Fixing the Astrolabe: Global Factors and Inflation Models

By Kristin Forbes[1]

Abstract

A trend-cycle decomposition shows that underlying price pressures in most advanced economies remain muted and well below inflation targets. Adding more comprehensive controls for global factors, such as exchange rates, global slack, oil prices, commodity prices, and producer pricing competition, can meaningfully improve the ability of simple models to explain inflation. The role of these global factors varies across time, as well as across countries, but has increased over the last decade for CPI inflation. Standard domestic variables, such as domestic slack and inflation expectations, are still important after controlling for global factors. Nonetheless, adding dynamic global factors can meaningfully improve the ability of simple Phillips curve models to understand inflation dynamics.

1 Introduction

Prince Henry of Portugal, one of the great navigators of the 15th century, relied on the astrolabe to determine latitude and help guide his ships. How would he have responded if his astrolabe started to over-predict the distance the ships had covered? Would he have kept relying on it to set his course – and assume it was just a temporary glitch that would fix itself? Or tweak the instrument to try to improve its reliability in the future? Or simply give up on the instrument and sail based on the more primitive techniques of looking at landmarks, feeling the wind, and relying on instinct?

This is not unlike the decisions central bankers are being forced to make today. In many countries, models and forecasts have consistently been over-predicting inflation. Are the errors temporary – possibly reflecting the unusual period of a prolonged post-crisis recovery followed by sharp falls in commodity prices? Does the basic framework for inflation models simply need some "tweaking" – such as how we measure slack or inflation? Or will monetary policy be forced to rely less on models and central bankers make decisions based more on the "winds" of current inflation and other key landmarks in the economy?

[1] MIT–Sloan School of Management, NBER and CEPR. Thanks to Kostas Theodoridis for assistance in the calculation of the trend-cycle components used in the paper. This paper draws heavily on Forbes (2018), which was prepared for 17th BIS Annual Research Conference held in Zurich on June 22, 2018.

My comments will tackle this question in four ways. First, I will discuss if inflation is really "off course" by using a different framework than the standard Phillips curve approach – a trend-cycle model. Second, I will assess if global factors are important in otherwise standard Phillips curve models. Third, I will examine if the role of these global factors has changed over time. Fourth and finally, I will evaluate how including these dynamic global variables affects the errors in a standard inflation model. I will conclude that adding dynamic global factors can meaningfully improve the ability of simple Phillips curve models to predict and understand inflation dynamics.

2 Is Inflation that Low?

A key focus of the conference this year is that inflation has been surprisingly muted given the solid recovery in economic growth, sharp falls in unemployment and closing of output gaps in many major economies. This interpretation of inflation as "too low" is based on a number of models that have a Phillips curve trade-off at their core, i.e., a negative relationship between domestic slack and wage or price inflation. Each of these models, from the simple one-equation Phillips curves to the more complicated DSGE models used by central banks, requires making a number of assumptions. Key decisions include how to measure slack and inflation (as discussed earlier today in Stock and Watson, 2018), how to measure inflation expectations (as discussed in Coibion *et al*., 2018), the appropriate lag structures to capture delayed effects of different variables, and what supply shocks to incorporate. Given that there are valid arguments for different approaches to these issues, I've found it helpful to use a less-structured framework as a cross-check for understanding inflation dynamics: a trend-cycle decomposition. This approach is "atheoretical" and does not require as many definitional or modelling assumptions. Instead, it simply uses the statistical properties of past inflation data to break inflation into two components: a slow-moving trend and shorter term cyclical movements (or a "cycle") around this trend.

There are several ways to do this type of trend-cycle decomposition, all of which build on the unobserved component stochastic volatility model (UCSV) developed by Stock and Watson (2007). I will focus on a variant called the "ARSV" approach, which was developed in Forbes, Kirkham and Theodoridis (2017) for the UK. This ARSV approach basically uses the UCSV model of Stock and Watson (2007), but allows the deviations in trend inflation to have an autoregressive component (as suggested in Chan, Koop, and Potter, 2013 and Cecchetti *et al*., 2017). To get a sense of whether inflation is unusually low, I will show you estimates for a selection of countries for the period from 2000q1 to 2017q4, based on quarterly, annualized, seasonally-adjusted inflation data.[2] Forbes (2018) provides additional details, as well as results of this trend-cycle decomposition for a larger set of countries.

