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

Ayşe Dur and Enrique Martínez-García

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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 introduce money and credit into the workhorse open-economy New Keynesian model. With this framework, we show that: (i) an efficient forecast of domestic inflation is based solely on domestic and foreign slack, and (ii) global liquidity (global money as well as global credit) is tied to global slack in equilibrium. Then, motivated by the theory, we evaluate empirically 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 U.S. data, we document that these global liquidity variables perform significantly better than their domestic counterparts and outperform in practice the poorly-measured indicators of global slack that global liquidity proxies for.

JEL Classification: F41, F44, F47, C53, F62.

Keywords: Global Slack, Global Liquidity, New Open-Economy Phillips Curve, Open-Economy New Keynesian Model, Forecasting.

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1 Introduction

Forecasting inflation—accurately and reliably—plays a critical role in policy-making and in the decisions of the private sector in undertaking their contractual and financial nominal commitments. In macroeconomic analysis and inflation forecasting, the New Keynesian Phillips curve has been widely used to capture the empirical relationship between inflation and the output gap, the unemployment rate, or even capacity utilization. However, the closed-economy Phillips curve seems to have flattened since the mid-1980s.[1] And, as documented by Atkeson and Ohanian (2001), closed-economy Phillips curve-based models did no longer yield more accurate forecasts than a naïve, 4-quarter random walk benchmark. A survey by Stock and Watson (2009), motivated by the Atkeson and Ohanian (2001) puzzle and related literature, still finds that forecasts based on economic models, including the Phillips curve, only occasionally performed well.[2]

A prominent explanation for the break in the forecasting performance of the closed-economy Phillips curve suggested in the literature is the role of globalization—that is, the greater integration of global markets in goods, labor, capital, and information. The literature has postulated the 'global slack hypothesis' suggesting that foreign slack, as well as domestic slack, drives cyclical domestic inflation, as a way to reconcile the Phillips curve relationship with the empirical evidence. The nexus between globalization, inflation, and monetary policy, in a relatively broad sense, has been discussed in academic and policy circles. Bernanke (2007), Rogoff (2007), Weber (2007), González and Parámo (2008), Mishkin (2009), and Papademos (2010) argued that globalization might have altered the inflation process.[3] Former ECB president Draghi (2015) pointed out the importance of global factors in a speech as follows:

> "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 seized on the idea of global inflation (see, e.g., Ciccarelli and Mojon, 2010; Kabukçuoğlu and Martínez-García, 2018), there is less work that has explored empirically how inflation is driven by global factors while bridging the gap with the New Keynesian

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[1]A broad literature investigates the flattening of Phillips curve focusing on alternative channels such as the anchoring effect of inflation targets (Roberts, 2006), increasing competition in the goods market (IMF, 2005, Zanetti, 2009, and Sbordone, 2010), downward wage rigidities (Akerlof et al., 1996), structural reforms (Thomas and Zanetti, 2009, Cacciatore and Fiori, 2016), lower trend inflation (Ball and Mazumder, 2011) and imperfect information (L'Huillier and Zame, 2015, Okuday et al., 2019). Stock and Watson (2007) took notice of the role of lower volatility in inflation in the U.S. and in the world during this period as well.

[2]See 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.

[3]See also Fisher (2005), Fisher (2006), and Woodford (2010) for further discussion on globalization and monetary policy.

theory behind it.[4] In light of this, we study the modeling and forecasting of U.S. inflation based on an open-economy New Keynesian model. A major caveat with the open-economy Phillips curve that arises in this framework is the need to find a reliable measure of the unobservable global output gap. Even when consistent data is available, most foreign output gap series can be too short and the macroeconomic data may not be fully reliable (on this point, 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 clouding the role that globalization has on domestic inflation.[5]

One of our key contributions precisely is to address the role of global slack on domestic inflation by suggesting other predictors with which the measurement problems that come with slack can be partly circumvented. We adopt a New Keynesian framework which can be viewed as an extension of the (closed-economy) money-in-the-utility New Keynesian model in Galí (2008) and Belongia and Ireland (2014) to the open-economy workhorse New Keynesian model of Martínez-García and Wynne (2010), Kabukçuoğlu and Martínez-García (2018), and Martínez-García (2019). In this setting, households can obtain liquidity services from real credit as well as real cash balances (although not necessarily as perfect substitutes of each other). We also introduce a stylized banking sector that levers the monetary policy transmission mechanism. All of this has the implication that fluctuations in money and credit do reflect—in equilibrium—the slack of the economy and, therefore, can be useful for inflation modeling and forecasting.[6]

This framework brings a monetarist flavor into the open-economy New Keynesian model—an issue that had not been studied in earlier work by Kabukçuoğlu and Martínez-García (2018), as well as in other related open-economy New Keynesian models such as Clarida at al. (2002)—to study the linkages between inflation, global money growth, and global credit growth. In this setting, a key theoretical result is that no measures other than domestic and foreign output gap would help improve the forecasts of (changes) in 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 with this model that the nominal measures of (i) global money gap and (ii) global credit gap contain information about the unobservable global output gap. This result turns out to

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[4]Complementing the findings of Ciccarelli and Mojon (2010), Kabukçuoğlu 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 purely statistical relationship between domestic and global inflation.

[5]There 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, Gruben and McLeod (2004), Borio and Filardo (2007), Eickmeier and Pijnenburg (2013), and Bianchi and Civelli (2015) provide supportive evidence while Ball (2006), Ihrig et al. (2010), 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.

[6]From a maximum likelihood estimation of a small scale closed-economy DSGE model, Ireland (2004) finds a related linkage between business cycle dynamics and money balances (albeit somewhat weak).

be particularly useful for inflation forecasting given that the global output gap is notoriously hard to obtain or construct in practice.

The model posits that global slack is a better predictor of domestic inflation than domestic slack alone and makes the case for exploring the predictive power of global money and global credit in lieu of the unobservable global slack. To explore that, we test the pseudo-out-of-sample predictive performance of these alternative Phillips-curve-based predictors (global money and credit gaps) and document their strong predictive performance for U.S. inflation, especially since the mid-1980s, when the closed-economy measures performed poorly. In our empirical forecasting exercises, we adapt these theoretical insights from the open-economy New Keynesian model and follow in the footsteps of Stock and Watson (2003), and more closely, Canova (2007) and 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 a simple autoregressive forecast of inflation as the benchmark to beat.[7]

The global measures we use are simply the arithmetic averages of first-differenced money and nonfinancial credit series from G7 countries. Our empirical investigation involves five decades of quarterly data. 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 recursively, until the last observation available in the our dataset (in general, until 2017:Q1).

Our metric for forecast accuracy is the MSFE of the open-economy Phillips-curve-based forecasting model with distributed lags of inflation and of the given predictors that we investigate, relative to the MSFE of the 'restricted' forecast derived from a nested univariate, autoregressive inflation process. We compute bootstrap standard errors for the MSFEs following Clark and Mc-Cracken (2006). We confirm the results of Atkeson and Ohanian (2001) with domestic slack (and similarly with global slack). We then document how the open-economy Phillips-curve-based forecasts based on our measures of global money and credit perform better predicting future U.S. inflation, including in the post-$2007 - 09$ recession period, while their closed-economy counterparts deteriorated since the mid-1980s.

Our results suggest that domestic credit growth helps forecast U.S. inflation only until the early 1990s, a pattern similar can be observed with U.S. money growth. In the Great Moderation era and onwards, the predictive accuracy of these domestic measures deteriorate significantly. The G7 averages of both money and credit growth, however, exhibit a better performance than the domestic measures in general from the earliest subsamples until the more recent subsamples. Moreover, the performance of G7 credit growth is clearly better for CPI inflation than PCE inflation, whereas G7 money supply performs well in forecasting both CPI and PCE inflation forecasts.

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[7]D'Agostino and Surico (2009), who use autoregressive distributed lag models like ours, show the results with U.S. M2 growth for the 1990:Q1-2006:Q2 period are weak, whereas the G7 average money growth does significantly better.

The main conclusion we draw here is that domestic inflation becomes more connected with global liquidity and less connected with domestic liquidity over the same period that the U.S. economy has become more integrated with the rest of the world.

The credit measures that we evaluate have received very little attention in 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. However, unlike us, they do not find evidence that such a channel works very well to help forecast inflation. Our work is more in line with that of Zanetti (2012) who considers a model augmented with the banking sector and finds that the linkages between inflation and the business cycle dynamics can be quite strong.[8] The policy implication of our findings is that credit aggregates, not just monetary aggregates, deserve greater attention going forward for inflation forecasting and monetary policy-making.

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 related to global slack, is discussed in subsection 2.1. We then move onto our empirical model and findings in Section 3 and conclude in Section 4.

2 Insights from Theory

In this paper, we augment the workhorse open-economy New Keynesian model of Martínez-García and Wynne (2010), Kabukçuoğlu and Martínez-García (2018), and Martínez-García (2019) with the provision of liquidity services from money and credit. Building on the related closed-economy New Keynesian setups discussed in Galí (2008) and Belongia and Ireland (2014), our extension of the open-economy model is 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. The model also features a stylized representation of the banking system which transforms local household's savings into local household liquidity via credit as an added monetary policy lever.[9]

2.1 The Workhorse Model with Money and Credit

Since the setup of the workhorse open-economy New Keynesian model we use is extensively discussed elsewhere, we put the emphasis on the log-linearized representation of its key equilibrium conditions and in their economic interpretation. There are two countries, *Home* and *Foreign*, of equal size. The structure of the workhorse open-economy New Keynesian model consists of three

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[8]Our paper draws conclusions on the importance of credit for policy-makers, and in doing so, also 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.

