Global Factors and Trend Inflation *†

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Abstract

We develop a model to empirically study the influence of global factors in driving trend inflation and the inflation gap.We apply our model to five established inflation targeters and a group of heterogeneous Asian economies. Our results suggest that while global factors can have a sizeable influence on the inflation gap, they play a more marginal role in driving trend inflation. Much of the influence of global factors in the inflation gap may be reflecting commodity price shocks. We also find global factors have a greater influence on inflation, and especially trend inflation, for the group of Asian economies relative to the established inflation targeters. A possible interpretation is that inflation targeting may have reduced the influence of global factors on inflation and especially so on trend inflation.

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1 Introduction

> *... are central banks still masters of their domestic monetary destinies? Or have they become slaves to global factors?* – Carney (2015)

Figure 1 presents year-on-year inflation in a number of industrialized countries to provide a flavour of global co-movement in inflation. Casual observation suggests inflation co-moves globally: a feature of the data that has been extensively statistically verified (e.g., see Ciccarelli and Mojon, 2010; Mumtaz and Surico, 2012). The stylized fact that inflation co-moves globally has led to interest in quantifying the role of global determinants of inflation (e.g., see Borio and Filardo, 2007; Neely and Rapach, 2011; Bianchi and Civelli, 2015) and examining the implications for monetary policy (Carney (2015)).

Our paper contributes to the debate on the role of global shocks in driving inflation. More specifically, the main contribution of our paper is to develop a unified framework to study the role of foreign shocks in driving the permanent and transitory component of inflation, which we interpret as trend inflation and the inflation gap respectively. To answer whether global factors have monetary policy implications, we view making the distinction between trend inflation and the inflation gap as key. For example, Draghi (2015b) states *"central banks typically choose to 'look through' such global forces until their effect on inflation fades out or until prices reverse"*. We interpret this statement as typical central banking doctrine that one should "look through" transitory or one-off changes in prices. Correspondingly, the degree of importance one should attach to the foreign determinants of domestic inflation from a policy perspective depends on how much foreign shocks feed into the trend, or the permanent component of, inflation. If the influence of foreign shocks are shown to be one-off or transitory, then the standard doctrine would be to "look through" or not respond to them. Our paper tackles this issue head-on by developing a model which quantifies the role of foreign shocks in the determination of trend inflation and the inflation gap.

We first apply our model to five advanced inflation targeting economies (Australia, Canada, New Zealand, Norway, and Sweden) to establish a benchmark, before applying the model to a more heterogeneous group of Asian economies. We highlight three main findings. First, a key result of our empirical exercise shows that while foreign shocks can have a sizeable influence on the inflation gap, they play a smaller role in driving trend inflation. This result is consistent with the idea that while foreign shocks may have a short to medium run impact on inflation, inflation in the long-run appears to be a monetary phenomenon largely determined by domestic monetary policy. Second, a suggestive candidate of these common foreign shocks could be oil and commodity price shocks. In particular, we find a large share of the identified foreign shocks may reflect commodity price shocks. Third, we uncover patterns which suggest inflation targeting may lead to foreign shocks having a smaller role in determining inflation, especially, that of trend inflation. We make this conclusion by comparing the share of foreign shocks driving trend inflation and the inflation gap of our benchmark group of advanced and established inflation targeters relative to the heterogeneous group of Asian economies.

Our empirical model can, at a broad level, be viewed as a Factor-Augmented Vector Autoregression (FAVAR). Using the FAVAR model, we construct trend inflation and the inflation gap consistent with the Beveridge and Nelson (1981)(BN) decomposition. By utilizing the BN decomposition, we adopt a similar concept of trend inflation and the inflation gap which is consistent with the wider trend inflation literature (see, e.g. Stock and Watson, 2007). Taking guidance from a well-established Structural Vector Autoregression (SVAR) literature, the small open economy structure which we adopt provides a clean identification of foreign and domestic shocks. Our empirical strategy uses the decomposition developed by Morley and Wong (2017) by decomposing trend inflation and the inflation gap into the identified foreign and domestic shocks, thus providing an account of the role of foreign and domestic shocks in driving both trend inflation and the inflation gap.

While Unobserved Components (UC) models have featured prominently in trend inflation literature (e.g., see Stock and Watson, 2007; Mertens, 2016; Chan, Clark, and Koop, 2017), we make a deliberate deviation from the UC literature in one important dimension; by allowing for multivariate information through the FAVAR framework. Our choice allows us to draw on a vast SVAR literature to identify foreign shocks, and thus tease out causality within our framework. Even so, we stress that the concept of trend inflation is identical to the UC framework, providing a natural link to this body of work. Our work is also related to the literature on the foreign determinants of inflation. In particular, much of the work on the globalization of inflation has looked at the influence of foreign *vis-a-vis* domestic slack in driving inflation (e.g. Borio and Filardo, 2007; Ihrig, Kamin, Lindner, and Marquez, 2010). Indeed, we concur, similar to others (e.g Milani, 2010; Eickmeier and Pijnenburg, 2013), that a regression against a foreign slack measure, such as a foreign output gap, is not sufficiently rich to tell apart the effect of domestic shocks from that of foreign shocks. In particular, if an economy is sufficiently open, then foreign shocks drive *both* the foreign and domestic slack, which means one cannot tell the influence of foreign shocks without a formal identification exercise, which is why we view our identification exercise as crucial. In this regard, we take a much broader perspective relative to the extant work of foreign determinants of inflation, which largely focus their attention to only a measure of foreign slack.

The rest of the paper is organized as follows. In Section 2, we provide a description and justification of our empirical methodology. In Section 3, we present trend inflation estimates fro Australia, Canada, New Zealand, Norway and Sweden. We also present our decomposition to understand the role of foreign shocks driving trend inflation and the inflation gap. Section 4 extends the analysis to a heterogeneous group of ten Asian economies and offers a more in-depth look into the role of inflation targeting. We offer some concluding remarks at the end.

2 Empirical Specification

We first estimate trend inflation and the inflation gap for five advanced inflation targeting economies, before extending our analysis to 10 Asian economies. Our benchmark five advanced economies are Australia, Canada, New Zealand, Norway and Sweden. Our choice of these five economies as a benchmark, besides their institutional similarities and being regarded as small open economies, is also driven by data considerations. These five economies have at least 25 years of reasonably good and consistent data. This period largely coincides with low inflation, and often an inflation targeting regime, which means the issue of dealing with any possible structural breaks is less relevant. It is natural therefore to first establish some observations about five similar economies with relatively good data, before we extend the analysis to a wider group of Asian economies, where data availability is of greater concern. We subsequently decompose the estimated trend inflation and inflation gap into components driven by foreign and domestic shocks for each country. The second part of our empirical exercise enables us to understand the role of foreign shocks on both trend inflation and the inflation gap. In the subsections that follow, we first introduce our trend-cycle decomposition. We then present our empirical model and briefly discuss our estimation strategy. We also detail our identification procedure to infer the role of foreign shocks.

2.1 Permanent-Transitory Decomposition

This subsection outlines the concepts of trend and gap which we use in this paper. We work with the Beveridge and Nelson (1981) (BN) decomposition to perform a trend-cycle decomposition on inflation. The BN decomposition has proven a useful approach to separate trend from cycle in a wide variety of settings (e.g. Evans and Reichlin, 1994; Morley and Piger, 2012; Kamber, Morley, and Wong, 2017). Moreover, the equating of trend inflation as the BN permanent component of inflation is now quite widespread within the empirical literature (e.g. Stock and Watson, 2007; Cogley, Primiceri, and Sargent, 2010). Our work follows in this tradition.

Let π_t represent the inflation rate and assume π_t evolves as a driftless random walk, which is consistent with the current practice of modeling trend inflation (e.g. Stock and Watson, 2007). We denote trend inflation as the BN permanent component of inflation, τ_t, as the long-horizon forecast of the level of inflation given the information at time t and a suitably specified time series model to form this expectation,

$$\tau_t = \lim_{j \to \infty} \mathbb{E}_t \pi_{t+j}. \quad (1)$$

The transitory component, $\tilde{\pi}_t$, is the inflation gap, where $\tilde{\pi}_t = \pi_t - \tau_t$. Let $\{\mathbf{y_t}\}$ be a vector of variables. We can write the law of motion of the state equation in $\{\mathbf{y_t}\}$ as a first order autoregressive process,

$$\mathbf{y_t} = \mathbf{B}\mathbf{y_{t-1}} + \mathbf{H}\boldsymbol{\nu_t} \quad (2)$$

where $\mathbf{B}$ is a companion matrix, $\boldsymbol{\nu_t}$ is a vector of serially uncorrelated forecast errors with covariance matrix, $\boldsymbol{\Sigma_\nu}$, and $\mathbf{H}$ is a matrix which maps the forecast errors to the companion form. Let $\Delta\pi_t$ be the first difference of inflation, $\mathbf{e_k}$ be a selector row vector with 1 as its k^{th} element and zero otherwise and $\Delta\pi_t$ be the k^{th} element of $\{\mathbf{y_t}\}$. Then trend inflation and the inflation gap, consistent with the BN decomposition can be written as (see, e.g. Morley, 2002)

$$\tau_t = \pi_t + \mathbf{e_k}\mathbf{B}(\mathbf{I} - \mathbf{B})^{-\mathbf{1}}\mathbf{y_t} \quad (3)$$
$$\tilde{\pi}_t = -\mathbf{e_k}\mathbf{B}(\mathbf{I} - \mathbf{B})^{-\mathbf{1}}\mathbf{y_t}. \quad (4)$$

Equations (3) and (4) make it clear that if we have an empirical model cast into a form like Equation (2), we can decompose inflation into its trend and gap components which is consistent with the BN decomposition. We work with what can broadly be described as a Factor-Augmented VAR (FAVAR). Our model choice can readily be cast into the form suggested by Equation (2) and allows us to model specific features of interest to our research question.

While our modeling choice deviates from Unobserved Components (UC) models of trend inflation (e.g. Stock and Watson, 2007; Mertens, 2016), our concept of trend is identical. This stems from the facts that (univariate) UC models possess an ARIMA reduced form (see Watson, 1986; Cochrane, 1994) and that the (filtered) trend from a UC model is equivalent to the BN permanent component (Morley, Nelson, and Zivot (2003)). By appealing to the BN decomposition, it is clear that our estimate of trend is conceptually identical to that of UC models. We now turn our attention to specifying our empirical model.

2.2 FAVAR Model

Our model bears close resemblance to a FAVAR model (e.g., Bernanke, Boivin, and Eliasz, 2005), though we deviate slightly to allow for some specific features of interest. The

FAVAR approach allows us to collect a range of economic data such as industrial production, unemployment, output and employment. We extract factors to account for all such relevant information without being constrained to collect the same data series across all countries, as these may sometimes be unavailable. This is helpful with regards to our modeling approach as our first order of interest is to model inflation. While we allow information such as real domestic economic activity to affect inflation, we are only interested to the extent we can include this as relevant information, rather than the actual series itself. The FAVAR approach allows us to account for the real economic environment as factors, without the constraint of specifying similar time series across all countries. The FAVAR approach thus offers a mean of specifying a similar empirical approach across a number of countries.

Before getting into specifics, it may be helpful to first provide a broad overview of our model. Our model can be thought of two large blocks, a foreign and domestic block. The two large blocks can also be further sub-divided into two smaller sub-blocks. The two sub-blocks of the foreign block are made up of commodity prices and factors extracted from taking principal components of a large international dataset. The commodity price sub-block is modeled using the real U.S. dollar price of energy, agricultural commodities, and metals and minerals from the World Bank's dataset, and are the same three commodity price series Fernández, Schmitt-Grohé, and Uribe (forthcoming) use to model foreign shocks in their paper. The domestic block is similarly made up of two sub-blocks. The first sub-block is made up of factors extracted from principal components of a dataset of domestic variables. The second sub-block includes the first difference of two inflation rates, CPI inflation, which we refer henceforth as headline inflation, and a core inflation measure, often taken to be CPI excluding food and energy. The foreign block is modelled as block exogenous to the domestic block to achieve identification of foreign shocks. This is an identifying restriction which has roots in the traditional small open economy SVAR literature which models the small open economy as too small to affect the foreign economy (e.g. Zha, 1999; Justiniano and Preston, 2010; Kamber, Karagedikli, Ryan, and Vehbi, 2016; Fernández, Schmitt-Grohé, and Uribe, forthcoming). Headline and core inflation are modeled as co-integrated, and thus by construction, share the same permanent component, which is trend inflation in our empirical exercise. The inflation gap is derived from the difference between headline and trend inflation. We model the entire system as a VAR process, with the block exogeneity and error correction term between the two inflation rates being our main deviations from a typical FAVAR model.

