t^*(i) = \frac{\varepsilon}{\varepsilon-1} \frac{\sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} MC_{t+s} P_{t+s}^{\varepsilon-1} Y_{t+s}}{\sum_{s\geq 0} \vartheta^s \Lambda_{t,t+s} P_{t+s}^{\varepsilon-1} Y_{t+s}} = P_t^* \tag{54}$$

Let $X_t^{aux,1}$ and $X_t^{aux,2}$:

$$X_t^{aux,1} = MC_t P_t^{\varepsilon-1} Y_t + \vartheta \Lambda_{t,t+1} X_{t+1}^{aux,1} \tag{55}$$

$$X_t^{aux,2} = P_t^{\varepsilon-1} Y_t + \vartheta \Lambda_{t,t+1} X_{t+1}^{aux,2} \tag{56}$$

Then the optimal reset price becomes:

$$P_t^* = \frac{\varepsilon}{\varepsilon-1} \frac{X_t^{aux,1}}{X_t^{aux,2}} \tag{57}$$

Hence, aggregating all prices into the price index:

$$
\begin{aligned}
P_t &= \left(\int P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} \\
&= \left((1-\theta) P_t^{*1-\varepsilon} + \theta P_{t-1}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}
\end{aligned}
$$

Hence we can write aggregate inflation as

$$
\begin{aligned}
\Pi_t &= \left((1-\theta) \left(\frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon} + \theta \right)^{\frac{1}{1-\varepsilon}} \\
&= \left((1-\theta) \left(\Pi_t^* \Pi_t \right)^{1-\varepsilon} + \theta \right)^{\frac{1}{1-\varepsilon}} \qquad \Pi_t^* = \frac{P_t^*}{P_t}
\end{aligned}
$$

Let $\tilde{X}_t^{aux,1} = \frac{X_t^{aux,1}}{P_t^{\varepsilon}}$ and $\tilde{X}_t^{aux,2} = \frac{X_t^{aux,2}}{P_t^{\varepsilon-1}}$. Let $MC_t^r = \frac{MC_t}{P_t}$. Then

$$
1 = (1-\theta) \left(\Pi_t^* \right)^{1-\varepsilon} + \theta \Pi_t^{\varepsilon-1} \tag{58}
$$

$$
\begin{aligned}
\Pi_t^* &= \frac{\varepsilon}{\varepsilon - 1} \frac{\tilde{X}_t^{aux,1}}{\tilde{X}_t^{aux,2}} && (59) \\
\tilde{X}_t^{aux,1} &= MC_t^r Y_t + \theta \Lambda_{t,t+1} \Pi_{t+1}^{\varepsilon} \tilde{X}_{t+1}^{aux,1} && (60)
\end{aligned}
$$

$$
\tilde{X}_t^{aux,2} = Y_t + \theta \Lambda_{t,t+1} \Pi_{t+1}^{\varepsilon-1} \tilde{X}_{t+1}^{aux,2} \tag{61}
$$

Equilibrium

The goods market equilibrium condition reads:

$$
C_t^C + C_t^U + G_t = Y_t
$$

Since

$$
\begin{aligned}
P_t C_t^C &= (1-\tau)(W_t N_t^C + \phi^C \Theta_t) \\
&= (1-\tau)\phi^C (W_t N_t + P_t Y_t - W_t N_t) \\
&= (1-\tau)\phi^C P_t Y_t
\end{aligned}
$$

we conclude that:

$$
\phi^C (1-\tau) Y_t + C_t^U + G_t = Y_t
$$

$$
C_t^U + G_t = (1 - (1-\tau)\phi^C) Y_t \tag{62}
$$

Let $N_t = \int N_t(i) di$ be the total demand for labor of intermediate goods firms. Then, labor market clearing implies:

$$
\begin{aligned}
N_t &= N_t^U + N_t^C \\
&= \left((1-\tau)\frac{W_t}{P_t}(C_t^U)^{-\frac{1}{\sigma}}\right)^{\frac{1}{\varphi}} + \left((1-\tau)\frac{W_t}{P_t}(C_t^C)^{-\frac{1}{\sigma}}\right)^{\frac{1}{\varphi}} \\
&= \left((1-\tau)\frac{W_t}{P_t}\right)^{\frac{1}{\varphi}} [(C_t^U)^{-\frac{1}{\sigma\varphi}} + (C_t^C)^{-\frac{1}{\sigma\varphi}}]
\end{aligned}
$$

$$
[(C_t^U)^{-\frac{1}{\sigma\varphi}} + (C_t^C)^{-\frac{1}{\sigma\varphi}}]^{-\varphi} N_t^{\varphi} = (1-\tau)\frac{W_t}{P_t} \tag{63}
$$

Log-linearization

The economy is log-linearized around the non-inflationary steady state, i.e. $\Pi_{ss} = 1$ and $Y_{ss} = Y_{ss}^p$.