[9]The full set of derivations of our model can be found in Dur and Martínez-García (2020).

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. We will show later in Section 2.1 the key theoretical relationships relevant for forecasting inflation implied by the model.

In terms of notation, we express all variables, G_t, in log deviations from steady state, $\overline{G}$, as $\widehat{g}_t \equiv \ln\left(\frac{G_t}{\overline{G}}\right)$. Similarly, we denote the deviation of the potential (or frictionless) value of that same variable from its steady state as $\widehat{\overline{g}}_t \equiv \ln\left(\frac{\overline{G}_t}{\overline{G}}\right)$. We use use the superscript $*$ to denote Foreign country variables.

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

$$\gamma\left(1 - 2\xi\right)\left(\mathbb{E}_t\left[\widehat{x}_{t+1}\right] - \widehat{x}_t\right) \approx \left(\left(1 - 2\xi\right) + \Gamma\right)\left[\widehat{r}_t - \widehat{\overline{r}}_t\right] - \Gamma\left[\widehat{r}_t^* - \widehat{\overline{r}}_t^*\right], \tag{1}$$

$$\gamma\left(1 - 2\xi\right)\left(\mathbb{E}_t\left[\widehat{x}_{t+1}^*\right] - \widehat{x}_t^*\right) \approx -\Gamma\left[\widehat{r}_t - \widehat{\overline{r}}_t\right] + \left(\left(1 - 2\xi\right) + \Gamma\right)\left[\widehat{r}_t^* - \widehat{\overline{r}}_t^*\right], \tag{2}$$

where $\Gamma \equiv \xi\left[\sigma\gamma + \left(\sigma\gamma - 1\right)\left(1 - 2\xi\right)\right]$. Here, $0 \leq \xi < \frac{1}{2}$ is the share of imported goods in the local consumption basket, $\sigma > 0$ is the elasticity of substitution between Home and Foreign bundles (the trade elasticity), and $\gamma > 0$ is the inverse of the elasticity of the intertemporal substitution on consumption. The real interest rates in the Home and Foreign countries are defined by the Fisher equations $\widehat{r}_t \equiv \widehat{i}_t - \mathbb{E}_t\left[\widehat{\pi}_{t+1}\right]$ and $\widehat{r}_t^* \equiv \widehat{i}_t^* - \mathbb{E}_t\left[\widehat{\pi}_{t+1}^*\right]$ respectively, $\widehat{i}_t$ and $\widehat{i}_t^*$ are the Home and Foreign short-term nominal interest rates, and $\widehat{\pi}_t$ and $\widehat{\pi}_t^*$ are the Home and Foreign inflation rates. Finally, the natural real rates that would prevail absent all nominal rigidities are denoted $\widehat{\overline{r}}_t$ for the Home country and $\widehat{\overline{r}}_t^*$ for the Foreign country.

Aggregate supply is represented with an open-economy New Keynesian Phillips curve relating each country's inflation, $\widehat{\pi}_t$ and $\widehat{\pi}_t^*$, to the Home and Foreign output gaps, $\widehat{x}_t$ and $\widehat{x}_t^*$, i.e.,

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

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

where $\Theta \equiv \left(1 - \xi\right)\left[\frac{\sigma\gamma - \left(\sigma\gamma - 1\right)\left(1 - 2\xi\right)}{\sigma\gamma - \left(\sigma\gamma - 1\right)\left(1 - 2\xi\right)^2}\right]$. Apart from the structural parameters described earlier, the inverse of the Frisch elasticity of labor supply $\varphi > 0$, the Calvo (1983) parameter $0 < \alpha < 1$, and the subjective intertemporal discount factor $0 < \beta < 1$ also enter into the composite coefficients of the Phillips curve equations. These Phillips curves represent the log-linear approximation to the aggregate dynamics of inflation arising from monopolistic competition and staggered price-

setting à la Calvo (1983). In doing so, the open-economy curves articulate the *global slack hypothesis* of Martínez-García and Wynne (2010) which postulates that global (rather than local) slack is what matters for the determination of local inflation when the economy is integrated with the rest of the world.

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

$$\widehat{i}_t \approx \psi_\pi \widehat{\pi}_t + \psi_x \widehat{x}_t + \widehat{v}_t, \tag{5}$$

$$\widehat{i}_t^* \approx \psi_\pi \widehat{\pi}_t^* + \psi_x \widehat{x}_t^* + \widehat{v}_t^*, \tag{6}$$

where $\widehat{i}_t$ and $\widehat{i}_t^*$ are the Home and Foreign short-term policy rates and $\widehat{v}_t$ and $\widehat{v}_t^*$ are the Home and Foreign monetary policy shocks, respectively. Here, $\psi_\pi > 0$ and $\psi_x \geq 0$ are the policy parameters that capture the sensitivity of the monetary policy rule to changes in inflation and the output gap.[10] The Taylor rule provides a rough historical description of monetary policy for the U.S. and, while sub-optimal, it shares a number of features and characteristics with the optimal monetary policy (see, e.g., Woodford, 2001; 2008).

The equilibrium conditions in the money and credit market can be derived from a money-and-credit-in-the-utility-function specification of the representative household in each country as follows,

$$\widehat{m}_t \approx \gamma \nu \widehat{c}_t - \nu \widehat{i}_t + \widehat{p}_t, \tag{7}$$

$$\widehat{m}_t^* \approx \gamma \nu \widehat{c}_t^* - \nu \widehat{i}_t^* + \widehat{p}_t^*, \tag{8}$$

where the parameter $\nu > 0$ denotes the elasticity of substitution between real money balances and real credit. These added equations can be interpreted as a variant of the equation of exchange that forms the basis of the quantity theory of money where $\widehat{m}_t$ and $\widehat{m}_t^*$ are the Home and Foreign moneyholdings, $\widehat{i}_t$ and $\widehat{i}_t^*$ are the Home and Foreign short-term interest rates, and $\widehat{p}_t$ and $\widehat{p}_t^*$ are the Home and Foreign CPI price level on each country's final consumption goods basket. Moreover, the Home and Foreign consumption bundles $\widehat{c}_t$ and $\widehat{c}_t^*$ can be expressed as,

$$\widehat{c}_t \approx \Theta \widehat{y}_t + (1 - \Theta) \widehat{y}_t^*, \tag{9}$$

$$\widehat{c}_t^* \approx (1 - \Theta) \widehat{y}_t + \Theta \widehat{y}_t^*, \tag{10}$$

which ties them to Home and Foreign output, $\widehat{y}_t$ and $\widehat{y}_t^*$, with the weights determined by the

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[10]Goes without saying that the parameter space that we describe here does not ensure the determinacy and uniqueness of the solution. However, we restrict ourselves going forward to the region of the parameter space for which a solution exists and is unique. For details on the determinacy region, see the companion technical appendix in Dur and Martínez-García (2020) that describes the full set of derivations of the model in greater detail.

composite coefficient $\Theta \equiv (1 - \xi) \left[\frac{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right]$.

The model also incorporates a stylized banking sector that takes deposits from households at the risk-free short-term interest rate and extends loans to households for which those lines of credit also provide liquidity services (albeit we allow for money and credit real balances to be imperfectly substitutable sources of liquidity services). In this setting, the amount of credit available in equilibrium is proportional to the money supply. Yet, whenever the monetary policy framework is invariant (no changes in reserve requirements, etc.) and the business model of the bank continues to be that of transforming deposits into loans operating under perfect competition, we find that the multiplier of total loans over money in equilibrium is expected to be constant.[11] In this case, the following log-linear relationship holds in each country,

$$\widehat{l}_t \approx \widehat{m}_t, \tag{11}$$

$$\widehat{l}_t^* \approx \widehat{m}_t^*, \tag{12}$$

where $\widehat{l}_t$ and $\widehat{l}_t^*$ are the Home and Foreign credit, respectively.

The frictionless equilibrium arises in the counterfactual case where we abstract from all frictions in the model assuming perfect competition and flexible prices. This allows us to unpack the Home and Foreign slack as:

$$\widehat{x}_t \equiv \widehat{y}_t - \widehat{\overline{y}}_t, \tag{13}$$

$$\widehat{x}_t^* \equiv \widehat{y}_t^* - \widehat{\overline{y}}_t^*, \tag{14}$$

where $\widehat{y}_t$ and $\widehat{y}_t^*$ are the observed Home and Foreign output and $\widehat{\overline{y}}_t$ and $\widehat{\overline{y}}_t^*$ are the Home and Foreign output potential (that is, the output that could be achieved in the frictionless case). We also define the natural interest rate as the weighted average of expected domestic and foreign output potential growth as follows:

$$\widehat{\overline{r}}_t \approx \gamma \left[\Theta \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1} \right] - \widehat{\overline{y}}_t \right) + (1 - \Theta) \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}^* \right] - \widehat{\overline{y}}_t^* \right) \right], \tag{15}$$

$$\widehat{\overline{r}}_t^* \approx \gamma \left[(1 - \Theta) \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1} \right] - \widehat{\overline{y}}_t \right) + \Theta \left(\mathbb{E}_t \left[\widehat{\overline{y}}_{t+1}^* \right] - \widehat{\overline{y}}_t^* \right) \right], \tag{16}$$

where $\Theta \equiv (1 - \xi) \left[\frac{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right]$. The potential output itself is just the weighted average of

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[11]In the background of this proportionality lie the details of how the central bank and banking system operate in each country, as described in the companion technical appendix in Dur and Martínez-García (2020). One of the important implications of the model is that credit (not just money) is another predictor worth exploring in our empirical work. This is a point that, to our knowledge, has not been highlighted elsewhere in the more theoretical literature.

