Mind the Gap!—A Monetarist View of the Open-Economy Phillips Curve

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Abstract

In many countries, inflation has become less responsive to domestic factors and more responsive to
global factors over the past decades. We study the linkages between domestic inflation and global liquidity
(money and household balances) and argue that it is important for inflation modeling and forecasting. We
introduce money and credit markets into the workhorse open-economy New Keynesian model. With this
framework, we show that: (i) an efficient forecast of domestic inflation must be based solely on domestic
and foreign slack, and (ii) global liquidity (either global money or global credit) is tied to global slack in
equilibrium. Then, motivated by the theory, we empirically evaluate the performance of open-economy
Phillips curve-based forecasts constructed using global liquidity measures (such as G7 credit growth and
G7 money supply growth) instead of global slack as predictive regressors. Using 50 years of quarterly
data, we document that these global liquidity variables perform significantly better than the domestic
variable counterparts and outperform in practice the poorly-measured indicators of global slack that global
liquidity proxies for.

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1 Introduction

This paper studies the linkages between inflation, global money, and global credit growth, in a framework that can be considered a novel interpretation of the open-economy Phillips curve—one that is reminiscent of the monetarist view. In this framework, liquidity growth is tied to the output gap at the global level, which has implications on inflation modeling and forecasting both in the short run and long run.

Forecasting inflation—accurately and reliably—plays a critical role for policy-making and for the decisions of the private sector in making long-term nominal commitments. In macroeconomic analysis and inflation forecasting, the traditional Phillips curve has been a widely used model that broadly captures the empirical relationship between inflation and unemployment rate, capacity utilization or output gap.

As documented by Atkeson and Ohanian (2001), the Phillips curve has flattened since the mid-1980s. Their finding was that the Phillips curve-based models did not yield more accurate forecasts than the naïve, 4-quarter random walk benchmark. Stock and Watson (2007) emphasized the role of lower volatility in inflation in the U.S. and in the world during this period. Forecasts under a Phillips curve specification have become, in turn, less accurate by the MSFE metric. A survey by Stock and Watson (2008) suggests recent forecasts based on economic models, including the Phillips curve, only occasionally performed well. This paper is motivated by this Atkeson and Ohanian (2001) puzzle and the literature related to it, considering their work a key threshold in forecasting inflation using Phillips curves in reduced form.¹

A prominent explanation to the break in the Phillips curve that is suggested in the literature is globalization—the integration of global markets in goods, labor, and capital. The recent literature postulates the ‘global slack hypothesis’, i.e. the hypothesis that foreign slack, as well as domestic slack, drives domestic inflation in the short-run, as a way to reconcile the Phillips curve relationship with the evidence in an increasingly more integrated world. The nexus between globalization, inflation, and monetary policy, in a relatively broad sense, has been discussed in academic and policy circles. Bernanke (2007), González-Páramo (2008), Mishkin (2007), Papademos (2007), Rogoff (2006), and Weber (2007) argued that globalization might have altered the inflation process, and moreover, monetary policy decisions might be affected by global economic conditions particularly in the short and medium runs.² Draghi (2015) pointed out the importance of global factors in a relatively recent speech:

"Over the last decade there has been a growing interest in the concept of “global inflation”.

This is the notion that, in a globalised world, inflation is becoming less responsive to domestic economic conditions, and is instead increasingly determined by global factors."

While Draghi (2015)’s speech hinged on the information content of global inflation for domestic inflation (see e.g. Ciccarelli and Mojon (2010)), there is still little work on how inflation is driven by global factors,

¹See also D’Agostino et al. (2006), and Rossi and Sekhposyan (2010), documenting a deterioration in inflation forecasts based on measures of economic activity during the Great Moderation. Moreover, Edge and Gürkaynak (2010), report an analogous result on the performance of inflation forecasts based on a medium-scale Dynamic Stochastic General Equilibrium (DSGE) framework during this period.

²It is important to note that while globalization might have challenged central banks with more complicated macroeconomic issues compared to the case of a closed economy, its impact on inflation should nevertheless be viewed as a complementary channel to monetary policy, rather than an alternative. See also Fisher (2005), Fisher (2006), and Woodford (2010) for further discussion on globalization and monetary policy.
and the theory behind it. In light of this, we study the modeling and forecasting of U.S. inflation based on the open-economy Phillips curve specification.

A major caveat with the open-economy Phillips curve is to find a reliable measure of the output gap—in general, the potential output is difficult to estimate for any given country. Moreover, most foreign output gap series can be too short and the macroeconomic data may not be reliable (see Martínez-García and Wynne (2010)). We argue that the lack of reliable and long enough global slack series might have shadowed the findings in the empirical literature, thereby giving little credit to the role of globalization on inflation.

One of our key contributions is to address the role of global factors on domestic inflation, by suggesting alternative specifications to the open-economy Phillips curve where the measurement problem with slack can be circumvented. We suggest proxies for global slack such as (i) the global money supply growth and (ii) global credit growth, using a fairly standard, two-country New Keynesian model with money and credit markets. The framework can be considered an extension to the (closed-economy) money-in-the-utility New Keynesian model in Galí (2008) where households can gain utility from real credit as well as cash balances. This captures the demand side of the money and credit market. We model the supply side of the market based on the balanced sheets of the monetary authority and the banking system. With a role for credit, our paper contributes to the theoretical understanding of the linkages between inflation, global economic activity and global liquidity which has not been studied in earlier open-economy New Keynesian models such as Kabukcuoglu and Martínez-García (2018), as well as other related open-economy NK models such as the model of Clarida et al. (2002).

In this setting, a key theoretical result is that no other measures than domestic and foreign output gap would help improve the forecasts of (changes) in the U.S. inflation. In other words, the efficient inflation forecast for an open economy should be based on the domestic and foreign output gap. We then show in this model that the nominal measures of (i) global money gap and (ii) global credit gap are proportional to the global output gap. This result turns out to be valuable and informative for inflation forecasting where global output gap is hard to obtain or construct in practice. We then test the pseudo out-of-sample predictive performance of these alternative Phillips curves based on global money and credit growth and document strong predictive performance for U.S. inflation, especially after the mid-1980s, where closed-economy measures have not performed well.

In our empirical forecasting exercises, we use these theoretical insights from the New Keynesian model to come up with proxies of global slack, and then follow Stock and Watson (2003) and more closely D’Agostino and Surico (2009). In particular, we rely on single-equation "economic models" to test the predictive performance of the global money and credit gap measures, using the autoregression of inflation as the benchmark. These global measures are simply the arithmetic averages of first-differenced money or nonfinancial credit

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3Complementing the findings of Ciccarelli and Mojon (2010), Kabukcuoglu and Martínez-García (2018) suggest an open-economy Phillips curve interpretation where the global output gap can be proxied by global inflation and the domestic output gap. The good predictive performance of global inflation can therefore be understood through the lens of the open-economy Phillips curve, going beyond a solely statistical relationship between domestic and global inflation.

4There is supportive work on the theoretical linkage between inflation and global economic activity, such as Binyamini and Razin (2007), and Martínez-García and Wynne (2010). The empirical evidence however, is somewhat inconclusive. Accordingly Borio and Filardo (2007) and Bianchi and Civelli (2015) provide supportive evidence while Ball (2006), Ihrig et al. (2007), Pain et al. (2006) find empirical results that do not support the global slack hypothesis. Milani (2010) and Milani (2012), among others, argue that the foreign economic activity has a role on domestic supply and demand, but its effect on domestic inflation is negligible, finding weak evidence for the global slack hypothesis.

Eickmeier and Pijnenburg (2013) showed evidence from 24 OECD countries that the common component of changes in unit labor costs has an important effect on inflation. They also consider movements in import price inflation, world interest rate as well as foreign competition and found that these global variables affect inflation.
series from G7 countries.

Our empirical investigation involves five decades of quarterly data under different specifications of the open-economy Phillips curve. We conduct pseudo out-of-sample forecasts for CPI and PCE measures of U.S. inflation at horizons 1, 4 and 12-quarters ahead. Our estimation and forecast periods include 80 quarters of data for each period. We go back as far as 1959:Q4 and perform forecasts under various subsamples shifting our starting date by one observation, until no more data are available (in general, until 2017:Q1).

Our metric for forecast accuracy is the MSFE of a reduced form of a new open-economy Phillips curve with distributed lags of inflation and any of the measures of slack that we investigate, relative to the MSFE of the ‘restricted’ forecast derived from a univariate, autoregressive process of inflation, hence we consider nested models. We compute bootstrap standard errors for the MSFEs following Clark and McCracken (2006). We document how the open-economy Phillips curve exhibits value in explaining U.S. inflation dynamics over time, including the post-Great Recession era, while the closed-economy counterpart deteriorated since the mid-1980s, confirming the results of Atkeson and Ohanian (2001).

Our results suggest that domestic credit growth helps forecast U.S. inflation only until the early 1990s—a pattern similar to those with domestic money growth. In the Great Moderation era and onwards, the predictive accuracy of these domestic measures deteriorates significantly. The G7 averages of both money and credit growth however, mostly exhibit a better performance than the domestic measure from the earliest subsamples until the recent subsamples. Moreover, the performance of G7 credit growth is clearly better for CPI inflation than PCE inflation, whereas G7 money performs well in both CPI and PCE inflation forecasts. The main conclusion is that domestic inflation becomes more connected with global liquidity and less connected with domestic liquidity, and the mechanism can be understood through the open-economy Phillips curve.