The Euler equation (43) is log-linearized as:

$$
c_t^U = \mathbb{E}_t c_{t+1}^U - \sigma(i_t - \mathbb{E}_t \pi_{t+1} - \rho) \tag{64}
$$

Equation (**??**) for goods market clearing implies the dynamic IS curve in the main text.

Log-linearizing equations (58) to (61) we obtain

$$
\begin{aligned}
0 &= (1-\vartheta)(1-\varepsilon)(\Pi^*)^{-\varepsilon}\pi_t^* + \vartheta(\varepsilon-1)(\Pi)^{\varepsilon}\pi_t \implies \pi_t^* = \frac{\vartheta}{1-\vartheta}\pi_t \\
\pi_t^* &= \tilde{x}_t^{aux,1} - \tilde{x}_t^{aux,2} \\
\tilde{x}_t^{aux,1} &= \frac{MC^r Y}{X^{aux,1}}\hat{mc}_t + \frac{MC^r Y}{X^{aux,1}} y_t + \vartheta\beta\tilde{x}_{t+1}^{aux,1} + \vartheta\beta\lambda_{t,t+1} + \varepsilon\vartheta\beta\mathbb{E}_t\pi_{t+1} \\
&= (1-\vartheta\beta)\hat{mc}_t + (1-\vartheta\beta)y_t + \vartheta\beta\tilde{x}_{t+1}^{aux,1} + \vartheta\beta\lambda_{t,t+1} + \varepsilon\vartheta\beta\mathbb{E}_t\pi_{t+1} \\
\tilde{x}_t^{aux,2} &= \frac{Y}{X^{aux,2}} y_t + \vartheta\beta\tilde{x}_t^{aux,2} + \vartheta\beta\lambda_{t,t+1} + (\varepsilon-1)\vartheta\beta\mathbb{E}_t\pi_{t+1} \\
&= (1-\vartheta\beta)y_t + \vartheta\beta\tilde{x}_t^{aux,2} + \vartheta\beta\lambda_{t+1} + (\varepsilon-1)\vartheta\beta\mathbb{E}_t\pi_{t+1}
\end{aligned}
$$

Combining all of the equations above we obtain:

$$
\begin{aligned}
\frac{\vartheta}{1-\vartheta}\pi_t =& (1-\vartheta\beta)\hat{mc}_t + (1-\vartheta\beta)y_t + \vartheta\beta\tilde{x}_{t+1}^{aux,1} + \vartheta\beta\lambda_{t,t+1} + \varepsilon\vartheta\beta\mathbb{E}_t\pi_{t+1} - \\
& (1-\vartheta\beta)y_t - \vartheta\beta\tilde{x}_t^{aux,2} - \vartheta\beta\lambda_{t,t+1} - (\varepsilon-1)\vartheta\beta\mathbb{E}_t\pi_{t+1} \\
=& (1-\vartheta\beta)\hat{mc}_t + \vartheta\beta(x_{t+1}^{aux,1} - x_{t+1}^{aux,2}) + \vartheta\beta\mathbb{E}_t\pi_{t+1} \\
=& (1-\vartheta\beta)\hat{mc}_t + \vartheta\beta\pi_{t+1}^* + \vartheta\beta\mathbb{E}_t\pi_{t+1} \\
=& (1-\vartheta\beta)\hat{mc}_t + \frac{\vartheta\beta}{1-\vartheta}\pi_{t+1} \\
\pi_t =& \frac{(1-\vartheta)(1-\vartheta\beta)}{\vartheta}\hat{mc}_t + \beta\pi_{t+1}
\end{aligned}
$$