Home and Foreign productivity,

$$\widehat{\overline{y}}_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\Lambda\widehat{a}_t + (1-\Lambda)\,\widehat{a}_t^*\right], \tag{17}$$

$$\widehat{\overline{y}}_t^* \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[(1-\Lambda)\,\widehat{a}_t + \Lambda\widehat{a}_t^*\right], \tag{18}$$

where $\Lambda \equiv 1 + (\sigma\gamma - 1)\left[\frac{\gamma\xi 2(1-\xi)}{\varphi\left(\sigma\gamma-(\sigma\gamma-1)(1-2\xi)^2\right)+\gamma}\right]$.

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

$$\begin{pmatrix} \widehat{a}_t \\ \widehat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix}\begin{pmatrix} \widehat{a}_{t-1} \\ \widehat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix}, \tag{19}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix}\right), \tag{20}$$

$$\begin{pmatrix} \widehat{v}_t \\ \widehat{v}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_v & 0 \\ 0 & \delta_v \end{pmatrix}\begin{pmatrix} \widehat{v}_{t-1} \\ \widehat{v}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^v \\ \widehat{\varepsilon}_t^{v*} \end{pmatrix}, \tag{21}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^v \\ \widehat{\varepsilon}_t^{v*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_v^2 & \rho_{v,v^*}\sigma_v^2 \\ \rho_{v,v^*}\sigma_v^2 & \sigma_v^2 \end{pmatrix}\right). \tag{22}$$

Note that in the New Keynesian model productivity shocks affect the dynamics of the economy only through their impact on the output potential (and, correspondingly, their impact on the natural rate of interest).

2.2 Practical Implications for Forecasting

Let us also define the vector of structural preference and policy parameters $\vartheta \equiv (\gamma, \varphi, \nu, \alpha, \beta, \xi, \sigma, \psi_\pi, \psi_x)^T$. Solving the system of log-linear equilibrium conditions described above under rational expectations, we can characterize several key structural relationships that help guide our efforts at empirically predicting and explaining inflation in the U.S.

First, we can express forecasts of expected domestic inflation changes in terms of Home and Foreign slack alone as follows,

$$\mathbb{E}_t\left(\widehat{\pi}_{t+j} - \widehat{\pi}_t\right) = -\frac{1}{2}\left(\frac{\lambda^W(\vartheta)}{\mu^W(\vartheta)} + \frac{\lambda^R(\vartheta)}{\mu^R(\vartheta)}\right)\widehat{x}_t - \frac{1}{2}\left(\frac{\lambda^W(\vartheta)}{\mu^W(\vartheta)} - \frac{\lambda^R(\vartheta)}{\mu^R(\vartheta)}\right)\widehat{x}_t^*, \tag{23}$$

where $\frac{\lambda^W(\vartheta)}{\mu^W(\vartheta)}$ and $\frac{\lambda^R(\vartheta)}{\mu^R(\vartheta)}$ are composite coefficients of the vector of deep structural parameters of the model ϑ. More generally, if we define $\widehat{\pi}_{t+h}^h \approx \frac{400}{h}\Sigma_{j=1}^h\widehat{\pi}_{t+j}$, we can write the forecast $h-$periods

ahead for domestic inflation as follows,

$$
\begin{aligned}
\widehat{\pi}^h_{t+h|t} &\equiv \mathbb{E}_t\left(\widehat{\pi}^h_{t+h}\right) = \frac{400}{h}\Sigma^h_{j=1}\mathbb{E}_t\left(\widehat{\pi}_{t+j}\right) = \\
&= 400\left(\widehat{\pi}_t - \frac{1}{2}\left(\frac{\lambda^W}{\mu^W} + \frac{\lambda^R}{\mu^R}\right)\widehat{x}_t - \frac{1}{2}\left(\frac{\lambda^W}{\mu^W} - \frac{\lambda^R}{\mu^R}\right)\widehat{x}^*_t\right).
\end{aligned}
\tag{24}
$$

This implies that no predictors other than domestic and foreign slack should help improve the forecast of changes in domestic inflation. This forecasting relationship indicates to us that closed-economy Phillips-curve-based forecasts may underperform even through the lens of the New Keynesian model because of a non-trivial omitted variable, foreign slack. However, while this forecasting relationship is informative given that it identifies a narrow set of predictors that are sufficient to forecast inflation, it poses compounding problems. Not only must we correctly measure the unobservable domestic slack, we must now deal with the even-harder task of obtaining plausible measures of foreign slack as well.

Second, theory suggests that other variables for which data is more readily available can also be used for forecasting inflation instead of the output gap. In particular, we focus on the liquidity services provided by money and credit (albeit as imperfect substitutes) in the model. Intuitively, what happens is that the liquidity services provided in equilibrium vary with economic activity—as can be seen from equations $(7) - (8)$ for money and similarly for credit given the relationship between money and credit in $(11) - (12)$. Hence, theory suggests that money (but also credit) can provide a sufficient signal about slack with which to forecast inflation. In fact, using equations $(7) - (8)$ and their frictionless counterparts, we can re-express the forecasting relationship in (23) as follows:

$$
\mathbb{E}_t\left(\widehat{\pi}_{t+j} - \widehat{\pi}_t\right) = -\frac{1}{\gamma\nu\left(1 - \frac{1}{\gamma}\psi_x\right)}\left[\frac{1}{2}\left(\frac{\lambda^W(\vartheta)}{\mu^W(\vartheta)} + \frac{\lambda^R(\vartheta)}{\mu^R(\vartheta)}\right)\widehat{m}^n_t + \frac{1}{2}\left(\frac{\lambda^W(\vartheta)}{\mu^W(\vartheta)} - \frac{\lambda^R(\vartheta)}{\mu^R(\vartheta)}\right)\widehat{m}^{n,*}_t\right].
\tag{25}
$$

The structure of this equation is similar to that of (23), but in this alternative specification we see that the nominal money gap in the Home and Foreign countries $\widehat{m}^n_t \equiv \left(\widehat{m}_t - \widehat{\overline{m}}_t\right)$ and $\widehat{m}^{n,*}_t \equiv \left(\widehat{m}^*_t - \widehat{\overline{m}}^*_t\right)$ helps us forecast Home inflation in place of Home and Foreign slack. An important caveat here is that to obtain this simple forecasting relationship we assume that, in the frictionless case, the Home and Foreign nominal money balances, $\widehat{\overline{m}}_t$ and $\widehat{\overline{m}}^*_t$, and their corresponding short-term nominal interest rates, $\widehat{\overline{i}}_t$ and $\widehat{\overline{i}}^*_t$, lead the CPI price level of both countries along the same path whether there are nominal rigidities in the economy or not.[12]

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[12]In the frictionless case, monetary policy has no real effects. Therefore, any monetary policy is consistent with the same allocation of resources (the same output potential and natural rate). In the technical appendix in Dur and Martínez-García (2020), we generalize this result considering what happens given any arbitrary monetary policy in the frictionless equilibrium. In summary, nominal money balances become an affine transformation of the slack measures and, therefore, that information content can still be exploited to forecast inflation. We also show that using real bal-

Third, as noted before, the relationship between money and credit in $(11) - (12)$ suggests that nominal credit gaps can be used in (25) as well. The model implies that, in equilibrium, the credit provided through the banking system would be proportional to the amount of money in the economy. While admittedly the banking sector remains fairly stylized in our model, we would argue that it is still worth exploring credit empirically as another inflation predictor. Theory suggests credit should respond—to some extent—to economic conditions and, in doing so, give us another signal about the unobservable slack in (23).

Finally, we should discuss some practical concerns regarding the mapping of the forecasting relationships in (23) and (25) into the sort of empirical models that we could bring to the data:

(A) The specification (23) effectively ties domestic inflation to the domestic output gap, $\hat{x}_t$ and foreign output gap, $\hat{x}_t^*$, with weights based on the deep structural parameters of the model. Considering various weighting schemes (including more theoretically-consistent weights), however, Kabukçuoğlu 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.[13] We also adopt that equal-weighting scheme as our benchmark in our subsequent empirical analysis and use it also when forecasting based on the specification in (25).

(B) One practical way of obtaining a gap measure would be first-differencing the (logs of) the output, money or credit series. Kabukçuoğlu and Martínez-García (2018) find that this filtering scheme appears to be work as well as other alternatives to pin down slack in terms of their out-of-sample inflation predictability, so we adopt the same approach in our empirical analysis here and extended it to the money and credit gap series.

Notice that these departures from the theoretically-motivated forecasting relationships in (23) and (25) necessarily imply that the empirical forecasting model that we use is no longer efficient even when the *true* data-generating process is that of the workhorse open-economy New Keynesian model. However, the premise of the theoretical model, which suggests that inflation is related to global liquidity through an open-economy Phillips curve relationship, still remains valid and (as we show later) is very much empirically relevant.

3   Empirical Analysis

Our empirical investigation of the open-economy Phillips curve-based forecasts starts with testing whether global slack helps predict inflation across various forecast horizons and different inflation measures. In theory, there should be no other predictors that help us to forecast future inflation that can outperform the forecasts attained with domestic and foreign output gap. In practice,

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ances as the observable predictors is another option to proxy for slack and report additional empirical results, but the empirical evidence based on real balances is quite similar to that obtained with money balances.