Related literature

On the theoretical approach: The credit channel in our current framework is highly detailed and has not been studied in the open-economy New Keynesian framework before. We present most of the details of this model in an online appendix and directly move on to the results for forecasting in the main paper. Accordingly, even though credit’s role for forecasting is shown to be similar to money, the extension of the open-economy framework to capture the credit channel is not straightforward. This channel constitutes one of the major differences between the current framework and the one in Clarida et al. (2002), Martínez-García and Wynne (2010), Martínez-García (2017), and Kabukcuoglu and Martínez-García (2018). Our empirical exercise is motivated by the implications derived from our theoretical framework.

On global slack: Kabukcuoglu and Martínez-García (2018) study both the in-sample and pseudo out-of-sample evidence on the open-economy Phillips curve for 14 advanced countries during the 1985-2015 period. They find mixed evidence for various measures of global slack. For most countries, they document strong predictive performance for measures of (i) global inflation and (ii) global inflation and domestic slack in-sample and out-of-sample. Kabukcuoglu and Martínez-García (2018) also argue that the former has no theoretical basis for inflation modeling, while the latter can be considered a proxy for global slack under a New Keynesian open-economy Phillips curve specification. Our findings for U.S. inflation forecasts based on global slack are similar—global slack performs well only occasionally, despite the fact that global slack is an efficient predictor of domestic inflation in theory. This result is also in line with numerous other empirical studies testing the predictive performance of global slack and finding mixed results.

On money supply: The predictive performance of monetary aggregates has been tested before, and these
exercises are mostly motivated by an alternative explanation: the quantity theory of money. D’Agostino and Surico (2012) study U.S. inflation predictability across monetary regimes using the time-varying VAR of money supply (M2) growth and inflation, based on a century of quarterly data. Their finding is, in periods where there is little or no anti-inflationary bias in policy, and no clear nominal anchor, inflation predictability with money growth strengthens. D’Agostino and Surico (2009) use autoregressive distributed lag models like ours, and show the results for U.S. M2 growth for the 1990:Q1-2006Q2 period are weak, whereas the G7 average money growth does significantly well, compared to the model with M2 growth, as well as the (closed-economy) Phillips curve and the naive specifications. Our work contributes to this strand of literature by introducing a different interpretation on the relationship between money and inflation through the open-economy Phillips curve; and by studying the time variation in the forecast performance of global money growth over the 50 years.

On credit: Our paper draws conclusions on the importance of credit for policy-makers, and in doing so, complements the work of Schularick and Taylor (2012), Jordà et al. (2013), Jordà et al. (2017), documenting the connection between credit and macroeconomic variables with historical data from various countries. We contribute to this literature by focusing on both the theory and the stylized facts for the information content of credit growth for inflation which has not been studied before. In particular, the credit measures that we evaluate have not been tested for inflation forecasting so far. Stock and Watson (1999b) evaluate the performances of only domestic credit measures, which are either subcomponents of the monetary aggregates (like the monetary base or reserves) or related to commercial and industrial loans. The latter group includes the truly credit-related variables in their analysis, but they are quite different than our measures of credit. Stock and Watson (1999b)'s focus on credit to firms is indeed sensible since credit to firms should be related with the tone of economic activity and the costs that the firms face. However, they do not find evidence that such a channel works very well to help forecast inflation. We consider credit at the global level, and in doing so, focus on the aggregate credit to the private sector, including both households and firms. Our findings show that global credit growth matters for forecasting inflation. One of our main empirical results is that the open-economy Phillips curve based on global credit growth performs better than global slack, as well as the closed-economy Phillips curves based on domestic slack, money, credit and the inflation autoregression. In our analysis with disaggregated series, we document that global household credit growth has more information content than firm credit for U.S. inflation.

We describe the theoretical foundations of the relationships between inflation and global liquidity in the open-economy New Keynesian model in Section 2. Our main theoretical result for forecasting, which suggests that global liquidity is proportional to global slack, is given in Proposition 2 in Section 2.1. We then move onto our empirical model and findings in Section 3 and conclude in Section 4.

2 Insights from Theory

This paper augments the workhorse open-economy New Keynesian model in Clarida et al. (2002), Martínez-García and Wynne (2010), Martínez-García (2017), and Kabucuoglu and Martínez-García (2018) with a money and credit market based on a money-and-credit-in-the-utility approach in which both real money balances and real borrowing enter into the household’s utility. This approach also extends the money-in-the-utility New Keynesian setup discussed in Gali (2008) introducing a loan demand from the household’s
optimization problem in order to capture the household’s liquidity gains derived from credit as well as from cash. The supply side of the money and credit markets is based on the simplified balance sheets of the banking system and of the central bank. Moreover, the central bank’s instrument variables are the monetary base and the refinancing rate at which the central bank provides liquidity (loans) to the banking system. Hence, the central bank does not exercise a direct control over the bond yield as in the standard cashless model but indirectly through its influence on the money and credit markets.

In Online Appendix A we describe in detail the main features of the open-economy New Keynesian framework with a money and credit channel maintaining the symmetry in the structure of both countries between households, firms, the banking system, and the central banks. We illustrate the model with the first principles from the Home country unless otherwise noted, and use the superscript * to denote Foreign country variables (or parameters). We focus our attention on the principal elements of departure from previous treatments of the workhorse open-economy New Keynesian model—notably those that relate to the credit channel.

In this section however, we briefly describe the building blocks of the workhorse open-economy NK model. Since the setup of the model we use is otherwise extensively discussed in Online Appendix A, here we shall put the emphasis on the key equations of its log-linearized representation and their economic interpretation.

At the core of this model we encounter an explicit open-economy version of the Phillips curve relating domestic inflation and global slack together. We will then show the key theoretical relationships relevant for forecasting inflation implied by the model in Section 2.1. We illustrate how the closed-economy Phillips curve is not the appropriate modelling specification for forecasting domestic inflation whenever the economy is integrated with the rest of the world through trade.

**The Workhorse Open-Economy New Keynesian Model.** There are two countries, Home and Foreign, of equal size. The core structure of the model consists of three log-linearized equations for each country and two fundamental exogenous shocks (productivity shocks and monetary shocks). That system of equations fully characterizes the dynamics of aggregate output, inflation, and the short-term nominal interest rate in both the Home and Foreign countries.

All other endogenous variables which describe the aggregate behavior of the economy in each country can be expressed as linear functions of the two fundamental shocks, aggregate output, inflation, and the short-term interest rate. We denote Foreign variables with an asterisk (*), and express all variables, $V_t$, in logs as $v_t \equiv \ln(V_t)$. To denote the deviation of a variable, $V_t$, in logs from its steady state, $V$, we use the notation $\hat{v}_t \equiv \ln(V_t/V)$. Similarly, we denote the deviation of the potential (or frictionless) value of that same variable from its steady state as $\hat{\tilde{v}}_t \equiv \ln(\tilde{V}_t/V)$.

*Aggregate demand* is described by a pair of open-economy IS equations that links the Home and Foreign output gaps, $\bar{x}_t$ and $\bar{x}^*_t$, to shifts in consumption demand over time and across countries as captured by domestic and foreign real interest rates, $\hat{r}_t$ and $\hat{r}^*_t$, in deviations from their respective natural (real) rates $\hat{\tilde{r}}_t$ and $\hat{\tilde{r}}^*_t$, i.e.,

\[
\gamma (1-2\xi) \left( \mathbb{E}_t [\bar{x}_{t+1}] - \bar{x}_t \right) \approx ((1-2\xi) + \Gamma) \left[ \hat{r}_t - \hat{\tilde{r}}_t \right] - \Gamma \left[ \hat{r}^*_t - \hat{\tilde{r}}^*_t \right],
\]

\[
\gamma (1-2\xi) \left( \mathbb{E}_t [\bar{x}^*_{t+1}] - \bar{x}^*_t \right) \approx -\Gamma \left[ \hat{r}_t - \hat{\tilde{r}}_t \right] + ((1-2\xi) + \Gamma) \left[ \hat{r}^*_t - \hat{\tilde{r}}^*_t \right],
\]

(1)
where \( \Gamma \equiv \xi [\sigma \gamma + (\sigma \gamma - 1) (1 - 2\xi)] \), and where \( \xi \) is the share of Home goods in the Foreign consumption basket, \( \sigma \) is the elasticity of substitution between Home and Foreign bundles, \( \gamma \) is the inverse of the elasticity of the intertemporal substitution on consumption. The real interest rates in the Home and Foreign country are defined by the Fisher equation as \( \hat{\pi}_t \equiv \hat{i}_t - \mathbb{E}_t [\hat{\pi}_{t+1}] \) and \( \hat{\pi}^*_t \equiv \hat{i}_t^* - \mathbb{E}_t [\hat{\pi}^*_{t+1}] \) respectively, \( \hat{i}_t \) and \( \hat{i}_t^* \) are the Home and Foreign short-term nominal interest rates, and \( \hat{\pi}_t \) and \( \hat{\pi}^*_t \) are the Home and Foreign inflation rates. The natural real rates that would prevail under flexible prices are denoted \( \hat{\pi}_t \) for the Home country and \( \hat{\pi}_t^* \) for the Foreign country.

