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**Forecasting Local Inflation with Global Inflation:
When Economic Theory Meets the Facts***

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Abstract

This paper provides both theoretical insight as well as empirical evidence in support of the view that inflation is largely a global phenomenon. First, we show that inflation across countries incorporates a significant common factor captured by global inflation. Second, we show that in theory a role for global inflation in local inflation dynamics emerges over the business cycle even without common shocks, and under flexible exchange rates and complete international asset markets. Third, we identify a strong "error correction mechanism" that brings local inflation rates back in line with global inflation which explains the relative success of inflation forecasting models based on global inflation (e.g., Ciccarelli and Mojon (2010)). Fourth, we argue that the workhorse New Open Economy Macro (NOEM) model of Martínez-García and Wynne (2010) can be approximated by a finite-order VAR and estimated using Bayesian techniques to forecast domestic inflation incorporating all relevant linkages with the rest of the world. This NOEM-BVAR provides a tractable model of inflation determination that can be tested empirically in forecasting. Finally, we use pseudo-out-of-sample forecasts to assess the NOEM-BVAR at different horizons (1 to 8 quarters ahead) across 17 OECD countries using quarterly data over the period 1980Q1-2014Q4. In general, we find that the NOEM-BVAR model produces a lower root mean squared prediction error (RMSPE) than its competitors—which include most conventional forecasting models based on domestic factors and also the recent models based on global inflation. In a number of cases, the gains in smaller RMSPEs are statistically significant. The NOEM-BVAR model is also accurate in predicting the direction of change for inflation, and often better than its competitors along this dimension too.

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1 Introduction

The idea that domestic inflation may depend on international conditions is not new. The main risk of ignoring international developments is to misinterpret the effect of domestic economic conditions and pursuing suboptimal macroeconomic policies as a result. Understanding the international linkages that affect inflation is, therefore, fundamental to develop better models for policy analysis and forecasting.

The paper investigates the hypothesis that inflation is a global phenomenon in an increasingly more integrated world, so the economic forces driving inflation in one country to some extent will permeate inflation everywhere else. In this paper, we tackle the question in two sequential steps. First, we study the joint dynamics of local and global inflation in the context of the workhorse New Open Economy Macro Model (NOEM) that constitutes the cornerstone of mainstream international macro (see, e.g., Clarida et al. (2002) and Martínez-García and Wynne (2010)). We show that global inflation captures a common factor across countries arising from spillovers through the trade channel, which does not necessarily emerge from common shocks.

Secondly, we show that local inflation can be represented with an error correction type of model that recognizes the structural relationship between global and local inflation. Finally, we investigate whether it is possible to exploit this global inflation component to improve the forecasting performance upon standard forecasting models. For that, we collect quarterly data on headline inflation, real GDP, industrial production, and on several monetary aggregates (M1, M2 and M3) for 17 OECD countries from the sources documented in Grossman et al. (2014).

Our main results can be summarized as follows:

First, we provide a very tractable framework to interpret the global determinants of global inflation and how those same economic forces are incorporated into local inflation. Our evidence conforms and is consistent with the global slack hypothesis (and the open-economy Phillips curve) articulated in Martínez-García and Wynne (2010) and Martínez-García and Wynne (2013).

Second, global inflation is an attractor for local inflation in the sense that differences across countries and, with respect to the mean, tend to disappear over the long-run. Furthermore, this implicit "error correction mechanism" which is derived from our workhorse New Open Economy Macro (NOEM) model—adopted from the framework derived in Martínez-García and Wynne (2010)—helps understand the role of global inflation in the prediction of local inflation across most countries at various horizons and sample periods as documented, among others, in Ciccarelli and Mojon (2010), Kabukcuoglu and Martínez-García (2014) and Ferroni and Mojon (2014).

Our forecasting model of inflation relies on aggregates for the other large economies in the sample to circumvent some of the difficulties associated with measurement and data availability noted in the work of Martínez-García and Wynne (2010). Our aggregate measures provide a reasonable approximation of the global economic forces at play since our country selection represents a large share of world output.¹ The model, however, exploits all the information available in the data from the rest of the world beyond that contained in global inflation alone. We argue that while there is a strong "error correction mechanism" that pulls local inflation in line with global inflation that can be exploited for forecasting (as shown in Ciccarelli

¹These 17 economies included in our empirical work represent more than 50 percent of world output according to their GDP based on PPP shares of world total from the IMF for most of the sample period since 1980. However, their combined share of world output has slid to around 40 percent since 2004 as emerging economies' share of world output has grown rapidly over the past 15 years.

and Mojon (2010)), global inflation alone is not a sufficient summary of all global factors that can help us forecast local inflation. As a result, our preferred forecasting model of inflation is one that fully incorporates the effects of cross-country spillovers. Our results suggest that such a model tends to consistently outperform the current crop of forecasting models of inflation and even traditional closed-economy Phillips-curve based models.

Third, we show that the solution to our workhorse NOEM model can be approximated by a finite-order VAR that we opt to estimate using Bayesian techniques. In general, our NOEM-BVAR produces mostly a lower root mean square prediction error (RMSPE) than its competitors. In a number of interesting cases, the gains in smaller RMSPEs are statistically significant. In particular, the NOEM-BVAR outperforms—or at least shows a predictive ability similar to—factor-augmented models for the case of the U.S. We also consider another measure of predictive success, the success ratio, to assess the ability of the forecast to correctly anticipate the direction of change in inflation. The NOEM-BVAR produces success ratios that are comparable or higher than those of its competitors. For most countries, the evidence suggests that the NOEM-BVAR produces statistically significant improvements in the accuracy of the direction of change forecasted for inflation.

We view our results in this paper as broadly supportive of the view that inflation should be modelled as a global rather than a purely local phenomenon. They also indicate that global inflation can help forecast, but it is not sufficient to exhaust all relevant information about the cross-country spillovers to be found in the international data. While our theoretical and economic analysis is by no means exhaustive, the evidence presented in this paper highlights the importance of recognizing those international spill-overs and incorporating them fully into our forecasting models. We view the proposed NOEM-BVAR model for forecasting inflation as an important benchmark for forecasting inflation across the world.

In the next section, we formulate the NOEM model and discuss its most important implications including the derivation of the "error correction mechanism" that ties local and global inflation and the more general state-space form of the solution. We also show that the NOEM solution can be effectively approximated with a finite-order VAR. In section 3, we report and discuss the main results and robustness checks comparing our preferred NOEM-BVAR model against a broad range of current models for inflation forecasting. Section 4 concludes with some final remarks.

2 A Theory of the Global and Local Dynamics of Inflation

Here we establish the basics of the workhorse NOEM model that allows us: (a) to understand the role that factors, such as global inflation, can play in domestic inflation, (b) to derive an "error correction mechanism" that shows how global inflation can be successfully leveraged to predict domestic inflation, and (c) to derive a VAR-type solution to be estimated and used to forecast inflation.

In this section, we show that the solution to the workhorse NOEM model can be cast in state-space form and approximated with a finite-order VAR. We estimate our preferred specification of the NOEM-BVAR with Bayesian techniques and show in the next section that such a model can be useful to predict inflation across countries and at different time horizons.

While recognizing the theoretical underpinnings of this "error correction mechanism" is an important contribution in light of the emerging empirical evidence based on forecasting models with global inflation

(e.g., Ciccarelli and Mojon (2010)), theory suggests that such a mechanism only offers a partial way of incorporating global factors and the importance of cross-country spillovers into a richer model for inflation forecasting.

Our NOEM-BVAR model is able to predict inflation, especially in the U.S., better than many conventional models including those that use global inflation factors exploiting the "error correction mechanism" that links them. In this section, however, we lay the groundwork by describing the building blocks of the workhorse NOEM model and our main theoretical results characterizing the form of its solution.

2.1 A Workhorse Open-Economy Model of Inflation Determination

Martínez-García and Wynne (2010) postulate a two-country dynamic stochastic general equilibrium model with complete asset markets and nominal rigidities subject to country-specific productivity and monetary shocks. The framework is related to that of Clarida et al. (2002), and is increasingly becoming the workhorse version of the New Open Economy Macro (NOEM) model for international macro.

The model of Martínez-García and Wynne (2010) is stationary, and only describes the behavior of the economy around its balanced growth path (BGP) but is otherwise agnostic about the BGP itself. Given that the model variables are assumed to represent stationary concepts, the specification of the trend component is unmodelled and has to be handled outside the model. Consistent with standard practice, the NOEM model is also written down under the assumption that inflation ought to be zero over the long-run.²

The NOEM model features two standard distortions in the goods markets: monopolistic competition in production and price-setting subject to a contract à la Calvo (1983). The key assumption on which monetary non-neutrality hinges upon is price stickiness. The standard version of the model of Martínez-García and Wynne (2010) also assumes producer-currency pricing (PCP), as in Clarida et al. (2002). The NOEM model abstracts from capital accumulation—considering only linear-in-labor technologies. It also adopts the cashless economy specification where money plays the sole role of unit of account—for further discussion, see chapter 2 in Woodford (2003)—and where exchange rates are fully flexible.

Martínez-García and Wynne (2010) derive the deterministic, zero-inflation steady state for the NOEM model, and log-linearize the equilibrium conditions around that steady state. The simplifications introduced in the model produce a very stylized economic environment after log-linearization, but at the same time provide a very tractable framework under monetary non-neutrality with which to explore the dynamics of local and global inflation. The log-linearized core equilibrium conditions can be summarized with an open-economy Phillips curve, an open-economy investment-savings (IS) equation and a Taylor rule for monetary policy in each country as shown in the following sub-section. The full details of the NOEM specification can be found in Tables 1 – 3 in the Appendix.

Martínez-García (2014) re-expresses the workhorse model of Martínez-García and Wynne (2010) into two separate sub-systems which ultimately describe the determinants of global inflation and also those of the inflation differentials across countries separately. The decomposition is based on the methods of Aoki (1981)

²Since inflation is costly in the presence of nominal rigidities, the assumption of a zero-inflation steady state rules out the existence of a long-run Phillips curve relating inflation to global economic activity. However, the NOEM model still retains a short-run open-economy Phillips curve relationship that is crucial for our subsequent analysis of the joint dynamics of local and global inflation. For a recent discussion on the role of non-zero long-run inflation in the context of related New Keynesian models, the interested reader is referred to Ascari and Sbordone (2014). It is worth noticing that the model of Martínez-García and Wynne (2010) also assumes an optimal (constant) labor subsidy funded with lump-sum taxes to eliminate the distortionary effects of monopolistic competition in the steady state. As a result, the steady states of the NOEM model and that of its frictionless counterpart with flexible prices and perfect competition are exactly the same.

and Fukuda (1993), and it suggests that the dynamics of inflation display a strong common component—measured by global inflation, an output-weighted average of each country’s inflation rate—even when all shocks are country-specific, that is, even when there are no common shocks driving the global cycle.

In this section, we flesh out the solution of the NOEM model by blocks using the insights gained from the work of Martínez-García (2014). This approach combined with the model can be naturally adopted to study the global and local dynamics of inflation relative to trend across countries. In this context, global inflation can be interpreted as the world inflation once we recognize the differences in economic size that exist across countries, while inflation differentials reflect the different responses to shocks across countries. We further argue that the general solution of the NOEM model can be approximated with a finite-order VAR, but that the decomposition of local inflation in a global and a differential component reveals a strong "error correction mechanism" that pulls local inflation towards global inflation. This economic insight into the inner workings of the NOEM model may explain some of the existing empirical work on global inflation (see, e.g., Ciccarelli and Mojon (2010)) and provide some validation for the global slack hypothesis (see, e.g., Borio and Filardo (2007) and the critique of Ihrig et al. (2007)).

We also find that these structural relationships can be useful to guide the construction of better forecasting models of local inflation using global inflation, a point which we address specifically in the next sub-section.

2.1.1 The Workhorse NOEM Model

The basic structure of the closed-economy New Keynesian model is given by a log-linearized system of three-equations—a Phillips curve, an investment-savings (IS) curve, and an interest rate-based monetary policy rule—that characterize the dynamics of output, inflation, and the short-term nominal interest rate.³ Goodfriend and King (1997), Clarida et al. (1999), and Woodford (2003) among others contributed to develop this framework from explicit optimizing behavior on the part of firms (price-setters) and households in the presence of monopolistic competition and sticky prices (nominal rigidities).

Clarida et al. (2002) extend the closed-economy New Keynesian model to a two-country setting. Building on that and related contributions, Martínez-García and Wynne (2010) show that the same basic structure of three log-linearized equations can be generalized to describe the dynamics of output, inflation, and the short-term rate when a country is open to trade with the rest of the world. The workhorse open-economy model of Martínez-García and Wynne (2010) synthesizes the key features underlying the New Open Economy Macro (NOEM) literature.

Since the building blocks of the NOEM model are otherwise extensively discussed in the work of Martínez-García and Wynne (2010), here we put the emphasis on understanding the dynamic behavior of the economy—inflation, in particular—when countries are intertwined through trade.

In the open-economy model of Martínez-García and Wynne (2010), both the Phillips curves and the IS curves of each country differ from those of their closed-economy counterparts as a result of the cross-country linkages that arise through the trade channel (with spillovers into inflation and aggregate demand). However, the workhorse NOEM model retains the view that monetary policy at the country level remains largely centered on attaining certain domestic—rather than global—stabilization objectives on output and inflation.