[13]See also Timmerman (2006) and particularly D'Agostino and Surico (2009) using equal weights in their work on global money growth and inflation forecasting.

standard measures of global slack yield mixed results in predicting inflation.[14] The difficulty, in part, in assessing the performance of global slack measures arises from the fact that the availability of data can be limited and the signal can be of varying quality across countries. Therefore, it becomes key to consider other variables that can proxy for global slack in forecasting inflation and are more accurately measured in the data. For that reason, we evaluate the predictive ability of the open-economy Phillips curve-based model using measures of global liquidity and global credit that, at least in theory, ought to contain information about the hard-to-measure fluctuations in global slack. The remainder of this section describes the data and the empirical forecasting models that we use and reports our key findings.

3.1 Data

All forecast exercises are conducted with quarterly data, starting from the earliest available date in our dataset up to 2017:Q4 (or latest observation available). The goal of our forecasting exercise is to evaluate the predictive performance of global (and domestic) factors across several subsamples over time, including the period of the $2007-09$ recession and onwards. Figures 1-2 plot all of these data series. We use raw series and implement a one-sided moving average seasonal adjustment filter whenever seasonal adjustment is necessary. The appendix to this paper gives a more detailed description of the sources of the data.

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

We perform inflation forecasts using (i) a domestic and (ii) a global slack measure under different Phillips-curve-based empirical forecasting models.[15] Our U.S. 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 (see, e.g., Kabukçuoğlu and Martínez-García (2018) and the references therein), we limit our analysis to these two measures only. That seems sufficient to confirm the results on domestic and global slack in the literature and facilitate a comparison with the alternative signals extracted from the money and credit data which we test in the current paper.

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[14]See, for instance, Kabukçuoğlu 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. Woodford (2008), Martínez-García and Wynne (2010) and Gerlach (2011), among others, also point out the problems of measuring and overestimating potential output, as a pitfall in Phillips curve-based forecasting.

[15]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. In the same vein, our analysis defines slack in terms of real GDP as this gives us a broader measure of real economic activity than unemployment. Moreover, doing so is also more consistent with the notion of slack motivated by the theory laid out in the paper.

We use the growth rate of M2 to construct the U.S. money gap and an average of the same data for the G7 countries as its global counterpart. To construct the G7 measure, we either use M2 or the closest monetary aggregate if M2 is not available, from national sources or from the Dallas Fed's Database of Global Economic Indicators (DGEI) (Grossman et al., 2014).[16] Analogously, we construct a measure of the global credit gap using the average growth rate of the credit series for the G7 countries. The credit data we use is defined as "credit from all sectors to the private non-financial sector" and its obtained from the BIS.[17]

3.2 Forecast Models

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 (2009) provide some empirical evidence in favor of the Phillips-curve-based empirical models as forecasting tools. Following Stock and Watson (2003), we refer to models with explanatory variables as economic models and we assess to what extent those economic models represent an improvement over a univariate autoregressive model for forecasting inflation. We consider Phillips-curve-based economic models and univariate autoregressive processes that can be cast into the general form of Model 1 and Model 2 below, respectively.

The Phillips-curve-based economic models that we use aim to evaluate the forecasting accuracy of our measures of global slack, the global money gap, and the global credit gap. We run forecasts based on the domestic counterparts of these global measures for comparison purposes.[18] Our empirical models for U.S. inflation forecasting are as follows: First, we consider the forecasting relationship that arises from the workhorse open-economy New Keynesian model (see (23) and (25)) relating domestic inflation to global economic activity with the following economic model (EM),

$$\widehat{\pi}^h_{t+h|t} = a_1 + \lambda_{11}(L)\,\widehat{\pi}_t + \lambda_{12}(L)\,\widehat{g}_t + \widehat{\epsilon}_{1,t+h}. \tag{Model 1}$$

where h denotes the quarterly forecasting horizon. We define h-quarter ahead (annualized) inflation $\widehat{\pi}^h_{t+h|t} \equiv \frac{400}{h} \times \left[\ln\left(\frac{P_{t+h}}{P_t}\right)\right]$, and forecast inflation for horizons ranging from 1 quarter-ahead to 12-quarters ahead. Similar to Woodford (2008), we consider inflation series in levels.

We reflect the forecasting relationships motivated by the open-economy New Keynesian model into the more flexible autoregressive distributed lag (ADL) specification. In doing so, we forecast

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[16]An analysis with Divisia monetary aggregates would be interesting, however, since these measures are not available for all G7 countries, we leave this for future work.

[17]Throughout our analysis, we do not use any real time data. However, it is worth noting that while real GDP is subject to revisions, monetary and credit aggregates are less prone to being revised. Hence, another potential advantage of using liquidity as a proxy for slack comes from that fact that liquidity measures are less sensitive to revisions.

[18]In practice, our forecast models are similar to those of D'Agostino and Surico (2009), who evaluate the forecasting performance of the average growth rate of broad money in the G7 economies against a benchmark autoregression over the 1990Q1:2006Q2 period. Canova (2007) also evaluated the performance of nominal and real money growth across G7 economies for the 1996:Q1-2000:Q4 period and found their performance is comparable to that of conventional Phillips-curve-based forecasts.

h-quarters ahead inflation, $\widehat{\pi}^h_{t+h|t}$, with the distributed lag of earlier inflation rates, $\widehat{\pi}_t$, and the distributed lag of the Phillips-curve-based predictors, $\widehat{g}_t$. In our evaluation of global Phillips-curve-based predictors $\widehat{g}_t$ is either the global output gap, the global money gap or the global credit gap; and, similarly, with closed-economy predictors, $\widehat{g}_t$ captures either the domestic output gap, the domestic money gap or the domestic credit gap. Note that this specification is also similar to the models employed in the literature, so it has the advantage to facilitate comparison.

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

$$\widehat{\pi}^h_{t+h|t} = a_2 + \lambda_2\left(L\right)\widehat{\pi}_t + \widehat{\epsilon}_{2,t+h}, \tag{Model 2}$$

following D'Agostino and Surico (2009), among others.[19] The number of lags for each variable in Model 1 as well as in Model 2 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 to four. The lag length selection for inflation in Model 1 is the same one identified for Model 2. In that way, inflation has the same number of lags in both models and, hence, Model 2 nests Model 1.

3.2.1 Forecasting Assessment

We investigate the forecasting performance starting as far back in time as possible given the time series length of each series available. We perform forecasts estimated by OLS based on the pseudo out-of-sample forecasting method and focus our attention on recursive subsamples of fixed size. Each subsample spans 80 quarters for the estimation sample followed by 80 quarters for the forecasting sample with one exception: we consider a 70 quarter estimation sample and 70 quarter forecasting sample in our assessment with output gap data since the global slack series in particular are relatively shorter.[20] From this, we document the evolution of the predictive accuracy of these forecasting models over a recursive sequence of subsamples of fixed size.

Our forecast evaluation metric, the relative mean squared forecasting error (MSFE), is the ratio of the MSFE of the economic model (Model 1) relative to that of the benchmark autoregressive model (Model 2). We assess the multi-step pseudo-out-of-sample forecasting performance of an economic model that incorporates Phillips-curve-based predictors relative to the forecast of a univariate autoregressive process based on the recursive path of the relative MSFE. Let T_0 denote the starting date and T_1 denote the end date for a given subsample. The estimation sample starts at T_0 and ends in $T_0 < t_0 < T_t$ and, accordingly, the forecasting begins in $t_0 + 1$ and ends in T_1.

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[19]See Stock and Watson (2007) and Faust and Wright (2013) for a broader discussion on the performance of the autoregressive model in inflation forecasting. Faust and Wright (2013) suggest that an AR(1) model with a fixed slope coefficient is in general a strong benchmark.

[20]Indeed, another practical advantage of using monetary aggregates or credit data to forecast inflation is precisely that we have longer time series with which to construct global predictors.

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 $j \in \{EM, AR\}$, 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 $T_1 - h$ as follows,

$$MSFE_j(h) \equiv \frac{1}{T_1 - h - t_0 + 1} \sum_{t=t_0}^{T_1-h} \widehat{\widehat{\epsilon}}^2_{j,t+h}, \tag{26}$$

where $\widehat{\widehat{\epsilon}}_{j,t+h}$ is the estimated forecast error for model $j \in \{EM, AR\}$ at date $t + h$. Notice that here we use the short-hand notation EM and AR to denote Model 1 and Model 2 as shown above. Starting with the initial observation in the full sample, we shift the estimation and forecasting subsamples forward by one quarter and repeat the forecasting exercise. We keep doing this recursively to explore the performance of each empirical model based on the relative MSFE over the full data sample.

Our empirical inferences are based on the F-statistic against the corresponding critical value based on a bootstrap algorithm described in Clark and McCracken (2006).[21] 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 forecasting variable, where the lag length for the forecasting variable and inflation are separately determined based on the SIC. The equations of this data-generating process are estimated by OLS with 5000 bootstrap iterations. 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 autoregressive 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 model, Model 1, against the alternative, 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 the 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, conditional on the null hypothesis of equal

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[21]The construction of F-statistics as well as t-statistics is 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.

forecast accuracy being false, the probability of rejecting such a null with the full sample GW test is very low. That is essentially what our implementation of the GW test would suggest.[22] 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 Main Empirical Findings

The results of the pseudo-out-of-sample forecasts with measures of domestic and global economic activity are reported in Figures 3-5. Our main findings can be listed as follows:[23]

First, with the CBO U.S. measure of output gap, we confirm the literature following Atkeson and Ohanian (2001), which finds that domestic slack does not help forecast inflation relative to the simple autoregressive process of inflation after the mid-1980s (Figure 3). 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 doubt on our ability to find empirical evidence of the role of global economic activity on the inflation dynamics.[24] Therefore, we turn to explore forecasts based on liquidity measures instead.