The assumption of price stickiness explains the wedge in the open-economy IS equations between the real interest rate and the natural real rate of interest that captures the distortionary effects of these nominal rigidities on aggregate demand, as shown in Eqs. (1) – (2). However, the Calvo parameter \( \alpha \), which determines the degree of nominal rigidities assumed by the model, does not appear explicitly in the coefficients of these equations. The import share \( \xi \) plays a prominent role in the open-economy IS equations as it directly affects the contributions of demand distortions arising in the local and export markets to the dynamic of the output gap of each country.

**Aggregate supply** is represented with an open-economy Phillips curve relating each country’s inflation \( \hat{\pi}_t \) and \( \hat{\pi}^*_{t} \), and to domestic and foreign output gaps, \( \hat{x}_t \) and \( \hat{x}^*_t \), i.e.,

\[
\hat{\pi}_t - \pi_t \approx \beta \mathbb{E}_t (\hat{\pi}_{t+1} - \pi_{t+1}) + \left( \frac{1 - \alpha}{\alpha} (1 - \beta \alpha) \right) \left[ ((1 - \xi) \varphi + \Theta \gamma) \hat{x}_t + (\xi \varphi + (1 - \Theta) \gamma) \hat{x}^*_t \right], \quad (3)
\]

\[
\hat{\pi}^*_t - \pi^*_t \approx \beta \mathbb{E}_t (\hat{\pi}^*_{t+1} - \pi^*_{t+1}) + \left( \frac{1 - \alpha}{\alpha} (1 - \beta \alpha) \right) \left[ ((\xi \varphi + (1 - \Theta) \gamma) \hat{x}_t + ((1 - \xi) \varphi + \Theta \gamma) \hat{x}^*_t \right], \quad (4)
\]

where \( \Theta \equiv (1 - \xi) \left[ \frac{\sigma \gamma - (\sigma \gamma - 1)/(1 - 2\xi)}{\sigma \gamma - (\sigma \gamma - 1)/(1 - 2\xi)} \right] \). Here, we introduce the rates of trend inflation at time \( t \), \( \pi_t \) and \( \pi^*_t \) respectively, following the (closed-economy) specification of Woodford (2008). These equations represent the log-linear approximation to the aggregate dynamics of inflation in a two-country model with Calvo (1983) sticky prices—which flesh out the global slack hypothesis relative global (rather than local) slack to local inflation. The variant of the model that we propose here follows Yun (1996), so in periods when firms do not re-optimize their prices they still get to increase them at the trend inflation rate. Departures of aggregate output from potential captured by the respective Home and Foreign output gaps create the gap between inflation and trend inflation modelled in Eqs. (3) – (4).

**Monetary policy rule** is represented with a reaction function à la Taylor (1993), where the central bank in each country targets domestic inflation and output gap with the domestic short-term nominal interest rate,

\[
\hat{i}_t \approx \hat{\pi}_t + \Psi_\pi (\hat{\pi}_t - \hat{\pi}_t) + \Psi_x \hat{x}_t + \psi_t, \quad (5)
\]

\[
\hat{i}^*_t \approx \hat{\pi}^*_t + \Psi_\pi^* (\hat{\pi}^*_t - \hat{\pi}^*_t) + \Psi_x^* \hat{x}^*_t + \psi^*_t, \quad (6)
\]

where \( \hat{\pi}_t \) and \( \hat{\pi}^*_t \) are the Home and Foreign central bank’s target inflation rates, respectively.\(^5\) We assume, as in Ireland (2007) and Woodford (2008), that the inflation target for each country follows a random walk,

\(^5\)We follow Woodford (2008) and consider this, historically, a rough description of monetary policy for the U.S. and other advanced countries studied in the empirical analysis of our paper.
i.e.,
\begin{align*}
\tilde{\pi}_t &= \tilde{\pi}_{t-1} + \tilde{\varepsilon}_t, \quad (7) \\
\tilde{\pi}_t^* &= \tilde{\pi}_{t-1}^* + \tilde{\varepsilon}_t^*, \quad (8)
\end{align*}

where \( \tilde{\varepsilon}_t \) and \( \tilde{\varepsilon}_t^* \) are i.i.d. shocks with zero mean. The Taylor rule also incorporates several features of an optimal monetary policy, from the standpoint of at least one simple class of optimizing models. (See Woodford (2001).)

In this setting, the Home trend inflation \( \pi_t \) corresponds in equilibrium to the Home central bank’s inflation target \( \pi_t \) (as in the closed-economy setting of Woodford (2008)). Similarly, the Foreign trend inflation \( \pi_t \) equals the Foreign central bank’s inflation target \( \pi_t \). To see that, one can interpret the indexation rate \( \pi_t \) as the Beveridge-Nelson (stochastic) trend of the domestic inflation process,

\( \pi_t = \lim_{j \to \infty} E_t (\tilde{\pi}_{t+j}) \). \quad (9)

The country’s inflation rate \( \tilde{\pi}_t \) in this model fluctuates around a stochastic trend given by the central bank’s inflation target. Hence, since we assume that the target follows a random walk, it must be the case that \( E_t (\tilde{\pi}_{t+j}) = \tilde{\pi}_t \) at any period \( j > 0 \). In that case, it results from the definition in (9) that \( \pi_t = \tilde{\pi}_t \) at every point in time. This shows that trend and target inflation must be equal in equilibrium.

*Domestic money growth* can be derived by first-differencing log-linear money demand equations motivated by a money and credit-in-the-utility-function argument, i.e.,

\begin{align*}
\Delta \tilde{m}_t &\approx \gamma v \Delta \tilde{y}_t - \nu \Delta \tilde{b}_t + \tilde{\pi}_t, \quad (10) \\
\Delta \tilde{m}_t^* &\approx \gamma v \Delta \tilde{y}_t^* - \nu \Delta \tilde{b}_t^* + \tilde{\pi}_t^*, \quad (11)
\end{align*}

where \( \tilde{m}_t \) and \( \tilde{m}_t^* \) are the Home and Foreign stock of money. *Domestic credit growth* in each country is given by

\begin{align*}
\Delta \tilde{l}_t &\approx \Delta \tilde{m}_t, \quad (12) \\
\Delta \tilde{l}_t^* &\approx \Delta \tilde{m}_t^*, \quad (13)
\end{align*}

where \( \tilde{l}_t \) and \( \tilde{l}_t^* \) are the Home and Foreign stock of credit, with their growth rates proportional to money growth. At the background of this proportionality lies the details of how the central bank and banking system operate in each country, as described in Online Appendix Section A3. This channel has been abstracted in the previous open-economy New Keynesian models. This is also one of the important implications of the model that will be discussed in Section 2.1 in the context of inflation forecasting.

We also define the natural interest rate as the weighted average of expected domestic and foreign pro-
where \( \Lambda \equiv 1 + (\sigma \gamma - 1) \left[ \frac{2(1 - z)}{\gamma (\sigma \gamma - (\sigma - 1)(1 - 2z)^2)} \right] \). The potential output as the weighted average of Home and Foreign productivity,

\[
\hat{y}_t \approx \left( \frac{1 + \phi}{\gamma + \phi} \right) [\Lambda \hat{a}_t + (1 - \Lambda) \hat{a}_t^*], \quad (16)
\]

\[
\hat{y}_t^* \approx \left( \frac{1 + \phi}{\gamma + \phi} \right) [(1 - \Lambda) \hat{a}_t + \Lambda \hat{a}_t^*], \quad (17)
\]

declare the Home and Foreign output gap as,

\[
\tilde{x}_t = \hat{y}_t - \hat{y}_t^* \quad \text{and} \quad \tilde{x}_t^* = \hat{y}_t^* - \hat{y}_t^*, \quad (18)
\]

and, finally, the terms of trade and terms of trade gap as

\[
\tilde{t} \approx \frac{(\hat{y}_t - \hat{y}_t^*)}{\sigma - (\sigma - \frac{1}{\gamma})(1 - 2z)^2} \quad \text{and} \quad \tilde{z}_t \approx \frac{(\tilde{x}_t - \tilde{x}_t^*)}{\sigma - (\sigma - \frac{1}{\gamma})(1 - 2z)^2}, \quad (20)
\]

respectively. Note that in this mode the real exchange rate is proportional to the terms of trade, i.e., \( \tilde{r}_t \approx \tilde{t} \tilde{t}_t(2z - 1) \).