The relevant log-linearized equations of the supply side are therefore:

$$\pi_t = \psi \hat{mc}_t + \beta \mathbb{E}_t \pi_{t+1} \tag{65}$$

$$\hat{mc}_t = w_t - a_t \tag{66}$$

The log linearized equilibrium conditions are:

$$(1-\phi^C)(1-\gamma)c_t^U + \gamma g_t = (1-(1-\tau)\phi^C)y_t \tag{67}$$

$$\sigma^{-1}\left[\frac{(\phi^C)^{-\frac{1}{\sigma\varphi}}c_t^C + (1-\phi^C)^{-\frac{1}{\sigma\varphi}}c_t^U}{(\phi^C)^{-\frac{1}{\sigma\varphi}} + (1-\phi^C)^{-\frac{1}{\sigma\varphi}}}\right] + \varphi n_t = w_t \tag{68}$$

$$y_t = a_t + n_t \tag{69}$$

Let's label $\Phi^C = \frac{(\phi^C)^{-\frac{1}{\sigma\varphi}}}{(\phi^C)^{-\frac{1}{\sigma\varphi}} + (1-\phi^C)^{-\frac{1}{\sigma\varphi}}}$. Hence, combining Equations (66), (67), (68), (69), we obtain a modified Phillips curve:

$$\begin{aligned}\hat{mc}_t &= \sigma^{-1}[\Phi^C c_t^C + (1-\Phi^C)c_t^U] + \varphi n_t - a_t && (70)\\ &= \left[\sigma^{-1}\left(\Phi^C + \frac{1-(1-\tau)\Phi^C}{(1-\gamma)}\right) + \varphi\right] y_t - \sigma^{-1}\frac{\gamma}{(1-\gamma)} g_t - (1+\varphi)a_t && (71)\end{aligned}$$

When prices are perfectly flexible we have that $\hat{mc}_t = 0$, which in turn means

$$y_t^n = \left[\sigma^{-1}\left(\Phi^C + \frac{1-(1-\tau)\Phi^C}{(1-\gamma)}\right) + \varphi\right]^{-1} \left[\sigma^{-1}\frac{\gamma}{(1-\gamma)} g_t + (1+\varphi)a_t\right] \tag{72}$$

By setting $y_t^p = \left[\sigma^{-1}\left(\Phi^C + \frac{1-(1-\tau)\Phi^C}{(1-\gamma)}\right) + \varphi\right]^{-1}(1+\varphi)a_t$, $\hat{y}_t = y_t - y_t^p$ and $\hat{g}_t = g_t - y_t^p$ we have

$$\pi_t = \kappa \hat{y}_t - \kappa^g \hat{g}_t + \beta \mathbb{E}_t \pi_{t+1} \tag{73}$$

Furthermore, we can add and subtract y_t^p and $\mathbb{E}_t y_{t+1}^p$ from the dynamic IS curve we get

$$\begin{aligned}y_t - y_t^p + y_t^p =& \mathbb{E}_t[y_{t+1} - y_{t+1}^p] + \mathbb{E}_t y_{t+1}^p + \mu^g(g_t - y_t^p - \mathbb{E}_t[g_{t+1} - y_{t+1}^p]) && (74)\\ &+ \mu^g(y_t^p - \mathbb{E}_t y_{t+1}^p) - \chi(i_t - \mathbb{E}_t\pi_{t+1} - \rho) && (75)\\ \hat{y}_t =& \mathbb{E}_t\hat{y}_{t+1} + \mu^g(\hat{g}_t - \mathbb{E}_t\hat{g}_{t+1}) - \chi(i_t - \mathbb{E}_t\pi_{t+1} - \rho) + (1-\mu^g)\mathbb{E}_t\Delta y_{t+1}^p && (76)\end{aligned}$$

Let $\hat{B}_t = \frac{B_t}{Y_t^p}$. Then, rewriting debt accumulation dynamics in terms of this ratio yields:

$$\hat{B}_t = \frac{Y_t^p}{Y_{t+1}^p}\frac{1+i_{t-1}}{\Pi_t}\hat{B}_{t-1} + \frac{G_t}{Y_t^p} - \tau\frac{Y_t}{Y_t^p} \tag{77}$$

Log-linearization around non-inflationary steady state:

$$\hat{B}\hat{b}_t = (1+i)\hat{B}\hat{b}_{t-1} + (1+i)\hat{B}(i_{t-1} - \pi_t - \rho) + \gamma\hat{g}_t - \tau\hat{y}_t - (1+i)\hat{B}\Delta y_t^p$$
$$\beta\hat{b}_t = \hat{b}_{t-1} + \beta\frac{\gamma}{\hat{B}}\hat{g}_t - \beta\frac{\tau}{\hat{B}}\hat{y}_t + (i_{t-1} - \pi_t - \rho) - \Delta y_t^p$$

with $1 + i = \beta^{-1}$. Let $\delta = \hat{B}^{-1} = \frac{Y}{B}$. Then:

$$\beta\hat{b}_t = \hat{b}_{t-1} + \beta\delta(\gamma\hat{g}_t - \tau\hat{y}_t) + (i_{t-1} - \pi_t - \rho) - \Delta y_t^p \tag{78}$$