Second, the predictive ability of the U.S. money gap (Figure 4) can be accredited over a longer period of time—mostly going into the late 1980s and early-1990s across the different inflation measures and horizons we consider. Hence, the U.S. money gap provides more positive results than the CBO U.S. output gap in this period. Afterwards, however, the measure never outperforms the forecasts from the simpler autoregressive model for inflation. Notice that this period is largely characterized by the Great Moderation, a more aggressive stance of monetary policy against inflation, and greater economic integration (globalization). The G7 money gap measure, which is available since the early 1960s, provides more accurate forecasts than the autoregressive process (and also than the U.S. money gap) in almost all subsamples (starting from the beginning of sample) and forecast horizons for both CPI and PCE inflation, in line with the findings of Canova (2007) and D'Agostino and Surico (2009, 2012).

Finally, the global credit growth measure (see Figure 5) exhibits similar patters to money

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[22]These results are available upon request.

[23]While our analysis focuses on open-economy measures, we compare our results to the closed-economy counterparts in order to highlight the role of global economic activity.

[24]In an earlier analysis whose results are not reported here but can be provided upon request, we considered several other measures of domestic and global slack. These measures are all based on a production function approach (hence more theoretically-consistent): CBO U.S., 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 robust evidence of good predictive performance using any of these slack measures either. Statistically-based measures such as the HP-filtered GDP (based on a 1-sided filter) are also weak predictors.

growth—mostly with CPI inflation. While U.S. credit growth never outperforms the simpler inflation autoregressive mode 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 reflect an unmodelled structural break during the $2007 - 09$ recession.[25] Even though, in theory, the global money and credit measures have the same implications for inflation predictability, in practice we observe some differences. These may stem from the differences in the data sources for money and credit. Nevertheless, we obtain qualitatively similar results under these measures.[26]

The main takeaway from these experiments is that globalization seems to have affected the U.S. inflation dynamics, justifying the use of an open-economy framework to model U.S. inflation. Moreover, recall that we do not motivate the use of money growth measures on the basis of the quantity theory of money, but take the alternative view that the information content of global liquidity (and even global credit) is consistent with the implications of the workhorse open-economy New Keynesian model because theory tells us that such measures are indeed related to slack in equilibrium.[27] In fact, what theory suggests is that money and even credit contain a signal about the amount of slack that we actually do not observe properly and, as such, can be exploited to forecast inflation. Hence, our empirical findings suggest that global liquidity measures can help us bridge the gap between the New Keynesian theory and the mixed or inconclusive results found in the literature with global slack measures as predictors of inflation. In a way, it also provides a monetarist and New Keynesian synthesis to our understanding of the inflation dynamics.

In light of the fact that global money and credit movements appear to contain a useful signal about the cyclical movements in inflation, these measures ought to be reconsidered as useful indicators for forecasters and policymakers to take into account.

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[25]The findings of Eickmeier et al. (2014) estimating a factor model support 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 $2007 - 09$ 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 subsamples that include the $2007 - 09$ recession episode. Our G7 money gap measure remains a strong predictor of inflation in the recession.

[26]As noted earlier, we have considered real measures of money and credit as alternative predictors as well. This exercise, however, leads qualitatively to similar results and so the interested reader is referred to Dur and Martínez-García (2020) for a full discussion.

[27]While global credit has not been tested before in the context of inflation forecasting, global money has been given 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) on the basis of the quantity theory of money. Moreover, notice here that our empirical exercise differs from D'Agostino and Surico (2009) in other dimensions as well. We focus not only on money, but also credit, including overall credit supply as well as household and firm credit (in subsection 3.4.1). Unlike D'Agostino and Surico (2009), we explore various subsamples, including the effective lower bound and post-$2007 - 09$ periods, documenting variations in predictive accuracy.

3.4 Dissecting the Evidence Further

3.4.1 The Role of Global Liquidity

Household Credit vs. Business Credit. The theoretical framework studied earlier suggests a relationship between inflation and credit to the economy. The baseline analysis we discussed previously is based on aggregated credit series that include both credit to households and credit to firms. Now we take a closer look at the components of this series and explore whether household credit or firm credit matter more for inflation predictability. Consistent with our model that features credit to households, our empirical analysis shows that household credit is indeed what matters most when predicting inflation in the U.S.

We use the BIS series for these two categories of credit (see the paper's appendix for further details) to investigate the capability of household and firm credit growth to predict inflation. We perform this at the domestic and global level, using the U.S. and the G7 average series, respectively.[28]

As the results in Figure 6 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. Instead, for the period where the series becomes available, G7 household credit growth is shown to perform better than the U.S. measure. Figure 7 suggests that firm credit growth is not as strong a predictor of inflation as household credit growth. 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 that we extract from this exercise is that what's most relevant for modeling and forecasting inflation in the U.S. is the credit to households. Furthermore, we also confirm that global credit—whether credit to households or credit to firms—is a better predictor than its domestic credit counterpart alone.

Money Supply vs. Interest Rates. Our analysis so far focused on liquidity measured either by the quantity of money or by credit available. Next, we ask whether a price-based measure can also help forecast inflation. In particular, we focus on the short-term interest rate dynamics, captured by the short-term nominal interest rate movements, $\Delta \widehat{i}_t = \widehat{i}_t - \widehat{i}_{t-1}$.[29] For the U.S. measure, we use the first differences of the Fed Funds rate. A global measure can then be constructed using the average interest rate changes across the G7 countries. To do so, we consider the money market rates for the rest of the G7 countries along with the U.S. Fed Funds rate.[30]

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[28]Because the G7 average is relatively short, we consider a relatively smaller window of 140 quarters (split into 70 quarters for estimation and 70 quarters for forecasting) instead of the 160 quarters in our other forecasting exercises.

[29]We use this measure as a proxy for the domestic interest rate gap (the interest rate in deviations from its counterpart in the frictionless case).

[30]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 this paper's appendix for additional details.)

The idea here is that these interest rate movements are the other side of the coin that moves with in sync with the amount of moneyholdings in the economy. Therefore, these interest rate changes can be an indirect proxy for the output gap and help forecast domestic inflation.[31] Considering all subsamples from the start date of our series and going through the most recent subsample, we evaluate the predictive power of interest rate movements including during the $2007 - 09$ recession. We document the following results in Figure 8:

First, the U.S. interest rate gap is a robust predictor of U.S. inflation as it outperforms the simpler autoregressive model in almost all subsamples, beginning from the earliest subsamples available. The relative MSFEs are statistically significant at but only slightly below 1 in value, so we can infer that this measure does not necessarily yield more accurate forecasts than the global liquidity measures discussed in our previous analyses (which tend to result in significantly lower relative MSFE values).

Second, the G7 interest rate gap beats the domestic interest rate gap measure occasionally, especially on short-term CPI inflation forecasts and medium-term PCE inflation forecasts. There is considerable success in the more recent periods that include the $2007 - 09$ recession. Nevertheless, the global interest rate gap measure does not appear to be as strong a predictor as global liquidity or the U.S. interest rate gap are.

We interpret these results as follows: First, the robust performance of the U.S. interest rate gap, once again, reminds us that the U.S. inflation is ultimately under the control of the Federal Reserve. So it should be no surprise that U.S. interest rate changes are a good predictor for U.S. inflation. Second, while in theory global interest rate gaps should help predict U.S. inflation better than the U.S. interest rate gap, in practice the advantage is not apparent. The empirical disconnect may reflect some important features of the international monetary system that have been left unmodelled. For instance, three of the economies in the G7—France, Germany, and Italy—have been in a currency union with a common policy rate since 1999. Hence, it is conceivable that the common interest rate gap measure that we use for these economies may not be as well aligned with the respective output gaps in each of these countries if instead reflects the amount of slack within the euro area as a whole.

Another reason for this apparent disconnect could be that the shadow rates that we use to assess the stance of monetary policy in the aftermath of the $2007 - 09$ recession when many of the G7 countries found themselves at the zero-lower bound are themselves a noisy signal on which to base our measures of the global (and even the U.S.) interest rate gap. We point this out because it is apparent to us that another important advantage of using quantity-based measures such as money or credit as predictors of inflation is precisely that their data—unlike for policy rates—is observable whether policy rates are at zero or above zero.

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[31]The role of interest rate movements on predicting inflation has been studied before. See for instance, Chowdhury et al. (2006) for the closed-economy finding and Eickmeier and Pijnenburg (2013) for the open-economy finding, providing supportive evidence for interest rates as predictors in the pre-$2007 - 09$ recession period.