³We denote $\hat{g}_t \equiv \ln G_t - \ln \bar{G}$ the deviation of a variable in logs from its steady-state. Hence, all variables are defined in log-deviations from steady-state.

The model of Martínez-García and Wynne (2010) neatly showcases the interconnectedness that arises through goods trade, while keeping most of the simplicity and tractability of the closed-economy New Keynesian model.⁴ The open-economy Phillips curve can be written for each country as follows,

$$\begin{aligned}\widehat{\pi}_t &\approx \beta \mathbb{E}_t(\widehat{\pi}_{t+1}) + \dots \\ &\Phi \left[(1 - \xi) \left(\varphi + \gamma \left(\frac{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right) \right) \widehat{x}_t + \xi \left(\varphi + \gamma \left(\frac{\sigma\gamma + (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right) \right) \widehat{x}_t^* \right] \quad (1)\end{aligned}$$

$$\begin{aligned}\widehat{\pi}_t^* &\approx \beta \mathbb{E}_t(\widehat{\pi}_{t+1}^*) + \dots \\ &\Phi \left[\xi \left(\varphi + \gamma \left(\frac{\sigma\gamma + (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right) \right) \widehat{x}_t + (1 - \xi) \left(\varphi + \gamma \left(\frac{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right) \right) \widehat{x}_t^* \right] \quad (2)\end{aligned}$$

where $\widehat{\pi}_t \equiv \widehat{p}_t - \widehat{p}_{t-1}$ and $\widehat{\pi}_t^* \equiv \widehat{p}_t^* - \widehat{p}_{t-1}^*$ denote Home and Foreign inflation (that is, quarter-over-quarter changes in the consumption price index, CPI), \widehat{p}_t and \widehat{p}_t^* denote the corresponding Home and Foreign CPI, and \widehat{x}_t and \widehat{x}_t^* define the Home and Foreign output gaps or slack (that is, the deviations of output from its potential under flexible prices and perfect competition).

The composite coefficient $\Phi \equiv \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right)$ is the common term on the slope of the open-economy Phillips curve, $0 < \beta < 1$ is the intertemporal discount factor, and $0 < \alpha < 1$ is the Calvo price stickiness parameter. The differences in slope coefficients for Home and Foreign slack that arise in (1)–(2) are related to the inverse of the Frisch elasticity of labor supply $\varphi > 0$, the elasticity of intratemporal substitution between Home and Foreign goods $\sigma > 0$, and the share of imported goods in the consumption basket $0 \leq \xi \leq \frac{1}{2}$.

The structural parameters α and ξ feature prominently among the parameters that determine the slope of the open-economy Phillips curve in (1) – (2). These parameters respectively characterize the fraction of firms that cannot update their prices in any given period (price stickiness) and the import shares (degree of openness). Price stickiness breaks monetary policy neutrality in the short-run, establishing a Phillips curve relationship between nominal (inflation) and real variables (slack). The assumption that household preferences for consumption goods are defined over imported as well as domestic varieties is what fleshes out the *global slack hypothesis* in the framework of Martínez-García and Wynne (2010)—that is, what gives theoretical content to the idea that in a world open to trade the relevant trade-off for monetary policy captured by the Phillips curve is between a country’s inflation and global (rather than local) slack.

The open-economy IS equations in (3) – (4) illustrate that the Home and Foreign output gaps, \widehat{x}_t and \widehat{x}_t^* , are tied to shifts in consumption demand over time and across countries,

$$\begin{aligned}\gamma(1 - 2\xi) \mathbb{E}_t[\widehat{x}_{t+1} - \widehat{x}_t] &\approx (1 - \xi)(\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)) \left[\widehat{r}_t - \widehat{r}_t \right] - \dots \\ &\quad \xi(\sigma\gamma + (\sigma\gamma - 1)(1 - 2\xi)) \left[\widehat{r}_t^* - \widehat{r}_t^* \right], \quad (3)\end{aligned}$$

$$\begin{aligned}\gamma(1 - 2\xi) \mathbb{E}_t[\widehat{x}_{t+1}^* - \widehat{x}_t^*] &\approx -\xi(\sigma\gamma + (\sigma\gamma - 1)(1 - 2\xi)) \left[\widehat{r}_t - \widehat{r}_t \right] + \dots \\ &\quad (1 - \xi)(\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)) \left[\widehat{r}_t^* - \widehat{r}_t^* \right], \quad (4)\end{aligned}$$

where the real interest rates in the Home and Foreign country are defined by the Fisher equation as $\widehat{r}_t \equiv \widehat{i}_t - \mathbb{E}_t[\widehat{\pi}_{t+1}]$ and $\widehat{r}_t^* \equiv \widehat{i}_t^* - \mathbb{E}_t[\widehat{\pi}_{t+1}^*]$ respectively, and \widehat{i}_t and \widehat{i}_t^* are the Home and Foreign short-term

⁴More details about the structure of the workhorse NOEM model can be found in the Appendix.

nominal interest rates. The natural real rates of interest that would prevail under flexible prices and perfect competition are denoted as \widehat{r}_t for the Home country and \widehat{r}_t^* for the Foreign country. In the IS equations, the consequences of price stickiness are reflected in the wedge between the real interest rate (the actual opportunity cost of consumption today versus consumption tomorrow) and the natural real rate of interest that captures its distortionary effects on aggregate demand as shown in (3) – (4). The Calvo parameter α , which determines the degree of nominal rigidities in the NOEM model, does not appear explicitly in these equations. In turn, the appetite for imported goods ξ plays a prominent role in the open-economy IS equations for both countries.

The Home and Foreign Taylor (1993)-type monetary policy rules complete the specification of the NOEM model. Monetary policy pursues the goal of domestic stabilization (even in a fully integrated world) and, hence, solely responds to changes in the local economic conditions as determined by each country's inflation and output gap. We assume *extrinsic* or exogenous inertia in the monetary policy rules described in (5) – (6) resulting in a specification of the policy rules consistent with the original set-up proposed in Taylor (1993),

$$\widehat{i}_t \approx \psi_\pi \widehat{\pi}_t + \psi_x \widehat{x}_t + \widehat{m}_t, \quad (5)$$

$$\widehat{i}_t^* \approx \psi_\pi \widehat{\pi}_t^* + \psi_x \widehat{x}_t^* + \widehat{m}_t^*, \quad (6)$$

where \widehat{m}_t and \widehat{m}_t^* are the Home and Foreign monetary policy shocks. The policy parameters $\psi_\pi > 0$ and $\psi_x > 0$ represent the sensitivity of the monetary policy rule to movements in inflation and the output gap, respectively. Under the assumption of *extrinsic* policy rules, we introduce persistence through the monetary policy shocks themselves.

The stochastic process for the Home and Foreign monetary policy shocks, \widehat{m}_t and \widehat{m}_t^* , in each country evolves according to the following bivariate autoregressive process,

$$\begin{pmatrix} \widehat{m}_t \\ \widehat{m}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix} \begin{pmatrix} \widehat{m}_{t-1} \\ \widehat{m}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix}, \quad (7)$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^m \\ \widehat{\varepsilon}_t^{m*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*} \sigma_m^2 \\ \rho_{m,m^*} \sigma_m^2 & \sigma_m^2 \end{pmatrix} \right). \quad (8)$$

The Home and Foreign monetary policy shock innovations are labeled $\widehat{\varepsilon}_t^m$ and $\widehat{\varepsilon}_t^{m*}$, respectively. We assume a common volatility $\sigma_m^2 > 0$, a common autoregressive parameter $-1 < \delta_m < 1$, and allow the cross-correlation of innovations between the two countries to be $-1 < \rho_{m,m^*} < 1$. While we adopt this particular representation based on the idea of *extrinsic* policy inertia, which allows for persistence in the shock process, the results that follow on the characterization of the solution do not hinge upon this particular assumption.⁵

The Home and Foreign natural rates of interest \widehat{r}_t and \widehat{r}_t^* can be expressed as functions of expected

⁵In fact, the same general form of the solution to the NOEM model can be easily extended to the case in which monetary policy rules are subject to i.i.d. monetary policy shocks but display *intrinsic* inertia through a smoothing parameter that gives weight to the actual short-term rate in the previous period (favoring a more gradual policy response to changes in economic conditions as a result).

changes in Home and Foreign potential output, i.e.,

$$\begin{aligned}\widehat{r}_t &\approx (1-\xi)\gamma \left(\frac{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \left(\mathbb{E}_t [\widehat{y}_{t+1}] - \widehat{y}_t \right) + \dots \\ &\quad \xi\gamma \left(\frac{\sigma\gamma + (\sigma\gamma - 1)(1-2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \left(\mathbb{E}_t [\widehat{y}_{t+1}^*] - \widehat{y}_t^* \right),\end{aligned}\tag{9}$$

$$\begin{aligned}\widehat{r}_t^* &\approx \xi\gamma \left(\frac{\sigma\gamma + (\sigma\gamma - 1)(1-2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \left(\mathbb{E}_t [\widehat{y}_{t+1}] - \widehat{y}_t \right) + \dots \\ &\quad (1-\xi)\gamma \left(\frac{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \left(\mathbb{E}_t [\widehat{y}_{t+1}^*] - \widehat{y}_t^* \right).\end{aligned}\tag{10}$$

Natural rates respond to expected changes in—rather than to the level of—real economic activity as measured by potential output. Here, \widehat{y}_t and \widehat{y}_t^* denote the corresponding Home and Foreign potential output in the context of the NOEM model. Potential output refers to the output that would prevail under competitive markets and flexible prices.

Home and Foreign potential output, \widehat{y}_t and \widehat{y}_t^* , can be expressed solely in terms of real shocks since monetary shocks have no real effects absent nominal rigidities, i.e.,

$$\begin{aligned}\widehat{y}_t &\approx \left(\frac{1+\varphi}{\gamma+\varphi} \right) \left(1 + (\sigma\gamma - 1) \left(\frac{2\gamma\xi(1-\xi)}{\varphi(\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2) + \gamma} \right) \right) \widehat{a}_t - \dots \\ &\quad \left(\frac{1+\varphi}{\gamma+\varphi} \right) \left((\sigma\gamma - 1) \left(\frac{2\gamma\xi(1-\xi)}{\varphi(\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2) + \gamma} \right) \right) \widehat{a}_t^*,\end{aligned}\tag{11}$$

$$\begin{aligned}\widehat{y}_t^* &\approx - \left(\frac{1+\varphi}{\gamma+\varphi} \right) \left((\sigma\gamma - 1) \left(\frac{2\gamma\xi(1-\xi)}{\varphi(\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2) + \gamma} \right) \right) \widehat{a}_t + \dots \\ &\quad \left(\frac{1+\varphi}{\gamma+\varphi} \right) \left(1 + (\sigma\gamma - 1) \left(\frac{2\xi\gamma(1-\xi)}{\varphi(\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2) + \gamma} \right) \right) \widehat{a}_t^*,\end{aligned}\tag{12}$$

where \widehat{a}_t and \widehat{a}_t^* denote the corresponding Home and Foreign productivity shocks in the model.

The stochastic process for Home and Foreign aggregate productivity, \widehat{a}_t and \widehat{a}_t^* , evolves according to the following bivariate autoregressive process,

$$\begin{pmatrix} \widehat{a}_t \\ \widehat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & 0 \\ 0 & \delta_a \end{pmatrix} \begin{pmatrix} \widehat{a}_{t-1} \\ \widehat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix},\tag{13}$$

$$\begin{pmatrix} \widehat{\varepsilon}_t^a \\ \widehat{\varepsilon}_t^{a*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*}\sigma_a^2 \\ \rho_{a,a^*}\sigma_a^2 & \sigma_a^2 \end{pmatrix} \right).\tag{14}$$

The Home and Foreign productivity shock innovations are labeled $\widehat{\varepsilon}_t^a$ and $\widehat{\varepsilon}_t^{a*}$, respectively. We assume a common volatility $\sigma_a^2 > 0$ and a common autoregressive parameter $0 < \delta_a < 1$. We allow the cross-correlation of innovations between the two countries to be $-1 < \rho_{a,a^*} < 1$.

The natural rates of interest and potential output are invariant to monetary policy and to the monetary policy shocks given that absent any frictions the principle of monetary neutrality holds. Natural rates and potential output, therefore, only respond to productivity shocks in this model. Finally, output in the Home country is defined as $\hat{y}_t \equiv \hat{y}_t + \hat{x}_t$ and similarly for output in the Foreign country $\hat{y}_t^* \equiv \hat{y}_t^* + \hat{x}_t^*$. Hence, the full extent of the real effects of monetary shocks on actual output comes from their contribution to movements in the output gap since potential—the other term in this decomposition—is unaffected.

2.2 Global vs. Local Inflation Dynamics

The NOEM model of Martínez-García and Wynne (2010) can be solved by blocks, using the decomposition method of Aoki (1981) and Fukuda (1993). For that, we define global aggregates \hat{g}_t^W and cross-country differentials \hat{g}_t^R as follows,

$$\hat{g}_t^W \equiv \frac{1}{2}\hat{g}_t + \frac{1}{2}\hat{g}_t^*, \quad (15)$$

$$\hat{g}_t^R \equiv \hat{g}_t - \hat{g}_t^*. \quad (16)$$

Then, solving the NOEM model in equations (1)–(6) together with the stochastic process for the productivity and monetary policy shocks reduces to solving two separate and smaller sub-systems that characterize the path of global endogenous variables and the path of differential variables given the definitions set in (15)–(16).