Finally, the law of motion for productivity shocks and monetary shocks is governed by

\[
\begin{pmatrix}
\hat{a}_t \\
\hat{a}_t^*
\end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a}^* \\
\delta_{a,a}^* & \delta_a \end{pmatrix} \begin{pmatrix} \hat{a}_{t-1} \\
\hat{a}_{t-1}^*
\end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_t^a \\
\hat{\varepsilon}_t^a^*
\end{pmatrix}, \quad (21)
\]

\[
\begin{pmatrix}
\hat{\varepsilon}_t^a \\
\hat{\varepsilon}_t^a^*
\end{pmatrix} \sim N \left( \begin{pmatrix} 0 \\
0 
\end{pmatrix}, \begin{pmatrix} \sigma^2_a & \rho_{a,a} \sigma_a^2 \\
\rho_{a,a}^* \sigma_a^2 & \sigma^2_a^*
\end{pmatrix} \right), \quad (22)
\]

\[
\begin{pmatrix}
\hat{\varepsilon}_t^v \\
\hat{\varepsilon}_t^v^*
\end{pmatrix} \sim N \left( \begin{pmatrix} 0 \\
0 
\end{pmatrix}, \begin{pmatrix} \sigma^2_v & \rho_{v,v} \sigma_v^2 \\
\rho_{v,v} \sigma_v^2 & \sigma^2_v
\end{pmatrix} \right), \quad (23)
\]

We summarize the parameters of the model that are introduced in this section in Table 1a. Notice that a full description of the model can be found in the Online Appendix along with a broader set of the parameters. In section B of the Online Appendix, we provide the system of equations characterizing the equilibrium.
Table 1a: Model parameters

<table>
<thead>
<tr>
<th>Structural parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intertemporal discount factor</td>
</tr>
<tr>
<td>Inverse of the intertemporal elasticity of substitution</td>
</tr>
<tr>
<td>Inverse of the Frisch elasticity of labor supply</td>
</tr>
<tr>
<td>Elasticity of substitution between real money and credit balances</td>
</tr>
<tr>
<td>Elasticity of substitution between Home and Foreign bundles</td>
</tr>
<tr>
<td>Share of imports in the consumption basket</td>
</tr>
<tr>
<td>Calvo (1983) price stickiness parameter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monetary policy parameters</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity to deviations from the inflation target</td>
</tr>
<tr>
<td>Sensitivity to deviations from the potential output target</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shock parameters</th>
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</thead>
<tbody>
<tr>
<td>Persistence of the productivity shock</td>
</tr>
<tr>
<td>Cross-country spillover of the productivity shocks</td>
</tr>
<tr>
<td>Volatility of the productivity shock</td>
</tr>
<tr>
<td>Correl. between Home and Foreign productivity innovations</td>
</tr>
<tr>
<td>Persistence of the monetary policy shock</td>
</tr>
<tr>
<td>Cross-country spillover of the monetary policy shock</td>
</tr>
<tr>
<td>Volatility of the monetary policy shock</td>
</tr>
<tr>
<td>Correl. between Home and Foreign monetary innovations</td>
</tr>
</tbody>
</table>

2.1 Key results for forecasting

We use the decomposition method to re-express the core linear rational expectations system that characterizes the log-linearized solution into two separate sub-systems that can be solved separately in order to characterize the dynamics of the world economy and the differential between the Home and Foreign countries (Aoki (1981), Fukuda (1993)).

The dynamics of the world economy and difference economy are described in Section C of the Online Appendix. Using the definitions for global and differential variables, we then back-out the dynamics of country-level inflation and derive our key structural relationships for predicting (and explaining) inflation.

We describe the dynamics of the domestic economy for the Home country only, but the approach is analogous to derive the same implications for the Foreign country inflation. We can express the forecast for domestic inflation in terms of the forecasts of global inflation and the inflation differential with the following transformation,

\[
E_t \left( \pi_{t+1} \right) = E_t \left( \pi_{t+1}^W \right) + \frac{1}{2} E_t \left( \pi_{t+1}^R \right).
\]

Using the structural relationships for global inflation and inflation differentials that come from the model,
it follows that,

\[
\mathbb{E}_t (\hat{\pi}_{t+j}) = \pi_t^W + \frac{1}{2} \pi_t^R
\]

\[
= \left( \pi_t^W - \frac{\lambda^W}{\mu^W} \hat{x}_t^W \right) + \frac{1}{2} \left( \pi_t^R - \frac{\lambda^R}{\mu^R} \hat{x}_t^R \right)
\]

\[
= \hat{\pi}_t - \frac{\lambda^W}{\mu^W} \hat{x}_t^W - \frac{1}{2} \frac{\lambda^R}{\mu^R} \hat{x}_t^R,
\]

where \( \hat{x}_t^R \equiv \hat{x}_t - \hat{\pi}_t \) is our definitions of slack differential and \( \hat{x}_t^W \equiv \frac{1}{2} \hat{x}_t + \frac{1}{2} \hat{\pi}_t = \hat{x}_t - \frac{1}{2} \hat{\pi}_t \) is the corresponding definition for global slack. Simply re-arranging, we can also express the \( j \)-periods ahead forecast for inflation at time \( t \), \( \mathbb{E}_t (\hat{\pi}_{t+j}) \), as follows,

\[
\mathbb{E}_t (\hat{\pi}_{t+j} - \hat{\pi}_t) = -\frac{\lambda^W}{\mu^W} \hat{x}_t^W - \frac{1}{2} \frac{\lambda^R}{\mu^R} \hat{x}_t^R.
\]

Predicting future inflation using the foreign and domestic output gaps alone would not be accurate since domestic inflation potentially has a stochastic trend while foreign and domestic slack are stationary; one needs to include among the regressors some variable with a similar stochastic trend to that of domestic inflation. Current inflation itself has the same stochastic trend, so including it to forecast future inflation takes care of the trend component without the need to include any additional regressors. The efficient forecasting relationship can be expressed as in Proposition 1.

**Proposition 1** No variables other than domestic and foreign slack should help improve the forecast of changes in domestic inflation. The forecasting relationship for domestic inflation implied by the workhorse open-economy New Keynesian model can be expressed as,

\[
\mathbb{E}_t (\hat{\pi}_{t+j}) = \hat{\pi}_t - \frac{1}{2} \left( \frac{\lambda^W}{\mu^W} + \frac{\lambda^R}{\mu^R} \right) \hat{x}_t - \frac{1}{2} \left( \frac{\lambda^W}{\mu^W} - \frac{\lambda^R}{\mu^R} \right) \hat{\pi}_t \]  

\[
(26)
\]

\[
= \hat{\pi}_t - \frac{\lambda^W}{\mu^W} \hat{x}_t + \frac{1}{2} \left( \frac{\lambda^W}{\mu^W} - \frac{\lambda^R}{\mu^R} \right) \frac{1}{2} \hat{x}_t^R
\]

\[
(27)
\]

\[
= \hat{\pi}_t - \frac{\lambda^R}{\mu^R} \hat{\pi}_t - \frac{1}{2} \left( \frac{\lambda^W}{\mu^W} - \frac{\lambda^R}{\mu^R} \right) \hat{x}_t^W.
\]

\[
(28)
\]

More generally, following Proposition 1 and using the fact that \( \hat{\pi}_{t+h} \approx \sum_{j=1}^{400} \hat{\pi}_{t+j} \), we can write the
actual forecast $h$–periods ahead for domestic inflation as follows,

$$\hat{π}_{t+h|t} = E_t(\hat{π}_{t+h}) = \frac{400}{h} \sum_{j=1}^{h} E_t(\hat{π}_{t+j}) = \frac{400}{h} \sum_{j=1}^{h} E_t(\hat{π}_{t+j})$$

(29)

$$= 400 \left( \frac{π_t - \frac{1}{2} \left( \frac{λ^W}{μ^W} + \frac{λ^R}{μ^R} \right) \bar{x}_t - \frac{1}{2} \left( \frac{λ^W}{μ^W} - \frac{λ^R}{μ^R} \right) \bar{x}_t^W}{1} \right)$$

(30)

$$= 400 \left( \frac{π_t - \frac{λ^W}{μ^W} \bar{x}_t + \left( \frac{λ^W}{μ^W} - \frac{λ^R}{μ^R} \right) \frac{1}{2} \bar{x}_t^R}{1} \right)$$

(31)

In other words, no other variable should help improve our forecast of domestic inflation if domestic slack and foreign slack are included in our forecasting model. The closed-economy counterpart of this result was similarly noted in Woodford (2008).

Furthermore, we can also use the world money (or credit) balances gap together with domestic slack to replace the hard-to-measure global slack and slack differentials in order to predict domestic inflation. Our key insights are summarized in the following proposition,

**Proposition 2** Global slack can be proxied by the global real money balances gap or, alternatively, by the real credit gap as follows,

$$\hat{π}_t^W = \frac{1}{2} \hat{π}_t + \frac{1}{2} \hat{π}_t^* \approx \frac{1}{X} \hat{m}_t^{r,W} \approx \frac{1}{X} \hat{m}_t^{r,W}$$

where $X \equiv γv \left(1 - \frac{1}{2} \left( -ψ \frac{λ^W}{μ^W} + ψ \right) \right)$, and global real money (credit) gap is defined as the equally-weighted average of domestic and foreign real money (credit) gap, $\hat{m}_t^{r,W} = \frac{1}{2} \hat{m}_t^r + \frac{1}{2} \hat{m}_t^r^*$ ($\hat{m}_t^{r,W} = \frac{1}{2} \hat{m}_t^r + \frac{1}{2} \hat{m}_t^r^*$). In the case where monetary policy is the same in both the actual economy and the frictionless potential, the price paths for both economies are the same, and hence, the world real money (credit) gap is equal to the world nominal money (credit) gap $\hat{m}_t^{n,W} = \hat{m}_t^{r,W}$.