3.4.2 The Role of International Relative Prices

Martínez-García and Wynne (2010) suggest a role for the real exchange rate gap as a proxy for global slack. They show that under a variant of the open-economy New Keynesian framework that Home and Foreign slack can be replaced in the Phillips curve (and similarly in the forecasting relationship spelled out in (23)) with domestic slack and the real exchange rate gap, where the real exchange rate gap can be defined as the deviation of the real exchange rate from its frictionless value. Hence, the information content of the real exchange rate can be exploited to forecast domestic inflation without having to rely on global slack (which we have already seen it is difficult to measure in practice).[32]

In light of this, we evaluate the real exchange rate gap, along with domestic output gap, as a candidate to proxy global slack in our economic model. We choose to work with REER rather than using other international relative prices (such as the terms of trade) because the REER series available to conduct our historical analysis is longer.[33] In our initial assessment of the forecasting model including the domestic output gap (CBO) and the REER gap, which is simply the log-differenced REER, we did not get very successful results. This could simply be because domestic slack is not a good forecasting variable to begin with, possibly shadowing the performance of the REER gap. Indeed, when we test the REER growth measure alone, we obtain significantly better results (see Figure 9). Interestingly, starting in the mid-1980s, the U.S. REER starts outperforming the autoregressive process. This variation in the predictive performance of the REER gap further supports our view that one must not ignore the open-economy dimension when forecasting inflation.

It is true that in more recent subsamples—starting in early 1990s—the good performance of the REER gap deteriorates. Nevertheless, we still believe that the forecasting power 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 a broad one—the former is a longer series than the latter, which helps us study the time-variation of the relative MSFEs. Unfortunately, the narrow measure captures only a group of advanced countries, leaving out major emerging countries such as China, which have become increasingly important for U.S. trade starting in the 1990s and more so since China's accession to the WTO in 2001. Data limitations prevent us from documenting the role of trade linkages more fully here, so we leave this open as an avenue for future research.

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[32]Stock and Watson (1999b) and Stock and Watson (2009) 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 here would suggest.

[33]In an earlier assessment focusing on the 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) the price of exports relative to imports, and (ii) the price of exports relative to imports ex. oil.

4 Conclusion

The seminal work of Atkeson and Ohanian (2001) documented a break in the Phillips curve relationship 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 in the U.S. However, we show that the Phillips curve is alive and well for forecasting. The key feature of our paper bridging the gap between theory and evidence on the Phillips curve is to consider its open-economy dimension rather than the more standard closed-economy one. We further model this in an open-economy New Keynesian model which explicitly incorporates a role for money and credit markets related to the provision of liquidity services. In this setting, we establish theoretically that global slack contains all the relevant information needed to forecast changes in domestic inflation. Furthermore, we also show that global liquidity and global credit indicators have information content about global slack that can be successfully leveraged to forecast domestic inflation. In the case of the U.S., simple measures of global money and credit growth that are easier to track are shown empirically to be more useful than existing measures of U.S. and foreign slack for inflation forecasting.

Our interpretation of how global liquidity and even global credit are linked to inflation in an open-economy New Keynesian setting has, to own knowledge, not been considered before. We recognize that it remains a challenging task to find reliable measures of global slack purely on measured economic activity. However, our empirical evidence based on U.S. data shows that money and credit have indeed predictive power for inflation even after the onset of the Great Moderation, albeit in global rather than local terms. The policy implication is that monetary aggregates and credit aggregates can be useful for monetary policymaking even when one approaches the question from a New Keynesian point of view where these variables (particularly money) have traditionally been relegated in the policy debate.

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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 Figures 1-2 where our series are depicted.

Here are some abbreviations: BEA = U.S. Bureau of Economic Analysis; BIS = Bank for International Settlements; BLS = U.S. Bureau of Labor Statistics; CBO = Congressional Budget Office; DGEI = Dallas Fed Global Economic Indicators (Grossman et al., 2014); FRED = Federal Reserve Bank of St. Louis Economic Data; IFS = International Financial Statistics; IMF = International Monetary Fund; OECD = Organization for Economic Co-operation and Development.

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 (Grossman et al., 2014) for the 1980:Q1-2017:Q1 period. For Germany, we use the Bundesbank M2 series for 1949:Q1-1979:Q4 and the DGEI (Grossman et al., 2014) for 1980:Q1-2017:Q1, 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 (Grossman et al., 2014) series for 1980:Q1-2017:Q1.