The definition of world aggregates in (15) implicitly assumes that both countries are identical in size—that is, both countries have the same share of household population and the same fraction of locally-produced varieties. As noted by Martínez-García (2015), this is quite significant because global variables are weighted not by how open countries are, but by their sheer economic size. Hence, we can decompose any local variable—local inflation in particular—into two components: one global component that is common across countries and another that accounts for the cross-sectional dispersion between the countries. For instance, inflation in the Home country can be expressed as $\hat{\pi}_t = \hat{\pi}_t^W + \frac{1}{2}\hat{\pi}_t^R$ while inflation in the Foreign country is equal to $\hat{\pi}_t^* = \hat{\pi}_t^W - \frac{1}{2}\hat{\pi}_t^R$. Understanding the dynamics of global inflation and the evolution of the cross-sectional dispersion of inflation is, therefore, all that we need to fully characterize the dynamics of local inflation.

The global economy model effectively takes the standard form of a closed-economy New Keynesian model, and can be interpreted accordingly. The system that describes the world economy can be written down with the following three equations,

$$\hat{\pi}_t^W \approx \beta \mathbb{E}_t [\hat{\pi}_{t+1}^W] + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) (\varphi + \gamma) \hat{x}_t^W, \quad (17)$$

$$\gamma (\mathbb{E}_t [\hat{x}_{t+1}^W] - \hat{x}_t^W) \approx (\hat{i}_t^W - \mathbb{E}_t [\hat{\pi}_{t+1}^W]) - \hat{r}_t^W, \quad (18)$$

$$\hat{i}_t^W \approx \psi_\pi \hat{\pi}_t^W + \psi_x \hat{x}_t^W + \hat{m}_t^W. \quad (19)$$

The difference system that describes the dynamics of the cross-country differentials can, in turn, be written

as,

$$\begin{aligned} \widehat{\pi}_t^R &\approx \beta \mathbb{E}_t \left[\widehat{\pi}_{t+1}^R \right] + \dots \\ &\quad (1 - 2\xi) \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) \left((\varphi + \gamma) - 2(\sigma\gamma - 1) \left(\frac{2\gamma\xi(1-\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \right) \widehat{x}_t^R, \end{aligned} \quad (20)$$

$$\gamma(1 - 2\xi) \left(\mathbb{E}_t \left[\widehat{x}_{t+1}^R \right] - \widehat{x}_t^R \right) \approx \left(\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2 \right) \left[\left(\widehat{i}_t^R - \mathbb{E}_t \left[\widehat{\pi}_{t+1}^R \right] \right) - \widehat{r}_t^R \right], \quad (21)$$

$$\widehat{i}_t^R \approx \psi_\pi \widehat{\pi}_t^R + \psi_x \widehat{x}_t^R + \widehat{m}_t^R. \quad (22)$$

Both sub-systems have half the size of the full NOEM model, but have essentially the same structure. We can re-express each one of these two sub-systems more compactly as follows,

$$\widehat{\pi}_t^j \approx \beta \mathbb{E}_t \left[\widehat{\pi}_{t+1}^j \right] + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) \Omega^j \widehat{x}_t^j, \quad (23)$$

$$\gamma \left(\mathbb{E}_t \left[\widehat{x}_{t+1}^j \right] - \widehat{x}_t^j \right) \approx \Delta^j \left[\left(\widehat{i}_t^j - \mathbb{E}_t \left[\widehat{\pi}_{t+1}^j \right] \right) - \widehat{r}_t^j \right], \quad (24)$$

$$\widehat{i}_t^j \approx \psi_\pi \widehat{\pi}_t^j + \psi_x \widehat{x}_t^j + \widehat{m}_t^j. \quad (25)$$

where

$$\Omega^j \equiv \begin{cases} (\varphi + \gamma), & \text{if } j = W, \\ (1 - 2\xi) \left((\varphi + \gamma) - 2(\sigma\gamma - 1) \left(\frac{2\gamma\xi(1-\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2} \right) \right), & \text{if } j = R, \end{cases} \quad (26)$$

$$\Delta^j \equiv \begin{cases} 1, & \text{if } j = W, \\ \left(\frac{\sigma\gamma - (\sigma\gamma - 1)(1-2\xi)^2}{1-2\xi} \right), & \text{if } j = R. \end{cases} \quad (27)$$

for any sub-system $j = \{W, R\}$.

Model Solution. The forcing processes for the generalized specification of the world and difference sub-systems given in (23) – (25) are specified by: a transformation of the natural interest rates, \widehat{r}_t^j , which inherits the properties from the productivity shock process; and, a transformation of the monetary policy shock process, \widehat{m}_t^j . Given the forcing processes derived from the stochastic processes for productivity and monetary policy shocks, we can replace now (25) into (23) – (24) to express the generalized system of equations that characterizes each sub-system of the NOEM model as follows,

$$M^j \widehat{Z}_t^j = N^j \mathbb{E}_t \left[\widehat{Z}_{t+1}^j \right] + Q^j \widehat{\varepsilon}_t^j, \quad (28)$$

where

$$\widehat{Z}_t^j = \left(\widehat{\pi}_t^j, \widehat{x}_t^j, \widehat{a}_{t-1}^j, \widehat{m}_{t-1}^j \right)', \quad (29)$$

$$\widehat{\varepsilon}_t^j = \left(\widehat{\varepsilon}_t^{aj}, \widehat{\varepsilon}_t^{mj} \right)', \quad (30)$$

and M^j , N^j and Q^j are conforming matrices for $j = \{W, R\}$. For reasonable parameter values, the matrix M^j is invertible and (28) can be re-written as,

$$\widehat{Z}_t^j = \Gamma^j \mathbb{E}_t \left[\widehat{Z}_{t+1}^j \right] + \Psi^j \widehat{\varepsilon}_t^j, \quad (31)$$

where $\Gamma^j = (M^j)^{-1} N^j$ and $\Psi^j = (M^j)^{-1} Q^j$ for $j = \{W, R\}$. Blanchard and Kahn (1980) provide conditions under which a unique stable solution exists for (31). Although it is not often easy to analytically derive the parameter restrictions that guarantee existence and uniqueness, numerical experiments show that the policy parameter ψ_π is key. We also find that the lower bound on ψ_π , above which the model attains determinacy, depends on the policy parameter ψ_x .

Interestingly, because the world sub-system behaves essentially as a closed-economy, the standard Taylor principle (i.e., $\psi_\pi > 1$) applies for this block of the NOEM model. In the full NOEM model, the Taylor principle remains broadly consistent with satisfying the Blanchard-Kahn conditions for determinacy for a wide range of plausible values of the other structural parameters. Any resulting discrepancies between the closed-economy Taylor principle and the exact thresholds that hold in this open-economy setting are essentially related to indeterminacy or non-existence problems arising in the component of local inflation that pins down the dispersion in macroeconomic performance across these two countries. We consider here only values on the parameter space for which uniqueness and existence can be guaranteed, and abstract from further discussion of other scenarios where indeterminacy or no-solutions emerge as an outcome.

We further partition \widehat{Z}_t^j into two blocks with $\widehat{Z}_{1t}^j = (\widehat{\pi}_t^j, \widehat{x}_t^j)'$ and $\widehat{Z}_{2t}^j = (\widehat{a}_{t-1}^j, \widehat{m}_{t-1}^j)'$ for $j = \{W, R\}$. Assuming the Blanchard-Kahn conditions are indeed satisfied and imposing $\lim_{T \rightarrow +\infty} (\Gamma^j)^T \mathbb{E}_t [\widehat{Z}_{1t+T}^j] = 0$, we characterize the solution of both sub-systems of the NOEM model in (31) in state space form as follows,

$$\widehat{Z}_{2t+1}^j = A^j(\theta) \widehat{Z}_{2t}^j + B^j(\theta) \widehat{\varepsilon}_t^j, \quad (32)$$

$$\widehat{Z}_{1t}^j = C^j(\theta) \widehat{Z}_{2t}^j + D^j(\theta) \widehat{\varepsilon}_t^j, \quad (33)$$

where $A^j(\theta)$, $B^j(\theta)$, $C^j(\theta)$ and $D^j(\theta)$ are conforming matrices for $j = \{W, R\}$, and θ is the vector of the structural parameters of the NOEM model that enter those matrices. The two structural parameters in the NOEM model most directly connected with defining the features of the trade channel—the elasticity of intratemporal substitution between Home and Foreign goods $\sigma > 0$ and the share of imported goods in the consumption basket $0 \leq \xi \leq \frac{1}{2}$ —do not appear in the composite coefficients of the solution to the world (or global) sub-system. These two parameters only matter for the solution of the difference sub-system and, therefore, for the cross-country differentials that arise in the model's solution.

We could apply the same mathematical reasoning to the full NOEM model represented in (1) – (6)—rather than to its constituent global and difference sub-systems—and infer that if a unique solution exists, then it must take the following state-space form,

$$\widehat{Z}_{2t+1} = A(\theta) \widehat{Z}_{2t} + B(\theta) \widehat{\varepsilon}_t, \quad (34)$$

$$\widehat{Z}_{1t} = C(\theta) \widehat{Z}_{2t} + D(\theta) \widehat{\varepsilon}_t, \quad (35)$$

where $A(\theta)$, $B(\theta)$, $C(\theta)$ and $D(\theta)$ are conforming matrices, $\widehat{Z}_{1t} = (\widehat{\pi}_t, \widehat{\pi}_t^*, \widehat{x}_t, \widehat{x}_t^*)'$, $\widehat{Z}_{2t} = (\widehat{a}_{t-1}, \widehat{a}_{t-1}^*, \widehat{m}_{t-1}, \widehat{m}_{t-1}^*)'$ and $\widehat{\varepsilon}_t = (\widehat{\varepsilon}_t^a, \widehat{\varepsilon}_t^{a*}, \widehat{\varepsilon}_t^m, \widehat{\varepsilon}_t^{m*})'$.⁶ Fernández-Villaverde et al. (2007) explore the link between Dynamic Stochastic General Equilibrium (DSGE) models and state space representations like the one described in (34) – (35)

⁶The solution in (34) – (35) shows that inflation and output in both countries, \widehat{Z}_{1t}^j , can be characterized as linear functions of a vector of state variables, \widehat{Z}_{2t}^j , and structural shock innovations, $\widehat{\varepsilon}_t^j$. Since the vector of structural shock innovations, $\widehat{\varepsilon}_t^j$, is normally distributed, then the Gaussian state-space representation of the solution in (34) – (35) implies that inflation and output are also normally-distributed processes (see Hamilton (1994) for further discussion on the Gaussian state-space model). Similarly for the solution of the model's two sub-systems defined in (32) – (33).

for the full NOEM model. Needless to say, the same link explains the state-space representation of the constituent sub-systems given in (34) – (35). Hence, the NOEM model—and its global and difference sub-systems too—can be approximated by a finite-order structural VAR model with identifying restrictions that are consistent with those of the NOEM model.

Fernández-Villaverde et al. (2007) precisely define the conditions under which a DSGE model such as our NOEM model and its corresponding world and difference sub-systems would be approximated by a finite-order VAR model. The solution of the NOEM model presented in this paper may equivalently be written down for the sub-systems whenever $A^j(\theta)$ is invertible as follows,

$$\widehat{Z}_{2t+1}^j = A^j(\theta) \widehat{Z}_{2t}^j + B^j(\theta) \widehat{\varepsilon}_t^j, \quad (36)$$

$$\widehat{Z}_{1t}^j = C^j(\theta) (A^j(\theta))^{-1} \widehat{Z}_{2t+1}^j + \left[D^j(\theta) - C^j(\theta) (A^j(\theta))^{-1} B^j(\theta) \right] \widehat{\varepsilon}_t^j, \quad (37)$$

and for the full NOEM model whenever $A(\theta)$ is invertible as,

$$\widehat{Z}_{2t+1} = A(\theta) \widehat{Z}_{2t} + B(\theta) \widehat{\varepsilon}_t, \quad (38)$$

$$\widehat{Z}_{1t} = C(\theta) (A(\theta))^{-1} \widehat{Z}_{2t+1} + \left[D(\theta) - C(\theta) (A(\theta))^{-1} B(\theta) \right] \widehat{\varepsilon}_t. \quad (39)$$

It can be shown that $D(\theta) = C(\theta) (A(\theta))^{-1} B(\theta)$ and similarly that $D^j(\theta) = C^j(\theta) (A^j(\theta))^{-1} B^j(\theta)$ for all $j = \{W, R\}$, so equation (37) simply relates the vector of endogenous variables $\widehat{Z}_{1t}^j = \left(\widehat{\pi}_t^j, \widehat{x}_t^j \right)'$ to the vector of exogenous shocks $\widehat{Z}_{2t+1}^j = \left(\widehat{a}_t^j, \widehat{m}_t^j \right)'$ and analogously equation (39) relates the vector of endogenous variables $\widehat{Z}_{1t} = \left(\widehat{\pi}_t, \widehat{\pi}_t^*, \widehat{x}_t, \widehat{x}_t^* \right)'$ only to the vector of exogenous shocks $\widehat{Z}_{2t+1} = \left(\widehat{a}_t, \widehat{a}_t^*, \widehat{m}_t, \widehat{m}_t^* \right)'$.