Model Specifics

Factors In the model, the domestic and foreign block each features a sub-block which uses factors extracted from international and domestic datasets. The international dataset includes economic indicators such as real GDP, industrial production, capacity utilization, output per person etc., for the U.S., U.K., Germany, France and Japan. To construct domestic factors, for each of the five advanced inflation targeting economies, we construct a dataset comprising, as much as possible, the same set of variables (see Data Appendix for the full list of variables). A possible cause of concern is the exclusion of data from China, which we make on practical grounds given they do not have a long data span given the earliest consistent quarterly data starts in 2001, but casual observation suggests a growing role in the global economy. Because we are using factors from five major economies to form an indicator of the global economic environment, the use of factors across five major economies should provide a reasonable guard against misspecifying the state of the global economic environment despite the omission of China. Moreover, we also include variables such as the Baltic Dry Index, which is sometimes taken as an indicator of global economic activity, in the international dataset when we construct factors. Lastly, commodity prices are in the foreign block. To the extent that commodity prices are driven by the state of the global economy means that the role of China is accounted for, albeit in an implicit fashion. All of these features should somewhat, if not fully, mitigate the omission of Chinese data from the construction of the foreign block.

Selection of Number of Factors To close the specification of our empirical model, we need to determine the number of retained foreign and domestic factors, η^* and η. Our objective with the modeling of factors is to model all relevant information. This is especially important in our context as informational deficiency may render the identified foreign shocks as non-fundamental (e.g., see Fernández-Villaverde, Rubio-Ramrez, Sargent, and Watson, 2007). We therefore use an informational sufficiency test based on the extracted factors as proposed by Forni and Gambetti (2014) to guide the specification of our FAVAR. We start with a baseline specification using the commodity price block, the first difference of headline and core inflation and a one principal component each from the international and domestic dataset. We first specify the domestic block by sequentially adding principal components from the domestic dataset for the equations in the domestic block until the included factor no longer Granger causes any of the included variables at a 5% level of significance. This specifies η. Following which, we then specify the number of retained factors from the international dataset, η^*, by similarly sequentially adding principal components from the foreign block until the included factor no longer Granger causes any of the other variables at a 5% level of significance.[1] We allow the number of domestic and foreign factors to differ between countries, but still maintain the domestic and foreign factor dichotomy in our empirical framework, a feature we can exploit to

[1]Note that we retain block exogeniety structure throughout our procedure of testing for Granger causality, which is why we test for Granger Causality from the principal components from the domestic dataset to only variables in the domestic block, but test for Granger causality from the principal components from the international dataset to all the variables in the model.

study the effect of foreign shocks.

Co-integration of Headline and Core Inflation The co-integration between headline and core inflation is not strictly necessary for constructing trend inflation and the inflation gap using the BN decomposition. However, given both core inflation and headline inflation should conceptually share the same trend, using some form of error correction mechanism between them should help us better identify the trend component. This is because core inflation is often regarded as removing the transitory component of inflation. Note that our approach does not systematically regard core inflation as trend inflation. If there are fluctuations in core inflation which the model interprets as transitory, the model will parse out these fluctuations when constructing trend inflation.

Model Summary Let the i^{th} factor from the foreign and domestic block be $f^*_{i,t}$ and $f_{i,t}$ respectively. Also let $PCOM_t$ be three real commodity prices in US dollars (energy, agriculture commodities, and metals and minerals), all deflated using the U.S. CPI. With η^* and η as the number of chosen foreign and domestic factors respectively, we denote $\boldsymbol{F^*_t} = [f^*_{1,t} f^*_{2,t} \dots f^*_{\eta^*,t}]$, $\boldsymbol{F_t} = [f_{1,t} f_{2,t} \dots f_{\eta,t}]$ and $\Delta\pi_t$ and $\Delta\pi^c_t$ as the first difference of quarter on quarter differences of headline inflation and core inflation respectively, with $\boldsymbol{Z_t} = [\Delta PCOM_t, \boldsymbol{F^*_{i,t}}, \boldsymbol{F_{i,t}} \Delta\pi^c_t, \Delta\pi_t]'$. We can write the following system and our restrictions as follows,

$$
\begin{aligned}
\boldsymbol{Z_t} &= \boldsymbol{\Gamma} \begin{pmatrix} \boldsymbol{Z_{t-1}} \\ \boldsymbol{Z_{t-2}} \\ \vdots \\ \boldsymbol{Z_{t-p}} \\ \pi^c_t - \pi_t \end{pmatrix} + \boldsymbol{\nu_t} \\
&= \begin{pmatrix} \boldsymbol{\Gamma^1_{FF}} & \boldsymbol{\Gamma^1_{FD}} & \boldsymbol{\Gamma^2_{FF}} & \boldsymbol{\Gamma^2_{FD}} & \dots & \boldsymbol{\Gamma^p_{FF}} & \boldsymbol{\Gamma^p_{FD}} & \boldsymbol{\Gamma^{ec}_{F}} \\ \boldsymbol{\Gamma^1_{D_1F}} & \boldsymbol{\Gamma^1_{D_1D}} & \boldsymbol{\Gamma^2_{D_1F}} & \boldsymbol{\Gamma^2_{D_1D}} & \dots & \boldsymbol{\Gamma^p_{D_1F}} & \boldsymbol{\Gamma^p_{D_1D}} & \boldsymbol{\Gamma^{ec}_{D_1}} \\ \boldsymbol{\Gamma^1_{D_2F}} & \boldsymbol{\Gamma^1_{D_2D}} & \boldsymbol{\Gamma^2_{D_2F}} & \boldsymbol{\Gamma^2_{D_2D}} & \dots & \boldsymbol{\Gamma^p_{D_2F}} & \boldsymbol{\Gamma^p_{D_2D}} & \boldsymbol{\Gamma^{ec}_{D_2}} \end{pmatrix} \begin{pmatrix} \boldsymbol{Z_{t-1}} \\ \boldsymbol{Z_{t-2}} \\ \vdots \\ \boldsymbol{Z_{t-p}} \\ \pi^c_t - \pi_t \end{pmatrix} + \boldsymbol{\nu_t} \\
&= \begin{pmatrix} \boldsymbol{\Gamma^1_{FF}} & 0 & \boldsymbol{\Gamma^2_{FF}} & 0 & \dots & \boldsymbol{\Gamma^p_{FF}} & 0 & 0 \\ \boldsymbol{\Gamma^1_{D_1F}} & \boldsymbol{\Gamma^1_{D_1D}} & \boldsymbol{\Gamma^2_{D_1F}} & \boldsymbol{\Gamma^2_{D_1D}} & \dots & \boldsymbol{\Gamma^p_{D_1F}} & \boldsymbol{\Gamma^p_{D_1D}} & 0 \\ \boldsymbol{\Gamma^1_{D_2F}} & \boldsymbol{\Gamma^1_{D_2D}} & \boldsymbol{\Gamma^2_{D_2F}} & \boldsymbol{\Gamma^2_{D_2D}} & \dots & \boldsymbol{\Gamma^p_{D_2F}} & \boldsymbol{\Gamma^p_{D_2D}} & \boldsymbol{\Gamma^{ec}_{D_2}} \end{pmatrix} \begin{pmatrix} \boldsymbol{Z_{t-1}} \\ \boldsymbol{Z_{t-2}} \\ \vdots \\ \boldsymbol{Z_{t-p}} \\ \pi^c_t - \pi_t \end{pmatrix} + \begin{pmatrix} \boldsymbol{\nu_t}^* \\ \boldsymbol{\bar{\nu}_t} \end{pmatrix}.
\end{aligned} \tag{5}
$$

Each row of the expanded $\mathbf{\Gamma}$ coefficient matrix in Equation (5) represents particular blocks. The first row represents the foreign block, which we denote as F, while the second and third row each represent a sub-block of the domestic block, which we denote as D_1 and D_2 respectively, or D if we refer to the entire domestic block. We write sets of coefficients as $\mathbf{\Gamma}_{ij}^{k}$ where i represents the block of equations which the coefficient belongs to, j represents the block or sub-block of the regressor and k represents the lag order. $\mathbf{\Gamma}_{i}^{ec}$ refers to the error correction term in the i^{th} block. To impose our block exogeniety identifying restriction, this implies $\mathbf{\Gamma}_{\boldsymbol{FD}}^{\boldsymbol{k}} = 0$, $\forall k$. Allowing for the cointegrating error correction term to matter only for headline and core inflation in the second sub-block of the domestic block implies $\mathbf{\Gamma}_{\boldsymbol{F}}^{\boldsymbol{ec}} = \mathbf{\Gamma}_{\boldsymbol{D1}}^{\boldsymbol{ec}} = 0$.

We leave details of the specific choice of data series to the appendix. The sample generally starts in 1992Q1 and ends in 2016Q4 to coincide with the low inflation, and possibly inflation targeting, regime.[2] While starting estimation from the 1980s (the date of the earliest available data) does not materially alter our main conclusions regarding the role of foreign shocks in the inflation gap and trend inflation, the sensitivity of the time series estimate of trend inflation suggests one needs to seriously address structural breaks in order to consider data from the 1980s. It is certainly worthwhile to address the breaks if one was interested in estimating a trend inflation model for a specific country. Our objective is, however, to draw conclusions by estimating the model on a wide variety of countries, we choose to restrict the sample rather than deal with each country on an individual basis.

2.3 Estimation

We opt for Bayesian estimation mainly to be able to use standard methods to apply shrinkage to mitigate possible overfitting. Given that a number of the specifications we estimate contain four or five retained factors and that we work with relatively short data samples for some countries, the possibility of overfitting becomes non-trivial. To keep our application of shrinkage as standard as possible, we use a class of widely used Bayesian VAR (BVAR) methods, often also referred to as the "Minnesota Priors" (e.g., see Litterman, 1986; Robertson and Tallman, 1999). The idea of this type of priors is to treat shorter lags as "more important" than longer lags when applying shrinkage.

Let $\beta_{i,j}^{p}$ represent the coefficient of the p^{th} lag in the i^{th} equation of the j^{th} variable and so represent elements of the matrix $\mathbf{\Gamma}$ that need to be estimated.[3] We set up the following priors on the means (expected values) and variances of the VAR coefficients that need to

[2]We start in 1994Q1 for Australia to coincide with inflation targeting. Our main conclusions regarding Australia do not change much qualitatively if we adjust the sample start date to 1992Q1 or even the 1980s, but the quantitative estimates of trend inflation appear to be affected by the non-inflation targeting period, so it seems prudent to just restrict the sample to the inflation targeting period.

[3]Recall that due to our block exogeneity identification restrictions, not all the VAR coefficients need to be estimated, and thus we do not specify a prior for those coefficients.

be estimated respectively

$$\mathbb{E}(\beta^p_{i,j}) = 0 \tag{6}$$

$$\mathbb{V}(\beta^p_{i,j}) = \begin{cases} \frac{\lambda^2}{p^2}, & \text{if i = j} \\ \frac{\lambda^2}{p^2}\frac{\sigma_i^2}{\sigma_j^2}, & \text{otherwise} \end{cases}. \tag{7}$$

The spirit of the Minnesota Priors is to shrink towards a random walk. Because we first difference all three commodity prices, headline and core inflation as well as any non-stationary data, and standardize data before extracting factors, a prior mean of zero treats all variables as *a priori* random walks. We set σ_k^2, the variance on the k^{th} equation, as the variance of the residuals from a univariate AR(4) regression fitted using least squares, as is common practice in the BVAR literature. We also require specifying a prior for our error correction terms for the headline inflation and core inflation equation. Let β_i^{ec} be the error correction term in the i^{th} equation. We use the following prior

$$\mathbb{E}(\beta_i^{ec}) = -0.5 \tag{8}$$

$$\mathbb{V}(\beta_i^{ec}) = \lambda^2 \tag{9}$$

Our prior suggest that for any deviation between headline and core inflation, we expect half of the gap is closed within the next quarter. The overall tightness of the prior is governed by one hyperparameter, λ. We set $\lambda = 0.2$ in our empirical exercise, which is a fairly common choice within the BVAR literature (e.g. Sims and Zha, 1998), with also corroborating evidence that this is a reasonably suitable choice for empirical work (see Carriero, Clark, and Marcellino, 2015).