We construct the U.S. money gap measure by log-differencing the U.S. M2 series, then multiply 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:Q1. 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
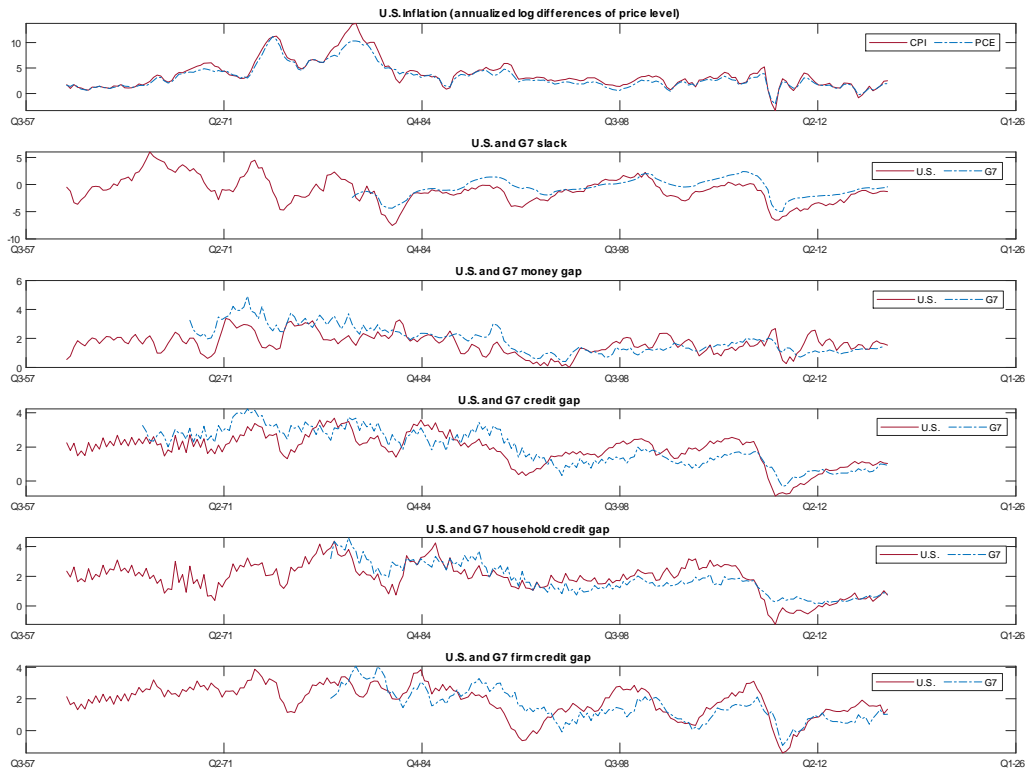
Figure B1. Time series plots of the data. All series except for slack are seasonally adjusted with a one-sided filter. All series are in percentage terms.
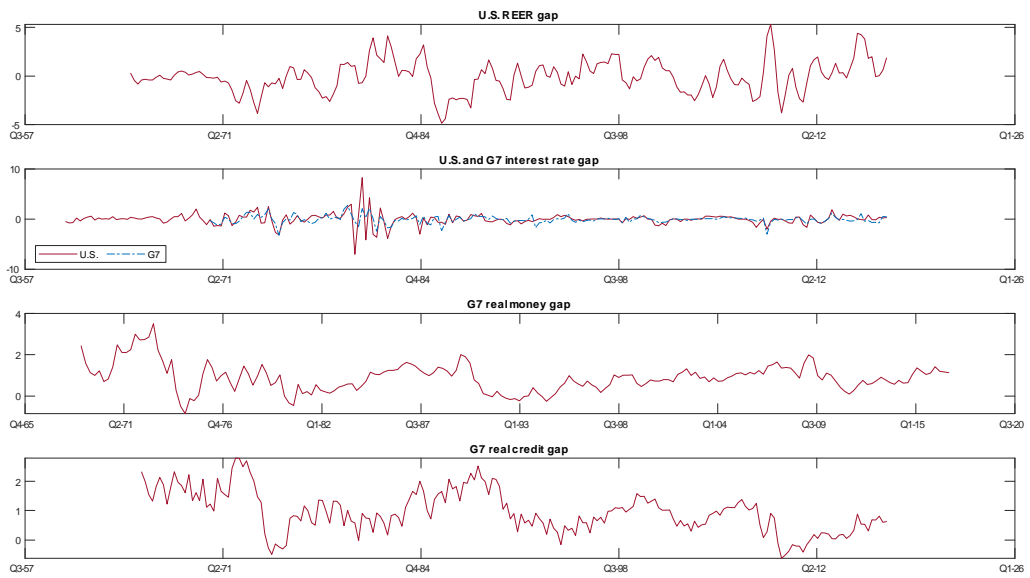
Figure B2. Time series plots of the data. All series except for interest rates are seasonally adjusted with a one-sided filter. All series are in percentage terms.
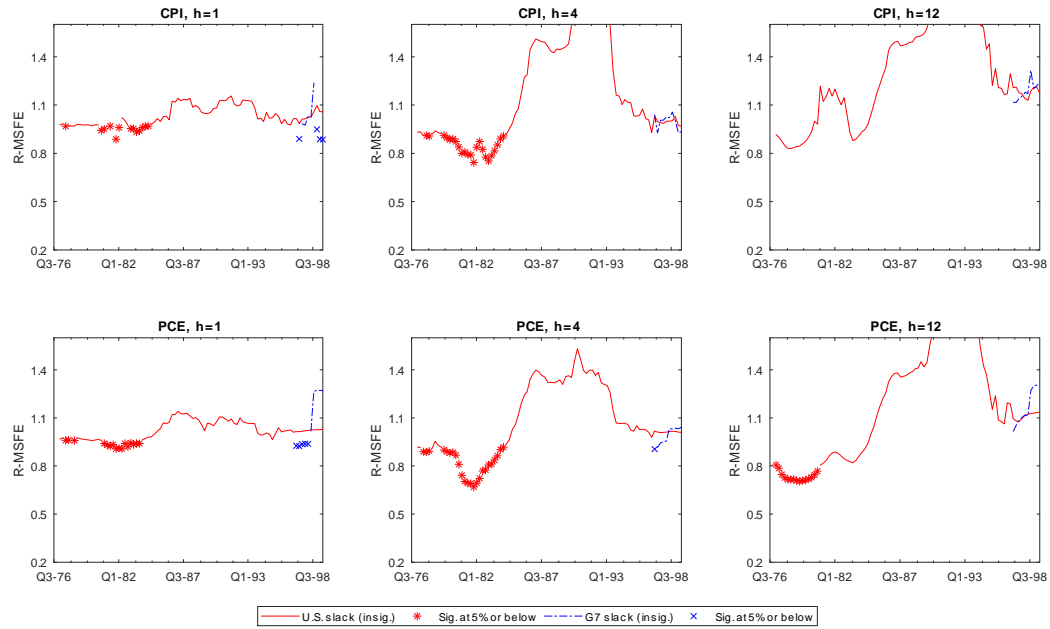
Figure B3. Evolution of the MSFEs of the forecasts with U.S. and G7 slack relative to the benchmark autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 70 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S. slack: There are 90 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1977:Q2, and the forecast sample starting in 1977:Q3 and ending in 1994:Q4. G7 slack: There are 10 subsamples, with the first estimation sample starting in 1980:Q1 and ending in 1997:Q2, and the forecast sample starting in 1997:Q3 and ending in 2014:Q4. For both measures, the last estimation sample starts in 1982:Q2 and ends in 1999:Q3, and the forecast sample starts in 1999:Q4 and ends in 2017:Q1.
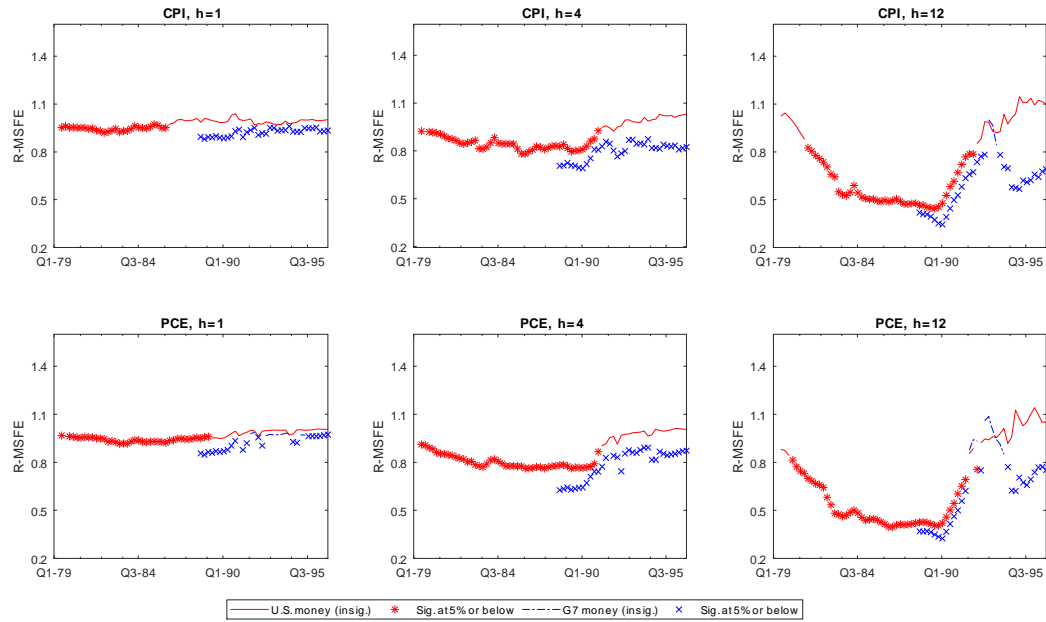
Figure B4. Evolution of the MSFEs of the forecasts with U.S. and G7 money gap relative to the benchmark autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 80 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S. money: There are 70 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1979:Q4, and the forecast sample starting in 1980:Q1 and ending in 1999:Q4. The last estimation sample starts in 1977:Q2 and ends in 1997:Q1, and the forecast sample starts in 1997:Q2 and ends in 2017:Q1. G7 money: There are 34 subsamples, with the first estimation sample starting in 1968:Q4 and ending in 1988:Q3, and the forecast sample starting in 1988:Q4 and ending in 2008:Q3. The last estimation sample starts in 1977:Q1 and ends in 1996:Q4, and the forecast sample starts in 1997:Q1 and ends in 2016:Q4.
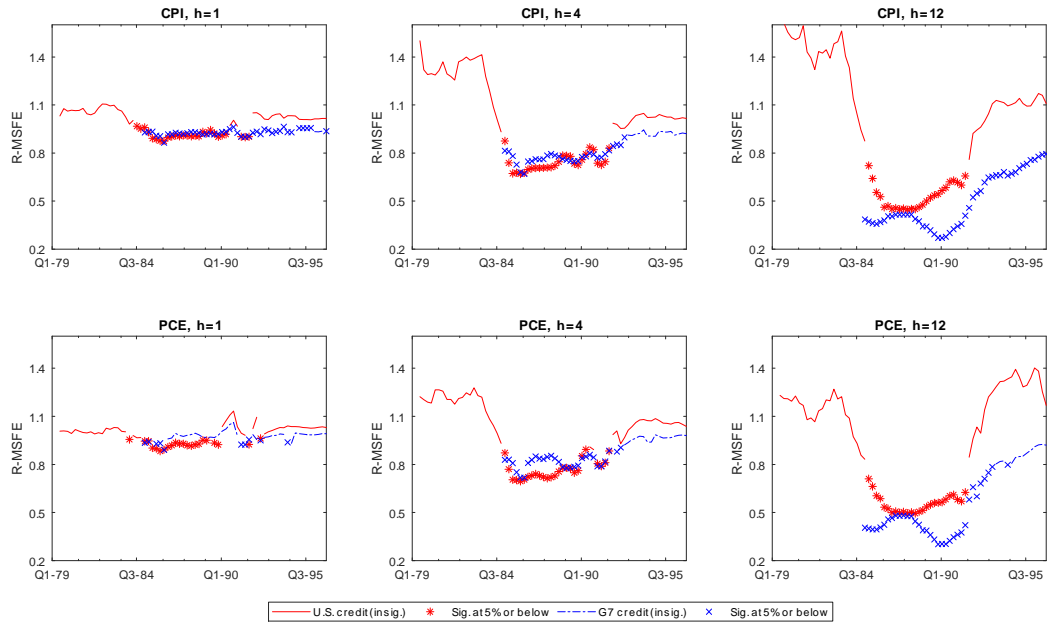
Figure B5. Evolution of the MSFEs of the forecasts with U.S. and G7 credit gap relative to the benchmark autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 80 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S. credit: There are 70 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1979:Q4, and the forecast sample starting in 1980:Q1 and ending in 1999:Q4. G7 credit: There are 48 subsamples, with the first estimation sample starting in 1965:Q3 and ending in 1985:Q2, and the forecast sample starting in 1985:Q3 and ending in 2005:Q2. For both measures, the last estimation sample starts in 1977:Q2 and ends in 1997:Q1, and the last forecast sample starts in 1997:Q2 and ends in 2017:Q1.
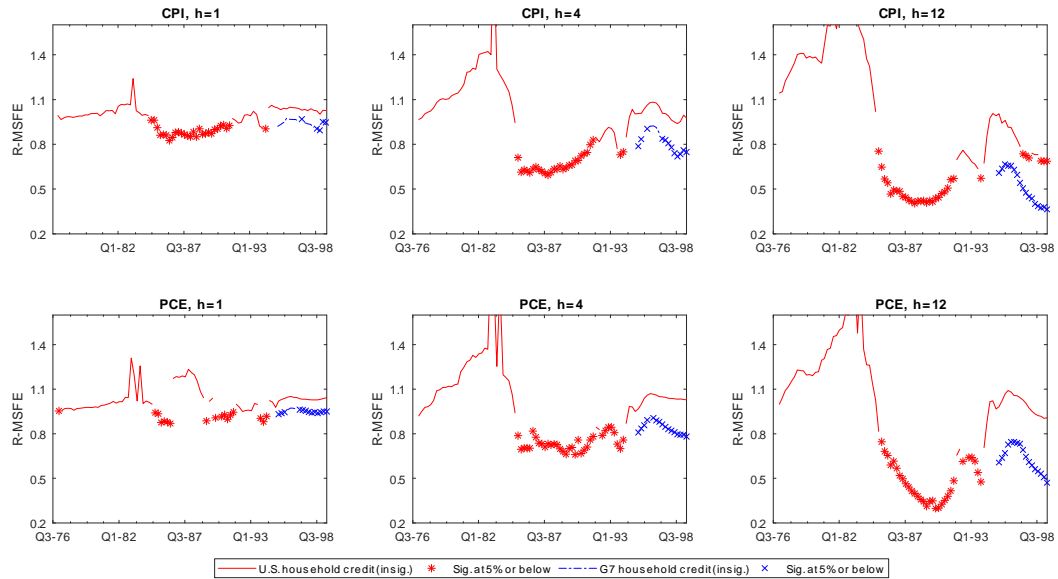
Figure B6. Evolution of the MSFEs of the forecasts with U.S. and G7 household credit gap relative to the benchmark autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 70 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S credit: There are 70 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1977:Q2, and the forecast sample starting in 1977:Q3 and ending in 1994:Q4. G7 credit: There are 14 subsamples, with the first estimation sample starting in 1978:Q4 and ending in 1996:Q1, and the forecast sample starting in 1996:Q2 and ending in 2013:Q3. For both measures, the last estimation sample starts in 1982:Q2 and ends in 1999:Q3, and the last forecast sample starts in 1999:Q4 and ends in 2017:Q1.
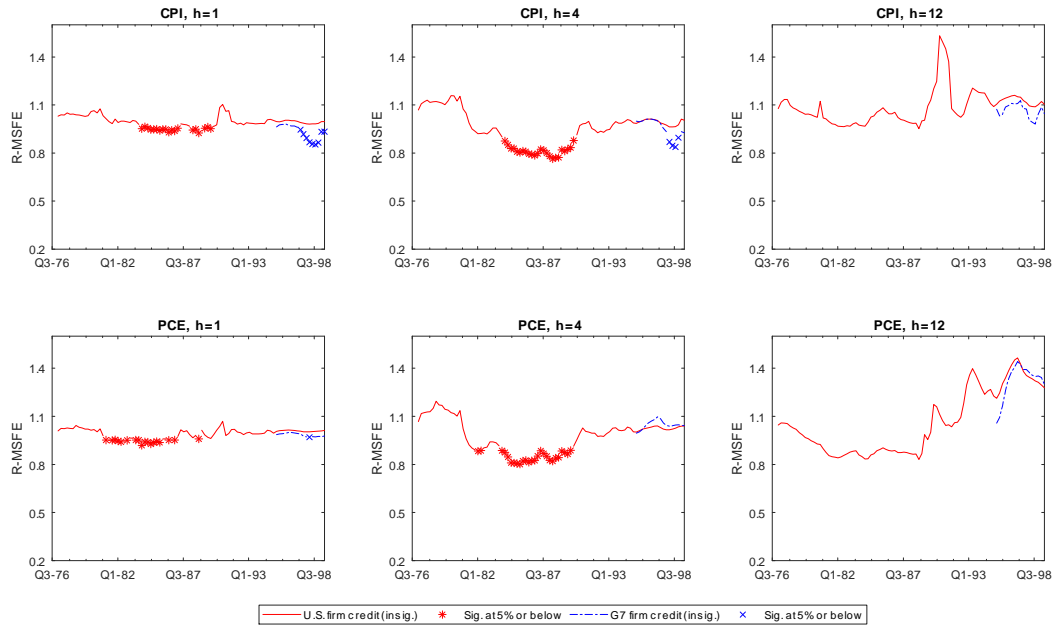
Figure B7. Evolution of the MSFEs of the forecasts with U.S. and G7 firm credit gap relative to the benchmark autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 80 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S. credit: There are 70 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1979:Q4, and the forecast sample starting in 1980:Q1 and ending in 1999:Q4. G7 credit: There are 48 subsamples, with the first estimation sample starting in 1965:Q3 and ending in 1985:Q2, and the forecast sample starting in 1985:Q3 and ending in 2005:Q2. For both measures, the last estimation sample starts in 1977:Q2 and ends in 1997:Q1, and the last forecast sample starts in 1997:Q2 and ends in 2017:Q1.
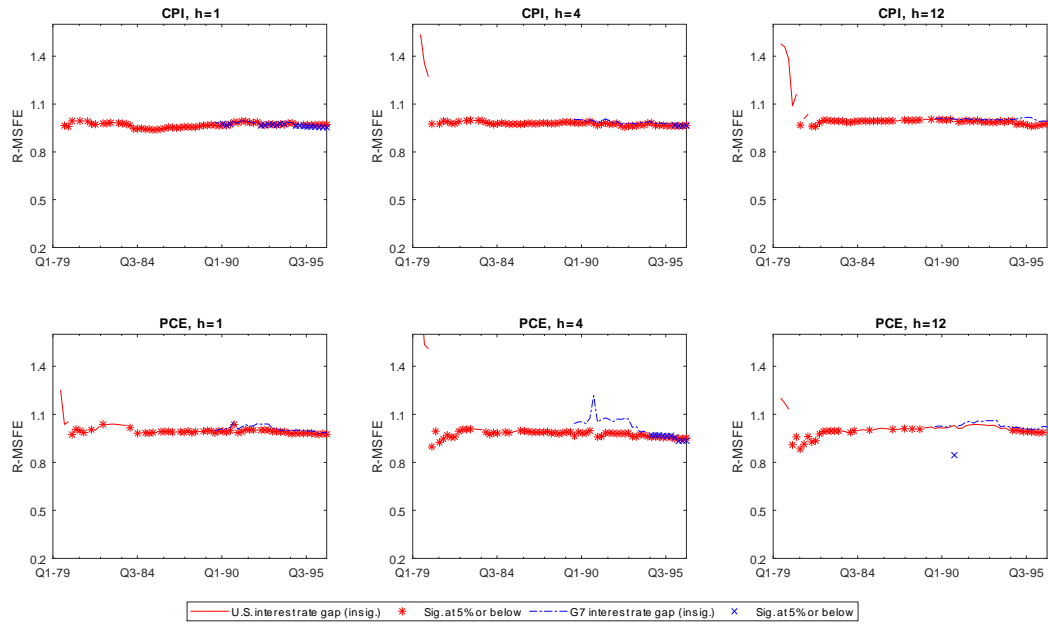
Figure B8. Evolution of the MSFEs of the forecasts with U.S. and G7 interest rate gap and the autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 80 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. U.S. rate: There are 70 subsamples, with the first estimation sample starting in 1960:Q1 and ending in 1979:Q4, and the forecast sample starting in 1980:Q1 and ending in 1999:Q4. G7 rate: There are 30 subsamples, with the first estimation sample starting in 1970:Q1 and ending in 1989:Q4, and the forecast sample starting in 1990:Q1 and ending in 2009:Q4. For both measures, the last estimation sample starts in 1977:Q2 and ends in 1997:Q1, and the last forecast sample starts in 1997:Q2 and ends in 2017:Q1.