Hence, substituting \widehat{Z}_{2t} in equation (39) using equation (38) yields a structural moving average representation of \widehat{Z}_{1t} in terms of the current and lagged structural shocks $\widehat{\varepsilon}_t$. Similarly, substituting \widehat{Z}_{2t}^j in equation (37) using equation (36) yields a structural moving average representation of \widehat{Z}_{1t}^j in terms of the current and lagged structural shocks $\widehat{\varepsilon}_t^j$. These moving average representations are invertible—the eigenvalues of $A(\theta)$ and $A^j(\theta)$ are less than unity in modulus—for reasonable parameter values, so Fernández-Villaverde et al. (2007)'s condition for the existence of an infinite-order VAR representation is satisfied. This structural VAR(∞) representation may, in turn, be reasonably approximated by a finite-order structural VAR model (as shown in Inoue and Kilian (2002)).

As it turns out, given that the productivity and monetary policy shock processes are assumed to follow a simple VAR(1) specification, it is easy to see that the vector of endogenous variables $\widehat{Z}_{1t} = \left(\widehat{\pi}_t, \widehat{\pi}_t^*, \widehat{x}_t, \widehat{x}_t^* \right)'$ whose dynamics are characterized by (38) – (39) inherits the same structure with one autoregressive lag. Similarly, a simple VAR(1) specification suffices to characterize the dynamics of the two constituent sub-systems for the transformation of the endogenous variables given in the vector $\widehat{Z}_{1t}^j = \left(\widehat{\pi}_t^j, \widehat{x}_t^j \right)'$ under the corresponding solution for (36) – (37).

Home and Foreign output gaps, \widehat{x}_t and \widehat{x}_t^* , are part of the system that characterizes the solution to the NOEM model and to its two constituent sub-systems but are not observable in reality. Aggregate output is observable and can be decomposed into potential output and the output gap, as indicated earlier. Given the characterization of the output potential in equations (11) and (12) as a function of the productivity shocks, we can simply recast the state-space solution of the NOEM model in terms of the vector of observables $\widehat{Z}_{1t} = \left(\widehat{\pi}_t, \widehat{\pi}_t^*, \widehat{y}_t, \widehat{y}_t^* \right)'$ instead. Under the maintained assumptions on the shock processes, this alternative

representation of the solution for endogenous variables that are also observable retains the simple VAR(1) model form of the original solution. An analogous argument applied to the solution of the two sub-systems on which we have decomposed the NOEM model for the vector $\widehat{Z}_{1t}^j = \left(\widehat{\pi}_t^j, \widehat{y}_t^j \right)'$.

Finally, we should note that a richer specification of the NOEM model with more complex dynamics for the shock processes driving the economy would surely require a more general form of the solution that has to be approximated with a VAR model of a higher order. For that reason, in our empirical implementation we take the simple VAR(1) representation as a reference but consider also specifications of the VAR model with an order higher than one as well.

2.3 Local Inflation's Attraction Towards Global Inflation

We aim to elicit relevant theoretical restrictions that can be exploited for tasks such as forecasting inflation. In the previous section, we characterize the finite-order VAR representation of the solution of the NOEM model and also the corresponding solution by blocks for the global and difference sub-systems. Our theoretical findings suggest that so-long as inflation differentials across countries are stationary around zero, as implied by the NOEM model, we should expect domestic inflation to be pulled towards global inflation as shocks feed through the economy.

In order to formalize this idea in more concrete terms within the workhorse NOEM model, let us recall that the definitions stated in (15) – (16) imply that Home and Foreign inflation relative to global inflation are equal to,

$$\widehat{\pi}_t - \widehat{\pi}_t^W = \frac{1}{2} \widehat{\pi}_t^R, \quad (40)$$

$$\widehat{\pi}_t^* - \widehat{\pi}_t^W = -\frac{1}{2} \widehat{\pi}_t^R. \quad (41)$$

The solution to the difference system posited in (36) – (37) can be extended to the case with observable output rather than with the output gap, as indicated before. Slightly abusing notation, we write the solution in that case as follows,

$$\widehat{Z}_{2t+1}^R = A^R(\theta) \widehat{Z}_{2t}^R + B^R(\theta) \widehat{\varepsilon}_t^R, \quad (42)$$

$$\widehat{Z}_{1t}^R = C^R(\theta) (A^R(\theta))^{-1} \widehat{Z}_{2t+1}^R, \quad (43)$$

where now we have that $\widehat{Z}_{1t}^R = \left(\widehat{\pi}_t^R, \widehat{y}_t^R \right)'$ while $\widehat{Z}_{2t}^R = \left(\widehat{a}_{t-1}^R, \widehat{m}_{t-1}^R \right)'$ and $\widehat{\varepsilon}_t^R = \left(\widehat{\varepsilon}_t^{aR}, \widehat{\varepsilon}_t^{mR} \right)'$ are as before. For reasonable parameter values, the matrix $C^R(\theta)$ is invertible in this alternative representation of the model solution. Hence, the solution to the difference system can be expressed as,

$$\begin{pmatrix} \widehat{a}_t^R \\ \widehat{m}_t^R \end{pmatrix} = A^R(\theta) \begin{pmatrix} \widehat{a}_{t-1}^R \\ \widehat{m}_{t-1}^R \end{pmatrix} + B^R(\theta) \begin{pmatrix} \widehat{\varepsilon}_t^{aR} \\ \widehat{\varepsilon}_t^{mR} \end{pmatrix}, \quad (44)$$

$$\begin{pmatrix} \widehat{\pi}_t^R \\ \widehat{y}_t^R \end{pmatrix} = C^R(\theta) (A^R(\theta))^{-1} \begin{pmatrix} \widehat{a}_t^R \\ \widehat{m}_t^R \end{pmatrix}, \quad (45)$$

or, more compactly, as,

$$\begin{pmatrix} \widehat{\pi}_t^R \\ \widehat{y}_t^R \end{pmatrix} = \widetilde{A}^R(\theta) \begin{pmatrix} \widehat{\pi}_{t-1}^R \\ \widehat{y}_{t-1}^R \end{pmatrix} + D^R(\theta) \begin{pmatrix} \widehat{\varepsilon}_t^{aR} \\ \widehat{\varepsilon}_t^{mR} \end{pmatrix}, \quad (46)$$

where $\widetilde{A}^R(\theta) \equiv C^R(\theta) A^R(\theta) (C^R(\theta))^{-1}$ and $D^R(\theta) = C^R(\theta) (A^R(\theta))^{-1} B^R(\theta)$.

The solution for the world sub-system that characterizes global inflation can also be determined analogously to (46), so it follows that,

$$\begin{pmatrix} \widehat{\pi}_t^W \\ \widehat{y}_t^W \end{pmatrix} = \widetilde{A}^W(\theta) \begin{pmatrix} \widehat{\pi}_{t-1}^W \\ \widehat{y}_{t-1}^W \end{pmatrix} + D^W(\theta) \begin{pmatrix} \widehat{\varepsilon}_t^{aW} \\ \widehat{\varepsilon}_t^{mW} \end{pmatrix}, \quad (47)$$

where $\widetilde{A}^W(\theta) \equiv C^W(\theta) A^W(\theta) (C^W(\theta))^{-1}$ and $D^W(\theta) = C^W(\theta) (A^W(\theta))^{-1} B^W(\theta)$. Taking the first row of the bivariate autoregressive system that characterizes the solution of the difference sub-system in (46) and using (40) to replace $\widehat{\pi}_t^R$ out, as well as a similar expression for \widehat{y}_t^R , it is possible to derive the following simple "error correction" representation for Home inflation relative to global inflation,

$$\widehat{\pi}_t = \widehat{\pi}_t^W + \widetilde{a}_{11}^R(\theta) (\widehat{\pi}_{t-1} - \widehat{\pi}_{t-1}^W) + \widetilde{a}_{12}^R(\theta) (\widehat{y}_{t-1} - \widehat{y}_{t-1}^W) + \frac{1}{2} d_{11}^R(\theta) \widehat{\varepsilon}_t^{aR} + \frac{1}{2} d_{12}^R(\theta) \widehat{\varepsilon}_t^{mR}, \quad (48)$$

where $\widehat{y}_t^R = 2(\widehat{y}_t - \widehat{y}_t^W)$, $(\widetilde{a}_{11}^R(\theta), \widetilde{a}_{12}^R(\theta))$ is the first row of the matrix $\widetilde{A}^R(\theta)$ and $(d_{11}^R(\theta), d_{12}^R(\theta))$ is the first row of the matrix $D^R(\theta)$. More generally, we can write the solution of the difference system as,

$$\begin{pmatrix} \widehat{\pi}_t \\ \widehat{y}_t \end{pmatrix} = \begin{pmatrix} \widehat{\pi}_t^W \\ \widehat{y}_t^W \end{pmatrix} + \widetilde{A}^W(\theta) \begin{pmatrix} \widehat{\pi}_{t-1} - \widehat{\pi}_{t-1}^W \\ \widehat{y}_{t-1} - \widehat{y}_{t-1}^W \end{pmatrix} + D^W(\theta) \begin{pmatrix} \widehat{\varepsilon}_t^{aW} \\ \widehat{\varepsilon}_t^{mW} \end{pmatrix}. \quad (49)$$

A similar set of expressions could be derived using (41) for Foreign inflation relative to global inflation and an analogous expression for Foreign output relative to world output.

Hence, we infer through the decomposition method of Aoki (1981) and Fukuda (1993) applied to the NOEM model that local inflation contains a strong "error correction mechanism" as indicated by equation (48) and the bivariate process in (49). Global inflation, therefore, is relevant to understanding the movements of local inflation and can be exploited for forecasting as well. However, we must recognize that the actual contribution of global inflation and the strength of the forces underlying the "error correction mechanism" shown here ultimately depend on the fundamental features of the economy—such as the prevailing monetary policy regime, the responsiveness of trade to terms of trade and the degree of openness of the countries.

The empirical relevance of the "error correction mechanism" highlighted by equation (48) and the bivariate process in (49), which brings local inflation in line with global inflation over time, can be seen in the performance of forecasting models that take advantage of global inflation to forecast local inflation (see, e.g., Ciccarelli and Mojon (2010)). However, a model such as that given by equation (48) and the bivariate process in (49) only incorporates part of the information that is relevant for forecasting local inflation as noted before. The model solution would not be complete without specifying a model for the determination of global inflation as in (47) as well.

Alternatively, we simply recognize that the solution to the full model takes a more general form given by the full system posited in (38) – (39). As indicated before, we can simply recast the state-space solution of the NOEM model in terms of the vector of observables $\widehat{Z}_{1t} = (\widehat{\pi}_t, \widehat{\pi}_t^*, \widehat{y}_t, \widehat{y}_t^*)'$. This follows naturally from

replacing the Home and Foreign output gaps, \hat{x}_t and \hat{x}_t^* , in the NOEM model described in (1) – (6) with the corresponding difference between actual output, \hat{y}_t and \hat{y}_t^* , and the model-consistent potential output, \hat{y}_t and \hat{y}_t^* , of each country—Home and Foreign potential output are themselves functions of the exogenous shocks, as shown in equations (11) and (12). Slightly abusing notation, it follows that the full NOEM model solution takes the following form,

$$\begin{pmatrix} \hat{\pi}_t \\ \hat{\pi}_t^* \\ \hat{y}_t \\ \hat{y}_t^* \end{pmatrix} = \tilde{A}(\theta) \begin{pmatrix} \hat{\pi}_{t-1} \\ \hat{\pi}_{t-1}^* \\ \hat{y}_{t-1} \\ \hat{y}_{t-1}^* \end{pmatrix} + D(\theta) \begin{pmatrix} \hat{\varepsilon}_t^a \\ \hat{\varepsilon}_t^{a*} \\ \hat{\varepsilon}_t^m \\ \hat{\varepsilon}_t^{m*} \end{pmatrix}, \quad (50)$$

where $\tilde{A}(\theta) \equiv C(\theta)A(\theta)(C(\theta))^{-1}$ and $D(\theta) = C(\theta)(A(\theta))^{-1}B(\theta)$. These theoretical constraints—if substantiated in the data—provide a useful empirical feature to improve our ability to forecast local inflation.

An important contribution of the model is that it explains the intuition why global inflation can be successfully used to predict domestic inflation—this is related to the structural "error correction mechanism" that we described here. If, for example, there is a positive productivity shock in the rest of the world, that shock increases the external potential output, thus also changing the relative output across countries, the terms of trade and ultimately inflation. The fact that foreign products become relatively cheaper as a result leads to a substitution effect away from domestic goods, so domestic inflation is affected through imported prices but also through the impact that these substitution effects have on the pricing decisions of domestic producers in their local markets. However, what the theory shows is that the empirical relationship between global and local inflation arises from these cross-country spill-overs—but such linkages only reflect part of the complex way in which global forces affect local inflation for open economies. We look at the empirical evidence through the lens of the full NOEM model instead in the next section and argue that recognizing the full structural model has statistical value for forecasting inflation.