We estimate the FAVAR with four lags, as typical for quarterly data, though with shrinkage the lag order becomes a second order issue. We do not estimate a constant in our specification and thus work with demeaned data for all our series, *except* for headline inflation and core inflation.[4] Because we used a conjugate Normal-Wishart prior, we can estimate the system with our priors and the respective block exogeniety restriction by combining restricted least squares and the use of of dummy observations (e.g., see Del Negro and Schorfheide, 2011). We leave the specifics of this procedure to the online

[4] Working with de-meaned data is analogous on placing a flat/uninformative prior on the constant, and so the unconditional mean of the time series coincide with the sample mean. By not de-meaning headline and core inflation and estimating the model without a constant, we are imposing a zero mean on the first difference of headline and core inflation. This models inflation as a random walk without drift. If a constant is included, then inflation will evolve as a random walk with drift, with the drift term being whatever unconditional mean is estimated. Besides viewing a drift term as an unsuitable choice for trend inflation modeling, a random walk without drift is also consistent with trend inflation modeling elsewhere in the literature (e.g. Stock and Watson, 2007; Mertens, 2016).

appendix. We thereafter take the posterior mode (which is analogous to the posterior mean in our class of models), cast it in the form implied by Equation (2) and use Equation (3) and (4) to apply the BN decomposition to get an estimate of trend inflation and the inflation gap.[5]

2.4 Decomposing the Role of Foreign Shocks

In order to identify the role of foreign shocks, a final step post-estimation is to orthogonalize the reduced form residuals, $\boldsymbol{\nu_t}$. Let $\boldsymbol{\epsilon_t^*}$ and $\boldsymbol{\bar{\epsilon}_t}$ represent the block of foreign and domestic shocks, which are the structural shocks of the model. The structural shocks are constructed to be uncorrelated across and to each other, so as to be able to ascribe a causal interpretation of foreign and domestic shocks. We now define a matrix, $\mathbf{A}$, which maps the reduced form shocks to the structural shocks where,

$$\begin{aligned} \mathbf{A}\boldsymbol{\epsilon_t} &= \boldsymbol{\nu_t} \\ \begin{pmatrix} \boldsymbol{A_{11}} & \mathbf{0} \\ \boldsymbol{A_{21}} & \boldsymbol{A_{22}} \end{pmatrix} \begin{pmatrix} \boldsymbol{\epsilon_t}^* \\ \boldsymbol{\bar{\epsilon_t}} \end{pmatrix} &= \begin{pmatrix} \boldsymbol{\nu_t}^* \\ \boldsymbol{\bar{\nu_t}} \end{pmatrix}. \end{aligned} \tag{10}$$

The triangular structure of $\mathbf{A}$ reflects an extension of the block exogeneity identification restriction. Note that because we do not attempt to separately identify individual foreign and domestic shocks, our identification procedure is sufficient to aggregate all the foreign and domestic shocks in our model.[6] Further disaggregation of foreign and domestic shocks will require stronger identification assumptions, which may be less tenable than the looser restriction we currently present. While we present stronger identification restrictions later in the paper to attempt to gain finer interpretation of the foreign shocks, we keep the foreign and domestic shocks dichotomy unless we explicitly state so.

To decompose trend inflation and the inflation gap into foreign and domestic shocks, Morley and Wong (2017) show that the BN permanent and transitory component can be written as a function of the history of forecast errors. This can be shown by recursively substituting Equation (2) into Equations (3) and (4) respectively and substituting $\mathbf{A}\epsilon_\mathbf{t} = \nu_\mathbf{t}$. After some algebraic manipulation we obtain,

[5] See Hamilton (1994) on a general exposition on casting VARs into the companion form implied by Equation (2) and Morley (2002) on details of casting the model which include the error correction terms into a form implied by Equation (2).

[6] To see this, suppose we had an orthonormal matrix $\boldsymbol{Q}$ where $\begin{pmatrix} \boldsymbol{Q_{11}} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{Q_{22}} \end{pmatrix}$ with $\boldsymbol{Q_{11}}$ and $\boldsymbol{Q_{22}}$ are similarly orthonormal. Then it is easy to see that even if we postmultiply $\mathbf{A}$ by $\boldsymbol{Q}$, $\boldsymbol{\Sigma_\nu} = \mathbf{AQQ'A'}$ is satisfied and this retains the relative shares of the aggregate foreign and domestic shocks unaltered but merely changes the individual and domestic foreign shocks.

$$
\begin{aligned}
\Delta\tau_t &= \mathbf{e_k}(\mathbf{I}-\mathbf{B})^{-1}\mathbf{A}\boldsymbol{\epsilon_t} && (11)\\
\tilde{\pi}_t &= -\mathbf{e_k}\left\{\sum_{\mathbf{i=0}}^{\mathbf{t-1}} \boldsymbol{B^{i+1}}(\mathbf{I}-\mathbf{B})^{-1}\mathbf{A}\boldsymbol{\epsilon_{t-i}}\right\} - \mathbf{e_k}\boldsymbol{B^{t+1}}(\mathbf{I}-\mathbf{B})^{-1}\mathbf{e_k}'\boldsymbol{\Delta\pi_0}. && (12)
\end{aligned}
$$

The final term in Equation (12) contains an initial condition, $\Delta\pi_0$, but the influence of the initial condition is expected to vanish towards zero given term, $\mathbf{B^{t+1}}$. Equations (11) and (12) show that the change of trend inflation and the inflation gap are just linear functions of the history of foreign and domestic shocks, which provides the basis for our subsequent analysis.

Comparing our Modeling Approach

Before we move on to discussing the results, it is worth contrasting our modeling choices relative to the wider literature. While there will nevertheless be pros and cons regarding any modeling choice, we wish to emphasize that many of our modeling choices are designed to best explore our focus on the importance of foreign shocks on the dynamics of inflation gap and trend inflation.

A Broader View of Foreign Shocks Our work builds on previous contributions on the globalization of inflation. In much of this work, which is notably inspired by Borio and Filardo (2007), the approach of studying the influence of globalization on inflation is to estimate Phillips Curves augmented by a foreign output gap. Another way of viewing this approach is that global slack, through foreign output gap, is an appropriate proxy for the influence of foreign shocks. A common approach for constructing a foreign slack measure is to extract the cyclical component from a weighted sum of aggregate global output using the HP filter. In our modeling approach, we take a broader view of the foreign determinants of inflation by identifying foreign shocks. To the extent that the existing work uses the foreign output gap as a proxy for foreign shocks, it is more likely that our approach, using a broader dataset, will better identify foreign shocks than a filtered component of weighted output.[7] Moreover, foreign shocks can drive both the domestic and foreign output gap and solely observing the foreign output gap without a formal identification exercise is insufficient to tell apart the role of foreign shocks or global determinants of inflation, a point which Eickmeier and Pijnenburg (2013) and Bianchi and Civelli (2015) attempt to address in their work. As argued by Ihrig, Kamin, Lindner, and Marquez (2010), the use of a foreign slack may represent an overly narrow

[7]Moreover, it is also well known that the HP filter produces spurious cycle, a point well covered in the rest of the literature that we do not wish to over emphasize (see, e.g. Cogley and Nason, 1995; Phillips and Jin, 2015; Hamilton, 2017).

concept of the role of the globalization of inflation. If one wishes to take a broader view that inflation could be driven by a multitude of foreign shocks, such as commodity price shocks or shocks to the foreign resource utilization that may not be adequately reflected in aggregate output, our approach is likely to be more accurate in determining the effects of foreign shocks.

Contrast with Multivariate UC Models Our work has links to more recent development of multivariate UC models, which follow the highly influential work of Stock and Watson (2007) (e.g. Kim, Manopimoke, and Nelson, 2014; Chan, Clark, and Koop, 2017; Chan, Koop, and Potter, 2016; Stock and Watson, 2016; Mertens, 2016). As we had previously mentioned, our approach can be interpreted similarly to a UC model given the equivalence between the BN trend and the UC (filtered) trend. What distinguishes our modeling approach is that we decompose the trend and cycle into the underlying shocks as in Morley and Wong (2017) and therefore we can ascribe a causal role for foreign and domestic shocks within our modeling framework. Our reading of the existing multivariate UC work is that while observables such as unemployment Chan, Koop, and Potter (2016) or the output gap Kim, Manopimoke, and Nelson (2014) may directly enter the law of motion of the inflation gap, designing testable restrictions to ascribe causality on trend inflation is challenging (see Uzeda, 2017, for an example). In this line of work, trend inflation often remains a driftless random walk, driven by its own shock. A strength of our approach is that we can ascribe a causal role of foreign shocks on trend inflation and the inflation gap by building on well-developed tools such as factor models and SVAR identification.

3 Benchmark Results

3.1 Trend Inflation Estimates

Figure 2 presents the estimates of trend inflation. The dotted line presents the quarter on quarter annualized inflation rates. In general, the trend inflation estimates move in similar fashion to inflation. While some of the trend inflation estimates appear to be more volatile than what one would extract from methods such as applying a bandpass or HP filter, we find our estimates for some, like New Zealand and Canada stay largely within their inflation target band.[8] That said, any comparison relative to an inflation target band, or inflation target, is only suggestive because the target is often couched in language that does not correspond with the concept of an infinite horizon forecast.[9]

[8] We present estimates with their inflation target bands in the online appendix to avoid cluttering up our figure.

[9] For example, Australia has an inflation target of *"2-3 percent over the business cycle"* while the Reserve Bank of New Zealand is charged to *"keep inflation within a range of 1 to 3 percent on average*

However, given that we are studying a sample of what many regard as successful inflation targeters, one's *a priori* expectation is that trend inflation estimates should not deviate too much from these target bands, and so this provides some evidence that we have successfully produced reasonable estimates of trend inflation.

The trend inflation estimates unsurprisingly mirror the inflation experiences of the five countries. It is misleading, however, to interpret the trend inflation estimates as "drawing a line through inflation" and not providing any value-added beyond looking at headline inflation. There are certainly periods where trend inflation deviates quite persistently from headline inflation. We first draw attention to the period post-2008, where inflation has been low relative to recent experience. We notice towards the end of the sample for Australia, New Zealand, Norway and Sweden (2012-2016) in Figure 2, the estimate for trend inflation is often persistently higher than the measured headline. This can be seen more strikingly in Figure 3, where we plot the trend inflation estimates relative to year on year inflation where we observe that a sizeable inflation gap has opened up towards the end of the sample. The wider literature suggests that these persistent deviations are related to the multivariate information which we introduce into the model. This is in contrast with univariate decompositions, for example Stock and Watson (2007). Because univariate methods have only a single source of information, they act like a filter which needs to "go through" the inflation data, eliminating persistent deviation between headline and the estimated trend inflation. In particular, it is known that the trend inflation estimate using a Stock and Watson (2007) univariate UC model does not allow a substantial inflation gap to open up because the inflation gap is modeled as a white noise process, and this has encouraged modeling features such as bounding trend inflation (Chan, Koop, and Potter, 2013) or adding multivariate information (Kim, Manopimoke, and Nelson, 2014). In particular, one of the main suggestive conclusions by Kim, Manopimoke, and Nelson (2014) is that the introduction of multivariate information is helpful in producing more persistent inflation gaps. To the extent that one, though not the only, interpretation of trend inflation is the analogous equating of trend inflation as the implicit inflation target (see Cogley and Sbordone, 2008; Cogley, Primiceri, and Sargent, 2010), allowing for persistence in the inflation gap would seem like a desirable modeling feature, and on the basis of our empirical results, it appears modeling multivariate information has allowed us to capture such features.

A more recent discussion has been on why inflation has been persistently low post 2008 and if inflation expectations may have become unanchored (e.g., see Draghi, 2015a; The Economist, 2015). If we take the trend inflation estimates from our sample of five advanced inflation targeting countries, our results suggest that a persistently negative inflation gap has opened up. If we interpret a corresponding large fall in trend inflation as analogous to an unanchoring of inflation expectations under the interpretation of trend inflation as the

over the medium term".

implicit inflation target, then our results would suggest that our five inflation targeters have performed reasonably well. In particular, trend inflation has remained reasonably close to, or at, the announced inflation target, and one can consider the fall of inflation post 2008 to be largely transitory, as it is expected to dissipate over time given it is estimated to be driven by a fall on the gap component of inflation.

3.2 How important are foreign shocks?

One advantage of our modeling strategy is that we are able to decompose and quantify the role of foreign shocks, relative to domestic shocks, to better understand the relative role of foreign shocks for driving both trend inflation and the inflation gap.