**Proof.** See the Online Appendix, section C1 for the world dynamics. ■

### 2.2 Practical implications

Before moving on to the empirical analysis, some practical concerns regarding the forecasting specification above can be discussed.

1. The specification (26) (or equivalently, (27) or (28)) in Proposition 1 effectively ties domestic inflation to domestic output gap, $\hat{x}_t$ and foreign output gap, $\hat{x}_t^*$, with weights based on the structural parameters of the model. Considering various weighting schemes (including more theoretically-consistent weights) however, Kabukcuoglu and Martínez-García (2018) find that an equal-weighting scheme appears to be a good approach for both in-sample and out-of-sample inflation predictability. (See also D’Agostino and Surico (2009), using equal weights in their work on global money growth and inflation forecasts, as well as Timmermann (2006) for the performance of equal weighting in forecast combinations). Hence, the output gap terms on the right hand side of (26) can be written solely in terms of a global output gap measure with equal weights, $\hat{π}_t^W \equiv \frac{1}{2} \hat{x}_t + \frac{1}{2} \hat{x}_t^*$. 

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2. Due to the difficulty of finding reliable output gap measures (to be discussed further in the next section), we then consider the implications of Proposition 2 as another identifying restriction, motivating the use of global (nominal) money or credit gap measures, $\hat{m}^{n,g,W}_t$ or $\hat{p}^{n,g,W}_t$, also equally-weighted, as proxies for $\tilde{x}^W_t$. In practice, one way of obtaining a gap measure would be first-differencing the (logs of) these money or credit series, which is our approach in the empirical analysis. Notice that any departure from the weights in (26) would imply that the forecast model is no longer efficient. However, the premise of the theoretical model, which suggests that inflation is tied to global liquidity through an open-economy Phillips curve relationship, still remains valid.

3 Empirical Analysis

The issue of how to measure the output gap—both domestic and foreign—has been known as a major challenge. For purely statistical approaches which in most cases derive potential output using actual (real) output series through a filtering technique (most commonly the HP filter), the choice of the filter is usually an arbitrary decision. In addition, applying these techniques is known to create end-point problems. For structural estimates of the output gap, relying on a production function (such as Cobb-Douglas) and quantifying the total factor productivity, the capital stock or labor employed tend to pose measurement problems, as well. (Gerlach (2011)).

Measuring the foreign output gap, however, is an even more challenging task since for the emerging market economies that are believed to potentially affect U.S. inflation, the data series to measure unemployment rates or capacity utilization in manufacturing are usually either too short or they are not available. Furthermore, there is no clear idea of how the dynamics of the foreign output gap affect domestic inflation. Therefore, estimating the open-economy Phillips curve based on the combination of domestic and foreign slack as a measure of the global slack is even more difficult. (See, Martínez-García and Wynne (2010), among others.)

Our empirical investigation of the open-economy Phillips curve forecasts starts with testing whether global slack helps forecast inflation across various forecast horizons and different inflation measures. Our first finding is that one should really ‘mind the gap’. Perhaps, in agreement with the existing empirical literature, a standard measure of global slack yields mixed results in predicting inflation. In theory, there should be no other current period variables that help us to forecast future inflation that can outperform the forecasts attained with the current period output gap (and lagged inflation). In practice, the difficulty of estimating the potential output and therefore deriving the output gap, makes slack measures less reliable. Therefore, it becomes key to consider other variables that can proxy for it in forecasting inflation and are more accurately measured in the data.

We evaluate the predictive ability of the open-economy Phillips curve using other variables that can be

---

6 Stock and Watson (1999b) evaluate the conventional Phillips curve-based forecast with unemployment and report that it can be improved with broader measures of economic activity. Lack of consistent data on unemployment across countries forces us to rely primarily on related measures of economic activity and slack. Globally, since data availability does not permit us to consider the role of unemployment in our analysis.

7 See, for instance, Kabukcuoglu and Martínez-García (2018) who find that global slack measures based on different income measures, country weighting schemes, and filtering techniques yield mixed results in inflation forecasting for a group of 14 advanced countries after the mid-1980s.

8 See Woodford (2008), for an example that shows that in a standard New Keynesian model this is the case. The paper, among others, also points out to the problem of overestimating the potential output, as a pitfall in Phillips curve-based policy making.
shown to be proportional to global slack in theory: global money gap and global credit gap. While our analysis focuses on open-economy measures, we compare our results from closed-economy counterparts in order to highlight the evidence on the role of global economic activity.

While global credit has not been tested before in the context of inflation forecasting, global money has been paid more attention in the literature. In particular, the measures of money growth are suggested to have information content for inflation forecasting (D’Agostino and Surico (2009)) due to the quantity theory of money. We take an alternative approach and rest our forecasting relationship on the global slack hypothesis: money has information content because it is related to the output gap under a standard New Keynesian model. A similar argument could be extended to credit growth, as well.

3.1 Data

All forecast exercises are conducted with quarterly data. We use raw series and implement a one-sided moving average seasonal adjustment filter whenever seasonal adjustment is necessary.

The U.S. inflation rate is calculated as annualized log-differences of quarterly series of two price indexes: consumer price index (CPI), and personal consumption expenditure deflator (PCE). Our theoretical framework defines price indexes closer to CPI and PCE, and therefore we conduct our analysis based on these two measures.

We perform inflation forecasts using (i) a domestic and (ii) a global slack measure under Phillips curve models. Our domestic measure is the quarterly CBO U.S. slack whereas the global slack measure is the IMF G7 series, which is available at an annual frequency. We disaggregate these annual series into quarterly frequency using the quadratic match average method. As there is already a vast amount of evidence based on domestic and global slack measures, we limit our analysis to these two measures only, which helps us confirm the results in the literature and facilitate a comparison with the new measures based on money and credit which are tested in the current paper.

We use the growth rate of M2 to construct the U.S. money gap, and an average of the corresponding series for G7 countries. In the G7 measure, we either use M2 or the closest monetary aggregate if M2 is not available.

We construct a measure of global credit gap, again, by using the average growth rate of the credit series from G7 countries. The credit data we use are defined as "credit from all sectors to the private non-financial sector" from the BIS.

Appendix A gives a more detailed description of the data. We conduct a series of other exercises that support our benchmark analysis. The data for these exercises are also described in Appendix A. Figures B1a-b in Appendix B plots all of these series.

3.2 Forecast Models

Following Stock and Watson (2003), we refer to models with explanatory variables as economic models and we assess to what extent these economic models represent an improvement over the univariate model.
of forecasting inflation. We consider bivariate forecast models for economic models and a univariate AR process for a benchmark specification, as described by Model 1 and Model 2 below, respectively. Hence, the bivariate economic models are used in order to evaluate the forecast accuracy of individual measures of global slack, global money gap, and global credit gap. We run forecasts based on the domestic counterparts of these measures as well.\textsuperscript{11} Our forecast models are the same as those of D’Agostino and Surico (2009), who evaluate the forecasting performance of the average growth rate of broad money in G7 economies with a benchmark autoregression in the 1990Q1:2006Q2 period. By following their approach, we provide an extensive documentation of how global liquidity matters for inflation predictability over various subsamples.

While Atkeson and Ohanian (2001) cast doubt on the predictive ability of Phillips curve-based forecasts, Stock and Watson (1999a), Stock and Watson (1999b) and Stock and Watson (2008) provide some empirical evidence in favor of the Phillips curve as a forecasting tool, suggesting that inflation forecasts generated with Phillips curve-based regressors generally are more accurate than forecasts based on other macroeconomic variables (including interest rates, money, and commodity prices).

Our forecast models are as follows. First, we consider the reduced-form representation of an open-economy NK Phillips curve relating inflation to global economic activity,

\[ \hat{\pi}^h_{t+|t} = a_1 + \lambda_{11} (L) \hat{\pi}_t + \lambda_{12} (L) \hat{g}_t + \hat{\epsilon}_{1,t+h}. \]  

(Model 1)

By denoting the quarterly forecast horizon as \( h \), it is possible to forecast \( h \)-quarters ahead inflation, \( \hat{\pi}^h_{t+|t} \), with the distributed lag of earlier inflation rates, \( \hat{\pi}_t \), to proxy for expected future inflation, and the distributed lag of the economic measure, \( \hat{g}_t \) (i.e. global output gap, global money gap or global credit gap). In our assessment with closed-economy measures, \( \hat{g}_t \) captures domestic output gap, domestic money gap or domestic credit gap.

Following Woodford (2008)’s argument, which is the closed-economy analogue of our Proposition 1, there should be no other variable than the output gap to forecast changes in domestic inflation. The lags of inflation help us take into account the unmodeled stochastic trend, without the need to use an additional variable that has a similar trend. We define \( h \)-quarter ahead (annualized) inflation \( \hat{\pi}^h_{t+|t} = \frac{400}{P_t^h} \times \ln(P_{t+h} / P_t) \), and forecast inflation for horizons ranging from 1 quarter-ahead to 12-quarters ahead. The number of lags for each variable is selected based on the Schwarz information criterion (SIC). To keep the model parsimonious, and since the frequency of the variables is defined as quarterly, the maximum possible lags allowed for each variable is set as four. Note that this specification is also similar to the models employed in the literature, so it has the advantage to facilitate comparison.