3 Empirical Findings: Forecasting Local Inflation with Global Inflation Models

We use end-of-quarter and seasonally-adjusted data for a sample of 17 OECD economies during the 1980Q1-2014Q4 period. We focus on quarter-on-quarter inflation rates (π_t) as measured by the headline Consumer Price Index (CPI). One reason to employ the CPI rather than other price indices is that CPI revisions are relatively small compared to those of, for example, the GDP price deflator (see, e.g., Faust and Wright (2013)). In this section, we omit the country subscript for each variable used to lighten the notation. Thus, for every country and quarter t in our sample $\pi_t = 400 \ln(CPI_t/CPI_{t-1})$. Table 4 reports the data sources and the transformations of variables. Further details of the variables used in each model are included in the next subsection.

3.1 Models and Forecast Evaluation

We evaluate a wide variety of models. Most of the models are suggested by the forecasting literature and, in particular, by Ferroni and Mojon (2014). Aside from univariate specifications and frequentist techniques,

we consider other elements and methods that have proved to be useful in inflation forecasting, such as factor components (Stock and Watson (2002), Ciccarelli and Mojon (2010)), Phillips-curve-typed features and commodity price indexes (Stock and Watson (1999)), and Bayesian vector autoregressions (Litterman (1984), Litterman (1986)).

The set of forecasting models is the following:

1. **Recursive autoregression, AR(p) model (RAR).**

$$M_1 : \pi_t = \phi_0 + \Phi(L)\pi_t + \epsilon_t$$

where $\Phi(L) = \phi_1 L + \dots + \phi_p L^p$ is a lag polynomial.

2. **Direct forecast, AR(p) model (DAR).**

$$M_2 : \pi_{t+h} = \phi_{0,h} + \Phi(L, h)\pi_t + \epsilon_{t+h}$$

where h denotes the forecast horizon and $\Phi(L, h) = \phi_{1,h} + \phi_{2,h}L + \dots + \phi_{p,h}L^{p-1}$ is a lag polynomial for a given horizon h .

3. **Driftless Random Walk (RW).**

$$M_3 : \pi_{t+h} = \pi_t + \epsilon_{t+h}$$

4. **AR(p) model with error correction (AR-EC).**

$$M_4 : \pi_{t+h} - \pi_t = \phi_{0,h} + \Phi(L, h)\Delta\pi_t + \epsilon_{t+h}$$

5. **Factor-Augmented AR(p) model (FAR).**

$$M_5 : \pi_{t+h} = \phi_{0,h} + \Phi(L, h)\pi_t + \Theta(L, h)\widehat{F}_t + \epsilon_{t+h}$$

where \widehat{F}_t denotes an estimated static factor component of the inflation rates of the countries in the sample.

6. **Factor-Augmented AR(p) model with error correction (FAR-EC).**

$$M_6 : \pi_{t+h} - \pi_t = \phi_{0,h} + \Phi(L, h)\Delta\pi_t + \Theta(L, h)\Delta\widehat{F}_t + \epsilon_{t+h}$$

7. **Factor-Augmented AR(p) model with idiosyncratic error correction term (FAR-IEC).**

$$M_7 : \pi_{t+h} - \pi_t = \phi_{0,h} + \Phi(L, h)\Delta\pi_t + \Theta(L, h)\Delta\widehat{F}_t + \beta_h e_t + \epsilon_{t+h}$$

where e_t is the residual from regressing the country inflation to a measure of global inflation. The latter is measured by a time-varying GDP-weighted average—with PPP-adjusted GDP shares—of the inflation rates in the sample.

8. Augmented Phillips Curve.

$$M_8 : \pi_{t+h} = \phi_{0,h} + \Phi(L, h)\pi_t + A(L, h)\Delta IPI_t + B(L, h)\Delta M2_t + C(L, h)\Delta P_t^{Com} + \epsilon_{t+h}$$

where IPI denotes the (log of) the industrial production index,⁷ and P^{Com} stands for the (logged) commodity price index. The latter is measured by a simple average of the price indexes of agricultural raw materials, beverages, metals and crude oil.

9. Augmented Phillips Curve with error correction.

$$M_9 : \pi_{t+h} - \pi_t = \phi_{0,h} + \Phi(L, h)\Delta\pi_t + A(L, h)\Delta IPI_t + B(L, h)\Delta M2_t + C(L, h)\Delta P_t^{Com} + \epsilon_{t+h}$$

10. **Bivariate BVAR (BVAR2-FP, BVAR2-MP).** Let $X_t = (\pi_t, \widehat{F}_t)'$, then the VAR model can be written as

$$M_{10}, M_{11} : X_{t+h} = \Phi_{0,h} + \Phi(L, h)X_t + \epsilon_{t+h}$$

where $\Phi_{0,h}$ is a vector of parameters, and $\Phi(L, h)$ denotes in this case a matrix of lag polynomials that depends on h , and the VAR is estimated using flat priors (M_{10}) and Minnesota priors (M_{11}). The values of the hyper-parameters used in each BVAR with Minnesota priors are $\mu_0 = 1$ (AR(1) coefficient dummies), $\lambda_1 = 0.5$ (overall tightness), $\lambda_2 = 1$ (cross-variable weight), and $\lambda_3 = 4$ (lag decay).

11. **Multivariate BVAR (BVAR4-FP, BVAR4-MP).** Redefining $X_t = (\pi_t, \Delta IPI, \Delta M2_t, \Delta P_t^{Com})'$, an analogous version of the previous VAR model is estimated using flat priors (M_{12}) and Minnesota priors (M_{13}).
12. **Bivariate BVAR with commodity price indexes (BVAR2-COM, BVAR2-FCOM).** An analogous version of the VAR model above is estimated using flat priors and $X_t = (\pi_t, \Delta P_t^{Com})'$ (M_{14}) and $X_t = (\pi_t, P_t^{FCOM})'$ (M_{15}), where P^{FCOM} is a MA-filtered commodity price index.
13. **NOEM-BVAR.** Finally, we estimate a BVAR of the NOEM model given by the matrix equation (50) using flat priors. That is, in the vector autoregression above we redefine $X_t = (\pi_t, \pi_t^*, y_t, y_t^*)'$, where π^* is the rest-of-the-world inflation, y is domestic HP-detrended (logged) real GDP, and y^* is the rest-of-the-world HP-detrended (logged) real GDP. For every country, π^* and y^* are calculated as the simple average of the inflation rates and detrended outputs, respectively, of the rest of the sample. Results with alternative measures are commented in subsection 3.3.

Pseudo out-of-sample forecasts are constructed by estimating recursively each model. The number of lags used in the baseline exercise for the competitor models is 2 (see also subsection 3.3 below). The forecast horizons are 1, 4 and 8 quarters. The prediction error is defined as the difference between actual and predicted values. The training sample is 1980Q2-2009Q2. For $h = 1$, for instance, the first forecast is made in the fourth quarter of 2008 and the last one is made in the fourth quarter of 2014.

We compute the root mean squared prediction error (RMSPE) for each country, model, and forecast horizon. Then, we report the Theil-U statistic, that is, the ratio of RMSPE of our NOEM-BVAR relative to

⁷We follow Stock and Watson (1999) here. They find that forecasts with a Phillips curve based on measures of real aggregate activity (e.g., industrial production index) outperform those that use unemployment rates.

the RMSPE of each competitor ($M_1 - M_{15}$). Values less than one imply that the NOEM-BVAR model has a lower RMSPE than does the competitive benchmark. To assess the statistical significance of the difference of the Theil's U-statistics from one, we use a simple one-sided Diebold-Mariano-West test and adjust the statistic if the models are nested according to Clark and West (2007). Values larger than 1.282 indicate that the null hypothesis of equal predictive accuracy is rejected at 10%.

In contrast to previous studies on inflation forecasting, we also assess the predictive ability of each model by country and forecasting horizon using the success ratio, which captures an estimate of the probability with which the forecast produced by a given model correctly anticipates the direction of change in inflation at a given forecast horizon. Tossing a fair coin on a sufficiently long sample already predicts the direction of change correctly about 50% of the time, so a model needs to attain a success ratio greater than 0.5 to provide an improvement in directional accuracy over pure chance.⁸ The statistical significance of the directional accuracy relative to pure chance (as implied by the directional accuracy of tossing a fair coin) is assessed based on our implementation of the test of Pesaran and Timmermann (2009).

3.2 Results

The ratios of RMSPEs for our set of forecasting models are reported in Tables 5, 6 and 7 (forecasts horizons 1, 4 and 8, respectively). In Table 5 we have fourteen different forecasts because the iterated and direct methods are equivalent when $h = 1$. The success ratios to assess the directional accuracy of the forecasts are reported in Tables 8, 9 and 10 (forecast horizons 1, 4 and 8, respectively). Some conclusions are worth mentioning:

1. In general, the NOEM-BVAR model mostly produces lower RMSPEs than its competitors (the number of shaded entries is larger than the non-shaded entries in each table). In a number of interesting cases, the gains in smaller RMSPEs are statistically significant. The NOEM-BVAR also produces success ratios generally above the 0.5 threshold and, often, statistically significant. The likelihood with which the NOEM-BVAR correctly anticipates the direction of change in inflation tends to be comparable or better than that of its competitors.
2. In the case of the U.S., the NOEM-BVAR always outperforms the rest of the models at the 1-quarter and the 8-quarter horizons. At the 4-quarter horizon, it tends to outforecast all of the models with a few exceptions in which the Theil's U-statistics are slightly above one. The success ratio of the NOEM-BVAR for the U.S. is statistically significant at all horizons and very close to the maximum attained by any model in each case.
3. Our NOEM-BVAR model outperforms—or at least shows similar predictive ability to—factor-augmented models in forecasting the U.S. inflation rate. At any horizon, the NOEM-BVAR model forecasts the U.S. inflation rate better than: (i) the factor-augmented univariate models (M_5 - M_7) and, mostly, by a statistically significant difference, and (ii) the factor-augmented BVAR models (M_{10} - M_{13}). In terms of directional accuracy, the NOEM-BVAR seems to be competitive or has a slight edge against factor-augmented univariate models (especially M_6) and factor-augmented BVAR models (in particular, M_{11} and M_{13}) at the 4- and 8-quarter horizons.

⁸The driftless random walk (RW) model predicts no change in the inflation rate. To assess directional accuracy we split the forecast changes in two categories: (i) positive changes and (ii) negative and null changes. Thus, predictions of the random walk model lie in the second category.

4. In the rest of the sample, the NOEM-BVAR's performance is relatively reasonable with the exceptions of U.K. and Turkey, especially at the 1- and the 4-quarter horizons.⁹ The success ratios of the NOEM-BVAR model are all above the 0.5 threshold, except for Turkey at the 1-quarter horizon. At the 4- and 8-quarter horizons, the success ratios for the U.K. and Greece respectively seat exactly at 0.5.
5. Across models, the median Theil's U-statistic favors the NOEM-BVAR in twelve out of fourteen models at the 1-quarter horizon, in seven out of fifteen models at the 4-quarter horizon, and in twelve out of fifteen models at the 8-quarter horizon. The models more frequently beaten by the NOEM-BVAR are the random walk (M_3), the augmented Phillips curve (M_9), and the factor-augmented BVARs (M_{11} , M_{13}). Not surprisingly, the NOEM-BVAR model clearly dominates in terms of directional accuracy those same models.

3.3 Robustness

We perform a number of robustness checks whose results are available upon request. We provide some comments next.

1. We report the driftless version of M_3 because we find that such specification usually outperforms the random walk with drift in our sample.
2. In the Augmented Phillips Curve models (M_8 , M_9), we evaluate other monetary aggregates. We find that the specification with M2 mostly outperforms those with M1 or M3.
3. We also estimate a NOEM-BVAR model of order 2. In general, the results are qualitatively similar or better with just one lag, which is in line with the lag order of the exogenous shocks usually assumed in the DSGE literature.
4. The use of one lag (instead of two) or Sims-Zha Normal-Wishart priors in the BVARs do not provide any significant gain in predictive ability of the models.
5. A GDP-weighted average of the inflation rates as a measure of global inflation (M_7) or rest-of-the-world inflation rate (NOEM-BVAR) does not change the main conclusions outlined above.
6. Forecasts with unrestricted VARs do not tend to provide lower RMSPEs than those with BVARs in our sample, nor an improvement in directional accuracy.
7. Other detrending techniques for output series, such as first differences or deterministic quadratic trends, do not entail a significantly different forecast performance for the NOEM-BVAR model.

4 Concluding Remarks

Inflation rates across the world tend to move together. In this paper we have shown that there is both a theoretical case and empirical evidence in support of a strong "error correction mechanism" that brings local inflation rates back in line with the rate of global inflation. We have also shown that global inflation models

⁹For the latter economy, this might suggest the need of alternative specifications for emerging market economies with a history of relatively high and more volatile inflation rates.

alone offer only a partial framework of the complex linkages with the rest of the world that can influence local inflation dynamics and we have proposed a full structural model to account for those. As a direct implication of this idea, we present empirical findings indicating that a parsimonious forecasting model of inflation that exploits the standard linkages that arise in the workhorse New Open Economy Macro (NOEM) model tends to outperform other more conventional forecasting models of inflation (even those based on global inflation alone).