Let N^* and M be the number of foreign variables and the total number of variables in the FAVAR system, respectively. The first difference of headline inflation is in the k^{th} position in the system, with $k > N^*$.[10] To calculate a variance decomposition, we can therefore manipulate Equations (12) and (11) to obtain (see also Morley and Wong, 2017)

$$\Psi_F^{\tau} = \frac{\sum_{j=1}^{N^*} \left\{\mathbf{e_k}(\mathbf{I}-\mathbf{B})^{-1}\mathbf{A}\mathbf{e}_{\mathbf{j}}'\right\}^2}{\mathbf{e_k}(\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\Sigma_\nu}(\mathbf{I}-\mathbf{B})^{-1\prime}\mathbf{e_k}'} \tag{13}$$

$$\Psi_F^{\tilde{\pi}} = \frac{\sum_{j=1}^{N^*} \left\{\mathbf{e_k}\left\{\sum_{\mathbf{i=0}}^{\mathbf{t-1}} \boldsymbol{B}^{\boldsymbol{i+1}}(\mathbf{I}-\mathbf{B})^{-1}\right\}\mathbf{A}\mathbf{e}_{\mathbf{j}}'\right\}^2}{\mathbf{e_k}\left\{\sum_{\mathbf{i=0}}^{\mathbf{t-1}} \boldsymbol{B}^{\boldsymbol{i+1}}(\mathbf{I}-\mathbf{B})^{-1}\right\}\boldsymbol{\Sigma_\nu}\left\{\sum_{\mathbf{i=0}}^{\mathbf{t-1}} \boldsymbol{B}^{\boldsymbol{i+1}}(\mathbf{I}-\mathbf{B})^{-1}\right\}'\mathbf{e_k}'}, \tag{14}$$

where Ψ_F^k is the share of foreign shocks in the variance decomposition, and $k \in \{\tau, \tilde{\pi}\}$, denotes the variance decomposition on trend inflation and the inflation gap, respectively. Figure 4 presents the relative share of foreign shocks in the variance decomposition of inflation gap and trend inflation. A first obsevation observation is that foreign shocks have a larger impact on the cycle relative to the trend. In particular, while foreign shocks explain about 20-30 % of the inflation gap for most countries (and 10% for Norway), they explain a much smaller share of trend inflation, often less than 10%. The share of trend inflation being very small suggests that inflation targeting may have negated the influence of foreign shocks on trend inflation as there is less room to persistently accommodate foreign shocks. We will return to looking into this more explicitly when we consider the larger sample of heterogeneous Asian economies.

Given our broad tentative conclusion that foreign shocks appear to explain a large share of the inflation gap, we aim to better understand these identified foreign shocks, with the tradeoff of making more stringent identifying assumptions. We therefore first make the

[10] Recall $N^* = \eta^* + 3$ as the foreign block contains η^* retained principal components from the international dataset and three commodity prices. $M = \eta + 2 + N^*$ as the domestic block contains η retained principal components from the domestic dataset, headline and core inflation.

distinction between commodity price shocks and other foreign shocks. We subsequently make a distinction between oil price shocks and other commodity prices under further identifying assumptions. We thus identify commodity price shocks by further assuming that the block of three commodity prices are pre-determined to the rest of the foreign block. This identifying assumption amounts to ordering the three commodity prices above the foreign factors. We also appeal to evidence provided by Kilian and Vega (2011), that oil prices appear to be pre-determined. These identifying assumptions about commodity prices appear at least defensible, to the extent that much of commodity supply is pre-determined from futures markets, and thus producers take at least some time before adjusting supply to price incentives. The additional identifying assumption we use has wider appeal, at least with regards to empirical work identifying oil or commodity price shocks (see, e.g. Bachmeier and Cha, 2011; Kilian and Lewis, 2011; Wong, 2015).[11]

Figure 5 presents a finer decomposition of foreign shocks on the inflation gap, by distinguishing between commodity price shocks and other foreign shocks. Overall, to the extent that foreign shocks drive the inflation gap, much of it may reflect commodity price shocks. About half or more of the share of foreign shocks appear to be commodity price shocks. If we further decompose commodity price shocks to oil price shocks and other commodity price shocks, we find that most of the commodity price shocks appear to just be real oil price shocks. Our results appear to be consistent with Kearns (2016), who finds that much of the correlated forecast errors of inflation globally can be explained by commodity price, or more specifically food and oil prices.

We stress that block exogeneity is sufficient to identify the role of foreign shocks and these are weaker identification assumptions than those needed to identify the causal role of commodity prices and oil prices. That is, our identification of foreign shocks is valid as long as one is prepared to accept the weaker block exogeniety restrictions, and this is regardless of the soundness or defensibility of the identification regarding commodity price shocks. If one is prepared to accept these more stringent identification restrictions, which are also used in the wider literature, it would appear that oil and commodity price shocks can explain a sizeable proportion of the inflation gap. We also contrast our results to Fernández, Schmitt-Grohé, and Uribe (forthcoming) who identify foreign shocks by only considering the three real commodity prices and interpret their results as foreign shocks explaining about one third of the business cycle.[12] While we have a more narrowly defined focus on modeling inflation, the main difference between our foreign block

[11]A more recent strand of the oil shocks literature decomposes oil price shocks into oil demand and supply shocks (see Kilian, 2009). Our interpretation of a real oil price shock is similar to that of Kilian and Edelstein (2009) and Wong (2015), who interpret the real oil price shock as reflecting the average share of the underlying oil demand and supply shocks weighted by the importance of the underlying shocks during the sample period. This interpretation is tenable under the Kilian and Vega (2011) interpretation of an oil price shock being pre-determined (see Kilian, 2008).

[12]Fernández, Schmitt-Grohé, and Uribe (forthcoming) consider a much broader impact of foreign shocks, studying the trade balance, terms of trade, GDP, consumption and investment.

and theirs is the existence of foreign factors extracted from the large FAVAR dataset in our case. We can interpret our finding that, at least for the modeling of inflation for these five advanced inflation targeting economies, Fernández, Schmitt-Grohé, and Uribe (forthcoming)'s strategy of using the three commodity prices alone may be sufficient to account for most foreign shocks.

3.3 Low Inflation post-2008

The documented results, while helpful in understanding inflation dynamics throughout the sample, may be less helpful in rationalizing the more recent low inflation. A feature of our modeling strategy is that we can decompose the role of foreign and domestic shocks for trend inflation and inflation gap between any two arbitrary periods t and $t+h$ through

$$
\begin{aligned}
\pi_{t+h} - \pi_t &= [\tau_{t+h} + \tilde{\pi}_{t+h}] - [\tau_t + \tilde{\pi}_t] && (15) \\
&= \tau_{t+h} - \tau_t + \tilde{\pi}_{t+h} - \tilde{\pi}_t && (16) \\
&= \sum_{j=0}^{h} \Delta\tau_{t+j} + \tilde{\pi}_{t+h} - \tilde{\pi}_t && (17) \\
&= \underbrace{\sum_{j=0}^{h} \Delta\tau_{t+j}(\epsilon^*)}_{\text{change in trend due to foreign shocks}} + \underbrace{\sum_{i=N^*}^{M} \sum_{j=0}^{h} \Delta\tau_{t+j}(\bar{\epsilon})}_{\text{change in trend due to domestic shocks}} \\
&+ \underbrace{\sum_{i=1}^{N^*} \tilde{\pi}_{t+h}(\epsilon^*) - \sum_{i=1}^{N^*} \tilde{\pi}_t(\epsilon^*)}_{\text{change in gap due to foreign shocks}} + \underbrace{\sum_{i=N^*}^{M} \tilde{\pi}_{t+h}(\bar{\epsilon}) - \sum_{i=N^*}^{M} \tilde{\pi}_t(\bar{\epsilon})}_{\text{change in gap due to domestic shocks}} && (18)
\end{aligned}
$$

The third line is due to the fact that we model trend inflation as a random walk without drift, and thus the change in trend inflation between two arbitrary periods is just the entire sequence of changes in the permanent component. Denote $\Delta\tau_t(\epsilon^*)$ and $\tilde{\pi}_t(\epsilon^*)$ as the components of the change in trend inflation and the inflation gap driven by foreign shocks and $\Delta\tau_t(\bar{\epsilon})$ and $\tilde{\pi}_t(\bar{\epsilon})$ the components driven by domestic shocks. We obtain the fourth line by using Equations (11) and (12), where the trend and gap in any period can be fully and linearly decomposed into components driven by foreign and domestic shocks, respectively.

The decomposition of the change in inflation between any two periods to four components can provide insights as to whether domestic or foreign shocks were dominant in the period of low inflation post-2008, and the extent to which these effects were permanent or transitory. We therefore focus our attention to two sub periods: the collapse of inflation during the Great Recession; and the low inflation period after the 2014 collapse in oil prices. These two sub-periods are of particular interest for our study because they represent periods of falling headline inflation with a clear identifiable link to global developments. For the first sub-period, we focus on the period 2008Q1-2009Q1. For the second sub-period, we focus on the period 2014Q1 to the end of the sample. We chose the start dates to be a period when inflation was generally taken to be somewhat stable. In the first sub-period, while the NBER dated the start of the U.S. recession in December 2007, inflation globally only collapsed and hit a trough in either 2008Q4 or (mostly) in 2009Q1. The second event, the collapse in crude oil prices, took place over a period of about 18 months. While the sharpest falls occurred from 2014Q3 to 2015Q1, there were significant falls in mid 2015Q1, which culminated in the trough of oil prices going slightly under $30 in January 2016. The oil price collapse coincided with a period of persistently low inflation. It lead to concerns over whether countries have fallen into a deflation trap or whether inflation expectations had become unanchored (e.g. Draghi, 2015a; The Economist, 2015), which make this episode a good test case for understanding the role of foreign shocks and whether their effects are permanent or transitory.

Figure 6 presents the change in the level of quarter on quarter headline inflation, with a corresponding decomposition of the change into the four components. The top panel focuses on the first sub-period 2008Q1-2009Q1. While drawing general conclusions across a number of countries can be challenging, we find a large share of the fall in inflation can be attributed to the inflation gap falling due to foreign shocks. The bottom panel presents the change in inflation for the latter period, 2014Q1-2016Q1. Unlike the first sub-period, we find the experience across all five open economies can be quite heterogeneous. For example, while inflation in Australia, Canada, and New Zealand fell, inflation in Norway and Sweden actually *rose*. When we perform the decomposition, it also becomes less clear that it was necessarily foreign shocks that were the main driver. For example, in Sweden, our decomposition suggests trend inflation rising due to domestic shocks, and in Norway, domestic shocks had a large role with both trend inflation and the inflation gap. At the same time, it appears that, in all five countries, domestic shocks seem to have propped up trend inflation, which partially or fully offset foreign shocks driving down trend inflation.

Overall, our assessment from studying these two episodes of falling headline inflation, with clear identifiable foreign dimensions, suggests that both episodes were different. During the large fall in inflation during the Great Recession, our results suggest that much of the fall is caused by foreign shocks but mostly transitory in nature. With the second episode, it is less obvious that foreign shocks were the dominant cause of low inflation. While we estimate foreign shocks to have exerted downward pressure on trend inflation in the post-2014 period, we find that this is somewhat offset by the effect of domestic shocks in the opposite direction. We can interpret this as being consistent with the intentions of domestic monetary authorities in the five inflation targeting regimes, which sought to offset the effect of downward pressure on trend inflation by foreign shocks.

3.4 Summary

Our empirical approach has produced trend inflation and inflation gap estimates for Australia, Canada, New Zealand, Norway, and Sweden in a sample period largely coinciding with inflation targeting. We subsequently identified foreign shocks within our empirical approach. Two key findings stand out. First, foreign shocks appear more important for the inflation gap relative to trend inflation. Second, when we further disaggregate the foreign shocks, much of the share of foreign shocks appears to reflect oil commodity price shocks. Our results so far thus suggest that the monetary policy implications of foreign shocks on domestic shocks change little of the standard monetary policy prescription. In particular, the effect of foreign shocks on our benchmark five inflation targeters does seem transitory, and therefore the standard monetary policy doctrine of necessarily ignoring transitory or one off effects applies.

We next extend our analysis to a group of Asian economies to contrast these findings against a group of countries that have very different monetary policy regimes and institutional features.

4 Extensions

4.1 Extending to a Group of Asian Economies

We now extend our analysis to a wider group of 10 Asian economies: China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore and Thailand. This group of heterogeneous countries contains a mix of advanced and emerging market economies, as well as a mix of different monetary policy and exchange rate regimes. At a base level, we investigate how many of our findings extend to a group wider than the benchmark. We therefore estimate the same model for each of the 10 Asian economies.[13] Data limitations are a greater concern with this group of countries given long consistent data coverage may be lacking. In general, we collect as many economic time series as we can to extract factors, though some of these countries may have as few as four or five variables to construct the domestic factors sub-block.[14]

We first ask if our conclusions about foreign shocks being more important for the inflation gap than the trend inflation hold with this larger sample of countries. Figure 7 presents these results [15] which suggest that our main conclusions carry over to the sample

[13]Given that we have economies like China and Japan in the sample of Asian economies, it is more debatable that a block exogeniety restriction is appropriate. Therefore, one needs to exercise some caution in reconciling these results with the main benchmark analysis.