CPI, h=1   **CPI, h=4**   **CPI, h=12**

PCE, h=1   **PCE, h=4**   **PCE, h=12**
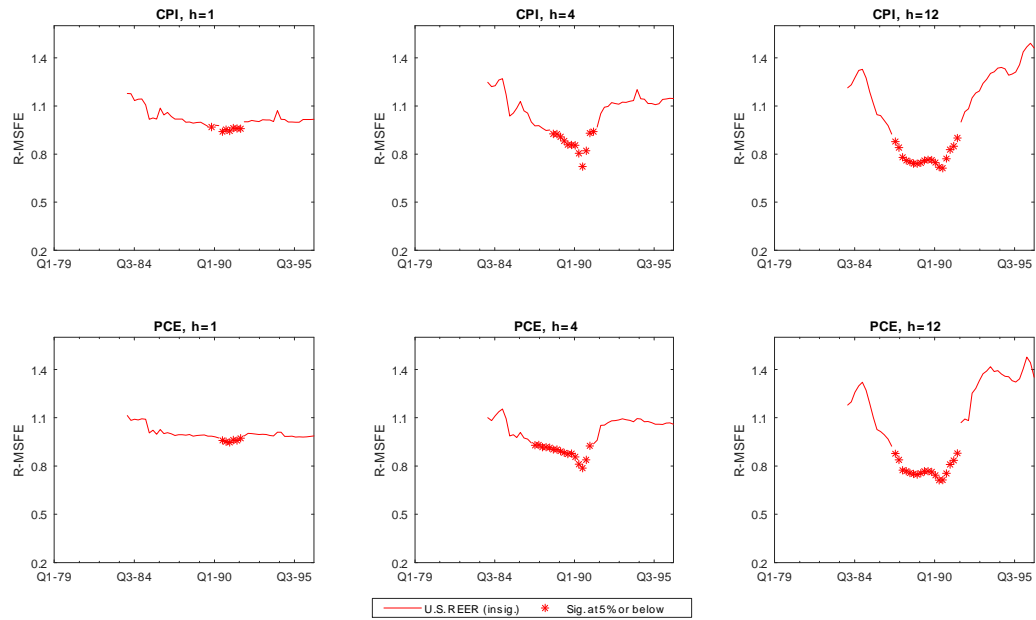
U.S. REER (insig.)   ✳ Sig. at 5% or below

Figure B9. Evolution of the MSFEs of the forecasts with U.S. REER gap and the autoregressive process of inflation. The vertical axis is for the relative MSFEs. In any subsample of the forecasting exercise, the estimation and forecast samples have 80 quarters of data each. The dates on the horizontal axis indicate the end of the estimation sample for a given subsample in our forecasting experiment. Sample start and end dates are given as follows. There are 52 subsamples, with the first estimation sample starting in 1964:Q3 and ending in 1984:Q2, and the forecast sample starting in 1984:Q3 and ending in 2004:Q2. The last estimation sample starts in 1977:Q2 and ends in 1997:Q1, and the last forecast sample starts in 1997:Q2 and ends in 2017:Q1.