One possible explanation for our results is that in the presence of a common component in the inflation process, the cross-country average with which we measure global inflation captures that common component netting out in the cross-section the idiosyncratic forces driving local inflation. Hence, a plausible explanation for some of the findings in the literature in support of global inflation is that it merely reflects a statistical phenomenon of "mean-reversion." However, we argue that there are deeper endogenous mechanisms at work that can result in the type of adjustment towards global inflation that we have investigated in this paper. Understanding those structural endogenous mechanisms is, therefore, crucial to interpret the forecasts as well as for policy analysis. Our theoretical work, in fact, suggests that the path of both global and local inflation will depend on the structural features of the economy and it can give rise to an "error correction mechanism" that brings local and global inflation in line even absent common shocks and with complete international asset markets and flexible exchange rates offering some buffer against the impact of foreign shocks.

We recognize that domestic inflation may still depend on common shocks and that some components of inflation are simply exposed or determined in global markets—e.g., commodity prices. However, monetary and real conditions within a country do still spill-over across countries, and are captured with a non-trivial global component of inflation. As indicated by Martínez-García and Wynne (2010), free floating exchange rates and complete international asset markets—thought to cushion the impact of foreign economic conditions—do not, in fact, negate the existence of a relationship between domestic inflation and global factors that we find useful to forecast inflation across most of the countries in our sample. In spite of differences in the exchange rate regime across countries and the abandonment of managed exchange rates in most countries since the collapse of Bretton Woods, we still find robust evidence in favor of the workhorse NOEM model as a benchmark framework for forecasting the local inflation of open economies.

Better monetary policy is often being posited as one of the key explanations for the improved macro-economic performance, especially during the Great Moderation period since the 1980s. This is precisely the period that we investigate in this paper from 1980 until 2014. Better policies appear to have spread out during the Great Moderation in our sample perhaps contributing to the observed importance of the global component of inflation across the countries in our sample. This hypothesis is difficult to disentangle in the data, but the theory on which we base our analysis suggests that differences in the monetary policy regime may matter for understanding the strength of the spillovers of global factors into local inflation. We leave the discussion of the role of monetary policy on global and local inflation for further research.

Still, the paper presented here has several important implications for policy analysis and policymaking that we want to highlight. First, it provides additional evidence on the empirical significance of the global slack hypothesis of Martínez-García and Wynne (2010) and Martínez-García and Wynne (2013) with our forecasting exercises. Second, we find that the contribution of global factors is not necessarily any less whenever the extent of a country's trade linkages is smaller (as noted in Martínez-García (2015)). For instance, the U.S. is strongly affected by developments in the rest of the world even though the U.S. does not

feature among the countries most open to trade and our preferred NOEM-BVAR model is particularly useful for forecasting U.S. inflation. In this regard, U.S. policymakers should not ignore developments in the rest of the world simply because of the traditionally low import and export shares of the U.S. economy providing a ‘false’ sense of security. Even when some countries are less affected by global inflation than others given their differences in terms of monetary policy or the strength of the trade linkages, very few can claim to be generally immune to global factors.

Finally, our analysis suggests that understanding the drivers of global inflation and how global inflation gets incorporated into local inflation is crucial for policy analysis and for the formulation of appropriate monetary policies. Central banks no longer can ignore how attaining their own domestic goals depends on the actions of central bankers and policy-makers in other parts of the world. Pursuing this research agenda is crucial to avoid the wrong inferences and policies that come into play when we misunderstand the ultimate determinants of domestic inflation—e.g., Martínez-García and Wynne (2014) warn us about the possibility of adopting a closed-economy specification for policy analysis which could lead to erroneous inferences about how a unilateral change in monetary policy affects the dynamics of the economy; Martínez-García (2015) warns us that ignoring the open-economy dimension could lead to confounding shocks that originate domestically with shocks that originate abroad which, in turn, can lead to the wrong understanding about the impact of a given type of shock on the economy.

Appendix

A Tables and Figures

Table 1 - New Open-Economy Macro (NOEM) Model: Core Equations	
Home Economy	
Phillips curve	$\hat{\pi}_t \approx \beta \mathbb{E}_t (\hat{\pi}_{t+1}) + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) [((1-\xi)\varphi + \Theta\gamma) \hat{x}_t + (\xi\varphi + (1-\Theta)\gamma) \hat{x}_t^*]$
Output gap	$\gamma(1-2\xi)(\mathbb{E}_t[\hat{x}_{t+1}] - \hat{x}_t) \approx (1-2\xi + \Gamma) [\hat{r}_t - \hat{r}_t^*] - \Gamma [\hat{r}_t^* - \hat{r}_t^*]$
Monetary policy	$\hat{i}_t \approx \psi_\pi \hat{\pi}_t + \psi_x \hat{x}_t + \hat{m}_t$
Fisher equation	$\hat{r}_t \equiv \hat{i}_t - \mathbb{E}_t[\hat{\pi}_{t+1}]$
Natural interest rate	$\hat{r}_t \approx \gamma \left[\Theta \left(\mathbb{E}_t[\hat{y}_{t+1}] - \hat{y}_t \right) + (1-\Theta) \left(\mathbb{E}_t[\hat{y}_{t+1}^*] - \hat{y}_t^* \right) \right]$
Potential output	$\hat{y}_t \equiv \left(\frac{1+\varphi}{\gamma+\varphi} \right) [\Lambda \hat{a}_t + (1-\Lambda) \hat{a}_t^*]$
Foreign Economy	
Phillips curve	$\hat{\pi}_t^* \approx \beta \mathbb{E}_t (\hat{\pi}_{t+1}^*) + \left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha} \right) [(\xi\varphi + (1-\Theta)\gamma) \hat{x}_t + ((1-\xi)\varphi + \Theta\gamma) \hat{x}_t^*]$
Output gap	$\gamma(1-2\xi)(\mathbb{E}_t[\hat{x}_{t+1}^*] - \hat{x}_t^*) \approx -\Gamma [\hat{r}_t - \hat{r}_t^*] + (1-2\xi + \Gamma) [\hat{r}_t^* - \hat{r}_t^*]$
Monetary policy	$\hat{i}_t^* \approx \psi_\pi \hat{\pi}_t^* + \psi_x \hat{x}_t^* + \hat{m}_t^*$
Fisher equation	$\hat{r}_t^* \equiv \hat{i}_t^* - \mathbb{E}_t[\hat{\pi}_{t+1}^*]$
Natural interest rate	$\hat{r}_t^* \approx \gamma \left[(1-\Theta) \left(\mathbb{E}_t[\hat{y}_{t+1}] - \hat{y}_t \right) + \Theta \left(\mathbb{E}_t[\hat{y}_{t+1}^*] - \hat{y}_t^* \right) \right]$
Potential output	$\hat{y}_t^* \equiv \left(\frac{1+\varphi}{\gamma+\varphi} \right) [(1-\Lambda) \hat{a}_t + \Lambda \hat{a}_t^*]$
Exogenous, Country-Specific Shocks	
Productivity shock	$\begin{pmatrix} \hat{a}_t \\ \hat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & 0 \\ 0 & \delta_a \end{pmatrix} \begin{pmatrix} \hat{a}_{t-1} \\ \hat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_t^a \\ \hat{\varepsilon}_t^{a*} \end{pmatrix}$
	$\begin{pmatrix} \hat{\varepsilon}_t^a \\ \hat{\varepsilon}_t^{a*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*} \sigma_a^2 \\ \rho_{a,a^*} \sigma_a^2 & \sigma_a^2 \end{pmatrix} \right)$
Monetary shock	$\begin{pmatrix} \hat{m}_t \\ \hat{m}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix} \begin{pmatrix} \hat{m}_{t-1} \\ \hat{m}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_t^m \\ \hat{\varepsilon}_t^{m*} \end{pmatrix}$
	$\begin{pmatrix} \hat{\varepsilon}_t^m \\ \hat{\varepsilon}_t^{m*} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*} \sigma_m^2 \\ \rho_{m,m^*} \sigma_m^2 & \sigma_m^2 \end{pmatrix} \right)$
Composite Parameters	
	$\Theta \equiv (1-\xi) \frac{\sigma\gamma - (\sigma\gamma-1)(1-2\xi)}{\sigma\gamma - (\sigma\gamma-1)(1-2\xi)^2}$
	$\Lambda \equiv 1 + (\sigma\gamma-1) \left[\frac{2\gamma\xi(1-\xi)}{\varphi(\sigma\gamma - (\sigma\gamma-1)(1-2\xi)^2) + \gamma} \right]$
	$\Gamma \equiv \xi[\sigma\gamma + (\sigma\gamma-1)(1-2\xi)]$

Table 2 - New Open-Economy Macro (NOEM) Model: Non-Core Equations	
Home Economy	
Output	$\hat{y}_t = \hat{y}_t + \hat{x}_t$
Consumption	$\hat{c}_t \approx \Theta \hat{y}_t + (1 - \Theta) \hat{y}_t^*$
Employment	$\hat{l}_t \approx \hat{y}_t - \hat{a}_t$
Real wages	$(\hat{w}_t - \hat{p}_t) \approx \gamma \hat{c}_t + \varphi \hat{l}_t \approx (\varphi + \gamma \Theta) \hat{y}_t + \gamma (1 - \Theta) \hat{y}_t^* - \varphi \hat{a}_t$
Foreign Economy	
Output	$\hat{y}_t^* = \hat{y}_t^* + \hat{x}_t^*$
Consumption	$\hat{c}_t^* \approx (1 - \Theta) \hat{y}_t + \Theta \hat{y}_t^*$
Employment	$\hat{l}_t^* \approx \hat{y}_t^* - \hat{a}_t^*$
Real wages	$(\hat{w}_t^* - \hat{p}_t^*) \approx \gamma \hat{c}_t^* + \varphi \hat{l}_t^* \approx \gamma (1 - \Theta) \hat{y}_t + (\varphi + \gamma \Theta) \hat{y}_t^* - \varphi \hat{a}_t^*$
International Relative Prices and Trade	
Real exchange rate	$\hat{r}s_t \approx (1 - 2\xi) \hat{tot}_t$
Terms of trade	$\hat{tot}_t \approx \left[\frac{\gamma}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right] (\hat{y}_t - \hat{y}_t^*)$
Home real exports	$\hat{exp}_t \approx \Xi \hat{y}_t + (1 - \Xi) \hat{y}_t^*$
Home real imports	$\hat{imp}_t \approx - (1 - \Xi) \hat{y}_t - \Xi \hat{y}_t^*$
Home real trade balance	$\hat{tb}_t \equiv \hat{y}_t - \hat{c}_t = \xi \left(\hat{exp}_t - \hat{imp}_t \right) \approx (1 - \Theta) (\hat{y}_t - \hat{y}_t^*)$
Composite Parameters	
	$\Theta \equiv (1 - \xi) \left[\frac{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right]$
	$\Xi \equiv \left[\frac{\sigma\gamma + (\sigma\gamma - 1)(1 - 2\xi)\xi}{\sigma\gamma - (\sigma\gamma - 1)(1 - 2\xi)^2} \right]$

Table 3 - New Open-Economy Macro (NOEM) Model: Parameters

Structural parameters	
<i>Non-policy parameters</i>	
β	Intertemporal discount factor
γ	Inverse intertemporal elasticity of substitution
φ	Inverse Frisch elasticity of labor supply
σ	Elasticity of substitution btw. Home and Foreign varieties
ξ	Share of import goods in the local consumption basket
α	Calvo (1983) price stickiness parameter
<i>Policy parameters</i>	
ψ_π	Policy response to inflation
ψ_x	Policy response to the output gap
Shock parameters	
δ_a	Persistence parameter in productivity
σ_a	Std. deviation of productivity innovations
ρ_{a,a^*}	Cross-correlation of productivity innovations
δ_m	Persistence parameter in the monetary shock
σ_m	Std. deviation of monetary shock innovations
ρ_{m,m^*}	Cross-correlation of monetary shock innovations

This table reports a list of the 14 structural (policy and non-policy) and shock parameters of the NOEM model that influence its short-run dynamics. A full description of the NOEM model and its parameters can be found in Martínez-García and Wynne (2010).

Table 4 - Data Sources for Forecasting

Concept	Data sources	Transformation
Headline CPI	National Statistical Offices and Central Banks; Grossman et al. (2014)	Quarter-over-quarter (%)
GDP	National Statistical Offices and Central Banks; Grossman et al. (2014)	Quarter-over-quarter (%)
Industrial production	National Statistical Offices and Central Banks; OECD; Grossman et al. (2014)	Quarter-over-quarter (%)
Money supply (M1, M2, M3)	National Statistical Offices and Central Banks	Quarter-over-quarter (%)
Commodity price index	IMF	Quarter-over-quarter (%)

This table reports the basic information about the data used in the forecasting exercise. The countries included in our forecasting exercises are: Australia, Austria, Belgium, Canada, France, Germany, Greece, Italy, Japan, Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The time series coverage spans the period between the first quarter of 1980 and the fourth quarter of 2014 across all variables and countries, with few exceptions. The monetary aggregates M1, M2 and M3 are, however, generally shorter time series.

The commodity price index is computed as a simple average of the price indexes of agricultural raw materials, beverages, metals and crude oil from the IMF. Country aggregation for the rest of the world is obtained with an arithmetic mean of the country variables. For model M7, we use the PPP-GDP weighted aggregates from Grossman et al. (2014). The data used to compute those weights for aggregation comes from the IMF.