[14]In the case where Japan is the domestic economy, data from the other four major economies are used to construct the foreign block. Otherwise, Japan is within the foreign block for all the other countries, as in our benchmark analysis.

[15]We relegate the plots of our trend inflation estimates for the 10 Asian economies to the online appendix.

of Asian economies. We also identify oil and commodity price shocks as in the case of inflation targeting economies and compute their share in the variance decomposition of trend inflation. These results are presented in Figure 8. Our conclusions that foreign shocks reflect largely, but not entirely, oil and commodity price shocks appears robust when considering a wider, more heterogeneous group of countries.

In sum, when we extend our analysis to a larger, and more heterogeneous group of Asian economies, the two key conclusions change little. We find consistent evidence that foreign shocks matter more for the inflation gap than trend inflation, and that much of the larger share in the inflation gap may well reflect oil and commodity price shocks. Therefore, there is sufficient evidence that our main results are not just confined to advanced inflation targeting small open economies, but remain fairly robust across countries with different development status and different monetary policy regimes.

4.2 Does Inflation Targeting Make a Difference?

A natural question is whether one could explain some of the cross sectional differences in the share of foreign shocks. Indeed, a natural grouping is to consider the group of established inflation targeters relative to the heterogeneous group of Asian economies. From Figures 4 and 7, we compare the average share of foreign shocks driving trend inflation and the inflation gap for the two groups. We present this in the left panel of Figure 9. Here, we get a sharp contrast where the benchmark inflation targeting group has a much lower share of foreign shocks driving both their trend inflation and the inflation gap. Indeed, the share of foreign shocks driving trend inflation is exceedingly low for the inflation targeting group that suggests a compelling case for an inflation targeting regime being more successful in reducing the share of foreign shocks.

Another specification we could consider is to estimate trend inflation for the whole sample for the benchmark countries rather than keeping to the largely inflation targeting period. While we had kept to starting our sample in the 1990s largely due to data quality and to avoid modeling possible structural breaks across a number of countries, we can interpret the share of foreign shocks in the entire sample as a weighted average of the largely inflation targeting period and the pre-inflation targeting period. The right panels of Figure 9 presents these results. In general, we find a greater share for foreign shocks driving trend inflation and the inflation gap with a sample encompassing pre-inflation targeting and the inflation targeting regime.

In sum, comparing our benchmark results relative to a group of heterogeneous Asian economies and a longer sample period, we find evidence that inflation targeting does reduce the influence of foreign shocks on inflation, especially on trend inflation. We need to be cautious in the interpretation, however, given the comparison is relative to five inflation targeters and we are only considering a very small sample. Nonetheless, the results appear sufficiently compelling to suggest a link between foreign shocks and inflation targeting. Moreover, as we mentioned, foreign shocks should only influence trend inflation if there is a systematic attempt by the domestic monetary authority to accommodate foreign shocks. Inflation targeting, as a monetary policy regime, is designed precisely to prevent such accommodation. In this regard, we expect inflation targeting regimes to have a smaller role for foreign shocks, and this is indeed consistent with the additional analysis.

5 Conclusion and Discussion

In this paper, we develop an open economy model to estimate trend inflation which allows us to quantify the role of foreign shocks in driving both trend inflation and the inflation gap. We focus most of the application to study five advanced inflation targeting economies, Australia, Canada, New Zealand, Norway and Sweden.

We highlight three key findings. First, we broadly find that foreign shocks appear to be more important for the inflation gap, relative to trend inflation. Second, we find that much of the reported shares of foreign shocks in the inflation gap and trend inflation may largely reflect oil and commodity price shocks. Our two conclusions are broadly supported when we expand the sample to a fairly heterogeneous sample of 10 Asia-Pacific economies, which feature of mix of emerging market and developed economies. Our third conclusion is that inflation targeting as a monetary policy regime, may reduce the influence of foreign shocks, especially on trend inflation. We conclude this mainly by finding the share of foreign shocks in our five established inflation targeters during the inflation targeting period is very small (less than 10% for the vast majority and often less than 5%) as compared to the group of Asian economies. We also find extending the sample period to a non-inflation targeting period for the five inflation targeters appears to reveal a larger share of foreign shocks driving both their trend inflation and inflation gap.

The overall conclusion from our findings suggest that even if foreign shocks matter for inflation, inflation in the long run ultimately remains a domestic monetary phenomenon. That is, without any accommodation of foreign shocks, foreign shocks should not explain anything about trend inflation. Perhaps most interestingly, because foreign shocks appear to be largely irrelevant for trend inflation in our sample of five advanced inflation targeting countries during the inflation targeting period, further suggests that the conventional wisdom that inflation in the long run is a monetary phenomenon is supported.

It is important to stress that the literature on the increase globalization of inflation pre-supposes that domestic inflation has become *more* sensitive to global slack, which is subtlety different from our work, as we only measure the average share of foreign shocks in trend inflation and the inflation gap over the entire sample. However, we do propose an empirical setup which allows for a broader view of global determinates (i.e. foreign shocks) that tackles a first order policy issue of whether the influence of foreign shocks is more transitory or permanent. This may provide a good starting point, that one may consider modeling time variation in future work in order to investigate whether inflation is increasingly globalized. However, we note that Bianchi and Civelli (2015) do explicitly model time variation in studying the effect of the increased globalization of inflation, albeit with a narrower focus on global slack, and find no evidence of time variation.

To return to the quote at the start of the paper, our results suggest that even if foreign shocks can drive inflation, this does not impede a central bank's ability to manage inflation. Indeed, our direct reply to Carney's quote is that central banks are still masters of their domestic monetary destinies. Foreign shocks might matter, but Milton Friedman's old adage about inflation ultimately remaining a domestic monetary phenomenon still seems relevant.

A1 Data Appendix

Table A1: Data Sources for Benchmark Five Countries

Series	Source	Transformation
Australia: Analytical Series for CPI inflation for Research Purposes	RBA	1
Australia CPI: All Groups excluding Food and Energy (NSA, Q3.11-Q2.12=100)	ANZ	1
Australia: Gross Domestic Product (SA, Mil.Chn.Q3:14-Q2:15.A$)	G10	1
Australia: GDP: Final Consumption Expenditure (SA, Mil.Chn.Q3:14-Q2:15.A$)	G10	1
Australia: GDP: Gross Fixed Capital Formation (SA, Mil.Chn.Q3:14-Q2:15.A$)	G10	1
Australia: 3-Month Bank Accepted Bills (AVG, %)	G10	0
Australia: Money Supply: M3 (EOP, SA, Bil.A$)	G10	1
Australia: Accumulation Index: S&P/ASX 200 (EOP,Dec-31-79=1000)	ANZ	1
Australia: Industrial Production excl Construction (SA, Q3.14-Q2.15=100)	G10	1
Australia: Labor Force: Unemployment Rate (EOP, SA, %)	G10	0
Australia: Labor Force: Employed (EOP, SA, Thous)	G10	1
Canada: Consumer Prices (2010=100, NSA)	IFS	1
Canada: Core Inflation Index (2007=100)	Outlook	1
Canada: Gross Domestic Product (SA, Mil.Chn.2007.C$)	G10	1
Canada: GDP: Final Consumption Expenditure (SA, Mil.Chn.2007.C$)	G10	1
Canada: GDP: Gross Fixed Capital Formation: Total (SA, Mil.Chn.2007.C$)	G10	1
Canada: 3-Month Treasury Bill Yield (AVG, %)	G10	0
Canada: Money Supply: M3+ (SA, Avg, Mil.C$)	G10	1
Canada: Industrial Share Prices (2010=100)	IFS	1
Canada: Industrial Production: Manufacturing, Mining & Utilities (SA, 2007=100)	G10	1

Canada: Unemployment Rate: 15 Years and Over (SA, %)	G10	0
Canada: Employment: 15 Years and Over (SA, Thous)	G10	1
New Zealand: Consumer Prices (2010=100, NSA)	IFS	1
New Zealand: Core Inflation Index (2009-10=100)	Outlook	1
New Zealand: Gross Domestic Product, Volume, Market Prices (Mil.Chn.2009-10.NZ$)	Outlook	1
New Zealand: Private Final Consumption Expenditure, Volume (Mil.Chn.2009-10.NZ$)	Outlook	1
New Zealand: Gross Capital Formation, Total, Volume (Mil.Chn.2009-10.NZ$)	Outlook	1
N.Z.: Money Market Rate: Overnight Interbank Cash Rate (% per annum)	IFS	0
New Zealand: Money: M3, Broad Money (EOP,Mil.NZ$, NSA)	IFS	1
New Zealand: Share Prices (2005=100)	IFS	1
New Zealand: Manufacturing Production (2010=100, SA)	IFS	1
New Zealand: HH Survey: Unemployment Rate (SA, %)	ANZ	0
New Zealand: HH Survey: Number Employed (SA, Thous)	ANZ	1
New Zealand: Manufacturing & Construction: Capacity Utilization (NSA, %)	G10	0
Norway: Consumer Prices (2010=100, NSA)	IFS	1
Norway: Core Inflation Index (2014=100)	Outlook	1
Norway: Gross Domestic Product (SA, Mil.Chn.2014.NOK)	G10	1
Norway: GDP: Total Consumption Expenditure (SA, Mil.Chn.2014.Kroner)	G10	1
Norway: GDP: Gross Fixed Capital Formation (SA, Mil.Chn.2014.NOK)	G10	1
Norway: Industrial Production excluding Construction (SWDA, 2005=100)	G10	1
Norway: Industrial Share Prices (2010=100)	IFS	1
Norway: Central Bank Policy Rate: Discount Rate (EOP, % per annum)	IFS	0
Norway: Number Employed (Thous, NSA)	IFS	1
Norway: Unemployment Rate (%, NSA)	IFS	0

Norway: Broad Money (EOP,Bil.Kroner, NSA)	IFS	1
Sweden: Consumer Prices (2010=100, NSA)	IFS	1
Sweden: Core Inflation Index (2015=100)	Outlook	1
Sweden: Share Prices [End of Month] (2010=100)	IFS	1
Sweden: Gross Domestic Product (SA, Mil.Chn.2015.SEK)	G10	1
Sweden: GDP: Private Consumption Expenditure (SA, Mil.Chn.2015.SEK)	G10	1
Sweden: GDP: Gross Fixed Investments (SA, Mil.Chn.2015.SEK)	G10	1
Sweden: Money Stock: M3 (EOP,Bil.Kronor)	IFS	1
Sweden: Total Employment (Thous.Persons)	Outlook	1
Sweden: Unemployment Rate (%)	Outlook	0
Sweden: 3-Month Treasury Discount Notes (%)	IFS	0

Notes: IFS: International Finance Statistics, RBA: Reserve Bank of Australia, ANZ: Australia & New Zealand database accessed through Haver, G10: G10 Database accessed through Haver, Outlook: OECD Outlook. Transformation 0 - Level or log level. 1 - Log first difference or first differenced

Table A2: Data Sources for International Block

Series	Source	Transformation
Commodity Prices		
Energy	Pink Sheet	1
Agriculture	Pink Sheet	1
Metals & Minerals	Pink Sheet	1
Variables Used to Construct Foreign Factors		
Baltic Dry Index	Bloomberg	0
France: Capacity Utilization: Total Industry (SA, %)	G10	0
France: Consumer Prices (2010=100, NSA)	IFS	1
France: Domestic PPI: Intermediate Goods (SA, 2010=100)	G10	1
France: Gross Domestic Product (SWDA, Mil.Chn.2010.Euros)	G10	1
France: Gross Fixed Capital Formation (SWDA, Mil.Chn.2010.Euros)	G10	1
France: Household Consumption (SWDA, Mil.Chn.2010.Euros)	G10	1
France: Industrial Production excluding Construction (SWDA, 2010=100)	G10	1
France: LFS: Unemployment Rate (SA, %)	G10	0
France: Money Supply: M2 (SA, EOP, Mil.Euros)	G10	1
France: Paris Stock Market: Price Index: SBF 250 (AVG, Dec-28-90=1000)	G10	1
France: Private Sector Employment [excluding Agriculture] (SA, Thous)	G10	1
Germany: Base Rate (EOP, %)	G10	0
Germany: Capacity Utilization: Manufacturing (SA, %)	G10	0
Germany: Consumer Price Index (SA, 2010=100)	G10	1
Germany: Employment (SA, Thous)	G10	1
Germany: GDP: Final Consumption (SWDA, Bil.Chained.2010.Euros)	G10	1