Finally, in order to compare the performance of Model 1 against a benchmark, we consider a univariate autoregressive (AR) process

\[ \hat{\pi}^h_{t+|t} = a_2 + \lambda_2 (L) \hat{\pi}_t + \hat{\epsilon}_{2,t+h}, \]  

(Model 2)

following D’Agostino and Surico (2009), among others.\textsuperscript{12} The lag length selection of Model 1 follows that of Model 2, and inflation has the same number of lags in both models. Hence Model 2 nests Model 1.

To be consistent with the theoretical framework, we consider inflation series in levels. We make a similar

\textsuperscript{11}Canova (2007) evaluated the performance of nominal and real money growth across G7 economies for the 1996-Q1-2000-Q4 period (or the subperiods) and found these results are comparable to Phillips curve based forecasts.

\textsuperscript{12}See Stock and Watson (2007) and Faust and Wright (2013) for a broader discussion on the performance of the AR model in inflation forecasting. Faust and Wright (2013) suggest an AR(1) model with a fixed slope coefficient is in general a strong benchmark.
argument as in Woodford (2008).

We document the evolution of the predictive accuracy of these models over different subsamples. In particular, we conduct a series of experiments going back in time to the extent that the series are available in order to make a robustness analysis, i.e., starting with the initial observation in the sample, we shift the estimation and forecast samples forward by one quarter and obtain the relative MSFEs of the forecasts for each subsample. Each subsample spans 80 quarters of an estimation sample and 80 quarters of a forecasting sample with one exception: we consider a 70-70 split in our experiments with output gap since the global slack series are too short.

### 3.2.1 Forecast Scheme

We perform forecasts based on the pseudo out-of-sample forecasting method and particularly focus on recursive samples. Therefore, at any given date $t$, we forecast inflation at date $t + h$ using all available data up to date $t$. The models are estimated by OLS. We assess the multi-step pseudo out-of-sample forecasting performance of a model that incorporates variables commonly thought as contemporaneous or leading indicators of inflation relative to the forecast of a univariate AR process.

Our forecast evaluation metric, the relative MSFE, is the ratio of the MSFE of the economic model (Model 1) relative to that of the benchmark AR model (Model 2). Let $T_0$ denote the starting date of the data series and $T_1$ denote the end. The estimation sample starts at $T_0$ and ends in $t_0$. We start by using all data up to date $t_0$ to forecast inflation at date $t_0 + h$. By adding data to the estimation sample, we keep estimating the parameters of the model of interest. The $h$-step recursive forecast continues until period $T_1 - h$ with a total of $T_1 - h - t_0 + 1$ steps. For a given model $j$, this procedure yields a sequence of forecast errors which helps us construct the MSFE of the model at horizon $h$ and from date $t_0$ to $T_1 - h$,

$$
MSFE_j(h) = \frac{1}{T_1 - h - t_0 + 1} \sum_{t=t_0}^{T_1-h} \hat{\epsilon}_{j,t+h}^2,
$$

where $\hat{\epsilon}_{j,t+h}$ is the estimated forecast error for model $j$ at date $t + h$.

### 3.2.2 Inference and Samples

Inference is based on the F-statistics against critical values based on a bootstrap algorithm described in Clark and McCracken (2006). In order to test the predictive ability of a single variable forecast as in Model 1, we define an equation for inflation (as governed by the restricted Model 2) and an equation for the predicting variable, where the lag length for the predicting variable and inflation are separately determined based on the SIC. The equations of the data generation process (DGP) are estimated by OLS with a number of bootstrap iterations equal to 5000.

We then have a one-sided test with the null hypothesis that an economic model (Model 1) does not yield more accurate forecasts than the AR process (Model 2), i.e. $MSFE_{AR} \leq MSFE_{EM}$, against the alternative that $MSFE_{AR} > MSFE_{EM}$. Throughout the paper, we report the relative MSFEs of a particular economic

---

13 The construction of F-statistics as well as t-statistics are described in Clark and McCracken (2001a), Clark and McCracken (2001b), and Clark and McCracken (2002). Inference can also be based on t-statistics, however, as suggested by these authors, F-type tests are more powerful than the corresponding t-type tests, and therefore we focus on F-statistics only.
model, Model 1 and the benchmark, Model 2. The null hypothesis is expressed as ‘the relative MSFE is greater than or equal to 1’. We report the statistical significance at 5% or below.

While we adopt the bootstrap algorithm of Clark and McCracken (2006) for empirical inference with recursive forecasts we did also consider the implementation of the fluctuations test of Giacomini and Rossi (2010) using Giacomini and White (2006) test statistic (Giacomini and Rossi (2010) refer to this as the GW test). This test statistic is also equivalent to Diebold and Mariano (1995) and West (1996) test statistics. Clark and McCracken (2013) note that the Diebold-Mariano-West framework is not supposed to be valid in general for the case of nested models that we have considered in this paper, although it may still work in finite samples. However, Giacomini and Rossi (2010) show in Monte Carlo experiments that the full sample GW test seems to have very low power—so conditional on the null hypothesis of equal forecast accuracy being false, the probability of rejecting such a null is very low. That is essentially what our implementation of the GW test would suggest.\footnote{These results are available upon request.}

\footnote{In an earlier analysis whose results are not reported here but can be provided upon request, we considered several measures of domestic and global slack. These measures are all based on a production function approach (hence more theoretically-consistent): CBO U.S., FRB Dallas U.S., FRB Dallas G7, FRB Dallas G28, IMF U.S., IMF Advanced, OECD U.S., OECD G7, and OECD Total. In the post-1980 period where most of these measures become available we find that it is not possible to find a robust predictive performance by these slack measures. One statistically-based measure, U.S. HP-filtered GDP (based on a 1-sided filter), is also a weak measure.}

14 In finite samples with the data we have, we generally find that the GW test imposes a threshold to detect differences in forecasting performance harder to cross than the test of Clark and McCracken (2006) does.

3.3 Empirical Findings

The results of the pseudo out-of-sample forecasts with measures of domestic and global economic activity are reported in Figures B2-B4. Our findings can be listed as follows:

1. With the CBO U.S. measure of output gap, we confirm the literature following Atkeson and Ohanian (2001), where domestic slack does not help forecast inflation relative to the simple AR process of inflation with various subsamples after the mid-1980s (Figure B2). The global slack measure, IMF G7, appears to do well only occasionally, and in short horizons in particular. Perhaps, it is possible to conclude that the series is too short to fully assess the predictive ability of global economic activity over time. Hence, we suggest that even if global slack is a good predictor of domestic inflation, poor measures of global economic activity and/or problems of data availability might cast problems in detecting the role of global economic activity on inflation dynamics. Therefore, we turn into forecasts with measures of liquidity.\footnote{In an earlier analysis whose results are not reported here but can be provided upon request, we considered several measures of domestic and global slack. These measures are all based on a production function approach (hence more theoretically-consistent): CBO U.S., FRB Dallas U.S., FRB Dallas G7, FRB Dallas G28, IMF U.S., IMF Advanced, OECD U.S., OECD G7, and OECD Total. In the post-1980 period where most of these measures become available we find that it is not possible to find a robust predictive performance by these slack measures. One statistically-based measure, U.S. HP-filtered GDP (based on a 1-sided filter), is also a weak measure.}

2. The predictive ability of domestic money gap (Figure B3) extends to a longer period of time—mostly into late 1980s and early-1990s across different inflation measures and horizons—hence, providing more positive results relative to the CBO U.S. output gap in this period. Later on, the measure never outperforms the inflation autoregression. Notice that this period is an era of Great Moderation, a more aggressive stance of monetary policy against inflation, and globalization. The G7 money gap measure, which has become available since the early 1960s, provides more accurate forecasts than the AR process (and therefore the domestic money gap) in almost all samples (starting from the beginning of sample) and forecast horizons for both CPI and PCE inflation. We make two comments in relation to the interpretation of money growth for forecasting inflation in the existing literature:
While it might be appealing to relate the performance of money growth to the quantity theory, it is not exactly clear how in the New Keynesian theory, money can be a predictor for inflation. Woodford (2008) argues that even a strong empirical evidence in the long run relation between money growth and inflation does not necessarily imply that money growth will be useful for forecasting inflation. The main reason, as he explains, is that cointegration of money growth with the inflation rate would imply that in order to forecast the average inflation rate in the long run, it would be sufficient to know what the average growth rate of money will be in the long run; and therefore no other variables would be necessary to forecast the average inflation rate over the same horizon. However, one does not know the long-run average money growth rate, as it is an endogenous variable with respect to the central bank’s policy. If it were an exogenous variable, then it could make sense to detect long run trends from the moving averages of recent observations.\(^{16}\)

We reconcile these different arguments as follows. In the context of the New Keynesian model, money indeed moves as a result of changes in endogenous variables that are themselves related to the output gap. As Woodford (2008) also argues, money demand is a residual in this model, however, it is one that we can measure more easily and that could still provide a signal for the output gap fluctuations that we can use to forecast future inflation. If we can say that in the context of this model the money growth in equilibrium is proportional to output gap, then money growth is a signal for a measure of slack that we actually do not observe properly (i.e. the output gap) and as such can still be exploited to forecast inflation. The same argument easily follows for global measures in an open-economy New Keynesian model.