Table 5 - One-Quarter Ahead RMSPE of the NOEM-BVAR Model Relative to Selected Benchmarks

	M ₁ /M ₂ RAR or DAR	M ₃ RW	M ₄ AR-EC	M ₅		M ₆		M ₇		M ₈		M ₉		M ₁₀		M ₁₁		M ₁₂		M ₁₃		M ₁₄		M ₁₅			
				FAR	EC	FAR	EC	FAR	IEC	Augmented Phillips C.	Augmented Phillips C.-EC	BVAR2 FP	BVAR2 FP	BVAR2 NP	BVAR2 NP	BVAR2 FP	BVAR2 FP	BVAR2 NP	BVAR2 NP	BVAR2 COM	BVAR2 COM	BVAR2 FCOM	BVAR2 FCOM				
Australia	0.778	0.831	0.717	0.971	0.866	0.894	0.753	0.745	1.008	1.016	0.753	0.758	0.777	0.744	0.777	0.744	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758	0.758
Austria	0.987	0.953	0.901	1.034	0.911	0.992	1.086	0.812	1.082	1.122	1.086	1.101	1.016	1.082	1.016	1.082	1.101	1.082	1.082	1.082	1.082	1.082	1.082	1.082	1.082	1.082	1.082
Belgium	0.883	0.937	0.777	0.863	0.748	0.804	0.969	0.777	0.970	1.021	0.969	0.979	0.845	0.979	0.845	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979
Canada	0.940	0.941	0.961	0.980	0.942	0.983	1.055	0.823	1.026	1.038	0.983	1.055	0.903	1.038	0.903	1.038	1.050	0.965	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979
France	0.895	0.963	0.892	0.743	0.735	0.823	0.803	0.837	0.892	0.959	0.823	0.803	0.831	0.892	0.831	0.892	0.918	0.850	0.918	0.918	0.918	0.918	0.918	0.918	0.918	0.918	0.918
Germany	0.967	0.879	0.955	0.900	0.848	0.878	0.894	0.821	1.048	1.018	0.878	0.894	0.821	0.878	0.821	0.878	0.925	0.924	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
Greece	1.180	1.308	1.233	0.952	1.039	1.162	0.983	1.197	0.896	1.073	1.162	0.983	1.197	0.896	1.073	0.905	0.938	1.006	0.905	0.905	0.905	0.905	0.905	0.905	0.905	0.905	0.905
Italy	0.955	1.035	0.958	0.879	0.926	0.898	1.061	0.881	0.910	0.952	0.898	1.061	0.881	0.910	0.952	0.965	0.981	1.043	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.965
Japan	0.934	0.868	0.890	0.974	0.936	0.976	1.029	0.796	0.969	0.982	0.976	1.029	0.796	0.969	0.982	0.976	1.027	1.039	0.976	0.976	0.976	0.976	0.976	0.976	0.976	0.976	0.976
Netherlands	0.995	0.934	1.012	0.997	0.986	1.011	1.012	0.910	1.069	1.026	1.011	1.012	0.910	1.069	1.026	1.011	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033	1.033
Portugal	1.039	1.004	1.050	0.901	1.033	1.038	0.959	0.958	0.912	0.945	1.038	0.959	0.958	0.912	0.945	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.988	0.988
Spain	0.905	0.967	0.894	0.836	0.889	0.891	0.845	0.832	0.857	0.915	0.891	0.845	0.832	0.857	0.915	0.871	0.794	0.794	0.794	0.794	0.794	0.794	0.794	0.794	0.794	0.794	0.794
Sweden	0.950	0.990	0.940	0.933	0.907	0.972	1.099	0.827	1.023	1.062	0.972	1.099	0.827	1.023	1.062	1.083	1.073	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083
Switzerland	0.988	1.061	0.964	0.926	0.872	0.893	1.051	0.837	0.997	1.079	0.893	1.051	0.837	0.997	1.079	1.034	0.960	1.034	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960
Turkey	1.857	2.008	2.163	1.566	1.769	1.748	1.617	2.042	1.182	1.644	1.748	1.617	2.042	1.182	1.644	1.693	1.198	1.693	1.198	1.198	1.198	1.198	1.198	1.198	1.198	1.198	1.198
United Kingdom	1.174	1.106	1.183	1.177	1.144	1.145	1.178	1.050	1.245	1.224	1.145	1.178	1.050	1.245	1.224	1.142	1.225	1.142	1.142	1.142	1.142	1.142	1.142	1.142	1.142	1.142	1.142
United States	0.880	0.803	0.811	0.924	0.780	0.887	0.927	0.737	0.982	0.981	0.887	0.927	0.737	0.982	0.981	0.921	0.931	0.921	0.921	0.921	0.921	0.921	0.921	0.921	0.921	0.921	0.921
Mean	1.018	1.034	1.018	0.974	0.961	1.000	1.019	0.934	1.004	1.062	1.000	1.019	0.934	1.004	1.062	1.026	0.967	1.026	0.967	0.967	0.967	0.967	0.967	0.967	0.967	0.967	0.967
Median	0.955	0.963	0.955	0.933	0.911	0.972	1.012	0.832	0.997	1.021	0.972	1.012	0.832	0.997	1.021	1.011	0.960	1.011	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960	0.960
#<1	13	11	12	14	13	12	8	14	9	6	12	8	14	9	6	7	11	7	11	7	13	13	13	13	13	13	13

Notes: Data are described in Table 4. Columns report the ratio of root mean squared prediction error (RMSPE) from the NOEM-BVAR model relative to the RMSPE of standard forecasting models (see section 3). Values less than one are shaded and imply that the NOEM-BVAR model has a lower RMSPE than does the competitive benchmark. Values in bold indicate that the null hypothesis of equal predictive accuracy is rejected at 10% level using a one-sided Diebold-Mariano-West statistic or the adjusted Clark-West statistic when models are nested.

Table 6 - Four-Quarter Ahead RMSPE of the NOEM-BVAR Model Relative to Selected Benchmarks

	M ₁ RAR	M ₂ DAR	M ₃ RW	M ₄ AR-EC	M ₅ FAR	M ₆ FAR EC	M ₇ FAR IEC	M ₈ Augmented Phillips C.	M ₉ Augmented Phillips C-EC	M ₁₀ BVAR2 FP	M ₁₁ BVAR2 MP	M ₁₂ BVAR4 FP	M ₁₃ BVAR4 MP	M ₁₄ BVAR2 COM	M ₁₅ BVAR2 FCOM
Australia	0.846	0.912	0.672	0.949	0.891	1.026	1.025	0.860	0.771	0.887	0.669	0.891	0.669	0.832	0.878
Austria	1.086	1.064	0.711	0.816	1.041	0.777	0.955	0.964	0.733	1.083	0.692	1.063	0.707	1.086	0.972
Belgium	1.025	0.991	0.776	0.789	0.975	0.796	1.023	1.004	0.619	1.070	0.762	1.079	0.761	1.020	0.879
Canada	1.041	1.025	0.749	0.862	1.072	0.874	1.022	0.908	0.640	1.102	0.715	1.008	0.715	1.067	0.987
France	1.036	0.994	0.866	0.872	0.903	0.839	0.880	1.028	0.861	1.018	0.806	1.008	0.805	1.086	1.038
Germany	1.130	1.171	0.921	1.010	1.153	0.968	1.219	1.118	0.647	1.214	0.897	1.161	0.896	1.160	1.108
Greece	1.011	1.085	1.122	1.153	0.927	1.101	1.116	1.113	1.113	0.864	1.117	1.407	1.117	0.956	1.181
Italy	0.977	0.917	0.925	0.843	0.924	0.864	0.926	0.906	0.678	0.975	0.860	0.953	0.860	0.937	0.868
Japan	1.078	1.037	0.902	0.892	1.027	0.915	1.006	1.043	0.806	1.038	0.878	1.075	0.877	1.077	0.891
Netherlands	1.037	1.036	0.861	0.892	1.081	0.884	1.065	1.108	0.824	1.116	0.850	1.129	0.852	1.073	0.858
Portugal	0.751	0.765	0.697	0.668	0.584	0.644	0.809	0.749	0.596	0.661	0.660	0.839	0.667	0.673	0.691
Spain	0.852	0.840	0.747	0.784	0.846	0.785	0.843	0.692	0.606	0.887	0.725	0.838	0.735	0.851	0.874
Sweden	0.988	1.022	0.839	0.944	1.025	0.941	1.110	1.070	0.740	1.017	0.810	1.191	0.822	0.927	1.076
Switzerland	0.953	1.195	0.875	1.404	1.157	1.452	1.467	1.128	1.128	1.033	0.862	1.063	0.877	1.017	1.349
Turkey	1.670	2.236	2.390	3.314	2.406	3.413	2.721	1.681	2.428	1.228	2.354	1.172	2.316	1.129	1.945
United Kingdom	1.586	1.612	1.252	1.581	1.477	1.468	1.636	1.257	1.023	1.548	1.251	1.862	1.248	1.636	1.455
United States	0.862	1.007	0.448	0.824	0.992	0.763	0.905	0.850	0.571	1.004	0.442	0.895	0.442	0.909	1.094
Mean	1.055	1.112	0.927	1.094	1.087	1.089	1.172	1.039	0.870	1.044	0.903	1.102	0.904	1.027	1.067
Median	1.025	1.025	0.861	0.892	1.025	0.884	1.025	1.028	0.740	1.033	0.810	1.075	0.822	1.020	0.987
#<1	7	6	14	12	8	12	5	7	13	5	14	5	14	7	9

Notes: Data are described in Table 4. Columns report the ratio of room mean squared prediction error (RMSPE) from the NOEM-BVAR model relative to the RMSPE of standard forecasting models (see section 3). Values less than one are shaded and imply that the NOEM-BVAR model has a lower RMSPE than does the competitive benchmark. Values in bold indicate that the null hypothesis of equal predictive accuracy is rejected at 10% level using a one-sided Diebold-Mariano-Watson or the adjusted Clark-West statistic when models are nested.

Table 7 - Eight-Quarter Ahead RMSPE of the NOEM-BVAR Model Relative to Selected Benchmarks

	M ₁	M ₂	M ₃	M ₄	M ₅	M ₆	M ₇	M ₈	M ₉	M ₁₀	M ₁₁	M ₁₂	M ₁₃	M ₁₄	M ₁₅
	RAR	DAR	RW	AR-EC	FAR	FAR EC	FAR IEC	Augmented Phillips C.	Augmented Phillips C.-EC	BVAR2 FP	BVAR2 NP	BVAR4 FP	BVAR4 NP	BVAR2 COM	BVAR2 FCOM
Australia	0.793	0.867	0.645	0.833	0.906	0.786	0.906	0.898	0.618	0.920	0.640	0.982	0.640	0.912	0.746
Austria	1.218	1.121	0.633	0.713	1.090	0.642	0.942	1.594	0.581	1.146	0.617	1.406	0.633	1.252	1.060
Belgium	0.981	0.939	0.646	0.695	1.063	0.656	1.152	1.224	0.602	1.041	0.642	1.180	0.644	1.039	0.828
Canada	0.899	0.993	0.567	0.690	0.991	0.660	0.953	1.068	0.400	0.997	0.530	1.054	0.530	1.005	1.083
France	0.917	0.959	0.728	0.717	0.925	0.670	1.054	1.032	0.635	0.953	0.670	1.041	0.670	1.050	0.909
Germany	1.111	1.103	0.775	0.829	1.110	0.747	1.028	0.970	0.475	1.166	0.747	1.093	0.747	1.170	1.128
Greece	0.732	0.990	1.020	1.257	0.867	0.936	0.899	1.545	1.057	0.778	1.176	1.317	1.176	0.812	1.091
Italy	0.961	0.994	0.845	0.825	0.934	0.748	1.018	0.953	0.627	0.957	0.795	1.019	0.795	1.002	0.925
Japan	1.103	1.109	0.817	0.882	1.073	0.870	0.976	1.038	0.817	1.066	0.778	1.071	0.778	1.106	0.905
Netherlands	1.075	1.150	0.734	0.771	1.067	0.759	1.064	1.150	0.735	1.152	0.712	1.182	0.723	1.153	1.017
Portugal	0.917	1.008	0.848	0.839	0.815	0.816	0.969	1.249	0.761	0.860	0.795	1.426	0.828	1.035	0.764
Spain	0.905	0.960	0.778	0.876	0.962	0.794	0.995	0.830	0.666	0.963	0.759	1.078	0.774	0.993	0.971
Sweden	0.914	1.003	0.728	0.971	0.980	0.996	1.207	1.312	0.651	0.958	0.717	1.368	0.736	0.987	1.070
Switzerland	0.722	0.891	0.655	0.989	0.895	0.706	0.799	0.940	0.894	0.863	0.643	0.844	0.655	0.831	0.973
Turkey	0.918	1.776	2.840	2.848	2.972	2.851	1.513	2.398	2.087	1.046	2.627	1.091	2.136	0.826	1.456
United Kingdom	1.134	1.163	0.790	0.915	1.062	0.930	1.021	0.759	0.563	1.119	0.795	1.109	0.786	1.169	0.985
United States	0.838	0.880	0.393	0.494	0.936	0.520	0.706	0.978	0.473	0.926	0.383	0.941	0.383	0.925	0.833
Mean	0.949	1.053	0.850	0.949	1.097	0.887	1.012	1.173	0.744	0.995	0.825	1.130	0.802	1.016	0.985
Median	0.917	0.994	0.734	0.833	0.980	0.759	0.995	1.038	0.635	0.963	0.717	1.091	0.736	1.005	0.973
#<1	12	9	15	15	10	16	9	7	15	10	15	3	15	7	10

Notes: Data are described in Table 4. Columns report the ratio of root mean squared prediction error (RMSPE) from the NOEM-BVAR model relative to the RMSPE of standard forecasting models (see section 3). Values less than one are shaded and imply that the NOEM-BVAR model has a lower RMSPE than does the competitive benchmark. Values in bold indicate that the null hypothesis of equal predictive accuracy is rejected at 10% level using a one-sided Diebold-Mariano-West statistic or the adjusted Clark-West statistic when models are nested.