Germany: GDP: Gross Fixed Capital Formation (SWDA, Bil.Chained.2010.Euros)	G10	1
Germany: Gross Domestic Product (SWDA, Bil.Chn.2010.Euros)	G10	1
Germany: Industrial Production: Total Industry ex Construction(SWDA, 2010=100)	G10	1
Germany: Money Supply: M2 (SA, EOP, Bil.Euros)	G10	1
Germany: PPI: Total Industry excluding Construction (SA, 2010=100)	G10	1
Germany: Registered Civilian Unemployment Rate (SA, %)	G10	0
Germany: Stock Market Indexes: DAX Performance Index (EOP, Dec-30-87=1000)	G10	1
Japan: Consumer Price Index (SA/H, 2015=100)	G10	1
Japan: Core Inflation Index (2005=100)	Outlook	1
Japan: Financing Bill Rate (% Per Annum)	IFS	0
Japan: GDP: Pvt Gr Dom Fxd Cap Form: Residential Bldgs (SA, Bil.Chn.2011.Yen)	G10	1
Japan: Gross Domestic Product (SA, Bil.Chn.2011.Yen)	G10	1
Japan: Industrial Production: Manufacturing (SA, 2010=100)	G10	1
Japan: Labor Force Survey: Total Employment (SA, 10,000)	G10	1
Japan: Money Supply: M2 (SA, 100 Mil.Yen)	G10	1
Japan: Operating Rate: Manufacturing (SA, 2010=100)	G10	0
Japan: Output Price: Manufacturing (SA, 2011=100)	G10	1
Japan: Tokyo Stock Price Index: Composite [TOPIX] (EOP,Jan-4-68=100)	G10	1
Japan: Unemployment Rate (SA, %)	G10	0
U.K.: GDP: Gross Fixed Capital Formation (SA, Mil.Chained.2013.Pounds)	G10	1
U.K.: GDP: Household Final Consumption Expenditure (SA, Mil.Chained.2013.Pounds)	G10	1
U.K.: Gross Domestic Product (SA, Mil.Chained.2013.Pounds)	G10	1
U.K.: Industrial Production excluding Construction (SA, 2013=100)	G10	1
U.K.: Industrial Share Prices (2010=100)	IFS	1

U.K.: LFS: Unemployment Rate: Aged 16 and Over (SA, %)	G10	0
U.S.: Capacity Utilization: Industry (SA, %)	G10	0
U.S.: Civilian Employment: 16 Years & Over (SA, Thous)	G10	1
U.S.: Civilian Unemployment Rate (SA, %)	G10	0
U.S.: Consumer Price Index (SA, 1982-84=100)	G10	1
U.S.: Dow Jones: 30 Industrial Stocks: Avg Price Close (AVG, May-26-1896=40.94)	G10	1
U.S.: GDP: Final Consumption Expenditures (SA, Bil.Chn.2009$)	G10	1
U.S.: GDP: Gross Fixed Capital Formation (SA, Bil.Chn.2009$)	G10	1
U.S.: Gross Domestic Product (SA, Bil.Chn.2009$)	G10	1
U.S.: Industrial Production excluding Construction (SA, 2012=100)	G10	1
U.S.: Money Supply: M2 (SA, Bil.$)	G10	1
U.S.: PPI: Finished Goods (SA, 1982=100)	G10	1
U.S.: Spot Oil Price: West Texas Intermediate [Prior'82=Posted Price] ($/Barrel)	G10	1
United Kingdom: 91-Day Treasury Bill Tender Rate, Disc Basis (%)	IFS	0
United Kingdom: RPI: All Items (2010=100)	IFS	1
United States: 3-Month Treasury Bill Auction Rate, Discount Basis (%)	IFS	0

Notes: Pink Sheet: World Bank, IFS: International Finance Statistics, G10: G10 Database accessed through Haver, Outlook: OECD Outlook. Transformation 0 - Level or log level. 1 - Log first difference or first differenced

Table A3: Data Sources for Emerging Asia

Series	Source	Transformation
China: Consumer Confidence (NSA, 1996=100)	EPR	0
China: Consumer Price Index (SA, 2015=100)	EPR	1
China: CPI ex Food	BIS(C)	1
China: Gross Domestic Product (SA, Bil.2015.Yuan)	EPR	1
China: Index of Industrial Value Added in 1990 Prices (SA, 2005=100)	EPR	1
China: Money Supply: M2 (EOP,SA, Bil.Yuan)	EPR	1
Core inflation		1
Hong Kong: CPI Composite: All Items (SA, Oct.14-Sep.15=100)	EPR	1
Hong Kong: CPI ex Food and Energy	HKMA	1
Hong Kong: Employment (SA, Thous)	EPR	1
Hong Kong: GDP: Gross Domestic Fixed Capital Formation (SA, Mil.Chn.2014.HK$)	EPR	1
Hong Kong: GDP: Private Consumption Expenditure (SA, Mil.Chn.2014.HK$)	EPR	1
Hong Kong: Gross Domestic Product (SA, Mil.Chn.2014.HK$)	EPR	1
Hong Kong: Interest Rate: Best Lending Rate (Avg, % per annum)	EPR	0
Hong Kong: IP: Manufacturing (SA, 2008=100)	EPR	1
Hong Kong: Money Supply: M2: Total (EOP,Mil.HK$)	EPR	1
Hong Kong: Stock Price Index: Hang Seng Bank (Jul-31-64=100)	EPR	1
Hong Kong: Unemployment Rate (SA, %)	EPR	0
India: 10-Year Government Bond Yield (EOP, % per annum)	EPR	0
India: Consumer Price Index (SA, 2012=100)	EPR	1
India: GDP at Market Prices (SA, Bil.Apr.11-Mar.12.Rupees)	EPR	1
India: IP: General Index (SA, Apr.04-Mar.05=100)	EPR	1

India: Money Supply: M2 (EOP, SA, Bil.Rupees)	EPR	1
India: RPI ex Food and Energy	EPR(C)	0
Indonesia: CPI: Total (SA, 2012=100)	EPR	1
Indonesia: GDP Deflator (SA, 2010=100)	EPR	1
Indonesia: GDP: Gross Fixed Capital Formation (SA, Bil.2010.Rupiahs)	EPR	1
Indonesia: GDP: Private Consumption Expenditure (SA, Bil.2010.Rupiahs)	EPR	1
Indonesia: Gross Domestic Product (SA, Bil.2010.Rupiahs)	EPR	1
Indonesia: IP: Manufacturing: Large & Medium Enterprises (SA, 2010=100)	EPR	1
Indonesia: MMkt Rate: Interbank Weighted Average (%)	IFS	0
Indonesia: Money Supply: M2 (EOP,SA, Bil.Rupiahs)	EPR	1
Korea: Capacity Util Index: Manufacturing (SA, 2010=100)	EPR	0
Korea: CPI: All Items (SA, 2015=100)	EPR	1
Korea: CPI: All Items excluding Agricultural Products & Oil (SA, 2015=100)	EPR	1
Korea: Employment (SA, Thous)	EPR	1
Korea: GDP: Final Consumption Expenditure (SA, Bil.Ch.2010.Won)	EPR	1
Korea: GDP: Gross Capital Formation (SA, Bil.Ch.2010.Won)	EPR	1
Korea: Gross Domestic Product (SA, Bil.Ch.2010.Won)	EPR	1
Korea: IP: Manufacturing (SA, 2010=100)	EPR	1
Korea: Monetary Stabilization Bonds: 364 days (% p.a.)	EPR	0
Korea: Reserve Money (Avg, SA, Bil.Won)	EPR	1
Korea: Stock Price Index: Korea Composite [KOSPI] (Dec-04-80=100)	EPR	1
Korea: Unemployment Rate (SA, %)	EPR	0
Malaysia: CPI: All Groups (SA, 2010=100)	EPR	1
Malaysia: Employment (SA, Thous)	EPR	1

Malaysia: Ex Food and Energy	BIS, Haver (C)	1
Malaysia: GDP: Gross Fixed Capital Formation (NSA, Mil.2010.Ringgit)	EPR	1
Malaysia: GDP: Private Final Consumption Expenditure (SA, Mil.2010.Ringgit)	EPR	1
Malaysia: Gross Domestic Product (SA, Mil.2010.Ringgit)	EPR	1
Malaysia: Industrial Share Prices (2010=100)	IFS	1
Malaysia: IP: Manufacturing (SA, 2010=100)	EPR	1
Malaysia: MMkt Rate: Overnight Interbank (%)	IFS	0
Malaysia: Money Supply: M2 (EOP,SA, Mil.Ringgit)	EPR	1
Malaysia: Unemployment Rate (SA, %)	EPR	0
Philippines: CPI: All Items (SA, 2006=100)	EPR	1
Philippines: CPI excluding volatile items	EPR	1
Philippines: Employment (SA, Thous)	EPR	1
Philippines: GDP: Gross Domestic Fixed Capital Formation (SA, Mil.00.Pesos)	EPR	1
Philippines: GDP: Private Consumption Expenditure (SA, Mil.00.Pesos)	EPR	1
Philippines: Gross Domestic Product (SA, Mil.2000.Pesos)	EPR	1
Philippines: Mfg Prodn: Volume Index: Manufacturing (SA, 2000=100)	EPR	1
Philippines: Money Market Rate: Overnight Loans (% per annum)	IFS	1
Philippines: Share Prices: Commercial (2010=100)	IFS	1
Philippines: Unemployment Rate (SA, %)	EPR	0
Singapore CPI: All Items (SA, 2014=100)	EPR	1
Singapore: CPI: All excl Accommodation & Priv Road Transport Costs(SA, 2014=100)	EPR	1
Singapore: Employment: All Industry Sectors (NSA, Thous)	EPR	1
Singapore: GDP: Consumption Expenditure (SA, Mil.2010.S$)	EPR	1
Singapore: GDP: Gross Capital Formation (SA, Mil.2010.S$)	EPR	1

Singapore: Gross Domestic Product (SA, Mil.2010.S$)	EPR	1
Singapore: IP: Manufacturing [excl Rubber Processing] (SA, 2015=100)	EPR	1
Singapore: Manpower Stats: UnEmpl Rate (SA, %)	EPR	0
Singapore: Money Supply: M2 (EOP,SA, Mil.S$)	EPR	1
Singapore: Prime Lending Rate (EOP,% per annum)	EPR	0
Singapore: Stock Price Index: Straits Times (Avg, 8-31-89=1396)	EPR	1
Thailand: CPI: All Commodities (SA, 2015=100)	EPR	1
Thailand: CPI excl Raw Food and Energy (SA, 2015=100)	EPR	1
Thailand: GDP: Gross Fixed Capital Formation (SA, Mil.Ch.02.Baht)	EPR	1
Thailand: GDP: Private Consumption Expenditure (SA, Mil.Ch.02.Baht)	EPR	1
Thailand: Gross Domestic Product (SA, Mil.Ch.02.Baht)	EPR	1
Thailand: MMkt Rate: Short-Term Interbank (%)	IFS	0
Thailand: Money Supply: M2 [calculated by Haver] (SA, EOP, Mil.Baht)	EPR	1
Thailand: Share Prices (2010=100)	IFS	1

Notes: EPR: Emerging Asia Dataset accessed through Haver, IFS: International Financial Statistics. (C) constructed through listed sources. Transformation 0 - Level or log level. 1 - Log first difference or first differenced

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Figure 1: Year on Year CPI Inflation for Selected Industrialized Countries