There is strong information content in global money growth for domestic inflation. The accuracy of forecasts prevails for the Great Moderation era as well as the recent periods of Great Recession (i.e. from 1984Q1 to the end of sample). When we consider U.S. money growth for predicting inflation, confirming the results of D’Agostino and Surico (2012), we document a good performance during the Great Inflation era (1971Q4-1983Q4) and a poor performance afterwards.

3. The global credit gap measure (see Figure B4) exhibits similar patterns to money growth—mostly with CPI inflation. While U.S. credit growth never outperforms the inflation autoregression after the early 1990s, the G7 measure appears to exhibit more information content for U.S. CPI inflation after that period. With PCE inflation however, there appear to be a break in the more recent subsamples, which might be related to the Great Recession.

Even though in theory the global money and credit measures have the same implications for inflation predictability, in practice, we observe some natural differences. These may stem from the differences in the data sources for money and credit, and the series may be revised differently. The global money measure includes series other than M2 for some countries (e.g. the closest measure for the U.K. is M4), which again, makes a difference in the construction of global liquidity measures. Nevertheless, we obtain qualitatively similar results under these measures.\(^{17}\)

\(^{16}\)Woodford (2008) also shows in a simple New Keynesian model where, in theory, money growth will not outperform slack even in the long run. It might be arguable whether money growth will not outperform slack, but the statement is valid as far as a standard New Keynesian model is considered.

\(^{17}\)While we appeal to Proposition 2 where nominal global liquidity measures appear to be sufficient proxies for global slack, we considered real measures as alternatives. This exercise however, is subject to limitations on the availability of PCE deflator series for G7 countries. See the Online Appendix Section D for a discussion.
The findings of Eickmeier et al. (2014) estimating a factor model are supportive of our analysis. Using a large set of financial and macroeconomic variables from 24 advanced and emerging countries, they find global monetary policy, global credit supply and global credit demand appear to be important common factors of global liquidity. Focusing on the Great Recession, Eickmeier et al. (2014) also argue that the response of monetary policy was more expansionary, while the global credit demand and supply remained tight. This is, indeed, in line with our findings on inflation predictability in the recent samples capturing the Great Recession episode. There is a liquidity expansion, where global money substituted global credit. Our G7 money gap measure remains a strong predictor of inflation in the recession.

Perhaps, the main takeaway from these experiments is that, globalization clearly affected the U.S. inflation dynamics, justifying the use of an open-economy framework to model U.S. inflation. Moreover, global money and credit movements appear to signal the movements in inflation even in the short run, providing a monetarist and Keynesian synthesis to the understanding of inflation dynamics. In light of this, these measures should become important tools for policymakers.

3.4 More on the role of global liquidity on U.S. inflation dynamics

3.4.1 The household and firm credit gap

The theoretical framework studied earlier suggests a relationship between inflation and the overall credit to the economy, and hence, the baseline analysis is based on an aggregate credit series. Now we take a closer look at the components of this series and address whether household credit or firm credit matters more for inflation predictability. Our analysis shows that household credit matters more.

We use the BIS series for these two categories of credit (See Appendix A for details) to investigate whether the household or firm credit growth has information content for inflation at the domestic and global level, using the U.S. and G7 average, respectively.\footnote{Because the G7 average is relatively short, we consider a relatively smaller window of 140 quarters instead of 160 in our forecasting exercises.}

As the results in Figure B5 indicate, the U.S. household credit growth appears to be a good predictor of U.S. inflation until early 1990s and does not provide much information content afterwards. In the periods where the series become available, the G7 household credit growth performs better than the U.S. measure. Figure B6 suggests that firm credit is not as strong predictor of inflation as household credit. There is some evidence in favor of global firm credit growth for CPI inflation but the results are not very robust in general. Therefore, the main conclusion from this exercise is that one does not gain much by focusing on the business side of credit in inflation modeling and forecasting. On the other hand, we confirm, that global credit—whether or not it is at the household or firm level— is a better predictor than its domestic counterpart.

3.4.2 The interest rate gap

Our analysis so far focused on liquidity, a measure of quantity in the money and credit markets. Next, we ask whether or not a price measure helps forecast inflation. In particular, we focus on the short term interest rate dynamics, captured by the short term nominal interest rate movements, $\Delta i_t = i_t - i_{t-1}$. We call this measure the domestic interest rate gap. A global measure can then be constructed by the average interest
rate changes across G7 countries. For the U.S. measure, we use the first differences of the Fed funds rate. For the global measure, we consider the money market rates for the rest of the G7 countries along with the U.S. interest rates. For Germany, Italy, and France, we consider the ECB refinancing rates in the post-1999 period. Finally, for the U.S., Japan, U.K. and the three euro area countries where the policy rates hit the zero lower bound, we replace these series with the shadow rates estimated by Krippner (2013) (See Appendix A for details). The idea, again, is that the interest rate gap can, indirectly, be a proxy for the output gap and therefore help forecast U.S. inflation in a Phillips curve-based relationship. Considering all subsamples from the start date of our series and going through the most recent subsample, we evaluate interest rate movements for the pre- and post-recession periods.\(^{19}\) We document the following results (See Figure B7):

1. The U.S. interest rate gap is a robust predictor of U.S. inflation as it outperforms the naive model in almost all subsamples, beginning from the earliest samples. The relative MSFEs are only slightly below 1, so it is possible to conclude that the measure itself does not necessarily yield more accurate forecasts than the global liquidity measures in the previous analyses.

2. The G7 interest rate gap can beat the domestic measure occasionally, especially in short-term CPI and medium-term PCE forecasts, and there is considerable success in the recent periods capturing the recession. Nevertheless, the measure does not appear as strong as global liquidity or the U.S. interest rate gap.

We interpret these results as follows. First, the robust performance of the U.S. interest rate gap, once again, reminds that the U.S. inflation is ultimately under the control of the Federal Reserve. So it should be no surprise that the domestic interest rate gap is a good forecasting variable for domestic inflation. Second, there may be a disconnect between the theoretical and empirical measure of the global interest rate gap due to the euro area countries. In particular, three economies in G7—France, Germany and Italy— have been in a currency union with a common interest rate. Therefore, the interest rate gap measure for these economies may not necessarily be aligned with their respective output gaps but more aligned with the output gap of the euro area as a whole.

### 3.5 The real exchange rate gap

In a previous study, Martínez-García and Wynne (2010) suggest a role for the terms of trade gap as a proxy for global slack. They show that under a variant of the open-economy New Keynesian framework and in a standard representation of the open-economy Phillips curve, global slack can be replaced with domestic slack and the terms of trade gap, where the terms of trade gap can be defined as the deviation of terms of trade from its frictionless value in the New Keynesian framework. Hence, the information content of terms of trade can be exploited to forecast domestic inflation without using the global slack, which is difficult to measure in practice. In principle, the particular open-economy New Keynesian model we study implies that the real exchange rate is also proportional to the terms of trade, so the forecasting performance of both variables should be the same. In more general models, the proportionality breaks down, but presumably

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\(^{19}\)The role of interest rate movements on predicting inflation has been studied before. See for instance, Chowdhury et al. (2006) for the closed economy and Eickmeier and Pijnenburg (2013) for the open economy finding supportive evidence for interest rates in the pre-recession period.

\(^{20}\)For example, the most recent subsample, the estimation sample covers 1977:Q2-1997:Q1 and the forecast sample covers 1997:Q2-2017:Q1 and therefore, the Great Recession.
we would still have a significant correlation between terms of trade and the REER that would explain if one variable is helpful to forecast inflation, the other one may be helpful, too.\textsuperscript{21}

In light of this, we evaluate the real exchange rate gap, along with domestic output gap, as a candidate to proxy global slack in the open-economy Phillips curve. We choose to work with REER rather than terms of trade since the series available is longer to conduct our historical analysis.

In our initial assessments with trivariate forecasting models with domestic output gap (CBO) and REER gap, which is simply the log-differenced REER series, we did not get very successful results.\textsuperscript{22} Once again, this might show that the poor measure of domestic slack is not a good forecasting variable after all, possibly shadowing the performance of the REER gap. When we test the REER measure alone using Model 1, on the other hand, we obtain better results (See Figure B8). Interestingly, starting in the mid-1980s, the U.S. REER starts outperforming the autoregressive process. This variation in the predictive performance of another global measure of economic activity supports our claims for the validity of the open-economy Phillips curve. In more recent subsamples—starting in early 1990s—the performance of REER deteriorates.

Nevertheless, we believe that the performance of trade-related measures requires a deeper analysis. For instance, due to data limitations, the REER measure we consider is based on a narrow definition rather than broad—the former is a longer series than the latter, which enables the study of the time-variation in forecasting performance. Unfortunately, the narrow measure captures only a group of advanced countries, leaving out countries such as China, which must have been important for U.S. trade starting in the 1990s. Data limitations prevent us from documenting the role of trade linkages fully and we would like to leave this as future work that is worth a deeper investigation.