Table 8 - Directional Accuracy: Success Ratio of One-Quarter Ahead Forecasts

	M ₁ /M ₂ RAR or DAR	M ₃ RW	M ₄ AR-EC	M ₅ FAR	M ₆ FAR EC	M ₇ FAR IEC	M ₈ Augmented Phillips C.	M ₉ Augmented Phillips C-EC	M ₁₀ BVAR2 FP	M ₁₁ BVAR2 MP	M ₁₂ BVAR4 FP	M ₁₃ BVAR4 MP	M ₁₄ BVAR2 COM	M ₁₅ BVAR2 FCOM	M ₁₆ NOEM BVAR
Australia	0.52	0.48	†	0.48	0.64	0.68	0.56	0.40	0.64	0.64	0.60	0.60	0.68	0.64	0.64
Austria	0.76	0.48	†	0.56	0.64	0.76	0.72	0.56	0.80	0.76	0.76	0.72	0.64	0.60	0.64
Belgium	0.68	0.44	†	0.56	0.48	0.60	0.68	0.40	0.64	0.64	0.60	0.68	0.68	0.68	0.64
Canada	0.60	0.56	†	0.56	0.56	0.64	0.60	0.60	0.68	0.68	0.64	0.68	0.56	0.64	0.68
France	0.60	0.40	†	0.52	0.52	0.60	0.48	0.56	0.60	0.64	0.60	0.52	0.56	0.72	0.68
Germany	0.68	0.44	†	0.52	0.56	0.52	0.44	0.52	0.72	0.72	0.64	0.44	0.68	0.68	0.56
Greece	0.44	0.52	†	0.56	0.60	0.48	0.48	0.48	0.44	0.48	0.44	0.48	0.44	0.64	0.56
Italy	0.60	0.44	†	0.52	0.48	0.56	0.52	0.56	0.44	0.48	0.56	0.56	0.60	0.64	0.52
Japan	0.68	0.40	†	0.56	0.76	0.76	0.60	0.48	0.72	0.72	0.68	0.60	0.60	0.68	0.60
Netherlands	0.68	0.60	†	0.64	0.60	0.60	0.60	0.44	0.72	0.72	0.64	0.56	0.60	0.52	0.56
Portugal	0.60	0.48	†	0.48	0.48	0.64	0.60	0.56	0.60	0.60	0.60	0.60	0.52	0.64	0.68
Spain	0.44	0.44	†	0.60	0.60	0.56	0.64	0.56	0.64	0.64	0.64	0.68	0.64	0.56	0.56
Sweden	0.52	0.44	†	0.48	0.44	0.52	0.72	0.44	0.60	0.64	0.72	0.72	0.60	0.72	0.60
Switzerland	0.56	0.52	†	0.68	0.60	0.60	0.64	0.52	0.60	0.60	0.56	0.64	0.56	0.56	0.68
Turkey	0.52	0.52	†	0.60	0.60	0.48	0.48	0.56	0.48	0.48	0.48	0.48	0.48	0.56	0.48
United Kingdom	0.52	0.60	†	0.60	0.56	0.48	0.52	0.52	0.56	0.52	0.44	0.60	0.56	0.44	0.56
United States	0.60	0.48	†	0.52	0.56	0.64	0.56	0.56	0.64	0.64	0.64	0.56	0.68	0.72	0.64
Mean	0.59	0.48		0.56	0.57	0.60	0.58	0.51	0.62	0.62	0.60	0.60	0.59	0.63	0.60
Median	0.60	0.48		0.56	0.56	0.60	0.60	0.52	0.64	0.64	0.60	0.60	0.60	0.64	0.60
#>0.5	15	6		14	13	14	13	11	14	14	14	14	15	16	16

Notes: Data are described in Table 4. Columns report the ratio of success in directional accuracy. Values greater than 0.5 are shaded. Values in bold indicate that the null hypothesis of no dependence between sign(forecast change) and sign(actual change) is rejected at 10% level using the Pesaran and Timmermann (2009) test. A "†" symbol at the right of each value indicates that the test statistic is unadjusted due to the presence of many forecasts in one direction.

Table 9 - Directional Accuracy: Success Ratio of Four-Quarter Ahead Forecasts

	M ₁ RAR	M ₂ DAR	M ₃ RW	M ₄ AR-EC	M ₅ FAR	M ₆ FAR EC	M ₇ FAR IEC	M ₈ Augmented Phillips C.	M ₉ Augmented Phillips C-EC	M ₁₀ BVAR2 FP	M ₁₁ BVAR2 MP	M ₁₂ BVAR4 FP	M ₁₃ BVAR4 MP	M ₁₄ BVAR2 COM	M ₁₅ BVAR2 FCOM	M ₁₆ NOEM BVAR
Australia	0.59	0.68	0.55	0.82	0.86	0.82	0.82	0.73	0.64	0.77	0.55	0.73	0.55	0.64	0.68	0.77
Austria	0.77	0.82	0.45	0.64	0.73	0.68	0.59	0.64	0.55	0.82	0.45	0.77	0.55	0.82	0.73	0.73
Belgium	0.64	0.55	0.45	0.64	0.64	0.64	0.59	0.59	0.41	0.55	0.45	0.59	0.45	0.55	0.50	0.55
Canada	0.55	0.55	0.50	0.59	0.59	0.59	0.59	0.68	0.55	0.68	0.50	0.64	0.50	0.64	0.68	0.64
France	0.59	0.55	0.50	0.59	0.55	0.59	0.59	0.50	0.45	0.59	0.50	0.55	0.50	0.55	0.59	0.73
Germany	0.64	0.64	0.50	0.59	0.64	0.59	0.59	0.59	0.50	0.64	0.50	0.64	0.50	0.59	0.59	0.59
Greece	0.41	0.55	0.59	0.50	0.45	0.45	0.50	0.77	0.64	0.45	0.59	0.77	0.59	0.45	0.50	0.55
Italy	0.55	0.41	0.50	0.41	0.36	0.41	0.45	0.36	0.50	0.59	0.50	0.55	0.50	0.50	0.32	0.55
Japan	0.73	0.73	0.36	0.59	0.73	0.64	0.77	0.82	0.55	0.68	0.36	0.82	0.36	0.73	0.68	0.77
Netherlands	0.77	0.77	0.50	0.55	0.73	0.55	0.73	0.68	0.68	0.82	0.50	0.82	0.50	0.77	0.64	0.73
Portugal	0.55	0.77	0.45	0.50	0.55	0.50	0.68	0.68	0.45	0.64	0.45	0.73	0.23	0.59	0.68	0.73
Spain	0.50	0.45	0.59	0.59	0.59	0.64	0.59	0.73	0.32	0.50	0.59	0.73	0.27	0.55	0.64	0.59
Sweden	0.55	0.59	0.50	0.55	0.68	0.50	0.68	0.73	0.55	0.59	0.50	0.77	0.45	0.55	0.64	0.73
Switzerland	0.59	0.68	0.45	0.68	0.64	0.68	0.64	0.68	0.73	0.59	0.45	0.64	0.55	0.64	0.77	0.64
Turkey	0.55	0.55	0.45	0.64	0.59	0.64	0.68	0.55	0.68	0.55	0.45	0.55	0.45	0.55	0.50	0.55
United Kingdom	0.64	0.55	0.59	0.64	0.59	0.59	0.59	0.59	0.59	0.55	0.59	0.55	0.45	0.64	0.55	0.50
United States	0.73	0.82	0.50	0.82	0.73	0.82	0.77	0.73	0.73	0.77	0.50	0.73	0.50	0.73	0.77	0.77
Mean	0.61	0.63	0.50	0.61	0.63	0.61	0.64	0.65	0.56	0.63	0.50	0.67	0.47	0.61	0.61	0.65
Median	0.59	0.59	0.50	0.59	0.64	0.59	0.59	0.68	0.55	0.59	0.50	0.64	0.50	0.59	0.64	0.64
#>0.5	15	15	4	14	15	13	15	15	11	15	4	17	4	15	13	16

Notes: Data are described in Table 4. Columns report the ratio of success in directional accuracy. Values greater than 0.5 are shaded. Values in bold indicate that the null hypothesis of no dependence between sign(forecast change) and sign(actual change) is rejected at 10% level using the Pesaran and Timmermann (2009) test. A "+" symbol at the right of each value indicates that the test statistic is undefined due to the presence of many forecasts in one direction.

Table 10 - Directional Accuracy: Success Ratio of Eight-Quarter Ahead Forecasts

	M ₁ RAR	M ₂ DAR	M ₃ RW	M ₄ AR-EC	M ₅ FAR	M ₆ FAR EC	M ₇ FAR IEC	M ₈ Augmented Phillips C.	M ₉ Augmented Phillips C.-EC	M ₁₀ BVAR2 FP	M ₁₁ BVAR2 MP	M ₁₂ BVAR4 FP	M ₁₃ BVAR4 MP	M ₁₄ BVAR2 COM	M ₁₅ BVAR2 FCOM	M ₁₆ NOEM BYAR
Australia	0.67	0.72	0.56	0.67	0.78	0.67	0.78	0.83	0.50	0.78	0.56	0.78	0.56	0.78	0.61	0.72
Austria	0.83	0.83	0.39	0.44	0.72	0.39	0.78	0.94	0.56	0.72	0.39	0.83	0.61	0.89	0.61	0.72
Belgium	0.78	0.61	0.56	0.56	0.67	0.56	0.72	0.72	0.44	0.67	0.56	0.72	0.44	0.67	0.67	0.67
Canada	0.61	0.72	0.56	0.78	0.78	0.78	0.72	0.67	0.72	0.78	0.56	0.72	0.56	0.72	0.78	0.78
France	0.61	0.61	0.61	0.67	0.61	0.67	0.61	0.50	0.56	0.67	0.61	0.56	0.61	0.56	0.50	0.72
Germany	0.72	0.67	0.50	0.50	0.67	0.50	0.67	0.67	0.44	0.67	0.50	0.67	0.50	0.67	0.61	0.67
Greece	0.22	0.56	0.78	0.72	0.33	0.67	0.33	0.89	0.72	0.28	0.78	0.94	0.78	0.33	0.56	0.50
Italy	0.72	0.72	0.56	0.61	0.67	0.56	0.72	0.72	0.44	0.72	0.56	0.72	0.56	0.72	0.50	0.78
Japan	0.61	0.72	0.33	0.39	0.72	0.39	0.72	0.67	0.39	0.72	0.33	0.72	0.33	0.61	0.56	0.67
Netherlands	0.72	0.78	0.56	0.56	0.72	0.61	0.72	0.83	0.50	0.78	0.56	0.78	0.56	0.78	0.72	0.72
Portugal	0.56	0.89	0.44	0.67	0.78	0.56	0.89	0.94	0.61	0.67	0.44	1.00	0.28	0.67	0.56	0.94
Spain	0.50	0.56	0.61	0.56	0.56	0.56	0.67	0.50	0.50	0.61	0.61	0.56	0.33	0.56	0.50	0.56
Sweden	0.44	0.50	0.61	0.67	0.50	0.61	0.39	0.78	0.39	0.61	0.61	0.72	0.50	0.50	0.56	0.67
Switzerland	0.56	0.67	0.50	0.61	0.72	0.61	0.61	0.67	0.72	0.67	0.50	0.67	0.56	0.61	0.83	0.83
Turkey	0.56	0.56	0.44	0.61	0.67	0.67	0.56	0.56	0.83	0.56	0.44	0.56	0.44	0.56	0.61	0.56
United Kingdom	0.83	0.72	0.67	0.61	0.67	0.61	0.83	0.61	0.44	0.72	0.67	0.72	0.67	0.78	0.61	0.67
United States	0.78	0.72	0.50	0.67	0.72	0.56	0.83	0.83	0.67	0.72	0.50	0.78	0.50	0.72	0.78	0.78
Mean	0.63	0.68	0.54	0.60	0.66	0.58	0.68	0.73	0.56	0.67	0.54	0.73	0.52	0.65	0.62	0.70
Median	0.61	0.72	0.56	0.61	0.67	0.61	0.72	0.72	0.50	0.67	0.56	0.72	0.56	0.67	0.61	0.72
#>0.5	14	16	10	14	15	14	15	15	8	16	10	17	9	15	14	16

Notes: Data are described in Table 4. Columns report the ratio of success in directional accuracy. Values greater than 0.5 are shaded. Values in bold indicate that the null hypothesis of no dependence between sign(forecast change) and sign(actual change) is rejected at 10% level using the Pesaran and Timmermann (2009) test. A "+" symbol at the right of each value indicates that the test statistic is undefined due to the presence of many forecasts in one direction.

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