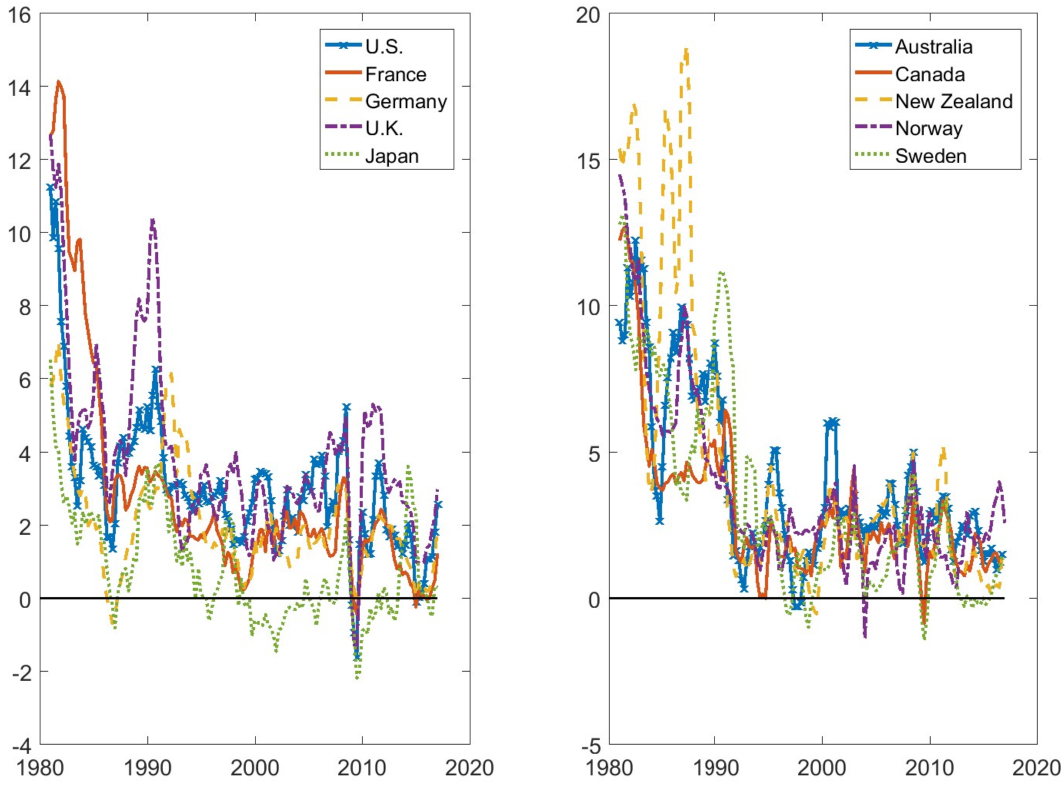
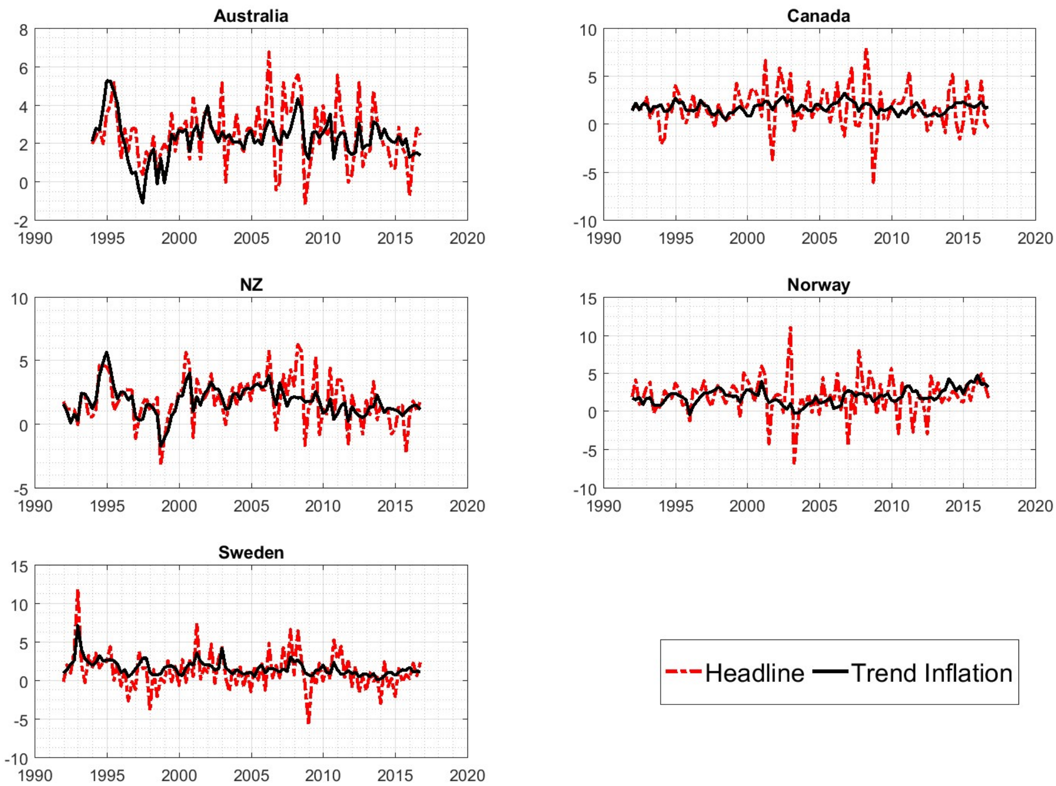
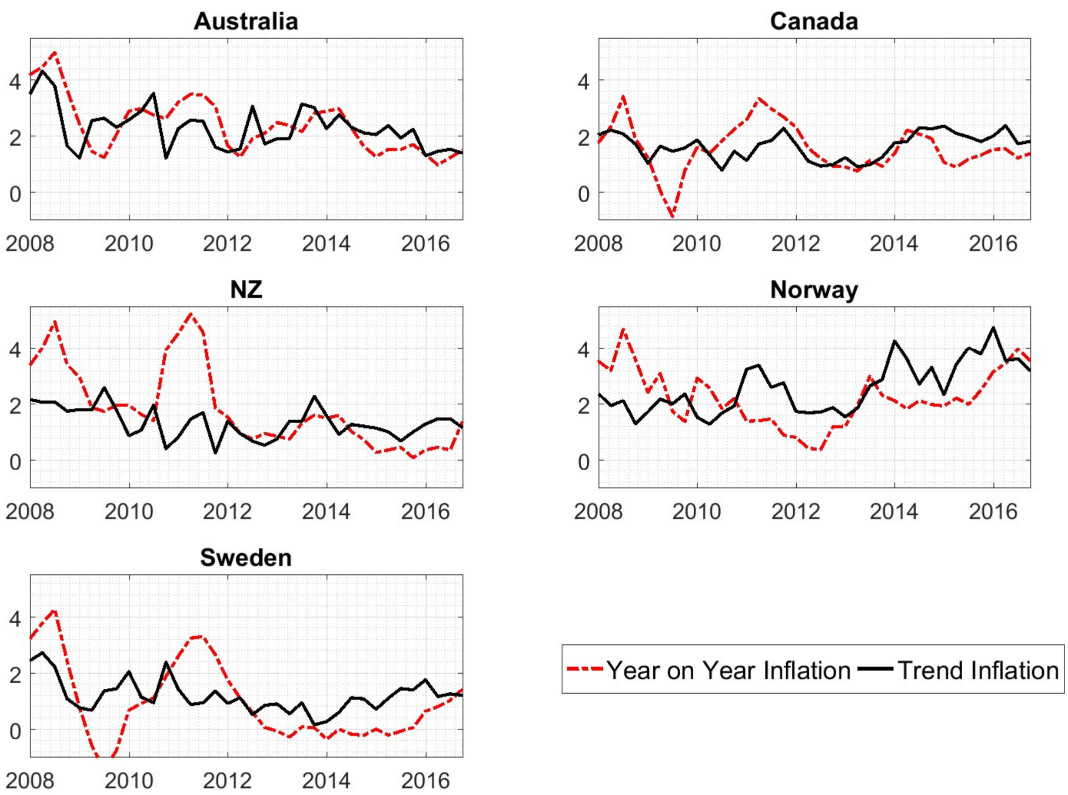


Figure 2: Trend Inflation Estimates



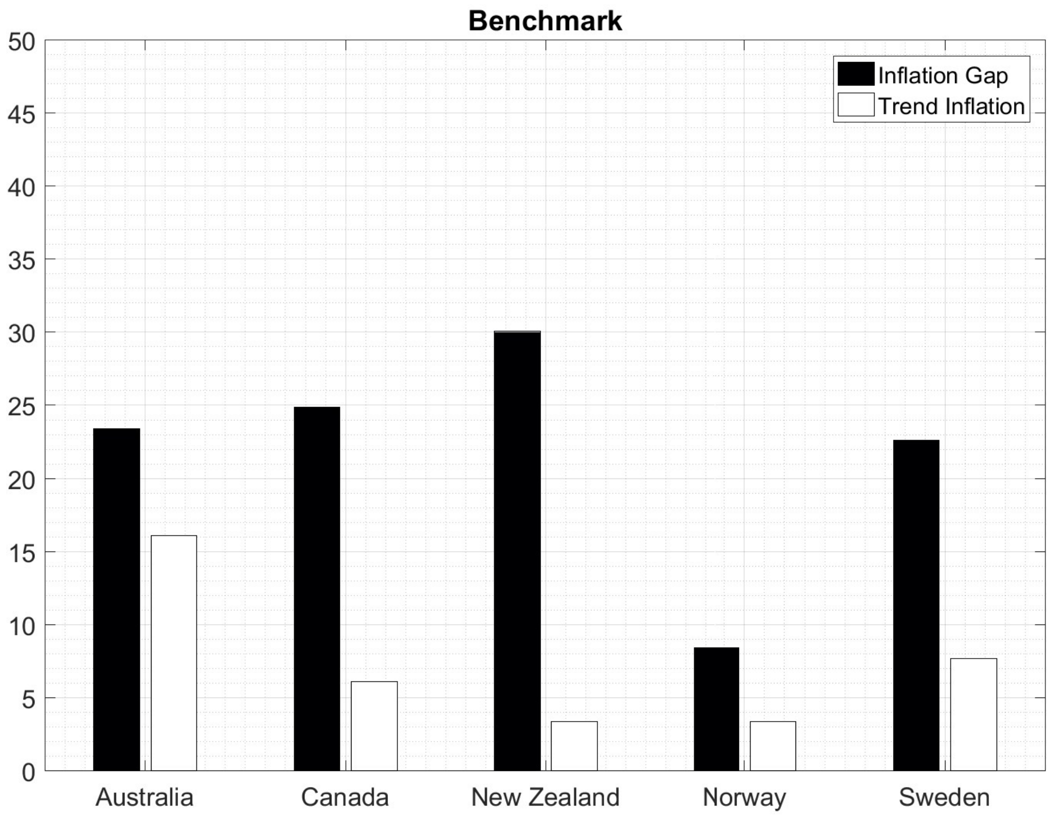
Notes: Trend inflation and headline inflation in annualized percentage terms. The dotted line is quarter on quarter CPI inflation. The thick line are the trend inflation estimates.

Figure 3: Trend Inflation Estimates



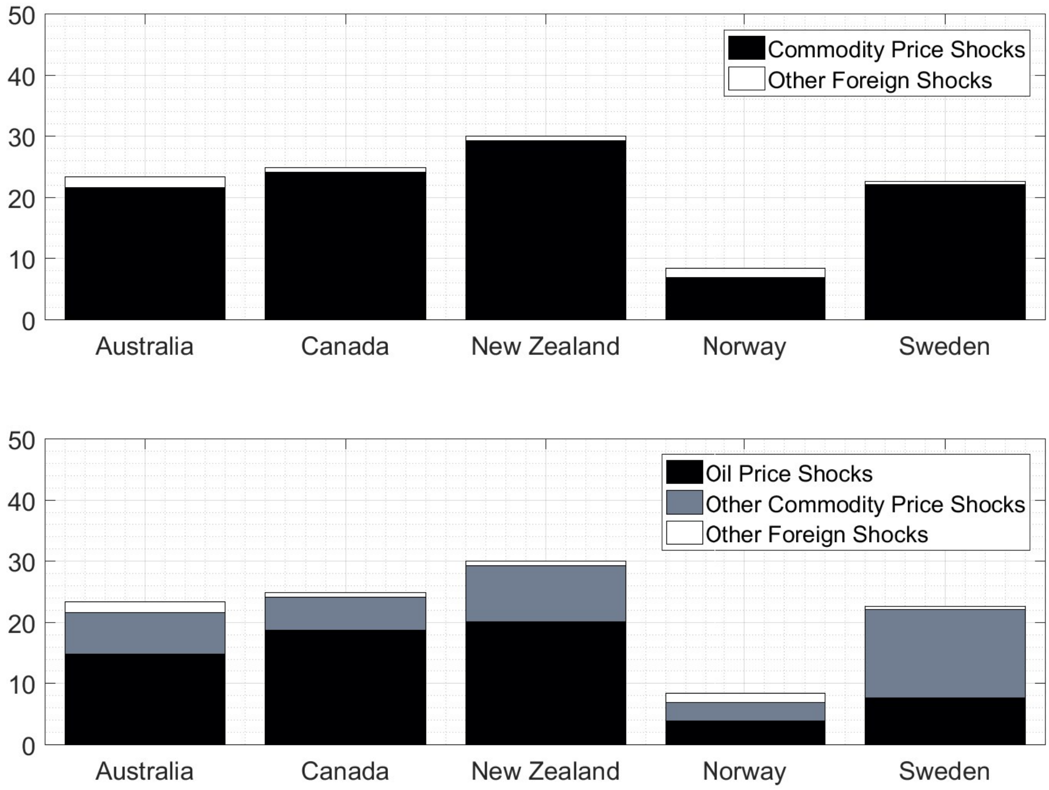
Notes: Trend inflation and headline inflation. The dotted line is year on year CPI inflation. The solid line is the trend inflation estimates.

Figure 4: Share of Foreign Shocks



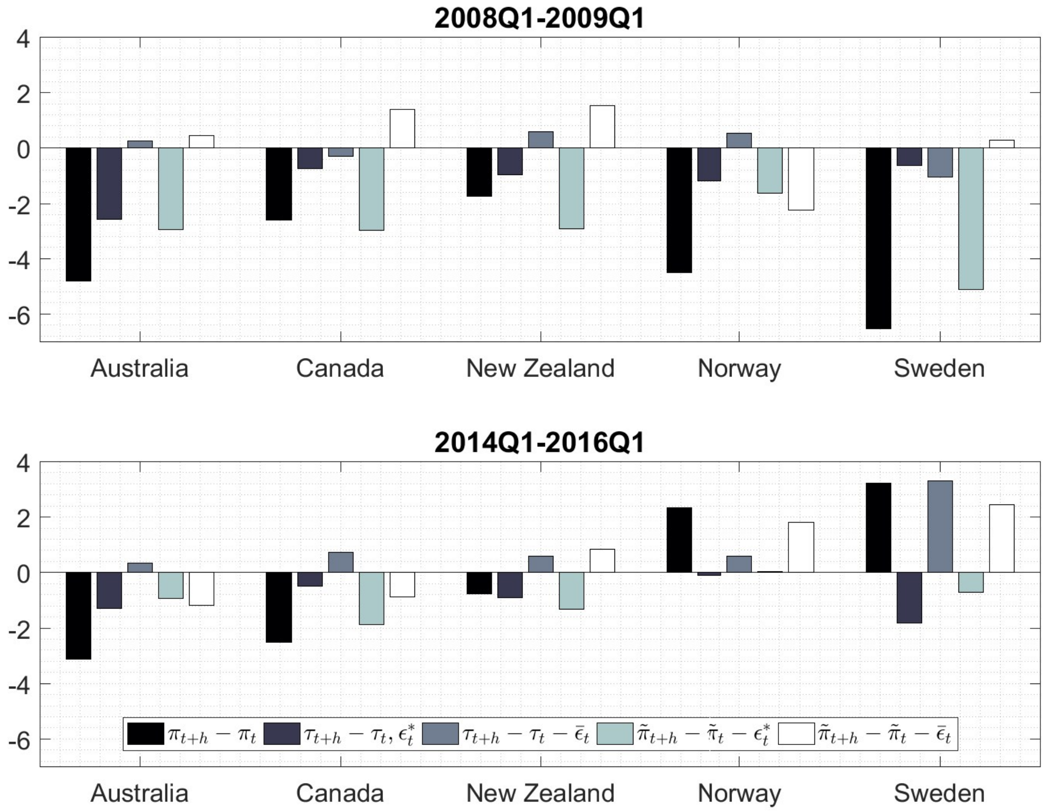
Notes: Both the shares of foreign and domestic shocks sum up to 100.

Figure 5: Share of Oil and Commodity Price Shocks for the Inflation Gap



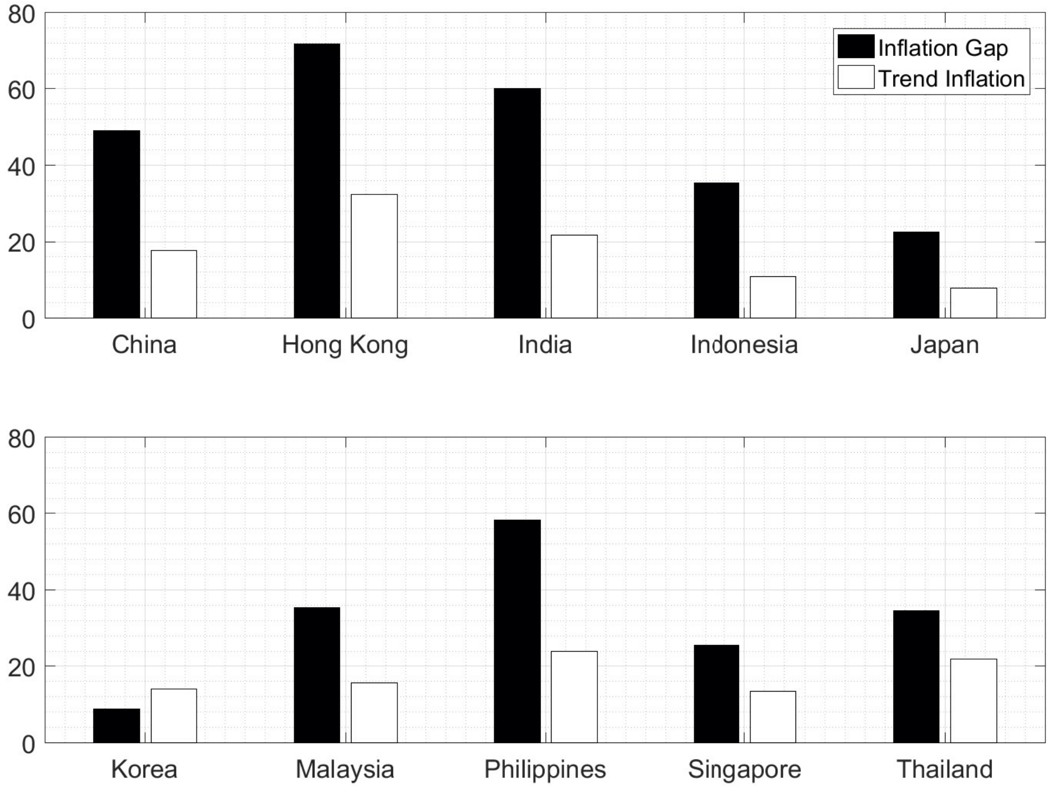
Notes: Both the shares of the commodity price shocks and the other foreign sum up to the sum of the foreign shocks. The foreign and domestic shocks (in Figure 4) in turn sum up to 100.

Figure 6: Decomposing Change in Inflation



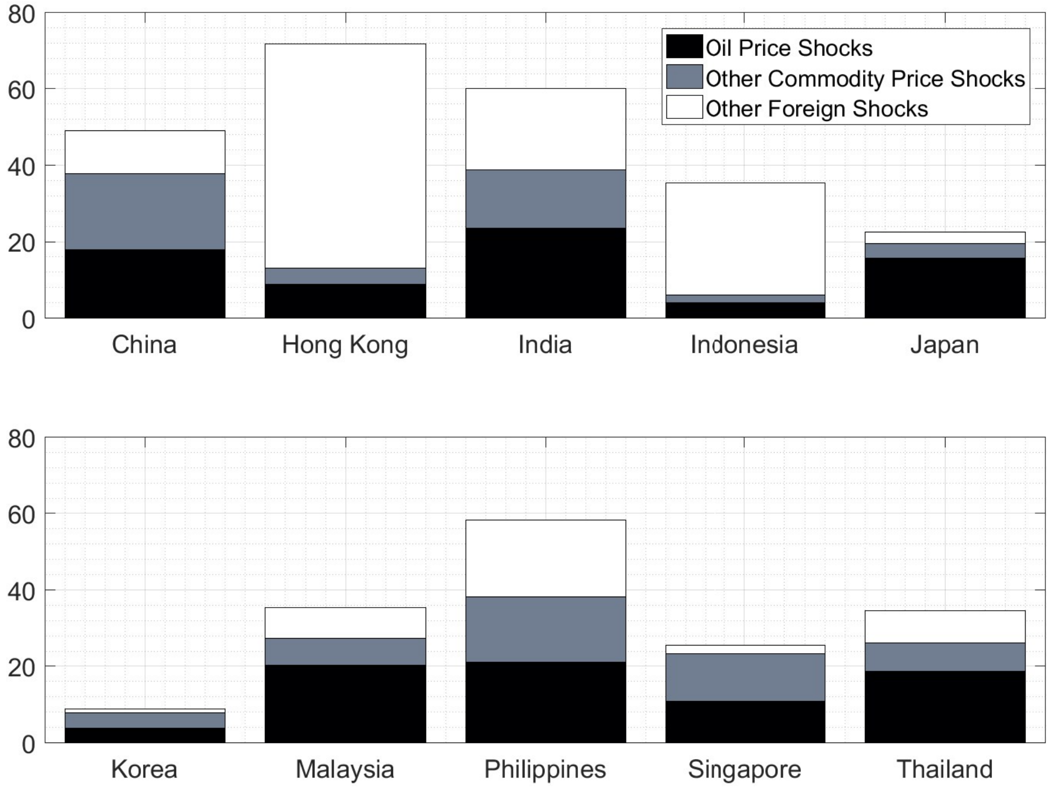
Notes: $\pi_{t+h} - \pi_t$ *- Total Change in quarter on quarter headline inflation.*
$\tau_{t+h} - \tau_t, \epsilon^*_t$ *- The change in trend inflation due to foreign shocks.*
$\tau_{t+h} - \tau_t, \bar{\epsilon}_t$ *- The change in trend inflation due to domesic shocks.*
$\hat{\pi}_{t+h} - \hat{\pi}_t, \epsilon^*_t$ *- The change in the inflation gap due to foreign shocks.*
$\hat{\pi}_{t+h} - \hat{\pi}_t, \bar{\epsilon}_t$ *- The change in the inflation gap due to domesic shocks.*
The four components sum up to the total change.

Figure 7: Share of Foreign Shocks



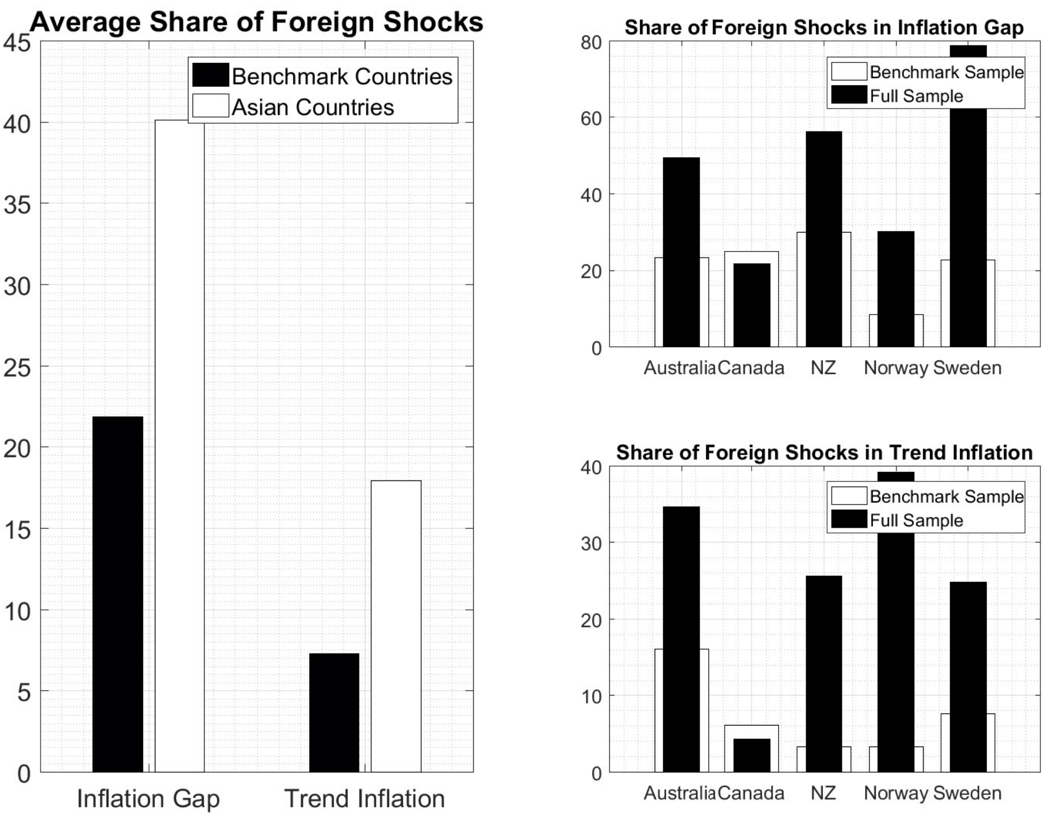
Notes: Both the shares of foreign and domestic shocks sum up to 100.

Figure 8: Share of Oil and Commodity Price Shocks for the Inflation Gap



Notes: Both the shares of the commodity price shocks and the other foreign sum up to the sum of the foreign shocks. The foreign and domestic shocks (in Figure 7) in turn sum up to 100.

Figure 9: Share of Foreign Shocks for Different Sample Groups



Notes: Results for benchmark sample are for the five countries with samples beginning in the 1990s. The shares for the benchmark sample are identical to those presented in Figure 4. Full sample refers to estimation for the benchmark countries estimation beginning in: Australia 1990Q1, Canada 1984Q3, New Zealand 1986Q2, Norway 1981Q2, Sweden 1987Q2.