4 Conclusion

The seminal work of Atkeson and Ohanian (2001) documented a break in the Phillips curve during the Great Moderation period. This basic statistical relationship between domestic inflation and domestic economic activity no longer seemed to work as a tool for inflation forecasting. Low forecast accuracy can be an issue not only with reduced-form forecasting models, but also with the Dynamic Stochastic General Equilibrium (DSGE) models that have become commonplace for policy analysis and forecasting, as indicated by Edge and Gürkaynak (2010). Focusing on the strand of literature that followed the work of Atkeson and Ohanian (2001), we find theoretical and empirical support for the validity of the global slack hypothesis based on its predictions about forecasting. We show that the Phillips curve is alive and well for forecasting, after all—so long as one considers an open-economy Phillips curve model rather than the standard closed-economy specifications. This is a major contribution of our paper bridging the gap between the theoretical and empirical open-economy literature.

In this open-economy New Keynesian framework, we establish theoretically that no variable other than global slack helps forecast changes in domestic inflation. We emphasize the importance of alterna-

\textsuperscript{21}Stock and Watson (1999b) and Stock and Watson (2008) evaluate the predictive ability of (nominal) U.S. trade-weighted effective exchange rate as well as a set of foreign exchange rates (Stock and Watson (1999b)). They find that these variables do not improve upon the autoregressive process of inflation or the Phillips curve-based forecasts, unlike what our findings suggest in the corresponding periods.

\textsuperscript{22}In an earlier assessment focusing on a subsample between 1980-Q1-2011-Q4, we found similar results with the U.S. terms of trade as well. The terms of trade measures we considered were (i) price of exports relative to imports (ii) price of exports relative to imports ex. oil.
tive measures that incorporate the same information as global slack for forecasting inflation with actual data since it is often a challenging task to find reliable measures of slack purely on measured economic activity. We argue that measures such as global credit growth or money growth, have information content about global slack that can be successfully leveraged to forecast domestic inflation—in the case of the U.S., these alternative measures can be more useful than existing measures of U.S. and global slack. Moreover, these variables perform well when compared against forecasts obtained with many conventional, domestic inflation-predictors such as: domestic slack, global slack, domestic money supply growth and domestic credit growth.

Our interpretation of how these variables are linked to inflation, which is derived from an open-economy New Keynesian model, has not been considered before. To do this, we first introduce an open-economy New Keynesian model which explicitly accounts for the role of money and credit markets. We then provide a New-Keynesian interpretation to the linkages between money, credit and inflation; and argue that the key structural transformation in the later part of the sample (since the onset of the Great Moderation) comes from the impact of globalization—we show empirically by showing that money growth and credit growth have power to predict inflation in the Great Moderation period albeit in global rather than local terms. The policy implication is that monetary aggregates or credit aggregates can be very valuable intermediate instruments for monetary policy whether one approaches the question from a New Keynesian point of view as much as when one approaches it from a classical monetarist point of view.

References


Appendix

A Data Description

All series are quarterly unless otherwise indicated. We use raw series in our exercises and implement a one-sided moving average seasonal adjustment filter whenever seasonal adjustment is necessary. See Figure B1 for a description of our series.


1. U.S. inflation

We consider four inflation measures: CPI and PCE All price series are quarterly, the beginning-of-period values of monthly series. The length of the inflation series used depends on the experiment and in particular, the data availability for other variables. In the longest experiment, our price indexes used in order to construct inflation measures start in 1959:Q2 and all end in 2017:Q1. All price indexes are seasonally adjusted. We use the annualized log differences of quarterly series to construct the inflation measures. Our CPI series is from BLS (via FRED); PCE from BEA (via FRED).

2. Monetary aggregates

All series are seasonally adjusted, quarterly (beginning-of-period aggregates of monthly series) and in terms of national currency. Our U.S. M2 series are from the IMF (via FRED), for 1959:Q1-2017:Q1. For Canada, we use M2 series from the IMF (via FRED) for 1968:Q1-2017:Q1. For Japan, M2 series are available for the 1967:Q1-2016:Q4 period from the IMF (via FRED). For UK, we have M4 series available from OECD (via FRED) for 1963:Q1-2013:Q4. For France, we splice the M2R series from the BIS for the 1961:Q1-1979:Q4 period (using the ECU rate) and the M2 series from DGEI for the 1980:Q1-2017:Q1 period. For Germany, we use the Bundesbank M2 series for 1949:Q1-1979:Q4 and the DGEI for 1980:Q1-2017:Q1. Again, we splice the two series using the ECU rate. We apply a similar procedure for Italy M2 series using data from the Bank of Italy for the 1948:Q4-1979:Q4 period and DGEI series for 1980:Q1-2017:Q1.

We construct the U.S. money gap measure by log-differencing the U.S. M2 series, then multiplied by 100. Hence a money gap measure is denoted in terms of percentages.

For the G7 money gap, we apply the same procedure on individual series and then consider the equal-weighted average of these series as a global money gap measure. The series starts from 1968:Q1 (due to the starting date of the Canadian series) and ends in 2016:Q4 (due to the ending date of the Japanese series).

3. Credit series

Overall credit measure: We use end-of-period, quarterly, long series on credit to non-financial sectors from the BIS for G7 countries. While data for various borrower-lender combinations are available, we choose lenders from ‘all sectors’ and borrowers from ‘private sector’ in order to be able to go back in time as far as
possible and to construct a measure as broad as possible. The series are adjusted for breaks for all countries. For Canada (Canadian dollar), Germany (euro), UK (Pound Sterling), Italy (euro), Japan (yen), and the U.S. (U.S. dollar), we start from 1964:Q4 while for France we start from 1969:Q4 (euro). All series end in 2017:Q4. In order to keep the G7 credit gap measure (which is calculated in a similar way to the money gap) as long as possible, we use the series from the six countries until 1969:Q4 and include the French series afterwards. For our forecasts, we use the first-differences of the logs of the series.

Household credit: We use end-of-period, quarterly series for credit to households and non-profit institutions serving households (NPISH) (at market value) from the BIS for G7 economies. The series are adjusted for breaks for all countries. The G7 average growth rates are based on Canada (Canadian dollar), Germany (euro), UK (Pound Sterling), Italy (euro), Japan (yen), and the U.S. (U.S. dollar), starting in 1978:Q2. The U.S. series starts in 1959:Q2. All series end in 2017:Q4. For our forecasts, we use the first-differences of the logs of the series.

Firm credit: We use the BIS series for credit to nonfinancial corporations from all sectors at market value for the U.S. and G7 economies. The series are adjusted for breaks for all countries. The G7 average growth rates are based on Canada (Canadian dollar), Germany (euro), UK (Pound Sterling), Italy (euro), Japan (yen), and the U.S. (U.S. dollar), starting in 1978:Q2. The U.S. series starts in 1959:Q2. All series end in 2017:Q4. For our forecasts, we use the first-differences of the logs of the series.

4. Slack series

Both slack measures are defined as ‘output gap in percentage of real GDP (%)’. The CBO measure for the U.S. output gap is quarterly and starts from 1960:Q2 and ends in 2017:Q1. The IMF G7 output gap series is annual. Therefore we interpolate the series by the quadratic match average method to disaggregate into quarterly frequency. The quarterly series covers the 1980:Q1-2017:Q1 period.

5. REER series

We use the BIS series for U.S. REER (narrow definition) since it is the longest series available. The series covers the 1964:Q1-2011:Q4 period, with the base year set as 2005=100 (average). For our forecasts, we use the first-differences of the log of REER.

6. Interest rates

We use first-differenced money market interest rates to construct the interest rate gap series. All series are quarterly, end-of-period values of monthly series. The U.S. series is the Fed funds rate from FRED, starting from 1960:Q1. For Canada, France, Germany, Italy, Japan, and UK we use the money market rates from the IFS. The series start in 1970:Q1 for France and Germany, 1971:Q1 for Canada and Italy, 1972::Q1 for UK, and 1985:Q3 for Japan. We use the ECB refinancing rate in 1999:Q1 and onwards for France, Germany, and Italy. Finally, we use Krippner (2013)'s estimates for shadow rates for Japan starting in 1995:Q3, for the U.S., U.K. and eurozone countries starting in 2008:Q4. All series end in 2017:Q1.
### B Figures

**FIGURE B1A.** Time series plots of the data. All series except for slack are seasonally adjusted with a one-sided filter. All series are in percentage terms.
FIGURE B1B. Time series plots of the data. All series except for interest rates are seasonally adjusted with a one-sided filter. All series are in percentage terms.
FIGURE B2. Evolution of the MSFEs of the forecasts with U.S. and G7 slack relative to the benchmark AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.
Figure B3. Evolution of the MSFEs of the forecasts with U.S. and G7 money gap relative to the benchmark AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.
Figure B4. Evolution of the MSFEs of the forecasts with U.S. and G7 credit gap relative to the benchmark AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.
FIGURE B5. Evolution of the MSFEs of the forecasts with U.S. and G7 household credit gap relative to the benchmark AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.

Legend:
- Blue line: U.S. household credit (insig.)
- Blue stars: Sig. at 5% or below
- Red line: G7 household credit (insig.)
- Red stars: Sig. at 5% or below
Figure B6. Evolution of the MSFEs of the forecasts with U.S. and G7 firm credit gap relative to the benchmark AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.
FIGURE B7. Evolution of the relative MSFEs of the forecasts with U.S. and G7 interest rate gap and the AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.
FIGURE B8. Evolution of the relative MSFEs of the forecasts with U.S. REER gap and the AR process of inflation. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment.