A dynamic panel threshold analysis of the inflation globalization hypothesis

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Abstract

We introduce two new features in the analysis of the relation between inflation and globalization under the Phillips Curve model, which leads to some clear empirical evidence in favor of the inflation globalization hypothesis. First, we investigate the relationship between inflation and foreign slack in a dynamic panel framework for a set of 28 OECD countries, and we find a significant role for the foreign gap, which is typically missing from individual-country analysis. Second, we augment this model with a threshold component, and we show that trade openness, used as a proxy for globalization, acts as a significant threshold variable for the effects of domestic and foreign slack on inflation. Importantly, the switch in the output gaps slopes from one regime to the other is consistent with the key predictions of the globalization hypothesis: the foreign output gap replaces the domestic as a determinant of domestic inflation in the open regime.

Keywords: Globalization, Inflation, Threshold Models, Foreign Output Gap.
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1 Introduction

Globalization has served as a catalyst for substantial changes in the behavior and functioning of the modern economy, and the importance of global factors for domestic policies has seen considerable emphasis and discussions both in policy and research circles. The Federal Reserve, for instance, has recently started to explicitly incorporate considerations about the global demand and global uncertainty in its policy decisions. In a speech to the Economic Club of New York in March 2016, Chairwoman Janet Yellen explained that the Federal Reserve's anticipated path of interest-rate increases for 2016 had to be revised downwards relative to the projections of the beginning of the year in response to the slowdown of the Chinese economy (Yellen, 2006). She says:

> "Although the baseline outlook has changed little on balance since December, global developments pose ongoing risks. These risks appear to have contributed to the financial market volatility witnessed both last summer and in recent months. One concern pertains to the pace of global growth, which is importantly influenced by developments in China. There is a consensus that China's economy will slow in the coming years as it transitions away from investment toward consumption and from exports toward domestic sources of growth.... [which] could have adverse spillover effects to the rest of the global economy. If such downside risks to the outlook were to materialize, they would likely slow US economic activity, at least to some extent, both directly and through financial market.... The FOMC left the target range for the federal funds rate unchanged in January and March, in large part reflecting the changes in baseline conditions that I noted earlier. In particular, developments abroad imply that meeting our objectives for employment and inflation will likely require a somewhat lower path for the federal funds rate than was anticipated in December."

A key concern for central bankers is the impact globalization can have on the domestic inflation process. One prominent view in this respect, known as the inflation globalization hypothesis, holds that highly interconnected markets will allow external factors to eventually replace the domestic determinants of inflation, so that local prices are guided primarily by global markets. Not surprisingly, this has very significant policy implications as it would leave inflation untethered from traditional monetary policy channels and could ultimately lead to changes in the way monetary policy is conducted. It is thus essential to evaluate the validity of the inflation globalization hypothesis and determine the exact role globalization plays in a country's inflation dynamics. Our paper shows that by adequately accounting for heterogeneity across countries as well as allowing globalization to affect inflation non-linearly, it is possible to find convincing empirical evidence in favor of the inflation globalization hypothesis.

The inflation globalization hypothesis is a radical departure from the traditional view of inflation dynamics being a function of inflation expectations and the current level of economic slack or resource utilization in the domestic economy. While monetary policy is still expected to influence inflation in the long run, the inflation globalization hypothesis allows foreign factors such as the level of global slack to play the dominant role in the short run dynamics. This is also in contrast to those who believe that globalization and increased competition has been a contributing factor in reducing inflation rates around the world, but without changing the underlying inflation process (Pain, Koske, and Sollie, 2006). The validity of the inflation globalization hypothesis would lead to fundamental changes in how inflation is modeled going forward along and force policy makers to place greater emphasis on global economic conditions.

A number of studies have examined the key prediction of the inflation globalization hypothesis that the role of the foreign output gap in the determination of the domestic inflation increases at the expense of the domestic output gap as a country becomes more integrated. This prediction is usually tested in the context of the Phillips Curve, which has been the workhorse model for inflation dynamics. The empirical findings however, have been mixed, with little consensus on the importance of the foreign output gap and thus globalization in a country's inflation process. Borio and Filardo (2007) highly cited findings show that including a measure of foreign slack in a reduced Phillips Curve framework is appropriate for every country in their sample. On the other hand, Ihrig, Kamin, Lindner, and Marquez (2010) illustrate that these results don't hold when a more traditional approach to inflation expectations is employed in the analysis.

We continue this line of inquiry but move away from the existing literature in two key aspects. First, we rely on a panel analysis to investigate the relationship between foreign output gap and inflation. Most of the previous work looks at this relationship at the individual-country level and the panel methods, if used, are often very basic and supplementary. However, a panel approach seems quite relevant as globalization measures such as trade openness exhibit considerable cross-sectional variation as compared to within country variation. In Figure 1, we illustrate the time change of trade openness, defined by the ratio of the sum of imports and exports to GDP, for 15 of the largest OECD countries. Although there is a clear upward trend in openness over these four decades, we observe a more striking variation of the degree of openness across countries, with relatively closed economies such as the US and Japan at one end of the spectrum and much more open economies such as Netherlands and Ireland on the other end. This important characteristic of the data can be used as a means to identify the effects of globalization on the inflation process. Indeed, Bianchi and Civelli (2015) find some preliminary evidence that the effect of the global economic slack on inflation is positively related to the degree of openness for their panel of countries.

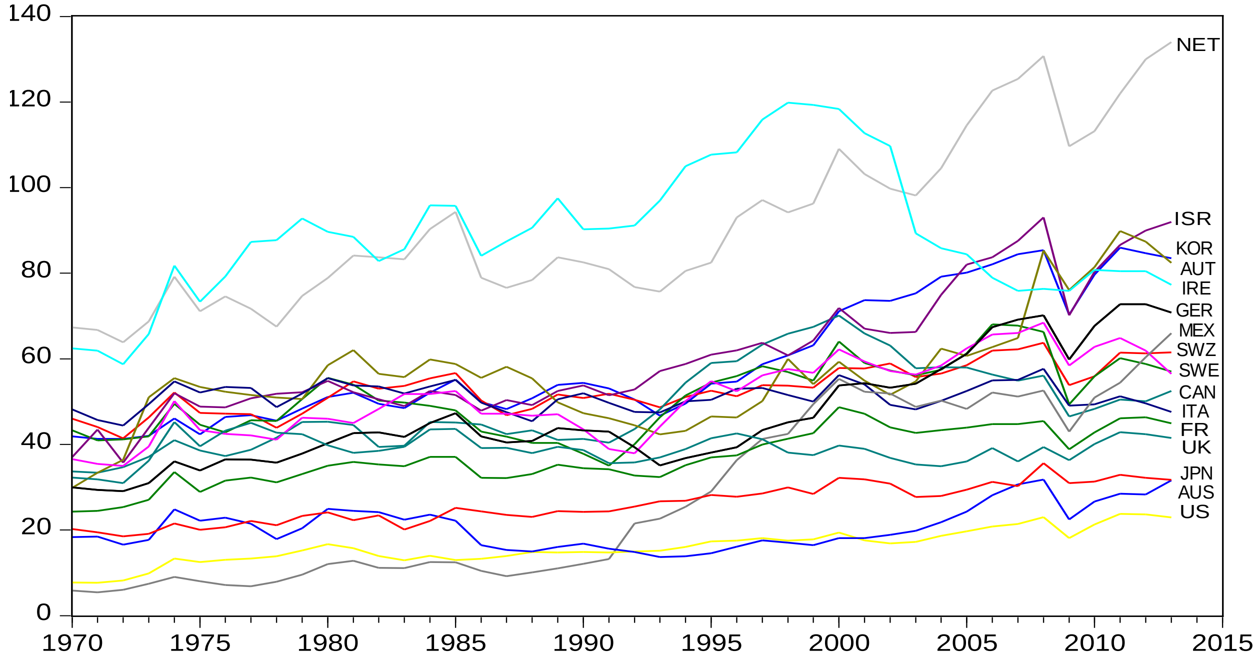

Figure 1: Evolution of Trade Openness (1970-2013) for the fifteen largest OECD economies.

The second and main contribution of our paper is that we allow a country's level of trade openness, used as a proxy of the country's degree of globalization, to act as a threshold variable in the inflation process. We can then determine the empirical relevance of a threshold effect of trade openness in our panel framework, such that inflation responds to external factors only after a certain level of openness has been achieved by a country. A number of economic factors can cause globalization to have a non-linear effect in the inflation process. For instance, Sbordone (2007) shows that globalization can affect the structural determinants of inflation by reducing the market power of domestic sellers through increased competition; however, it may be the case that domestic companies only start to pay attention to foreign competitors after losing a significant level of market share. At the individual country level, Ahmad and Civelli (2016) examine this non-linearity for a sample of OECD countries, and show that for some countries the observed changes in openness are not large enough to induce structural changes in the inflation dynamics. Thus the potential of non-linearity should not be omitted from any analysis of the inflation globalization hypothesis.

For our empirical analysis, we rely primarily on the dynamic panel GMM methodology developed in Arellano and Bond (1991), which provide consistent and efficient estimates of the panel model in the presence of lagged dependent variables. Thus the Arellano and Bond (1991) framework is very convenient to incorporate inflation dynamics that are given by a backward-looking Phillips Curve model. In our analysis, we concentrate on the backward-looking Phillips Curve specification as it has been shown to be a better empirical fit in capturing inflation dynamics (Rudd and Whelan, 2007). However, this methodology can be extended to embed the New Keynesian Phillips Curve models, developed by Galı and Gertler (1999), and so we also examine a model that is consistent with a structural interpretation of the inflation globalization hypothesis. Finally to augment the dynamic panel model with a threshold component, we follow the recent contributions by Caner and Hansen (2004) and Kremer, Bick, and Nautz (2013), that gives consistent estimates of the threshold for panel data even in the case of endogenous regressors. Thus our paper is also part of the new empirical literature that analyzes threshold behavior in a dynamic panel setting.

Our dynamic panel Phillips Curve model is employed on the entire group of 28 OECD countries for the period 1970-2013. Two important results emerge from our estimates. First, we see strong evidence that the foreign output gap is statistically significant and of the same magnitude as the domestic output gap in the country's inflation process. These results also hold when we account for instrument proliferation in the dynamic panels and the possibility of endogenous explanatory variables. Our main findings are also not affected either by the inclusion of traditional controls such as movement in the real exchange rate or import prices, or by restricting the sample period to control for clear changes in monetary policy regimes.

The second key finding of our analysis is that there is significant evidence of non-linearity in our dynamic panel Phillips curve framework with countries seeing a meaningful shift in their inflation dynamic once a level of openness is reached. Crucially, the switch in the output gap slopes from one regime to the other is consistent with the key predictions of the inflation globalization hypothesis in that the foreign output gap coefficient increases and switches from non-significant to significant in the more open regime, while the domestic output gap coefficient moves in the opposite direction and loses significance in the more open regime. The estimated threshold model thus shows a clear link between a country's level of openness and the impact domestic and foreign economic conditions have on it's inflation dynamics. Our estimated 90% confidence interval of $[35-57]$, for the openness threshold value, can be further used by policy makers as a guide on when to direct their attention to the influence of external forces in the inflation process. For instance, our results suggest that the level of US openness is still too low to allow the foreign output gap to significantly affect domestic inflation, which suggests that the reasons of the current US mild inflation are more likely to be found in the dynamics of domestic macroeconomic forces. Hence, although plausible, some of the concerns expressed above by Chairwoman Yellen might still have only a limited relevance for the US monetary policy.

The remainder of the paper is organized as follows. In Section 2, we review the current literature with regards to the inflation globalization hypothesis. Section 3 looks at the motivation of a panel approach and its validity for our dataset. Section 4 describes our OECD dataset while Section 5 reports the main findings of the dynamic panel analysis. Section 6 examines the panel threshold model for the inflation globalization relationship. Finally Section 7 concludes.

2 The relationship between globalization and inflation

2.1 Theoretical Framework

The New Keynesian Phillips Curve (NKPC) has emerged as the workhorse model of inflation dynamics in a general equilibrium setting. Derived from micro-foundations of optimizing firms with rational expectations and nominal price rigidities, the NKPC provides a structural relationship between inflation and domestic firms' marginals costs. The real marginal costs in the aggregate will generally be proportional to the domestic output gap and so the NKPC, like the traditional Phillips Curve before it, allows the country's level of resource utilization to act as a major determinant in the inflation process.[1]

Using the NKPC framework to model inflation dynamics in the context of an open economy, however, creates a few more challenges. One approach is to assign external factors a limited role in determining inflation dynamics for an open economy, typically in the form of supply shocks. However the increased level of globalization that has taken place in recent years in the form of greater openness to trade, financial integration, and higher mobility across factor markets might have very well changed the nature of the country's inflation process. So it may now be the case that domestic prices in highly integrated economies are influenced more by global markets, rather than local markets.

In order to get a better understanding of the different channels through which globalization can influence consumer prices in the NKPC framework, Sbordone (2007) suggests decomposing the relationship between consumer price inflation and domestic output into three separate parts. First, changes in consumer prices reflect price dynamics of both domestic and foreign goods, and so there is a direct link between the CPI and import prices. Secondly, there is a relationship between the domestic marginal cost of production and domestic prices. Lastly, there is a link between the costs of production and the economy's total domestic output. We next discuss how globalization can potentially impact each of these relationships and the existing empirical evidence over its effect on the country's inflation process.

2.1.1 Import Prices and the CPI

Prices of import goods reflect a direct channel through which increased globalization can impact a country's CPI inflation. Since an increase in the share of consumption that is imported will tend to

[1] Despite the strong theoretical foundations of the NKPC, there is still a robust debate over the empirical suitability of the NPKC over the traditional backward-looking Phillips Curve in capturing inflation dynamics. See for example Rudd and Whelan (2007) and Gali, Gertler, and Lopez-Salido (2005).

lead to greater sensitivity of the CPI to import prices, it represents the least controversial aspect of the role globalization can have in the inflation process (Ihrig, Kamin, Lindner, and Marquez, 2010). However, as discussed in Borio and Filardo (2007) and Ihrig, Kamin, Lindner, and Marquez (2010), import prices are not a 'sufficient statistic' for capturing the full influence of foreign markets on domestic prices. Notably, import prices are unable to capture the impact of global markets on firms with significant exports and thus their pricing decision in the domestic markets. They also do not capture the cost of goods that would be potentially imported if domestic prices were to rise above their foreign counterparts. Finally, import prices ignore the effect globalization has on the factor markets, as domestic resource suppliers are more likely to curtail their prices if there is a chance that they could be replaced by foreign resources through an outsourcing of the production process.

Given these limitations, it is not surprising that import prices have generally been found to have a modest effect on inflation. Kamin, Marazzi, and Schindler (2006) explored the effect increased exports of Chinese goods had on the inflation performance of its trading partners and found a relatively small impact, with most countries seeing a decrease of less than 0.25% in their annual inflation rates. For a group of advanced economies, IMF (2006) also finds that the role of import prices in keeping inflation low was limited, so that on average only about one-tenth of an import price decline passes through into inflation during the first year, and this effect disappearing after a couple of years. Ihrig, Kamin, Lindner, and Marquez (2010) also find a weak relationship of import prices affecting inflation and no evidence of this effect increasing with trade openness. Conversely, Pain, Koske, and Sollie (2006) show a positive and significant impact of import prices on CPI inflation for a group of OECD economies.[2]

2.1.2 Marginal Cost and Inflation

The relationship between inflation and marginal cost is one of the key determinants of the slope of the NKPC curve. As trade tends to increase the degree of competition, one possibility is that domestic firms may face a more elastic demand due to globalization, and it forces them to take into account other sellers' prices when setting their own price. In a NKPC model, Sbordone (2007) considers such a scenario where the elasticity of demand is a function of the firm's relative market share. This in turn implies that the firm's desired markup also varies with the number of goods traded and thus directly impacts the link between inflation and marginal cost. With this framework, Sbordone (2007) is able to show that globalization, by reducing the market power of

[2]They rely on an error correction model for price dynamics in their analysis, and so it is unclear whether these findings hold under a traditional Phillips Curve framework.

domestic sellers, can indeed diminish the sensitivity of inflation to domestic output fluctuations.[3] In an open economy NKPC setting with pricing complementarities, Guerrieri, Gust, and López-Salido (2010) also show that variations in desired markups of domestic firms are due to changes in competitive pressure from abroad. Chen, Imbs, and Scott (2009) further find empirical evidence that increased import penetration in the EU manufacturing sectors reduced markups and caused manufacturing prices to rise at a lower rate.[4]

2.1.3 Marginal Cost and Domestic Output

In a closed economy there is a strong link between a firm's marginal costs and domestic resource utilization, as changes in output away from the economy's potential level puts pressure on resource suppliers and causes them to change their prices in response to these economic circumstances. However, as the country becomes integrated in the global economy, imports can be used to satisfy increases in domestic demand while exports can make up for a lack of domestic demand. Similarly, high labor and capital mobility leads to a reduction in the inflationary effects of domestic output fluctuations (Razin and Binyamini, 2007) and makes the prices in these factor markets more responsive to global economic conditions. In the case of an open economy, there is also a need for some measure of the global resource utilization in the country's inflation process, with higher global demand raising domestic inflation by increasing demand for both domestic goods and resources (Engel, 2013). As pointed out by Borio and Filardo (2007), this framework ultimately implies that excess demand should be aggregated at the product rather than the country level, as low demand of a good in one country can be countered by high demand in another.

The extension of the NKPC framework to a small open economy provides a theoretical basis for including the level of slack in the global economy in a country's inflation process. As shown in Gali and Monacelli (2005), domestic inflation now depends on the weighted average of the domestic and foreign output gaps, with the weights representing some preference for home goods.[5] The inclusion of the foreign output gap in the country's open economy NKPC shows that along with the direct effects of trade on the price level, such as deviations in the import prices or the real exchange rate, there is also a need for some measure of excess global demand in the economy's inflation process. Zaniboni (2008) further showed that the foreign output gap continues to play an important role even when different assumptions are made on the pricing behavior of the exporting firms, including the case of local currency pricing.

[3] Note that a flatter Phillips Curve makes it more costly for the central bank to bring inflation to desired target levels. Razin and Binyamini (2007) argues that globalization thus forces monetary authorities to become more aggressive toward inflation and reduce the weight on the domestic output gap in their loss functions.

[4] Similarly, Auer and Fischer (2010) and Auer, Degen, and Fischer (2013) find that greater competition from low-wage countries reduced producer prices in labor-intensive sectors for both the US and the EU.

[5] Clarida, Galı, and Gertler (2002) and Corsetti and Pesenti (2005) make use of this modeling framework to further analyze how openness affects optimal monetary policy.

2.2 Empirical Evidence on the Inflation Globalization Hypothesis

A general expression for the open-economy NKPC model in Gali and Monacelli (2005) is given as

$$\pi_t = \alpha E_t \pi_{t+1} + \beta Y_t^d + \gamma Y_t^f + \varepsilon_t \tag{1}$$

where π_t is inflation, $E_t\pi_{t+1}$ is the expected inflation next period, Y_t^d and Y_t^f are the current domestic and foreign output gaps, respectively.[6] Generally, in the empirical literature, lags of inflation are often used as a proxy for $E_t\pi_{t+1}$, so that equation (1) becomes a purely backward-looking Phillips Curve. It is also common in this analysis to add controls for import prices or the terms of trade to capture the direct impact of trade on the price level.

As discussed in Section 2.1, globalization can effect the slope of the output gaps in equation (1) in two key ways. First, as economies become more open, the traditional relation between short-run inflation and the domestic output gap weakens, resulting in lower values of β in (1). Second, as a country becomes integrated in the global economy, the foreign output gap plays a larger role in the country's inflation process, indicating higher γ values in (1). The empirical findings, however, are quite ambiguous on both these fronts of the inflation globalization hypothesis, with considerable debate on the actual impact globalization has had on a country's inflation dynamics.

While most empirical studies find that the response of inflation to domestic resource utilization has indeed diminished in recent years (Roberts et al., 2006; Borio and Filardo, 2007; Kuttner and Robinson, 2010), there is mixed evidence on the role globalization played in this decline. IMF (2006) include an interaction term for the domestic output gap and trade openness in their panel Phillips Curve and find a strong link between greater openness and the reduction in sensitivity of inflation to the domestic output gap for their sample of advanced economies. Dexter, Levi, and Nault (2005) also show that for the U.S. the inclusion of trade in the inflation process increases the size and significance of the domestic capacity utilization term. On the contrary, Ihrig, Kamin, Lindner, and Marquez (2010) and Ball (2006) find little evidence from their own panel estimates that the decline in the output gap slope was due to increased openness. Using a state-space framework, López-Villavicencio and Saglio (2014) also determine that openness is not responsible for the flattening of the Phillips Curve in the cases of the U.S., France, and the U.K.

A number of studies have also investigated the role of the foreign output gap in the inflation process, using a model similar to equation (1). For a sample of 16 OECD economies, Borio and Filardo (2007) find that the foreign output gap is statistically significant in explaining inflation dynamics

[6] A simple micro-founded derivation of equation (1) can be found in Martinez-Garcia and Wynne (2010).

and that these findings hold for different measures of the foreign output gap. In the case of the U.S., Gamber and Hung (2001) show that globalization in the late 90's increased the sensitivity of inflation to foreign economic conditions. Wynne and Kersting (2007) also find similar evidence that global slack matters for the U.S. inflation process.

Ihrig, Kamin, Lindner, and Marquez (2010) reexamine the findings of Borio and Filardo (2007) and find that the foreign output gap becomes insignificant when more traditional proxies for expected inflation such as π_{t-1} and earlier lags are used instead in these estimations.[7] Calza (2009) also finds that global output gaps have little success in explaining domestic inflation for the Euro area as a whole. Using a structural model for the G7 countries, Milani (2010) determines that global output impacts domestic inflation only indirectly and thus should not be included in the Phillips Curve specification. Finally, Bianchi and Civelli (2015), employing a time-varying VAR model, show that for most countries in their sample, the effects of the foreign output gap on inflation are comparable to those of the domestic output gap, but these effects have also not grown over time.

We will be using a similar framework as (1) to evaluate the effect globalization has had on the country's inflation dynamics, but in a panel setting. We also depart from previous studies by explicitly allowing a country's level of trade openness, used as a proxy for the degree of globalization of a country, to have a non-linear role in the inflation process. There are a number of economic circumstances that can contribute to such a non-linear relationship. It is quite possible that a firm needs to lose a significant level of market share before it experiences a change in it's demand elasticity from an increase in competition. In this instance, there needs to be some level of import penetration in the domestic markets for local firms to start taking into account the prices of foreign firms when setting their desired markups. Similarly, a role for the global output gap exists in the inflation process if increases in domestic demand can be satisfied with imports and if firms can overcome a lack of domestic demand through export sales. However, this implies that consumers view foreign goods as close substitutes to domestic goods, and firms believe that foreign markets can easily replace domestic markets as a key source of revenue. So here again we might have a scenario where a country might need to reach some level of openness for consumers to become comfortable with foreign good and for firms to develop relationships in foreign markets in order for the global output gap to matter in the country's Phillips Curve. Exploring this nonlinearity in a systematic manner should allow us to get a better understanding on the role globalization plays in the inflation process.

[7] In particular, Borio and Filardo (2007) use the trend of core inflation as a proxy for inflation expectations which, as discussed in Ihrig, Kamin, Lindner, and Marquez (2010), causes the residuals to become auto-correlated and the model misspecified.

3 Empirical Motivation for the Panel Strategy

One of the goals of this paper is to properly account for variation in inflation and openness across countries so that we can evaluate the inflation globalization hypothesis as well as identify potential nonlinearities in this relationship. As shown by Figure 1, a key issue with analyzing the impact of globalization on inflation at the country level is that some countries, during the sample period, may not experience changes in their level of openness large enough to see an impact from trade openness on inflation. On the contrary, the large differences in openness across countries can provide useful information for the identification of the effects of globalization. With a panel approach, we can blend the inter-country differences with the intra-country dynamics so that a more complete picture emerges. However, we first need to make sure that a panel analysis is actually valid for our dataset. Thus, in this section, we begin with some simple analysis at the individual-country level for our sample OECD countries using annual data over the period 1970-2013, which will serve as a motivation for the empirical approach in the rest of the paper. We also postpone to Section 4 a detailed description of the sources of the data and of the transformations necessary to construct the dataset suitable for the panel analysis in Sections 5 and 6.

We consider the following linear model of inflation:

$$\pi_t = \alpha\pi_{t-1} + \beta Y_t^d + \gamma Y_t^f + \varepsilon_t \tag{2}$$

Equation (2) is often used in the literature to empirically specify the NKPC given in (1) (see, for instance, Ihrig, Kamin, Lindner, and Marquez, 2010). While equation (2) lacks a structural interpretation, it still provides a suitable reduced-form analysis of the underlying inflation dynamics. Further, there is some evidence that when compared with forward-looking models the backward looking model is a better empirical fit (Rudd and Whelan, 2007) and also more structurally stable (Estrella and Fuhrer, 2003).

The estimates of the individual Phillips Curve model given by equation (2), provide strong support for utilizing cross-sectional differences in openness to help understand the role of globalization in the inflation process. Figure 2 shows the estimates of the foreign output gap coefficient γ for our sample of 28 OECD countries plotted against the country's average level of openness.[8] We see that the countries with higher levels of openness are more likely to have a significant role for the foreign output gap in their inflation process. Such a finding is consistent with the inflation globalization hypothesis of a positive relation between globalization and the effects of global economic slack on inflation. Figure 2 also indicates the potential of non-linearity in the relationship between inflation

[8] These estimates are based on annual data for the period 1970-2013.

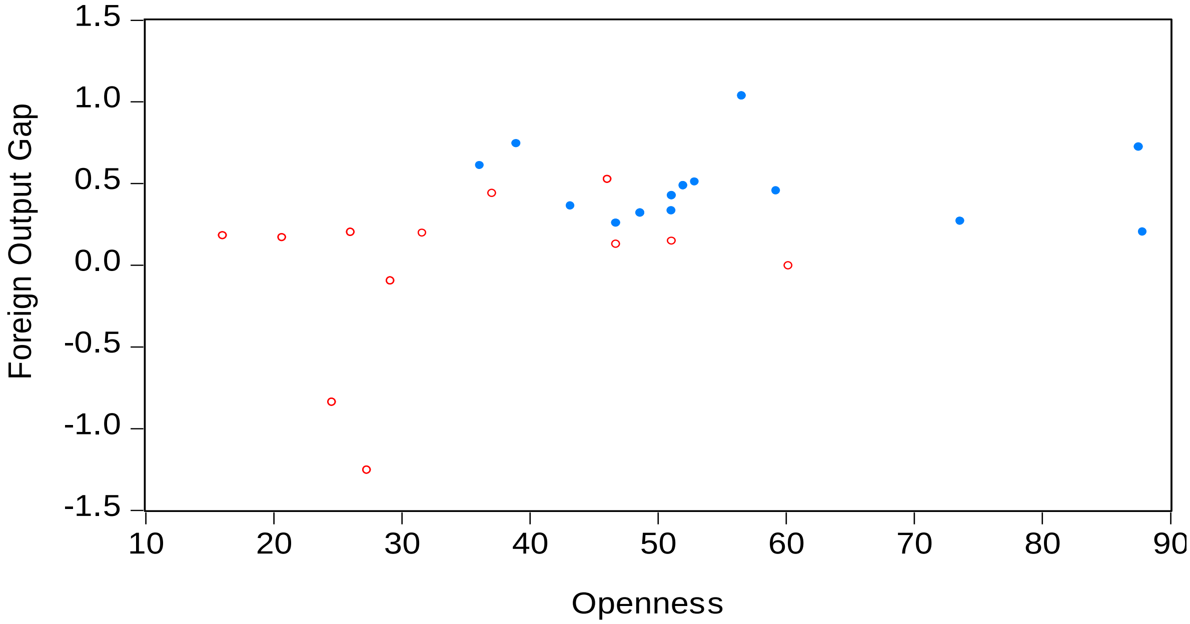

Figure 2: Estimates of the foreign output gap coefficient in the Phillips Curve model 2 at the individual country-level along with the average degree of openness of the country. Blue (red) indicate slope estimates significant (insignificant) at the 10% confidence level.

and globalization, with a country having to achieve some level of openness for the foreign output gap to matter in the inflation process. We will analyze the possibility of such threshold behavior more thoroughly in Section 6.

3.1 Is a Panel Analysis Valid?

In standard panel treatments, the assumption is that the slope coefficients are constant across cross-sections with allowances made for varying intercepts to capture some of this cross-sectional as well as time-specific heterogeneity (treated as either fixed or random effects). But this assumption of poolability may not hold in a dynamic panel setting, especially with large N and T, and thus needs to be explicitly tested for in the empirical analysis (Pesaran and Smith, 1995).

For relatively small N, the F-test can be used to test for poolability with the constant slope assumption treated as a linear restriction on the N individual equations given by (2).[9] Two variants of the F-test are available, depending on the variance structure of the disturbance vector $\varepsilon = [\varepsilon_1', \varepsilon_2', ... \varepsilon_N']'$, where the ε_i are the individual $T \times 1$ error terms. If these disturbances are assumed

[9]Defining the vector of coefficients of the i^{th} equation as Θ_i and the corresponding vector of coefficients of the pooled model Θ, the null hypothesis can be expressed as $\Theta_i = \Theta \; \forall i$.

to be conditionally homoscedastic, so that $E[\varepsilon'\varepsilon] = \sigma^2 I_{NT}$, then the standard F-test can be applied, with each of the N equations in the unrestricted model estimated separately by OLS. Alternatively, a Roy-Zellner test as in the Seemingly Unrelated Regressions (SUR) framework (Zellner, 1962) can also be applied; this test allows for both heteroscedasticity and contemporaneous cross-correlations among the individual disturbances.[10] Bun (2004) has shown that the finite sample performance of these tests is actually quite poor (a strong tendency to over-reject) in dynamic panel models with a full disturbance covariance matrix. So we use the bootstrap procedure in Bun (2004) to also obtain the p-values for these tests.

Table 1 shows the results for the poolability tests conducted on equation (1) for our sample countries. We see from the simple F-tests that the null of poolability is not rejected for both the asymptotic and the bootstrapped p-values. Allowing for only the intercepts to vary (so the restricted case is then estimated by the Fixed Effects estimator) also does not impact these findings. We next turn to the Roy-Zellner test, which allows for the more realistic scenario of countries with hetroscedastic disturbances. Based on the high bootstrapped p-values in Table 1 we determine that pooling our data for 1 is appropriate.[11] Finally, for robustness we also conduct a Hausman test for poolability, as suggested in Pesaran, Smith, and Im (1996), where we compare the Fixed Effect estimator with the Mean Group estimator (Pesaran and Smith, 1995). The Hausman test is unable to reject the null that the Fixed Effect estimator is more efficient, and so again indicating that these countries can be pooled to analyze inflation dynamics.

3.2 Panel Unit Root Tests

As in the case of univariate analysis, unit roots can also lead to spurious regressions and misleading inference in a panel framework. This is especially a concern with inflation, which is often associated with high levels of persistence(Culver, 1997). So we next determine the stationarity of our panel series by applying some basic panel unit root tests.

Table 2 gives the results of these panel unit root tests.[12] We first consider the standard LLM test of Levin, Lin, and Chu (2002), which assumes a common autoregressive parameter for all countries as well as no correlation among the cross-sectional units, except for common time effects.[13] Based on the LLM bias-adjusted t^*statistic, the null of unit root is rejected for all of our series. We then

[10] A feasible GLS estimator is then used to separately estimate the N equations for the unrestricted case.

[11] For these tests, we see a strong difference between the asymptotic and the bootstrapped p-values. However, Bun (2004) showed in simulations that classical asymptotic tests in dynamic panels have substantial size distortions and so a bootstrap is needed for accurate inference.

[12] These tests are based on the model $\triangle y_{it} = \alpha_i + \phi_i y_{i,t-1} + \sum_{j=1}^{p} \gamma_{ij} \triangle y_{i,t-j} + \mu_{it}$ with $H_0 : \phi_i = 0$ for all i. See Baltagi and Kao (2000) for more details.

[13] We account for cross-sectional correlation in these tests by using data demeaned from common time effects.

conduct the IPS test following Im, Pesaran, and Shin (2003) which, unlike the LLM test, allows for heterogeneous intercepts and slopes for each country. The results from the IPS test, controlling for serially correlated errors, are broadly similar, and we continue to find little evidence for a unit root in these panel series. Finally, we also conduct the Hadri (2000) LM test which instead tests for the null that the data are stationary and can be used in cases where N is not too large. Table 2 shows that the Hadri LM test is not able to reject the null of stationarity for all of these series. So based on these tests, we will continue to treat all of our variables including inflation as stationary in the empirical analysis.[14]

4 The Dataset

For our analysis, we improve on the dataset used in Bianchi and Civelli (2015) by extending it to 28 OECD countries over the period 1970 to 2013. For each country, the dataset for the baseline specification of the regression model includes domestic inflation, the domestic and foreign output gaps, a measure of trade openness, the effective real exchange rate and import price index. We briefly describe this dataset in this section, while more details on the particular countries and sources is available in Appendix A.

As is the standard in this literature, we use the Consumer Price Index (CPI) as our measure of the domestic price level. Like Borio and Filardo (2007) and Bianchi and Civelli (2015), the inflation rate is computed as the log-difference of the domestic CPI index relative to the previous year. For the robustness analysis, we also obtain data for core inflation using CPI (excluding all food and energy prices). Trade openness is calculated as the ratio of the sum of imports and exports to GDP, with all the values in nominal terms. The domestic output gap of a country is constructed as the percentage deviation from the HP-filtered real GDP series taken as a proxy for the potential GDP (we account for the end-of-sample problem by forecasting the real GDP for each country five years ahead before applying the filter).

Following Bianchi and Civelli (2015), the foreign output gap and the effective real exchange rate are calculated by weighting the trading partners of each country. The foreign output gap for a country is then just the trade-weighted average of the domestic output gaps of all the other countries in our sample, and it is then specific to each country. To get accurate trade weights we include more than 70 other countries in our sample universe.[15] The same procedure applies to the construction of the country-specific real exchange rates. The pairwise nominal exchange rates are deflated by

[14]For a sample of OECD countries, Basher and Westerlund (2008) find inflation to be stationary even with panel unit root tests that allow for cross-sectional dependence and the possibility of structural change.

[15]The list of countries and details on the trade weight calculations are in the appendix A.

the CPI of the respective country, and aggregated using the same trade-based weights. Finally, the import price deflator is also used to capture the direct effects of trade on the price level.

Table 3 reports the summary statistics for these variables pooled across countries and years for a total of 1,232 observations. For each variable in Table 3, we compare its within standard deviation, which measures the variability across time, and its between standard deviation, the variability across countries.[16]. We see that the between variability of trade openness is nearly twice the value of its within variation, indicating that there is substantially more variation in openness between countries than over time. However, for all the other variables, including inflation, much of the underlying variation is a result of changes over time. Thus a panel analysis, can use this cross-country variation in openness to better capture the relationship between inflation and globalization.

Finally, we will take three-year averages of the data, instead of annual values, to estimate the dynamic panel models. This ensures that we have a short panel with T (15 periods) smaller than N (the 28 countries), which can be efficiently estimated by the dynamic panel GMM estimator. By using three-year averages, we in effect move away from the short-run fluctuations in inflation and, arguably, are better able to capture the impact of the gradual changes in openness. Such an approach has been commonly used in the empirical growth literature, where usually five-year averages are taken to investigate growth relationships which unfold over the longer term. However, for robustness we will also consider results estimated with annual data.

5 Dynamic Panel Analysis

5.1 Empirical Framework

We modify equation (2) to obtain the following dynamic panel Phillips Curve:

$$\pi_{it} = \rho\pi_{i,t-1} + \beta Y_{it}^{d} + \gamma Y_{it}^{f} + \eta_i + \varepsilon_{it} \tag{3}$$

where i is the country identifier, t is a period index, η_i is the country-specific error term, ε_{it} is the idiosyncratic shock, the lag term is a proxy for inflation expectations and the output gaps are defined as before. We again focus on a backward-looking model for inflation dynamics, while postponing the estimation of a more structural panel Phillips Curve specification for Appendix D.

[16]Within, s_w, and between, s_B, standard deviations are respectively defined for a variable z_{it} with $1 < i < N$ and $1 < t < T$ by $s_W^2 = \frac{1}{NT-N}\sum_{i=1}^{N}\sum_{t=1}^{T}(z_{it} - \bar{z}_i)^2$ and $s_B^2 = \frac{1}{N-1}\sum_{i=1}^{N}(\bar{z}_i - \bar{z})^2$

Due to the dynamic nature of model, $\pi_{i,t-1}$ is endogenous in equation (3) since $E[\pi_{i,t-1}\eta_i] > 0$. The standard Fixed Effects (Within-Group) estimator also can not be used to eliminate η_i as it will be biased and, for small T, inconsistent as well (Nickell, 1981). One popular approach to eliminate the fixed effects η_i in a dynamic panel framework is to apply instead a first-difference transformation on (3)and then instrument the endogenous lag term. With predetermined initial conditions, $E[\pi_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})] = 0$ for $s \geq 2$, $t = 3, .., T$, and so $\pi_{i,t-2}$ and earlier lags are valid instruments for ($\pi_{i,t-1}-$ $\pi_{i,t-2}$). For a given set of instruments the estimation can be done by either 2SLS (Anderson and Hsiao, 1981) or General Method of Moments (GMM) with the GMM being more efficient when errors are not assumed to be independent (Arellano and Bond, 1991).[17]

We will use two tests to determine the validity of the instruments in the dynamic panel GMM estimation. The first is the traditional Hansen (1982) J-test of over-identifying restrictions, with the null that the selected instruments are all exogenous. The Hansen test can also be extended to determine the validity of only a subset of the instruments, by looking at the difference in the J statistics when both the full and subset of instruments are used in the estimation. While high p-values from the Hansen tests support the choice of instruments, a concern with this test is that it quickly becomes undersized once the number of instruments increases. Indeed, Roodman (2009) shows that the results of these tests are questionable once the instrument count exceeds N in the estimation, as is often the case in dynamic panel estimations.

We also use the Arellano and Bond (1991) serial correlation test to determine the appropriateness of the lagged terms as instruments in the difference equation (so for example $\pi_{i,t-2}$ is not a valid instrument for ($\pi_{i,t-1}-$ $\pi_{i,t-2}$) if ε_{it} is serially correlated with $\varepsilon_{i,t-1}$). The Arellano and Bond (1991) test checks for the n^{th} order serial correlation in the levels equation by examining if the residuals of the differences equation are correlated at order $n + 1$. A failure to reject the null of no serial correlation supports the lags used as instruments in the dynamic panel estimation.

5.2 First Results

Table 4 illustrates the estimates of the panel model in equation (3), with three-year averaged data. This first round of results provides new evidence that shows how the impact of the foreign output gap on the domestic inflation process is statistically significant and, at least, of the same magnitude as that of the domestic output gap. Thus adding the cross-section dimension to the analysis of the Phillips Curve reveals a significant effect of the foreign output gap that would otherwise be underestimated in the basic regressions at individual country level.

[17] We do not use the System GMM estimator (Blundell and Bond, 1998) in our analysis as it requires a much stronger assumption that the correlation between π_{it} and η_i is constant over time, so that deviations of the country's inflation from it's long run mean is uncorrelated with η_i.

The first two columns of Table 4 show the Pooled OLS (POLS) and Fixed Effect (Within Mean) estimates with robust standard errors clustered at the country level. The lagged inflation term is significant in both cases and, as expected from individual country Phillips Curve estimates, quite large (0.82 and 0.70 respectively). However, due to the endogeneity of the lagged term, the Pooled estimate is going to be biased upward while the Fixed Effect estimate is going to be biased downward (Bond, 2002). The domestic gap is significant in both cases, but the foreign output gap is significant at the 10% level only in the Fixed Effect estimation. These output gap coefficients however, can also be biased depending on how correlated they are with the lagged inflation term.[18]

To eliminate the fixed effects η_i, we next turn to the first-differences transformation. The 2SLS estimator is initially used, with $\pi_{i,t-2}$ serving as instrument for $(\pi_{i,t-1} - \pi_{i,t-2})$ in the first-differenced equation. The estimates shown in the column (3), though, are dramatically different as the lagged inflation term now has a value greater than 1, making the Phillips Curve unstable, and both gaps are no longer significant. However, 2SLS estimates will not be not accurate if the errors are not independent, as is the case here with $(\varepsilon_{it} - \varepsilon_{i,t-1})$ correlated with $(\varepsilon_{i,t-1} - \varepsilon_{i,t-2})$. So a GMM estimator is needed to account for this non-spherical error term in the first-differenced equation.

Columns (4) and (5) in Table 4 show the GMM estimates of the first-differences equation in which all valid lags of inflation are used as instruments (a total of 94 instruments). An issue with GMM estimations in small samples is that the estimated standard errors are downward biased. We thus employ a small-sample bias correction, following Windmeijer (2005), to obtain reliable standard errors for the two-step GMM estimator.[19] We see from Table 4 that both the one-step and two-step GMM estimators give nearly identical results.[20] The lagged inflation term has a coefficient of 0.74, a reasonable value falling between the earlier POLS and Fixed Effect estimates. Further, both gaps are significant with the foreign output gap larger than the domestic output gap. Finally, in column (6) we employ the forward-orthogonal deviation transformation instead of first-differences to eliminate the fixed effect term.[21] Importantly, this transformation allows independent error terms to remain independent even after the transformation, a feature which can be used in the estimation of dynamic panel threshold models. The coefficients in column (6) are similar to previous estimates, with both the domestic and foreign output gaps now significant at the 5% level. Since switching from first-differences to forward-orthogonal deviations does not impact the main results, we will focus on this transformation for our remaining panel analysis.

[18] The foreign output gap is also significant when we use the Fixed Effect estimator on the annual data. A larger T dimension reduces the Fixed Effects bias and makes the estimates more reliable. See Appendix B for more details.

[19] Note that the weighting matrix for the one-step GMM estimator does not depend on any estimated parameter and so gives consistent estimates of the standard errors.

[20] The constant for these GMM estimations is obtained from the levels equation and does not affect either the estimates or the standard errors of the other variables.

[21] This transformation is expressed as $y^*_{it} = c_{it}(y_{it} - \frac{1}{T_{it}} \sum_{s>t} y_{is})$, where c_{it} is a scaling factor that normalizes variances across observations. See Arellano and Bover (1995) for more details.

5.3 Concerns with Dynamic Panel GMM Estimation

A number of recent studies, including Bazzi and Clemens, 2013, Roodman, 2009 and Bun and Windmeijer, 2010, have cast doubt on the dynamic panel GMM estimations that have been employed in prominent empirical applications. In particular, three key issues have been raised in regards to this estimation methodology:

1. The number of instruments used.
2. Potentially weak instruments.
3. Endogeneity concerns.

We address each of these issues as it relates to our own dynamic panel GMM estimates presented in Table 4 and show that our findings remain robust in these scenarios.

5.3.1 Instrument Proliferation

Since lags of the dependent variable are often used as instruments in the GMM estimation of dynamic panels, more and more lags become valid instruments as the time period increases. This proliferation of instruments, however, is not without costs as discussed in Roodman (2009). First, a large number of instruments can overfit the endogenous variables, leading to biased estimates in the second stage of the estimation (in theory, the more the instruments there are the closer we get to the original biased OLS estimates). A large number of instruments also weakens the Hansen test for instrument validity, so in extreme cases the null is never rejected (Bowsher, 2002). Given these concerns, we check the adequacy of our dynamic panel estimates by reducing the number of lags used as instruments in the GMM estimation.

Table 5 reports the results of the two-step GMM estimation of equation (3) with the reduced instrument set. We employ a forward-orthogonal deviation transformation to eliminate the fixed effects in these estimations. We start by only using the two-period lags of inflation from the full instrument set, which gives us a total of 28 instruments in the GMM estimation. Encouragingly, the estimates are similar to those seen in column (6) of Table 4, with both the domestic and foreign output gaps remaining significant at the 5% level. The next four columns look at the sensitivity of these estimates by changing the instrument set as we go from only using the most recent valid lag of inflation in each time period (a total of 16 instruments), to collapsing the full instrument set (again 16 instruments), to collapsing the second-lag instrument set (which corresponds to using just the two lags $\pi_{i,t-2}$ and $\pi_{i,t-3}$ as instruments) and to finally collapsing the first-lag instrument set (which corresponds to the just identified case with only one lag $\pi_{i,t-2}$ as the instrument).[22] We see that in most of these cases, the estimates for the domestic and foreign output gaps remain significant and are similar to the full-instrument estimates, while the lagged inflation term continues to have theoretically appropriate values.[23]

With the reduced number of instruments we are also able to use the Hansen test of instrument validity with greater confidence. Based on the p-values we can not reject the null of valid instruments for most of the instrument sets in Table 5 (the sole exception is the one-lag instrument set). We also use the Difference-in-Hansen test to look at the validity of a subset of the instrument variables, in particular if the foreign and domestic output gaps are exogenous and so can be used to instrument themselves in the transformed panel equation. The high p-values from these tests generally support treating these output gaps as exogenous. Finally, the Arellano and Bond (1991) serial correlation test indicates that there is no second-order correlation in the residuals of the first-differences equation, so lags $\pi_{i,t-2}$ and earlier can be used as valid instruments for $(\pi_{i,t-1} - \pi_{i,t-2})$ in the tranformed equation.[24]

5.3.2 Weak Instruments

Even with valid instruments, the IV estimates from 2SLS or GMM can still be biased if there is weak correlation between the instruments and the endogenous variables. The bias of the IV estimator increases as the correlation weakens and approaches the initial biased OLS estimates (Stock, Wright, and Yogo, 2002). Furthermore, inference in the presence of weak instruments leads to misleading results, especially in tests of over-identifying restrictions (Hahn and Hausman, 2002).

It is thus necessary to test the strength of the instruments used in the estimation. The Kleibergen and Paap (2006) LM test can be used to test the rank condition of the instruments and is also robust to non-i.i.d. errors. A rejection of the null then implies that the structural equation is properly identified. To test for weak instruments, Stock and Yogo (2005) also propose an F-statistic in the first-stage regressions that is based on the Cragg and Donald (1993) Wald statistic and is able to incorporate multiple endogenous variables. Notably, Stock and Yogo (2005) apply this F-statistic to construct critical values that can be used to identify instruments as weak for certain levels of relative bias of the IV estimator and for the degree of size distortions in the Wald test.[25]

[22] See appendix C for more details on the instrument sets made by these methods.

[23] Using a first-differences transformation with the reduced instrument set also gives similar results to the corresponding full instrument estimates in Table 4.

[24] This test is still applied on the first-differenced equation since all the residuals will be interconnected after the forward-orthogonal deviation transformation.

[25] These critical values depend on the type of IV estimator being used along with the number of endogenous variables and excluded instruments in the regression.

The preceding tests have been designed to detect weak instruments in the case of linear IV models, and as of now there are no corresponding tests that are applicable in the dynamic panel GMM framework.[26] Thus we follow the approach in Bazzi and Clemens (2013) and test the strength of the instrument matrix in the underlying GMM estimations by using the 2SLS estimator instead. Bun and Windmeijer (2010) have shown that weak instrument tests for 2SLS in a cross-sectional setting can be generalized and prove informative in the panel framework as well. Overall, this is a very simple and transparent way to test the instrument strength in a closely related estimation framework, and has been used recently by Bazzi and Clemens (2013) to show that many of the empirical results in the growth literature are biased due to weak instruments.

Table 6 shows the results of these weak instrument tests for each of the instrument set used in Table 5.[27] We see from Table 6 that the Kleibergen-Paap LM test strongly rejects the null, indicating that these instrument sets are appropriate for identifying the structural equation. The Cragg-Donald Wald statistic, based on the first-stage regressions, is also quite high for all of these instrument sets. Comparision with the corresponding Stock and Yogo (2005) critical values shows that these instruments are sufficiently strong such that the asymptotic relative bias of the 2SLS estimator is less than 10%, making the IV estimates based on these instruments reliable for inference.[28] Table 6 also reports the Kleibergen-Paap Wald statistic which allows for the possibility of non i.i.d. errors.[29]

5.3.3 Potential Endogeneity of the Output Gaps

The Hansen tests in Table 5 are generally supportive of the validity of the instruments used in the GMM estimation, including treating the output gaps as exogenous variables. However, as discussed in Martinez-Garcia and Wynne (2010), output gaps in practice are measured with considerable error since potential output is not directly observable, and further aggregate data from emerging economies, needed to construct foreign output gaps, is unreliable and often times incomplete. Given this bias from measurement error and the potential of past shocks to influence the output gaps, the exogenity of the output gaps may not hold in equation (3). So we next examine the robustness of our findings by changing the instruments used for the output gaps. More specifically, instead of treating both output gaps as strictly exogenous, we consider the scenario where the output gaps

[26]These tests do not extend to the GMM estimator, which being a non-linear estimator does not have an exact sampling theory (Stock, Wright, and Yogo, 2002).

[27]When conducting these weak instrument tests, all regressors in the 2SLS estimation are first transformed by forward-orthogonal deviations in order to match the dynamic panel model estimated by GMM in Table 5.

[28]The Crarg-Donald statistic was found to be smaller when a first-differences transformation of equation (3) was used in the analysis, suggesting that lagged levels are potentially stronger instruments if the level equation undergoes a forward-orthogonal transformation.

[29]The Stock and Yogo (2005) critical values are, however, only valid for the i.i.d. case, and so caution needs to be exercised when using them with the Kleibergen-Paap Wald statistic (Baum, Schaffer, and Stillman, 2007).

are treated as either predetermined variables ($E[Y_{is}\varepsilon_{it}] = 0$ for $s \geq t$) or as endogenous variables ($E[Y_{is}\varepsilon_{it}] = 0$ for $s > t$).[30]

The results of these estimations, again based on the forward-orthogonal deviation transformation, are reported in Table 7. We exercise caution with regards to the number of lags of the output gaps that are used as instruments, and we use the same instrument set for the endogenous lagged inflation term (the Two Lags IV set in Table 5) in all of these estimations. The first three columns of Table 7 treat the output gaps as predetermined variables. We see that reducing the instrument set for the output gaps has little impact on these estimates. In all three columns, both gaps are significant and similar in size to those found in Table 5. Further, the Hansen test is unable to reject the validity of the lags of output gaps as instruments in these estimations. In the last three columns of Table 7 we treat the gaps as endogenous and continue to see significant domestic and foreign output gap estimates. So we see support for our earlier findings even when the domestic and foreign output gaps are not treated as strictly exogenous in the estimation.

5.4 Robustness Checks

We now look at the validity of our main findings by adding external controls to the inflation process such as the real exchange rate and import prices as well as by restricting the sample to periods after 1984. Our overall goal in this section is to see whether these changes impact the output gap responses, especially the significance of the foreign output gap that was found in the earlier dynamic panel estimations.

5.4.1 External Controls

From a theoretical perspective, Engel (2013) and Zaniboni (2008) have shown that besides the foreign output gap, the exchange rate depreciation (under producer currency pricing) or the term of trade (under local currency pricing) has a direct effect on inflation in the New Keynesian Phillips framework. Empirically, Mihailov, Rumler, and Scharler (2011) find that the relative change in the terms of trade is a more important factor in driving inflation than the current domestic output gap for a sample of OECD countries. Thus we use the year-to-year change in the trade-weighted real exchange rate as our main control for the direct effects of trade on domestic prices. However, for

[30] Both predetermined and endogenous variables allow past shocks to influence the current values. However, endogenous variables are also correlated with the current error term as well.

robustness, we also allow import prices inflation, given by the year-to-year change in the domestic import price deflator, to have a direct role in the country's inflation process.[31]

Table 8 gives the estimates of the dynamic Phillips Curve with the trade controls for the full sample period. We again look at different sets of instruments for the same specification to ensure that our findings are robust to the choice of instrument set. In the first two columns, we see that the foreign output slopes remain significant but are slightly diminished in terms of magnitude from the estimates in Table 5. One aspect could be that the real exchange rate variable is now capturing some of the impact of globalization on inflation. Indeed, the real exchange rate term has a negative sign, which is appropriate since an appreciation of the real exchange rate should lead to lower inflation. Still, Table 8 shows that the impact from changes in the real exchange rate is not strong enough to be a significant determinant in the inflation process. In columns (3) and (4) we also test our model with just the real exchange rate term (excluding the foreign output gap term) in our specifications and find it to have little significance in the inflation dynamics.

In columns (5) to (8), we examine the impact on the dynamic panel estimates from the inclusion of the import prices inflation as a control variable. We observe that even with the addition of the import prices term, the foreign output gap retains its significance in the inflation process. On the contrary, the domestic output gap, while significant, has a much lower magnitude than the earlier estimates. Our estimates also show that import prices inflation has a significant and positive effect on domestic inflation, indicating a direct effect on the CPI from trade and globalization. A similar finding is seen when only the import prices inflation term is included with the domestic output gap in columns (7) and (8). Finally, in the last four columns of Table 8, we include trade openness as a direct determinant of inflation and see little change from the baseline results, with trade openness having a slight negative effect on inflation levels.[32] Samimi, Ghaderi, Hosseinzadeh, and Nademi (2012), using a broad measure of globalization, have also shown that inflation is generally lower in more open countries. Overall, the results in Table 8 support the use of the foreign output gap, under a Phillips Curve framework, as a good measure to capture the full effects of trade and globalization in a country's domestic inflation process.

5.4.2 Subsample Analysis

We next restrict our sample to only periods after 1984. The significant decrease in inflation rates for the OECD countries in the early 80's was often a result of more aggressive central bank actions, so

[31] In our analysis we examine these external controls as separate cases since including them altogether in a single model can lead to issues of over-fitting and inaccurate inference. Borio and Filardo (2007) employed a similar strategy to test for the impact of traditional controls on their open-economy Phillips Curve estimates.

[32] As in IMF (2006), we also considered the interaction term of the foreign output gap and trade openness in these specifications, but it was found to be non-significant.

it might be less appropriate to link this decline solely with a country's higher levels of globalization and trade openness (Calza, 2009). Since the restricted sample 1984-2013 has a smaller T dimension, we use annual data instead of three-year averages in this analysis.

Columns (1) to (4) of Table 9 gives the estimates of (3) using annual data from 1984-2013. We continue to observe that the foreign output gap is significant and has a bigger impact on inflation than the domestic output gap across the instrument sets, and with the real exchange rate depreciation as the external control term as well. However, we do see a drop in the magnitude of the domestic and foreign output gaps as compared to the full sample estimates, a reflection of the improved monetary policy in this era. In columns (5) to (8), we exclude the years after 2007 to avoid the impact of the global financial crisis which led a number of countries to undertake unconventional monetary policy measures as well as caused a sharp decline in international trade (Wynne and Kersting, 2009). As observed in these columns, there is little change from our earlier results. Finally, in the last four columns of Table 9, we further restrict our sample to the period 1984-1998 in order to exclude the effects of the common monetary framework that was adopted by some of the European Monetary Union (EMU) member countries in our panel (Grüner and Hefeker, 1999). The estimates for the foreign output gap remain significant and with similar magnitudes, so we can be reasonably confident that the increased impact of the foreign output gap on inflation dynamics is not an artifact of some of our panel countries having a single monetary regime in the latter years of the sample.

6 Threshold Analysis

Using a dynamic panel framework, we have shown a clear role for globalization factors, such as the foreign output gap, in the standard Phillips Curve. We now turn our attention towards investigating whether there is a further layer in the relation between globalization and inflation. Ahmad and Civelli (2016), focusing at the individual level for a sample of OECD countries, have shown that trade openness is a significant threshold variable for most countries' Phillips Curve. By explicitly modeling the threshold effect in a panel setting, we are able to exploit not only the time variation in openness at the country level, but also the substantial differences in openness across countries. Thus we should be able to get more robust estimates of the threshold in a panel framework, and be able to identify the role globalization has in changing the inflation process. The estimated threshold for openness can then be used as a guide to identify the regions where foreign factors start to dominate domestic factors in determining the dynamics of domestic inflation.

6.1 Methodology

We investigate potential non-linearity in the inflation globalization relationship using the following dynamic panel threshold Phillips Curve model:

$$\pi_{it} = \rho_i \pi_{i,t-1} + (\beta_1 Y_{it}^d + \gamma_1 Y_{it}^f) I(Open \le \tau) + (\beta_2 Y_{it}^d + \gamma_2 Y_{it}^f) I(Open > \tau) + \eta_i + \varepsilon_{it} \qquad (4)$$

where trade openness acts as the threshold variable in the relationship between inflation and the output gaps and causes the switch from one regime to another. Trade openness is a popular proxy for a country's level of globalization and is especially relevant because inflation in an open-economy Phillips Curve is affected by external factors primarily through the trade channel. Model (4) allows openness to influence only the slopes of the gaps, while the persistence of inflation is the same for each regime. In our analysis, the possible non-linear effects on the autoregressive component were quite modest with very small gains in terms of in-sample fit from allowing the lags to switch as well.[33] Bick (2010) has further shown that regime intercepts can often play a significant role in the panel threshold estimation. So we allow for different regime intercepts by including a constant term in one of the regimes of equation (4). Overall, this threshold model incorporates potential non-linearity in a simple manner such that the foreign output gap impacts inflation only after a country achieves a certain degree of openness.

Hansen (1999) has developed an asymptotic theory that can be used for both estimating and testing non-dynamic panel threshold models. The key is to eliminate first the fixed effects using the standard within-mean transformation and then, as in the cross-sectional framework (Hansen, 2000), the consistent estimate for the threshold is the one that minimizes the residual variance of the regression. The standard approach is to use a grid search over all the values of the threshold variable and then, conditional on this threshold value, estimate the remaining variables in each regime by least squares. An F-test or the heterscedasticity-consistent Wald Test can be used to determine if the slopes in the two regimes are significantly different from one another and thus the overall appropriateness of the non-linear model.[34] However, the distribution of these test statistics is non-standard, so Hansen (1999) suggests using a bootstrap approach to approximate the asymptotic null distribution of the test statistic.

The above approach is valid only when all the explanatory variables in the model are strictly exogenous. Caner and Hansen (2004) extend the threshold model to account for the possibility of

[33]This is not surprising as generally central bank policies are considered to be the main factor that drives shifts in the formation of inflation expectations (Bianchi, 2013).

[34]The Wald Statistic is calculated as $W_T(\gamma) = \left[\hat{\theta}_1(\gamma) - \hat{\theta}_2(\gamma)\right]' \left[\hat{V}_1(\gamma) - \hat{V}_2(\gamma)\right]^{-1} \left[\hat{\theta}_1(\gamma) - \hat{\theta}_2(\gamma)\right]$ where for a given value of γ in the grid search, $\hat{\theta}_1$, $\hat{\theta}_2$ are the slope estimates and $\hat{V}_1$,$\hat{V}_2$ the estimated covariance matrices in each regime. The maximum W_T from the grid search is then be used to test $H_0 : \theta_1 = \theta_2$.

endogenous regressors by performing the threshold estimation in three stages. First, they regress the endogenous variables on the instruments along with the other exogenous explanatory variables in the model. Second, they use these predicted values of the endogenous variables instead of the actual values in the grid search for finding the threshold estimate. Lastly, the estimated threshold is used to split the sample, and a 2SLS or GMM estimator is used to get the coefficient estimates in each regime.

The endogenous threshold framework in Caner and Hansen (2004) can be adapted to the non-dynamic panel case by simply removing the individual-specific fixed effects and then proceeding as before. However, with dynamic panels the within-mean transformation cannot be used to eliminate η_i because it leads to inconsistent estimates due to the correlation between the transformed dependent variables and the error term. The first-differences transformation is also not appropriate, as it causes the transformed error terms to become serially correlated.[35] On the other hand, the forward orthogonal transformation is able to remove η_i while also preserving the original error structure and so maintains the serial independence of the transformed error term (Arellano and Bover, 1995). Kremer, Bick, and Nautz (2013) were the first to make use of this approach, showing with a Monte Carlo study that it leads to significant improvement in the estimation of dynamic panel threshold models. [36]

We follow a similar methodology in estimating the dynamic panel threshold model given in (4). We first use a forward orthogonal transformation on all the variables, except the threshold variable and the instruments (the lagged inflation terms). We regress the transformed endogenous variable π^*_{t-1} on the selected instrument set, and their predicted values are then used in the grid search procedure. We conduct the grid search on the sorted values of the threshold variable, which have been trimmed 15% on each side to ensure enough observations in each regime.[37] Using the consistent threshold estimate, we estimate model (4) with GMM to obtain the coefficients in each regime (for the GMM estimation we employ the same robust weighting matrix that was used in the dynamic panel analysis with all the standard errors adjusted using the Windmeijer (2005) correction). Finally we employ a bootstrap procedure, as described in Caner and Hansen (2004), to test the statistical significance of the threshold in our model.[38]

[35] An independent error term is a key requirement for the asymptotic distribution theory derived in Hansen (1999).

[36] This methodology has been also used to investigate the non-linear impact on economic growth from public debt (Baum, Checherita-Westphal, and Rother, 2013) as well as from financial development (Law and Singh, 2014).

[37] For consistency with transformed regressors, the last observation of openness, for each country, is also excluded.

[38] In the bootstrap, $\pi^*_i = \hat{e}_i(\gamma)\eta_i$ is first computed where $\hat{e}_i(\gamma)$ is the estimated residual of the threshold model for each value of γ and η_i iid $N(0,1)$. In repeated draws, this variable is used instead of $\pi_{i,t}$ in the estimation of (4) and the maximum Wald statistic W^*_T is obtained from the grid search each time. The asymptotic bootstrap p-value is then the percentage of bootstrap samples for which W^*_T exceeds W_T.

6.2 Threshold Estimates

Table 10 gives the results of the dynamic panel threshold estimation. As in the dynamic panel analysis, having a large set of instruments can potentially bias the estimates of the threshold model. Thus we remain conservative in the choice of the lagged inflation terms used in the instrument set, restricting them to the collapsed, two lags only, and one lag only options. Allowing the model to have regime intercepts, we see that the estimated threshold τ is around 52%, which splits the sample into 246 observations in the closed regime and 146 observations in the open regime (so more observations classified in the closed than open regime for this threshold estimation). The 90% Confidence Interval (CI) for τ is given by [35, 57], and notably this CI is also robust across the different instrument sets used in Table 10.[39] Further, the bootstrapped p-values for the Wald test reject the null of no-threshold for this model at least at 10% level for the three specifications. So we can conclude that trade openness does indeed have some non-linear effect on a country's inflation dynamics through the output gaps.

We next look at the change in the output gap slopes as we go from the less to more open regime. If the inflation globalization hypothesis is valid, then we would expect the following:

1. In the more open regime, the response of inflation to the domestic output gap, β should decline and become less significant.
2. In the more open regime, the foreign output gap should replace the domestic output gap, indicating a more significant and larger estimate of γ.

Examining Table 10 and focusing on the collapsed instrument set in column (1), we see that in the less open regime the domestic output gap is highly significant, while the foreign output gap is not significant. However, in the more open regime we see a clear shift in the output gap slopes as the domestic output gap declines sharply and is no longer significant in the inflation process. On the contrary, the foreign output gap slope in the open regime is now significant and with a much larger magnitude than the domestic output gap slope. Based on these estimates, we can conclude that the foreign output gap replaces the domestic output gap as key determinant of inflation in the more open regime. Table 10 also shows that this trend is consistent across the different instrument sets. In particular, with only the last inflation lag as an instrument, the model is just identified, and so this shift in dynamics is even robust to the particular weighting matrix employed in the GMM estimation. Overall, these are very strong findings in support of the view that once a country reaches a sufficient level of openness, external economic factors, rather than domestic conditions, determine the country's inflation dynamics.

[39] The CI is constructed using the Likelihood Ratio statistic and is given by $\Gamma = \{\tau : LR(\tau) \leq C(\alpha)\}$, where $C(\alpha)$ is the 90% percentile of $LR(\tau)$. As in Caner and Hansen (2001), the CI is also robust to heteroscedasticity.

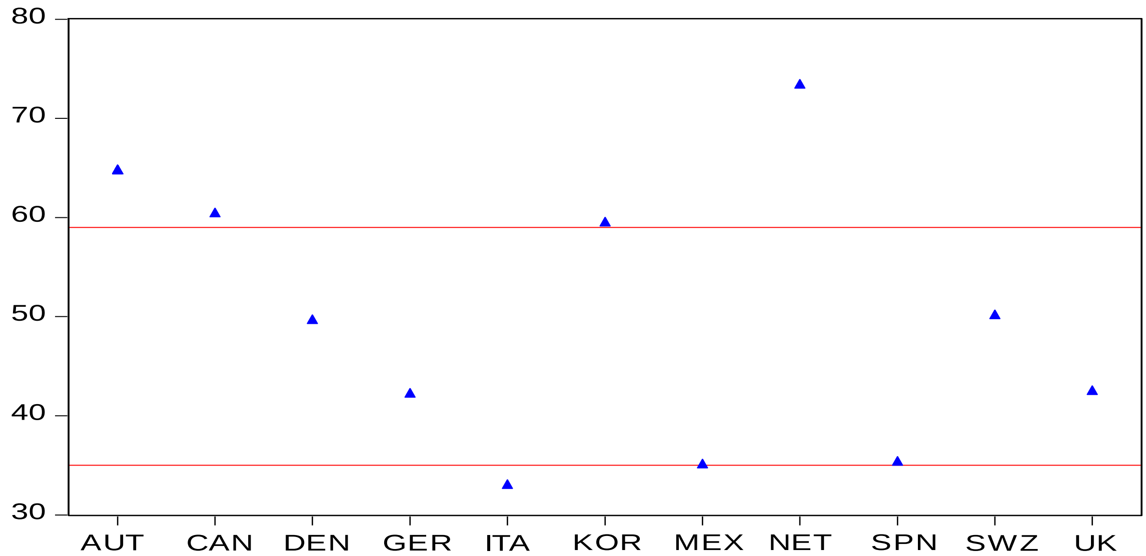

Figure 3: Individual thresholds for the countries are taken from Ahmad and Civelli (2016) and the estimated 90% Confidence Interval from the dynamic panel threshold model.

We next look at the usefulness of our panel threshold estimates of trade openness, and in particular the lower bound of the estimated CI, in determining whether a given country is integrated with the global economy. Ahmad and Civelli (2016) estimate a non-linear Phullips Curve at individual level for a set of 16 countries, and they find that the median threshold for the countries that had a significant non-linear effect on inflation from openness was about 45%, which is relatively similar to the panel threshold estimate of 51%. Figure 3 plots the country-specific thresholds from Ahmad and Civelli (2016) and illustrates that most of them fall within the 90% CI of the trade openness threshold found from the panel estimations.[40] This comparison is encouraging, as it provides support for the panel threshold analysis and suggests that the $[35 - 57]$ range for trade openness can be effectively used by individual countries as a guide to determine whether they should start to concentrate on external forces when formulating inflation policies.

6.3 Robustness

We examine the robustness of the estimates in Table 10 by conducting a variety of additional empirical checks. These consist of excluding some influential open-economies, changing the time frame of the analysis, and finally conducting the estimation using core CPI as the inflation measure.

Table 11 shows the results of these robustness checks. For each case, we consider the instrument set

[40]These individual threshold estimations were done on quarterly data for the sample period 1985-2006 using a backward-looking open-economy Phillips Curve model.

with two-lags only and one-lag only to ensure that the estimates are consistent across the different instrument sets. We first look at the specification of (4) without regime-specific intercepts and see very little change in either the estimates of the threshold or the regime coefficients. So excluding regime intercepts from our model does not impact our results. We then exclude the countries that are closely integrated with the global economy from our analysis. In particular Belgium, Luxembourg and Netherlands, the three countries with the highest average levels of openness in our sample, are removed from the panel threshold estimation. Columns (3) and (4) show that their removal only has a marginal impact on the regime slopes while the estimated threshold for openness is again close to 52%. As in Baum, Checherita-Westphal, and Rother (2013), we also conduct an exclusion exercise where one county is eliminated at a time from the estimation and find that none of the countries had a meaningful impact on either the estimated threshold or the confidence interval. Thus we can be quite confident that our estimated threshold for openness is not being driven by the very open economies in the sample.

We then estimate the panel threshold model from 1984 onward in order to avoid possible structural breaks in the inflation process due to changes in monetary regimes in the early ′80s (Rapach and Wohar, 2005).[41] In columns (5) and (6), we continue to see a significant threshold effect from openness on the country's inflation dynamics with the bootstrapped p-values from the Wald test continuing to reject the null of no threshold effect. So evidence of non-linearity in the inflation globalization relationship remains even after accounting for the significant monetary policy changes in this era. The estimated threshold for this period is slightly higher at 57% but we still have a similar 90% CI of $[38 - 58]$. The domestic output gap is again significant only in the closed regime while the foreign output gap is only significant in the open regime.

Finally in the last two columns of Table 11, core inflation instead of CPI inflation is used in the threshold estimation. This substitution basically strips the more volatile food and energy prices from the CPI and allows us to focus on a narrower and more policy-oriented definition of inflation. Due to missing observations, this analysis is also conducted for the 1984-2013 sample period.[42] As seen the estimates with core inflation are similar to those found with the CPI as the inflation series. We see a decline in the magnitude of the domestic output coefficient from the closed to open regime, while the foreign output gap coefficient sees a gain in both magnitude and significance in the open regime. Overall the robustness checks conducted in Table 11 support our earlier dynamic panel threshold estimates and we can be confident in using them as a guide for policy decisions.

[41] In these estimations we continue to use three-year averages for all variables. The estimates with annual data our similar, however, Hansen (1999) developed his asymptotic theory for a large number of cross-sections in the panel and so it is unclear how valid these threshold estimates are when N is small relative to T.

[42] Hungary and Israel are excluded from these estimations because their core CPI series were incomplete in this time period.

6.3.1 External Controls

In this section, we consider specifications of the dynamic panel threshold Phillips Curve in which traditional external factors, such as real exchange rate depreciation and import prices inflation, also have a role in determining domestic inflation. Table 12 reports the results when changes in the real exchange rate and the import price index are used as additional control variables for the full sample period. As with the output gaps, we allow the impact of the real exchange rate and import price to vary across the two regimes. The first two columns show, based on the Wald Test, that trade openness still acts as a meaningful threshold in the inflation process when the real exchange rate depreciation is used as the additional control variable. We also see that the switch in the output gap slopes is consistent with the inflation globalization hypothesis, and that there is little change in the estimated threshold or the confidence intervals with the addition of the real exchange rate variable. Notably the estimates for the real exchange rate term are not significant in either of the two regimes. In columns (3) and (4), we further consider the scenario where only the real exchange rate depreciation is included with the domestic output gap in the Phillips Curve model and again find it to be insignificant in both regimes. For these estimates we are also unable to reject the null of no threshold effect from trade openness on the country's inflation dynamics.

In columns (5) and (6) of Table 12, we turn to specifications that include import prices as an external control in (4).[43] The results are generally robust to the use of import price inflation as we continue to see a significant change in the foreign output gap coefficients from the closed to open regime; however, the domestic output gap is now insignificant in both of the regimes. The estimates also show that import prices play a strong role in the closed regime, which diminishes slightly in the more open regime. It is important to stress here that the effects of globalization on inflation related to the foreign output gap channel might in many ways overlap with import prices, since a positive foreign output gap causes an increase in the prices of foreign goods and so results in higher import prices for the domestic economy. So it becomes difficult to empirically disentangle the effect of the foreign output gap from that of import prices, and thus in columns (5) and (6) we find much lower values of the foreign output gap coefficient in the open regime for this specification.[44] Finally in the last two columns, we see that having import prices alone is not enough to detect nonlinearity in the Phillips Curve, with the high bootstrapped p-values from the Wald test indicating little threshold effect from openness in this instance.

[43] Due to missing observations, Israel is excluded from these estimations.

[44] A similar finding was seen for the dynamic panel estimates with import prices in 5.4.1.

7 Conclusion

There are strong implications for monetary policy if inflation is indeed influenced more by global conditions, rather than domestic ones. For one, a diminishing response to domestic factors makes it more costly to stabilize inflation through standard policy actions (Calza, 2009). Alternatively, policy makers may feel that increased competition due globalization adequately anchors inflationary tendencies, and so are able to concentrate more on increasing domestic output levels (López-Villavicencio and Saglio, 2014). Given these important policy consequences, it is imperative to identify the exact role globalization plays in the inflation process.

Our paper makes a significant contribution by finding strong evidence in favor of including the global slack as a determinant in a country's domestic inflation process. We first show that cross-sectional variation in openness can be effectively used in a dynamic panel Phillips Curve model to identify the impact of foreign influence, represented by the foreign output gap, on domestic inflation levels. In contrast to previous empirical literature that looks at this relationship at the individual-country level, the larger cross-sectional differences in openness provide more suitable conditions to detect the potential effects of globalization. This result is also robust to the instrument proliferation and weak instrument problems that are often associated with the dynamic panel GMM methodology.

We then extend our modeling framework so that openness can have a non-linear role in the inflation process. Applying the dynamic panel threshold methodology, given in Kremer, Bick, and Nautz (2013), we show that trade openness is a significant threshold variable and leads to an economically meaningful change in a country's inflation dynamics. The estimates of the panel threshold model are also consistent with the inflation globalization hypothesis, with the foreign output gap replacing the domestic output gap as the driver of domestic inflation in the more open regime. Our threshold approach thus provides a suitable tool to inform the policy making process with respect to the influence of relevant external forces.

In our analysis, we have utilized a country's level of trade openness to capture its degree of integration in the global markets. However, globalization is a complex phenomenon that can be measured across various economic, social and political dimensions (Dreher, Gaston, and Martens, 2008). It would be interesting to examine if other economic measures of globalization such as integration in financial markets and labor mobility can also have non-linear effects on the inflation process. A further possibility is to treat this non-linearity as a Markov-Switching Process (Hamilton, 1989), which can then be incorporated in a DSGE model (Farmer, Waggoner, and Zha, 2009) to better understand the structural underpinnings of this relationship. For as we have empirically shown, non-linearity needs to be explicitly modeled and included in the analysis of the inflation globalization hypothesis.

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Tables

Table 1: Testing for Poolability

	Statistic	p-value	
		classic	bootstrap
F-test (intercept and slopes)	1.08	0.27	0.41
F-test (slopes only)	1.09	0.27	0.35
Roy-Zellner test (intercept and slopes)	6.33	0.01	0.82
Roy-Zellner test (slopes only)	7.89	0.01	0.47
Hausman test	0.22	0.97	.

Note: 1000 repetitions used for the bootstrapped p-values.

Table 2: Panel Unit Root Tests

	LLC test (common)		IPS test (individual)		Hadri test	
Null:	All panels have unit root		All panels have unit root		All panels stationary	
	t^*	p-value	W_t	p-value	Z_τ	p-value
Inflation	-2.78	0.00	-3.65	0.00	1.17	0.12
Openness	-1.78	0.03	-2.70	0.00	1.09	0.27
Dom Gap	-5.84	0.00	-8.40	0.00	-1.43	0.92
For Gap	-2.87	0.00	-4.19	0.00	2.74	0.03
Real Exch	-23.89	0.00	-24.30	0.00	1.00	0.16

Note: Lag length selected based on BIC criteria. The tests assume asymptotic normality.

Table 3: OECD Summary Statistics (1970-2013)

Variable	Mean	Std Dev	Within	Between	Min	Max
Inflation	9.60	20.96	18.45	14.08	-4.48	73.82
Openness	45.70	21.02	10.65	18.18	5.43	151.04
Dom Gap	0.02	4.56	4.60	0.20	-21.76	18.62
For Gap	0.40	2.47	2.50	0.21	-4.91	10.83
Real Exch	0.25	6.20	6.24	0.57	-32.66	32.38

Table 4: First Panel Results

Equation	(1) Pooled OLS Levels	(2) Fixed Effects Levels	(3) 2SLS Difference	(4) 1-step GMM Difference	(5) 2-step GMM Difference	(6) 2-step GMM Orthogonal
Lag Inf	0.803***	0.704***	1.365***	0.743***	0.743***	0.735***
	(0.03)	(0.02)	(0.07)	(0.04)	(0.04)	(0.04)
Dom Gap	0.369**	0.302**	0.475	0.383*	0.389*	0.325**
	(0.17)	(0.14)	(0.33)	(0.22)	(0.22)	(0.14)
For Gap	0.437	0.453*	0.474	0.549**	0.539*	0.449**
	(0.27)	(0.23)	(0.69)	(0.28)	(0.28)	(0.22)
Constant	1.433**	2.360***	-0.105	1.968***	1.912***	2.037***
	(0.60)	(0.23)	(0.18)	(0.67)	(0.65)	(0.69)
Observations	392	392	364	364	364	364
RMSE	10.99	10.71	18.31	13.53	13.53	11.11

Note: Estimates of panel Phillips Curve: $\pi_{it} = \rho\pi_{i,t-1} + \beta Y_{it}^{d} + \gamma Y_{it}^{f} + \eta_i + \varepsilon_{it}$ for period 1970-2013 (three-year averages). Standard errors robust to heteroskedasticty and clustered at the country level in parentheses. For GMM estimation, the equation is transformed using either the first-differences or the forward orthogonal deviation. The 2-step GMM estimators also apply the Windmeijer finite-sample correction for the standard error calculations. Time dummies are not reported. ***, **,* indicate significance at the 0.10, 0.05 and 0.01 level respectively.

Table 5: Reduced Instrument Estimates

IV Set ($\pi_{i,t-1}$)	(1) *Second-lag*	(2) *First-lag*	(3) *Collapsed*	(4) *Two Lags*	(5) *One Lag*
Lag Inf	0.763***	0.771***	0.856***	0.922***	0.889***
	(0.06)	(0.06)	(0.05)	(0.07)	(0.05)
Dom Gap	0.334**	0.329**	0.316**	0.202**	0.399**
	(0.15)	(0.16)	(0.15)	(0.10)	(0.19)
For Gap	0.457**	0.431**	0.427**	0.652***	0.4730*
	(0.23)	(0.21)	(0.19)	(0.20)	(0.25)
Number of Instruments	28	16	16	5	4
p-values					
AR(2) test	0.25	0.25	0.25	0.23	0.23
Hansen J-test	0.28	0.05	0.10	0.22	.
Difference-in-Hansen test	0.71	0.46	0.20	.	.

Note: Equation transformed using forward-orthogonal deviations. The Second-lag and First-lag instrument set for $\pi_{i,t-1}$ include only two-period and one-period lags respectively. These can be reduced further with Roodman (2009) collapse option to obtain the Collapsed, Two Lags only and the One Lag only instrument sets. Time dummies not included when calculating number of instruments. AR(2) test for null that residuals from first-difference equation exhibit no second order serial correlation. The Hansen J-test is distributed as chi-square under the null that all the instruments used are valid.

Table 6: Weak Instrument Tests

IV Set ($\pi_{i,t-1}$)	(1) *Second-lag*	(2) *First-lag*	(3) *Collapsed*	(4) *Two lags*	(5) *One lag*
Excluded Instruments	25	13	13	2	1
Kleibergen-Paap LM Stat	45.38	27.71	39.28	7.31	5.62
	(0.01)	(0.00)	(0.00)	(0.03)	(0.02)
Cragg-Donald Wald Stat	96.73	160.23	103.73	64.32	128.88
Kleibergen-Paap Wald Stat	117.51	81.25	16.15	46.91	80.18
Stock-Yogo critical values					
Relative bias > 10%	11.38	11.52	11.52	.	.
Size of 5% test >15%	38.77	24.42	24.42	11.59	8.96

Note: These tests are conducted with 2SLS where the number of excluded instruments are the lags of inflation in the IV set. Null of Kleibergen-Paap LM test is that the structural equation is underidentified with p-values in parenthesis. With one endogenous variable, the Cragg-Donald Wald test is analogous to the standard first stage F-test (the Kleibergen-Paap Wald test extends it to the case of heteroskedastic disturbances).

Table 7: Controlling for Potential Endogeneity

	Predetermined			Endogenous		
	(1)	(2)	(3)	(4)	(5)	(6)
IV Set ($Y_{i,t}$)	*Collapsed*	*Two lags*	*One Lag*	*Collapsed*	*Two lags*	*One Lag*
Lag Inf	0.857***	0.881***	0.923***	0.852***	0.853***	0.929***
	(0.05)	(0.05)	(0.07)	(0.05)	(0.04)	(0.08)
Dom Gap	0.431**	0.312**	0.229**	0.423*	0.189	0.470
	(0.21)	(0.12)	(0.10)	(0.23)	(0.25)	(0.35)
For Gap	0.433*	0.408**	0.624***	0.605*	0.729*	0.161
	(0.24)	(0.20)	(0.20)	(0.32)	(0.42)	(0.34)
Total Instruments	31	7	5	29	7	5
p-values						
AR (2) test	0.25	0.25	0.24	0.25	0.24	0.24
Hansen J-test	0.50	0.12	0.22	0.34	0.16	0.22

Note: When output gaps are taken as predetermined(endogenous) then Y_{t-1} (Y_{t-2}) and earlier lags are used in the instrument set. For all of these cases, two lags of inflation: $\pi_{i,t-2}$ and $\pi_{i,t-3}$ are used as the instruments for inflation.

Table 8: Trade Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IV Set ($\pi_{i,t-1}$)	*Collapsed*	*One Lag*	*Collapsed*	*One Lag*	*Collapsed*	*One Lag*	*Collapsed*	*One Lag*	*Collapsed*	*One Lag*	*Collapsed*	*One Lag*
Lag Inf	0.861***	0.894***	0.871***	0.900***	0.823***	0.817***	0.795***	0.814***	0.833***	0.860***	0.835***	0.864***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.04)	(0.04)	(0.05)	(0.04)
Dom Gap	0.363***	0.438**	0.390***	0.534***	0.112**	0.110**	0.189***	0.189**	0.331**	0.384**	0.396***	0.475***
	(0.13)	(0.20)	(0.10)	(0.17)	(0.05)	(0.05)	(0.05)	(0.05)	(0.15)	(0.18)	(0.12)	(0.15)
For Gap	0.369**	0.453*			0.408***	0.436***			0.399**	0.440*		
	(0.17)	(0.24)			(0.10)	(0.11)			(0.17)	(0.24)		
Real Exchange	-0.204	-0.263	-0.215	-0.278								
	(0.22)	(0.26)	(0.20)	(0.26)								
Price Imports					0.258***	0.260***	0.289***	0.294***				
					(0.06)	(0.05)	(0.05)	(0.05)				
Openness									-0.051	-0.068*	-0.049	-0.071*
									(0.03)	(0.03)	(0.03)	(0.03)
Instruments	17	5	16	4	17	5	16	4	17	5	16	4
p-values												
AR(2)	0.25	0.24	0.25	0.24	0.97	0.94	0.44	0.47	0.25	0.24	0.25	0.24
Hansen J-Test	0.11	.	0.47	.	0.04	.	0.07	.	0.60	.	0.28	.

Notes: Number of instruments does not include time dummies. Real Exchange is the year to year change in the trade-weighted real exchange rate. Import price inflation is measured as the year to year change in (log-)domestic import price deflator. See also Table 5.

Table 9: Dynamic Panel GMM estimates (Annual data)

	Period: 1984-2013				Period: 1984-2006				Period: 1984-1999			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IV Set ($\pi_{i,t-1}$)	*Collapsed*	*One lag*	*Collapsed*	*One lag*	*Collapsed*	*One lag*	*Collapsed*	*One lag*	*Collapsed*	*One lag*	*Collapsed*	*One lag*
Lag Inf	0.935***	0.941***	0.942***	0.949***	0.934***	0.946***	0.945***	0.954***	0.887***	0.900***	0.886***	0.911***
	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.11)	(0.10)	(0.11)	(0.02)	(0.02)	(0.03)	(0.02)
Dom Gap	0.047	0.057**	0.076*	0.084**	0.050*	0.068**	0.072*	0.106**	0.127***	0.133***	0.093	0.169**
	(0.03)	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.09)	(0.07)
For Gap	0.229***	0.262***	0.180***	0.214***	0.170**	0.257*	0.123**	0.175	0.229***	0.244*	0.278***	0.240 **
	(0.06)	(0.10)	(0.05)	(0.07)	(0.07)	(0.17)	(0.06)	(0.12)	(0.07)	(0.13)	(0.09)	(0.12)
Real Exchange			-0.083	-0.130			-0.070*	-0.153			-0.149	-0.286*
			(0.07)	(0.09)			(0.04)	(0.11)			(0.17)	(0.14)
Instruments	8	4	9	5	8	4	9	5	8	4	9	5
p-values												
AR(2)	0.67	0.65	0.80	0.89	0.69	0.64	0.82	0.97	0.37	0.37	0.34	0.30
Hansen J-Test	0.27	.	0.26	.	0.11	.	0.15	.	0.19	.	0.21	.

Notes: See also Table 5.

Table 10: Dynamic Panel Threshold estimates

		(1)	(2)	(3)
	IV Set ($\pi_{i,t-1}$)	*Collapsed*	*Two Lags*	*One Lag*
	Threshold	51.79	51.93	51.93
	90% CI	[35.44, 57.05]	[35.44, 57.05]	[35.44, 57.05]
	Lag Inf	0.8637***	0.8472***	0.8957***
		(0.05)	(0.23)	(0.20)
Open $\leq \tau$ (235 obs)	Intercept	0.8977	0.0674	0.0337
		(0.71)	(2.26)	(1.87)
	Dom Gap	0.4948***	0.4878**	0.6831***
		(0.20)	(0.24)	(0.27)
	For Gap	0.3409	0.5621	0.3084
		(0.26)	(0.37)	(0.41)
Open $> \tau$ (129 obs)	Dom Gap	0.0642	0.0605	0.0541
		(0.10)	(0.14)	(0.14)
	For Gap	0.6873**	0.8822**	0.8987***
		(0.32)	(0.38)	(0.36)
	Instruments	18	7	6
	Hansen J-test	0.14	0.22	.
	Wald Stat	6.29	7.90	8.97
	Bootstrap p-value	0.12	0.08	0.04

Note: Panel threshold estimate of model: $\pi_{it} = \rho_i \pi_{i,t-1} + (\delta + \beta_1 Y_{it}^d + \gamma_1 Y_{it}^f) I(Open \leq \tau) + (\beta_2 Y_{it}^d + \gamma_2 Y_{it}^f) I(Open > \tau) + \eta_i + \varepsilon_{it}$ for the sample period 1970-2013 (three year averages). Intercept term captures the difference in the Open and Closed intercepts. Threshold was estimated such that each regime has at least 15% observations. Wald Stat is the maximum value from the grid search and tests for the null of no-threshold effect. The corresponding p-value, as in Caner and Hansen (2004), is bootstrapped with a 1000 replications.

Table 11: Robustness of Dynamic Panel Threshold Estimates

		No-regime constant		Exclude outliers		Period:1984-2013		Core Inflation	
		(1)	(2)	(3)	(4)	(7)	(8)	(7)	(8)
	IV Set (π_{t-1})	Two Lags	One Lag	Two Lags	One Lag	Two Lags	One Lag	Two Lags	One Lag
	Threshold	51.79	51.82	51.79	51.82	57.67	57.65	45.00	51.00
	90% CI	[35-57]	[35-57]	[33-53]	[33-53]	[38-60]	[38-58]	[40-57]	[40-57]
	Lag Inf	0.845***	0.896***	0.846***	0.897***	0.882***	0.882***	0.845***	0.930***
		(0.25)	(0.21)	(0.21)	(0.21)	(0.16)	(0.16)	(0.16)	(0.07)
Open$\leq \tau$	Dom Gap	0.472*	0.689***	0.473**	0.690***	0.271**	0.249**	0.242***	0.256***
		(0.26)	(0.28)	(0.24)	(0.28)	(0.10)	(0.11)	(0.10)	(0.07)
	For Gap	0.577	0.305	0.577	0.305	0.022	0.203	-0.173	-0.120
		(0.37)	(0.40)	(0.35)	(0.40)	(0.19)	(0.34)	(0.31)	(0.22)
Open $> \tau$	Dom Gap	0.081	0.056	0.079	0.047	0.019	0.019	0.123***	0.099**
		(0.19)	(0.14)	(0.20)	(0.15)	(0.04)	(0.04)	(0.04)	(0.04)
	For Gap	0.854**	0.896***	1.136**	1.202**	0.328***	0.325***	0.152*	0.202**
		(0.44)	(0.36)	(0.55)	(0.49)	(0.11)	(0.11)	(0.09)	(0.08)
	Open Regime	130	130	92	92	63	63	92	87
	Close Regime	234	234	233	233	153	153	116	121
	Instruments	6	5	6	5	6	5	6	5
	Wald Stat	7.86	8.78	7.63	6.46	6.13	5.87	5.71	7.99
	Bootstrap p-value	0.06	0.02	0.06	0.08	0.08	0.09	0.16	0.08

Note: Total observations are the sum of Open and Close Regimes. BEL, LUX and NET are excluded as outliers in (3) and (4). Core inflation measured as the year to year change in the CPI excluding food and energy prices for the time period 1984-2013. See also Table 10.

Table 12: Threshold Estimates with External Controls

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IV Set (π_{t-1})	Two Lags	One Lag	Two Lags	One Lag	Two Lags	One Lag	Two Lags	One Lag
	Threshold	51.82	51.82	48.23	48.23	55.12	55.12	38.89	38.89
	90% CI	[36-57]	[36-57]	[36-57]	[36-57]	[36-57]	[36-57]	[36-57]	[36-57]
	Lag Inf	0.847***	0.899***	0.855***	0.897***	0.704***	0.711***	0.700***	0.701***
		(0.21)	(0.21)	(0.20)	(0.21)	(0.10)	(0.10)	(0.10)	(0.10)
Open$\leq \tau$	Dom Gap	0.560**	0.760**	0.675***	0.703**	0.204	0.203	0.348*	0.329
		(0.24)	(0.29)	(0.25)	(0.25)	(0.15)	(0.15)	(0.24)	(0.25)
	For Gap	0.539	0.287			0.305	0.291		
		(0.34)	(0.39)			(0.28)	(0.28)		
	Real Exchange	-0.306	-0.357	-0.385*	-0.411*				
		(0.21)	(0.22)	(0.23)	(0.23)				
	Price Imports					0.358***	0.356***	0.399***	0.402***
						(0.06)	(0.06)	(0.08)	(0.06)
Open$> \tau$	Dom Gap	0.052	0.048	0.300**	0.409**	0.102	0.096	0.177***	0.177***
		(0.14)	(0.14)	(0.13)	(0.16)	(0.37)	(0.12)	(0.06)	(0.06)
	For Gap	0.892**	0.907**			0.369*	0.416**		
		(0.38)	(0.38)			(0.21)	(0.22)		
	Real Exchange	0.110	0.080	0.140	0.068				
		(0.34)	(0.34)	(0.31)	(0.32)				
	Price Imports					0.098**	0.099**	0.244**	0.243**
						(0.05)	(0.05)	(0.07)	(0.07)
	Open Regime	130	130	174	174	99	99	239	239
	Close Regime	234	234	190	190	252	252	112	112
	Instruments	7	6	6	5	7	6	6	5
	Wald Stat	7.71	8.09	4.61	6.12	17.18	17.14	3.46	3.45
	Bootstrap p-value	0.08	0.08	0.24	0.12	0.00	0.00	0.38	0.37

Note: Sample period 1970-2013. See also Table 8 and Table 10.

Appendix

A Construction of OECD Dataset

We analyze the following twenty eight OECD countries in our panel: U.S., U.K., Germany, France, Italy, Spain, Ireland, Denmark, Netherlands, Austria, Switzerland, Canada, Mexico, Australia, Japan, South Korea, Belgium, Luxembourg, Norway, Sweden, Finland, Greece, Iceland, Portugal, Turkey, Hungary, Israel and New Zealand. In addition to these countries, an additional seventy countries were also included for the construction of the trade weights.

A.1 Sources

The main sources are the OECD Statistics database (STAT), the IMF's Direction of Trade (DOT) and International Financial Statistics (IFS) and the Penn World Table Version 8.0 (PWT).

CPI: This series is mainly from the FSI with 2010 set as the base year (the average of the CPI indices at that year is set to 100). For Hungary, the GDP deflator (PWT) was used instead. Data for Core Inflation comes from the OECD's Main Economic Indicators.

Real GDP: STAT and PWT are used to get the real output values. To improve data quality, we use historical data from Maddison (1995) for Yugoslavia, USSR, and Czechoslovakia. The output gap is then constructed as $gap_{i,t} = \frac{gdp_{i,t}}{pot_{i,t}} - 1$ where the Potential GDP is obtained from an HP filter on the real GDP series. This gap measure is similar to one used by the OECD's Economic Outlook.

Trade Openness: Exports, Imports and GDP (all in nominal terms) are obtained from STAT to calculate this measure for the countries in our sample. Due to missing observations, PWT (openc) was used for Hungary, Israel, Luxembourg and Mexico.

Import Prices: Import price index from the OECD Economic Outlook dataset.

Nominal Exchange Rates: We use the US dollar as pivotal currency for the bilateral exchange rates between the US and the other countries in the sample; this allows the creation of a pair-wise dataset for each country. The data are originally reported in units of a currency necessary to buy one US dollar and we express the exchange rates in units of foreign currency necessary to buy one unit of domestic currency. To avoid shifts in the definition of the accounting unit of the numeraire, we always use the most recent monetary unit adopted by a country as reference unit.[45]

[45] The members of the EMU switch to the common currency in 1999.

Trade Flows: DOT provides the pairwise trade flows among countries in our sample universe. The flows are measured in current U.S. dollars for all countries. DOT treats Belgium and Luxembourg separately only after 1997, and Germany is defined as West Germany before 1991 reunification.

A.2 Trade Weights

Trade-based weights are used for the construction of the foreign output gap and the real exchange rate. The weights are obtained starting from the series of the pairwise import and export flows among a set of about 100 countries which, besides the 28 OECD countries in our sample, includes the major world economies. The weights are computed following the approach used by the Federal Reserve Board in the construction of its effective real exchange rate (Loretan, 2005).

Trade weights for imports, exports and third party ($w^m, w^x$and w^p) are determined according to:

$$w^m_{i,j,t} = \frac{M_{i,j,t}}{\sum_{j=1}^{N_t} M_{i,j,t}} \tag{5}$$

$$w^x_{i,j,t} = \frac{EX_{i,j,t}}{\sum_{j=1}^{N_t} EX_{i,j,t}} \tag{6}$$

$$w^p_{i,j,t} = \sum_{k\neq j\neq i}^{N_t} w^x_{i,k,t} \frac{w^m_{k,j,t}}{1 - w^m_{k,i,t}} \tag{7}$$

where $M_{i,j}$and $EX_{i,j}$ indicate imports from country j to i and exports from i to j. Weights are then aggregated as

$$w_{i,j,t} = 0.5w^m_{i,j,t} + 0.5(0.5w^x_{i,j,t} + 0.5w^p_{i,j,t}) \tag{8}$$

The foreign output gap for country i is then the weighted average, using the weights in (8), of the domestic output gap for all the other countries in the sample universe. Similarly the real exchange rate index I_t for country i, using these same weights, is the geometrically weighted average of the bilateral exchange rates so that

$$I_{i,t} = I_{i,t-1} \prod_{j=1}^{N(t)} \left(\frac{e_{i,j,t}}{e_{i,j,t-1}} \right)^{w_i,j,t} \tag{9}$$

and $e_{i,j,t}$ is the real exchange rate between country i and j.

B Bias-corrected Fixed Effects Estimation

In our analysis of the inflation globalization hypothesis, we have relied on the Arellano and Bond (1991) GMM methodology to account for the fixed effects term η_i and get consistent estimates of the dynamic panel model. One reason for this choice, is that in a dynamic panel framework the traditional Fixed Effects (within mean) estimator is biased for finite T (Nickell, 1981). However, for large T, it is still consistent, so an alternate approach in estimating dynamic panel models is to use the Fixed Effects estimator with an approximation made to correct for the small sample bias. In a Monte Carlo study, Judson and Owen (1999) have shown that for macro panels, where N is typically small, the bias-corrected Fixed Effects estimator is more accurate and with a smaller variance than the GMM estimators. Thus in this section we estimate (3) using annual data (so large T) with the bias-corrected Fixed Effects estimator and examine whether this impacts our main findings.

Kiviet (1995; 1999) has developed higher-order asymptotic expansion techniques to approximate the small-sample bias of the Fixed Effects estimator up to an accuracy of order T^{-1}, $N^{-1}T^{-1}$ and $N^{-1}T^{-2}$ respectively. In order to calculate the bias terms in practice, a consistent estimator is first needed to get estimates for the lagged term and the residual variance. Kiviet (1995) suggests using 2SLS, as in Anderson and Hsiao (1981), or GMM, as in Arellano and Bond (1991), to get these estimates and then plug them in the desired bias-approximation formula. The bias-corrected Fixed Effects estimates (FE^c) are then obtained by just subtracting these bias approximations from the original Fixed Effects coefficients.

Table 13 reports the panel estimates for the whole sample period (1970-2013) and sub-sample period (1984-2013) using annual data. We first examine the standard Pooled OLS and Fixed Effects estimates which show significant coefficients for both the domestic and foreign output gaps. Since these estimates are biased due to the presence of the lagged dependent variable, we next turn to the bias-corrected Fixed Effects estimates.[46] We use both the AH (Anderson and Hsiao, 1981) and the AB (Arellano and Bond, 1991) estimators to initialize the bias correction terms and see similar coefficient estimates for the two output gaps in columns three and four. The estimated coefficients in these two columns have an approximation error of order $O(N^{-1}T^{-1})$.[47] In both cases, the foreign output gap is significant while the domestic output gap is of smaller magnitude and not significant at the 10% level. As in Bun and Kiviet (2001), a parametric bootstrap procedure has been applied to get the estimated standard errors for these bias-corrected Fixed Effects estimators. Overall we continue to find significance of the foreign output gap in our panel analysis despite relying

[46]These estimates were obtained using the STATA code `xtlsdvc` described in Bruno (2005).

[47]Note that Bun and Kiviet (2003) showed that the $O(T^{-1})$ bias term was able to account for 90% of the true bias in most instances.

on a different empirical methodology, which increases the robustness of our results in Section 4. Finally, a Mean Group estimator, as proposed in Pesaran and Smith (1995), is also used to allow for heterogeneous slope coefficients in (3) and we see little change in the significance of these two output gaps in the inflation process.

Table 13: Fixed Effect Results (Annual Data)

Period: 1970-2013

	(1) POLS	(2) FE	(3) FE$^c(AH)$	(4) FE$^c(AB)$	(5) MG
Lag Inf	0.851***	0.766***	0.766***	0.817***	0.769***
	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)
Dom Gap	0.100**	0.079**	0.078	0.084	0.066***
	(0.03)	(0.03)	(0.09)	(0.08)	(0.02)
For Gap	0.375***	0.315***	0.329**	0.279**	0.359***
	(0.09)	(0.09)	(0.15)	(0.13)	(0.11)
RMSE	11.52	11.26	17.69	11.50	11.16

Period: 1984-2013

	(1) POLS	(2) FE	(3) FE$^c(AH)$	(4) FE$^c(AB)$	(5) MG
Lag Inf	0.922***	0.823***	0.885***	0.898***	0.659***
	(0.05)	(0.11)	(0.03)	(0.03)	(0.04)
Dom Gap	0.057**	0.062***	0.072*	0.066 *	0.094**
	(0.02)	(0.02)	(0.04)	(0.03)	(0.03)
For Gap	0.202***	0.135**	0.132*	0.156**	0.153***
	(0.06)	(0.05)	(0.07)	(0.07)	(0.04)
RMSE	3.58	3.44	4.28	3.10	3.02

Note: Time dummies not shown. Bootstrapped standard errors for bias-corrected Fixed Effect Estimates.

C Instruments in Dynamic Panel Models

The instrument matrix Z_i for $(\pi_{i,t-1} - \pi_{i,t-2})$ in the GMM estimation of (3) can be represented as:

$$\begin{bmatrix} \pi_{i1} & 0 & 0 & 0 & 0 & 0 & ... & 0 \\ 0 & \pi_{i2} & \pi_{i1} & 0 & 0 & 0 & ... & 0 \\ 0 & 0 & 0 & \pi_{i3} & \pi_{i2} & \pi_{i1} & ... & 0 \\ . & . & . & . & . & . & ... & . \\ 0 & 0 & 0 & 0 & 0 & 0 & ... & \pi_{i,T-2} \end{bmatrix} \tag{10}$$

with Z_i capturing the $\frac{(T-2)(T-1)}{2}$ moment conditions $E[\pi_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})] = 0$ for $t \geq 3$, $s \geq 2$..[48] Note that this matrix includes separate instruments for each time period so that in period $t = 3$ π_{i1} is a valid instrument, in period $t = 4$ both π_{i1} and π_{i2} are valid instruments and finally in the last period $t = T - 1$ the set of valid instruments is given by $\{\pi_{i1}, \pi_{i2}, ...\pi_{i,T-2}\}$.

We next discuss the methods that we employed to reduce the number of instruments given in (10).[49] One approach is to cap the number of instruments per periods by using the previous k lags only, making the instrument count linear in T.

Setting $k = 2$, then gives us the **Second-Lag** instrument set:

$$\begin{bmatrix} \pi_{i1} & 0 & 0 & 0 & 0 & ... & 0 & 0 \\ 0 & \pi_{i2} & \pi_{i1} & 0 & 0 & ... & 0 & 0 \\ 0 & 0 & 0 & \pi_{i3} & \pi_{i2} & ... & 0 & 0 \\ . & . & . & . & . & ... & ... & . \\ 0 & 0 & 0 & 0 & 0 & ... & \pi_{i,T-3} & \pi_{i,T-2} \end{bmatrix} \tag{11}$$

Setting $k = 1$, then gives us the **First-Lag** instrument set:

$$\begin{bmatrix} \pi_{i1} & 0 & 0 & ... & 0 & 0 \\ 0 & \pi_{i2} & 0 & ... & 0 & 0 \\ 0 & 0 & \pi_{i3} & ... & 0 & 0 \\ . & . & . & ... & . & 0 \\ 0 & 0 & 0 & ... & \pi_{i,T-3} & 0 \\ 0 & 0 & 0 & ... & 0 & \pi_{i,T-2} \end{bmatrix} \tag{12}$$

[48] These moment conditions are derived by assuming uncorrelated error terms $E(\varepsilon_{is}\varepsilon_{it}) = 0$, $\forall\ s \neq t$ and predetermined initial conditions $E(\pi_{i1}\varepsilon_{it}) = 0$, $t \geq 2$.

[49] For more details on these methods, please refer to Roodman (2009).

Another approach proposed by Roodman (2009) is to collapse the instruments in (10) so that one column is made for each lag distance (with zeros substituted for missing values).[50] A potential advantage of this approach is that no lags are actually dropped and so are able to retain more information. The two methods can also be combined to further reduce the number of instruments.

Collapsing (10) gives us the **Collase** instrument set:

$$\begin{bmatrix} \pi_{i1} & 0 & 0 & 0 & \dots & 0 \\ \pi_{i2} & \pi_{i1} & 0 & 0 & \dots & 0 \\ \pi_{i3} & \pi_{i2} & \pi_{i1} & & & . \\ . & . & . & & & . \\ \pi_{i,T-2} & \pi_{i,T-3} & \pi_{i,T-4} & . & \dots & \pi_{i1} \end{bmatrix} \tag{13}$$

Collapsing (11) gives us the **Two Lags** instrument set

$$\begin{bmatrix} \pi_{i1} & 0 \\ \pi_{i2} & \pi_{i1} \\ \pi_{i3} & \pi_{i2} \\ . & . \\ \pi_{i,T-2} & \pi_{i,T-3} \end{bmatrix} \tag{14}$$

Finally, collapsing (12) gives us the **One Lag** instrument set

$$\begin{bmatrix} \pi_{i1} \\ \pi_{i2} \\ \pi_{i3} \\ . \\ \pi_{i,T-2} \end{bmatrix} \tag{15}$$

which is the exact instrument ($\pi_{i,t-2}$) used by Anderson and Hsiao (1981) for their 2SLS estimation.

[50] Roodman (2009) showed that this imposes the moment condition $E[\pi_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})] = 0$ for each $s \geq 2$.

C.1 Forward-Orthogonal Deviation Transformation

Here we show that the instrument set for the forward-orthogonal deviation transformations is the same as the one used with the first-differences transformation. For simplicity, lets consider the AR(1) panel model for inflation:

$$\pi_{it} = \alpha\pi_{i,t-1} + \eta_i + v_{it} \tag{16}$$

Assuming uncorrelated error terms and predetermined initial conditions, implies the following moment condition:

$$E[\pi_{i,t-s}(v_{it} - v_{i,t-1})] = 0 \; t \geq 3, \; s \geq 2 \tag{17}$$

Letting $c_{it} = \sqrt{\frac{T-t}{T-t+1}}$, then equation (16) under a forward-orthogonal deviation transformation can be expressed as:

$$\begin{aligned}
t = 2: \quad & c_{i2}\left[\pi_{i2} - \frac{1}{T-2}(\pi_{i3} + ...\pi_{iT})\right] = \alpha c_{i1}\left[\pi_{i1} - \frac{1}{T-1}(\pi_{i2} + ...\pi_{iT})\right] + c_{i2}\left[v_{i2} - \frac{1}{T-2}(v_{i3} + ...v_{iT})\right] \\
t = 3: \quad & c_{i3}\left[\pi_{i3} - \frac{1}{T-3}(\pi_{i4} + ...\pi_{iT})\right] = \alpha c_{i2}\left[\pi_{i2} - \frac{1}{T-2}(\pi_{i3} + ...\pi_{iT})\right] + c_{i3}\left[v_{i3} - \frac{1}{T-3}(v_{i4} + ...v_{iT})\right] \\
& \vdots \\
t = T-1: \quad & c_{iT}\left[\pi_{i,T-1} - \pi_{iT})\right] = \alpha c_{i,T-1}\left[\pi_{i,T-2} - \frac{1}{2}(\pi_{i,T-1} + \pi_{iT})\right] + c_{iT}\left[v_{i,T-1} - v_{iT})\right]
\end{aligned}$$

In period $t = 2$, π_{i1} is a valid instrument as (16) implies it is uncorrelated with all the future errors $v_{i2}, ...v_{iT}$ (Bond, 2002). Similarly in period $t = 3$, both π_{i1} and π_{i2} are valid instruments, while in last period $t = T-1$, the set of valid instruments for $(v_{i,T-1} - v_{iT})$ is $\{\pi_{i1}, \pi_{i2}, ...\pi_{i,T-2}\}$. Stacking these instruments will give us the same matrix (10) used in the first-differences transformation.

D Hybrid Phillips Curve Model

In this section, we augment the dynamic panel Phillips Curve model given in (3) with an explicit forward-looking component to capture inflation expectations. This Hybrid Phillips Curve specification is derived from the price-setting behavior of profit maximizing firms and so benefits from a structural interpretation that is lacking with pure backward-looking Phillips Curve models(Galı and Gertler, 1999). It is important to stress that our goal here is only to examine the inflation globalization hypothesis for a different Phillips Curve specification and not on the overall validity of the Hybrid Phillips Curve.[51] The Hybrid Phillips Curve in a panel setting can be expressed as:

$$\pi_{it} = \alpha E_t \pi_{t+1} + \rho \pi_{i,t-1} + \beta Y_{it}^d + \gamma Y_{it}^f + \eta_i + \varepsilon_{it} \tag{18}$$

A number of ways have been proposed to adequately account for the expected inflation term in the estimation of (18). One popular approach, as discussed in Mavroeidis, Plagborg-Møller, and Stock (2014), is to use the realized values of future inflation and then estimate (18) with some external instruments in a GMM framework. Instruments that have been used in the literature include the lags of inflation itself, the domestic output gap and the interest rate spread.[52] Due to data limitations, we do not have access to the interest rate spreads for all the countries in our sample, and so will instead use the lags of the growth in the money supply (M2) as a proxy for monetary policy.

Table 14 presents the estimates of (18). Following Mavroeidis, Plagborg-Møller, and Stock (2014), we use 4 lags of inflation and 2 lags of the output gaps and M2 growth rates as excluded instruments (all of them collapsed in the panel setting). We observe that the forward term has a larger value than the backward term, so that inflation is better captured as a forward-looking process even in the panel framework. Focusing on the output gaps, we see that the foreign output is highly significant while the domestic output is insignificant in all of these models. So again the role of the foreign output gap does not diminish even when incorporating it in the hybrid Phillips Curve. These results also hold when we do not use the lags of the output gaps as excluded instruments.

We next include the change in real exchange rate as a control variable in (18). For a sample of OECD countries,Mihailov, Rumler, and Scharler (2011) using a hybrid Phillips curve has shown that the relative change in the terms of trade is a more important factor in driving inflation than

[51] There is considerable controversy on the empirical fit of the Hybrid Phillips Curve with Rudd and Whelan (2007) showing that the backward factor dominates. Galı and Gertler (1999) and Galı, Gertler, and Lopez-Salido (2001),on the other hand, show that the forward-term is statistically and economically more meaningful than the backward-term in the inflation dynamics of the US and European countries.

[52] The lags of labor share of output has also been used as an instrument in some instances.

the current domestic output gap. However, based on columns three and four we see that the foreign output gap maintains its significance while the real exchange rate has little power in explaining inflation dynamics (in these estimations two lags of the real exchange rate are also used as excluded instruments). In the last two columns, we exclude the foreign output gap and see that the domestic output gap gains significance but that the real exchange rate is still not statistically meaningful. So overall we do not find much evidence that the real exchange rate, as a proxy for the terms of trade, has a strong influence in the country's inflation process.

Table 14: Hybrid Phillips Panel Estimation

Additional Instruments	(1) Two Lags of M2 and Gaps	(2) Two Lags of M2 only	(3) Two Lags of M2 and Gaps	(4) Two Lags of M2 only	(5) Two Lags of M2 and Gaps	(6) Two Lags of M2 only
Exp Inf	0.627***	0.635***	0.624***	0.634***	0.648***	0.664***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)
Lag Inf	0.485***	0.475***	0.489***	0.479***	0.514***	0.487***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Dom Gap	0.119	0.189	0.076	0.135	0.172*	0.052
	(0.16)	(0.21)	(0.14)	(0.21)	(0.09)	(0.12)
For Gap	0.603**	0.628**	0.524*	0.528*		
	(0.26)	(0.32)	(0.28)	(0.33)		
Real Exch			0.041	0.031	-0.046	-0.038
			(0.12)	(0.12)	(0.15)	(0.12)
Total Instrument	11	9	12	10	13	9
p-values						
AR(2) Test	0.28	0.27	0.28	0.28	0.29	0.29
Hansen J-Test	0.16	0.11	0.20	0.15	0.30	0.30

Note: Estimation period 1970-2013 (three-year averages). All cases use four lags of inflation as instruments.