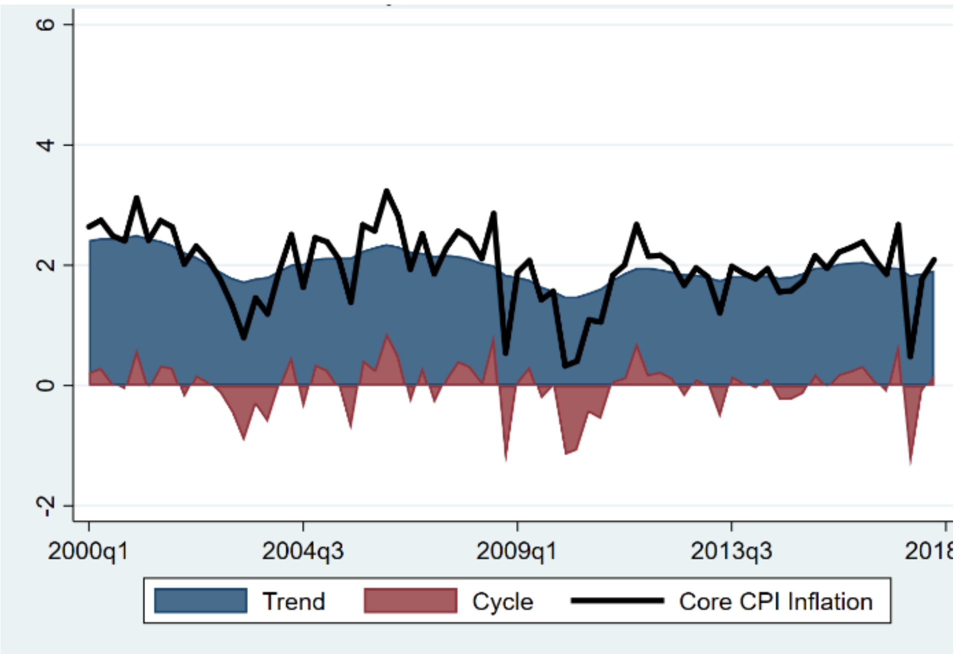
[2] The first 12 observations for each country were used to calibrate the prior information. See Forbes, Kirkham and Theodoridis (2017) for details of this methodology, and Forbes (2018) for details on the sample and statistical properties when applied to the cross-section of countries used below.

Charts 1 and 2 show results for two countries where inflation is close to or above target: the United States and United Kingdom.[3] The black line shows quarterly inflation, with the share identified as "trend" shaded in blue and as the "cycle" in red. In both cases, much of the volatility in inflation is driven by the cyclical component, including the surprising weakness in inflation in the US during 2017 (which was generally not predicted in inflation models). This volatility in inflation, however, generally tracks movements in the slow-moving trend, which was 1.9% for the US and 2.7% in the UK in 2017Q4. This slow moving trend also fluctuates – especially in the UK where the recent waves roughly correspond to fluctuations in sterling. Even in the US, however, trend core CPI inflation has been below 2% for much of the decade since the global financial crisis.

Chart 1

United States: Trend and Cycle Core CPI Inflation

(core inflation)



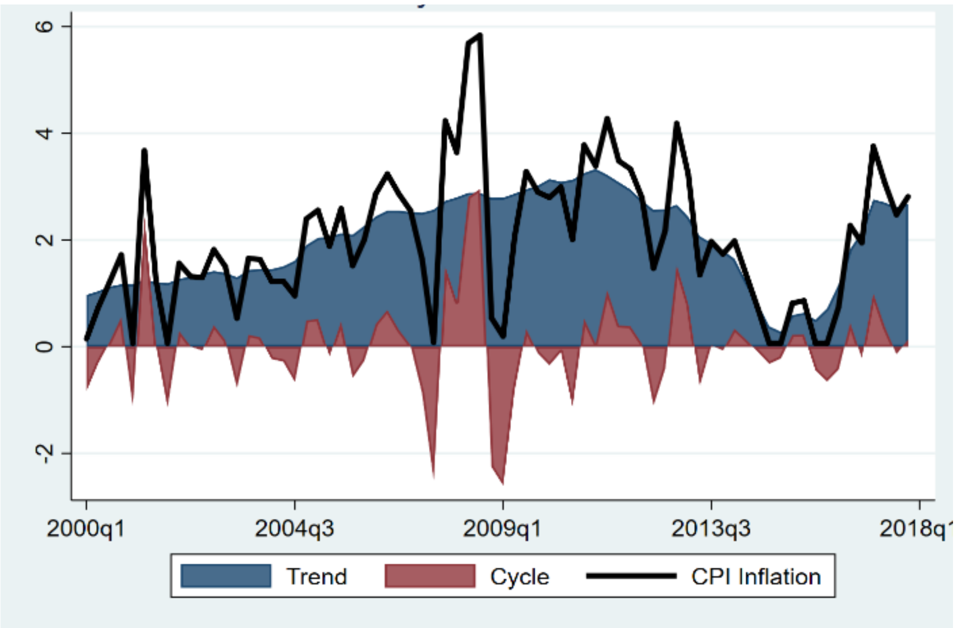
Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

3 I focus on headline CPI inflation for most of the following graphs as inflation targets generally focus on CPI inflation. For the US, however, I focus on core CPI inflation, which is closer to their target.

Chart 2

United Kingdom: Trend and Cycle Core CPI Inflation

(CPI inflation)



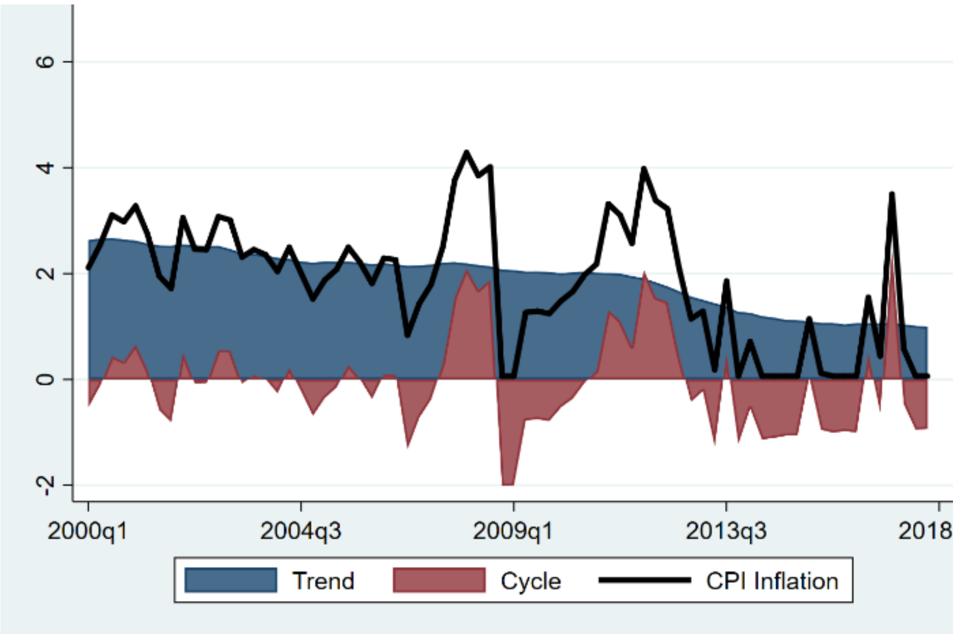
Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

Examples of advanced economies where trend inflation is close to or above target, however, are limited. Most of the advanced economies for which data is available have trend inflation in 2017q4 well below their targets (based on this methodology). For example, Charts 2 and 3 show Italy and Portugal, with patterns typical of many countries in the euro zone; trend inflation declines towards 2% after the euro was adopted, followed by sharp cyclical drags in inflation during the global financial crisis (2008-2009) and euro debt crisis (2012-2014), and a decline in trend inflation from around 2012. Trend inflation remains well below the 2% inflation target in both countries at the end of 2017 (at 1.4% in Portugal and 1.0% in Italy). This decline in trend inflation is also shared by most of the "core" euro area countries that have not been the focus of concerns about debt sustainability and where headline inflation has recently increased. For example, Charts 5 and 6 show that trend inflation in France and Germany was also well below 2% at the end of 2017 (at 0.9% and 1.4%, respectively) with a portion of the recent pickup in CPI inflation driven by the "cycle" and therefore less likely to be persistent.

Chart 3

Italy: Trend and Cycle Core CPI Inflation

(CPI inflation)

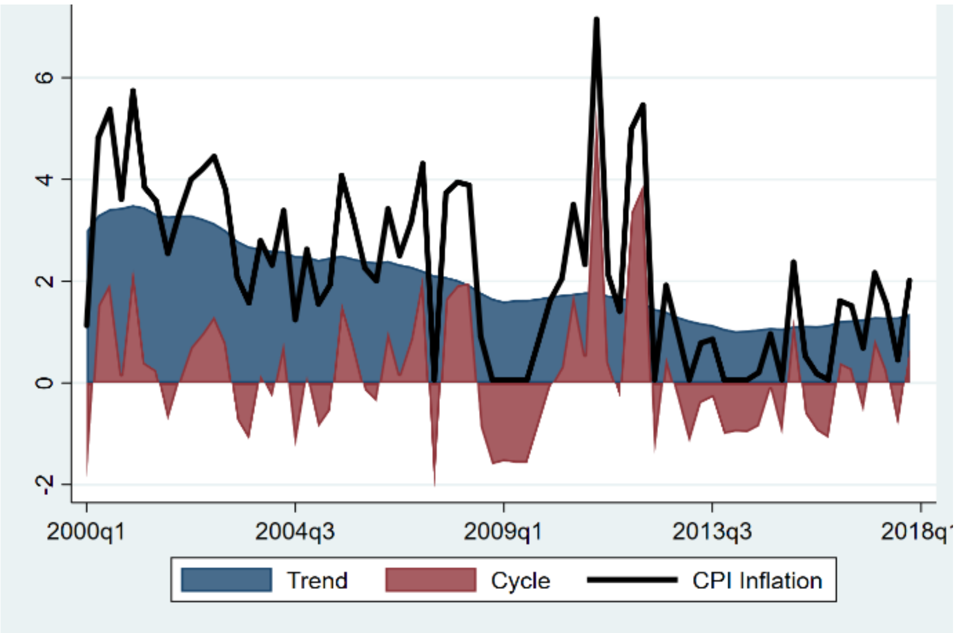


Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

Chart 4

Portugal: Trend and Cycle Core CPI Inflation

(CPI inflation)

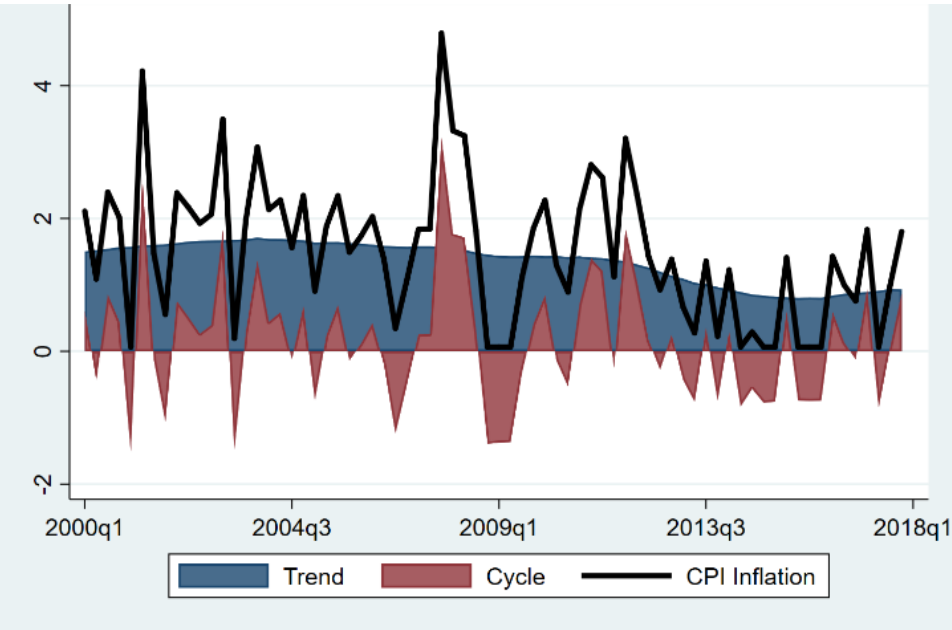


Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

Chart 5

France: Trend and Cycle Core CPI Inflation

(CPI inflation)

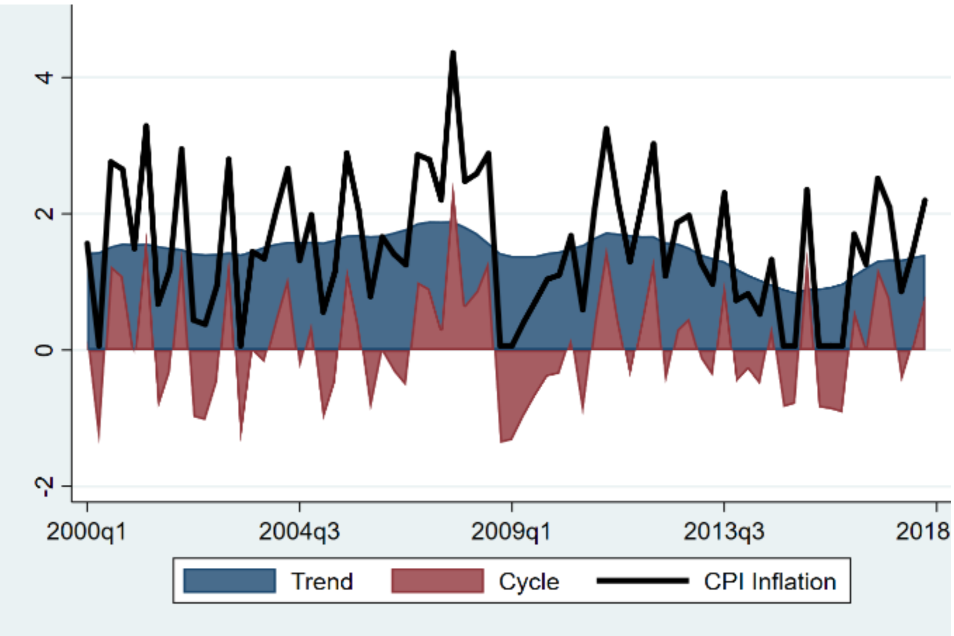


Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

Chart 6

Germany: Trend and Cycle Core CPI Inflation

(CPI inflation)



Sources: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

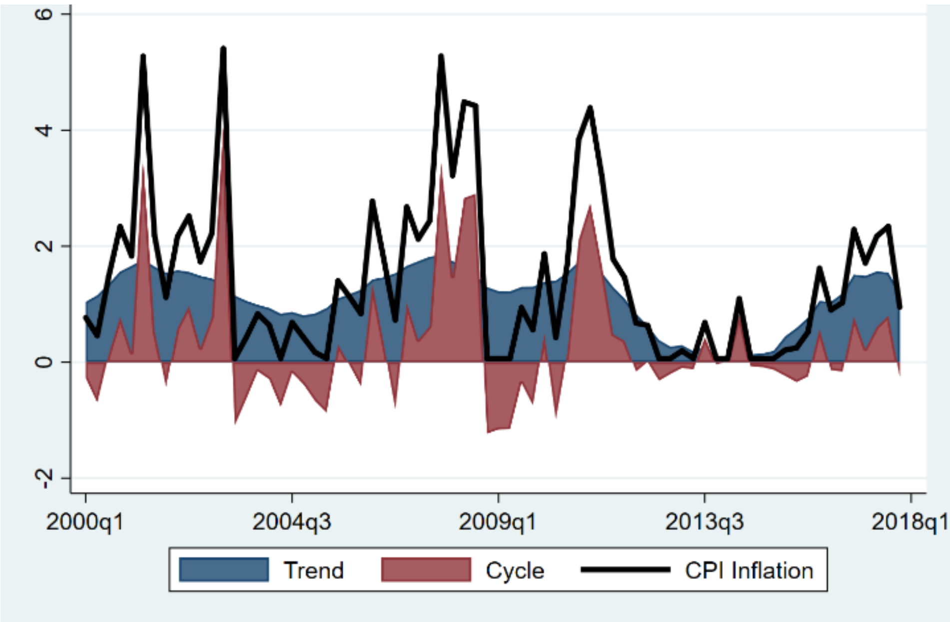
This pattern of weak trend inflation is not just shared by countries in the euro area, but also most advanced economies. As a final example, consider the two countries in

Charts 7 and 8 that currently have unemployment around or below their estimated natural rates, but have struggled to boost inflation to 2%: Sweden and Japan. In Sweden, CPI inflation has picked up sharply from near zero in periods during 2012-2015, but this decomposition suggests that almost half of this rebound is cyclical, so that trend inflation was still only 1.2% in 2017Q4. In Japan, trend inflation has been near zero for almost 15 years, and although it picked up to 0.4% at the end of 2017 – its highest level since 1995q1 – it still has a ways to go to reach 2%.

Chart 7

Sweden: Trend and Cycle Core CPI Inflation

(CPI inflation)

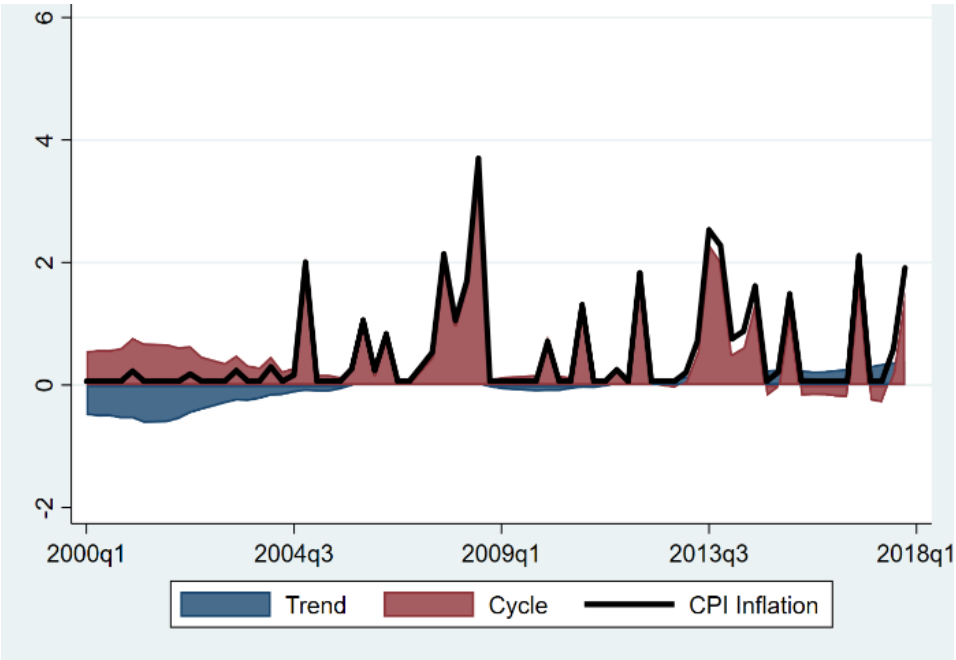


Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

Chart 8

Japan: Trend and Cycle Core CPI Inflation

(CPI inflation)



Source: Based on data in Forbes (2018).
Notes: Calculated using ARSV model developed in Forbes, Kirkham and Theodoridis (2017).

These graphs show a diversity of country experiences in terms of what share of inflation is explained by movements in the short-term cyclical and slower-moving trend components, as well as how stable (or not) is the slow moving trend. One pattern in most of the graphs, however, is the widespread "softness" in inflation. Even in countries such as the US, UK, Sweden and Japan, where output gaps are basically closed (to the best extent that we can estimate them), inflation is not accelerating at the pace one might expect at this stage of the business cycle. Many other countries have experienced solid recoveries and sharp falls in unemployment, and even if there is still some slack (such as many euro area countries), underlying trend inflation still remains muted and well below 2%. Of the 28 advanced economies in the sample for which there is sufficient data to calculate the trend, only 4 had trend inflation either above or within 0.1 percentage points of 2% at the end of 2017 (Australia, Norway, the United Kingdom and United States).

Why are inflationary pressures so muted in advanced economies around the world? Why is there a seeming disconnect between the stage of the economic cycle and inflation?

3 What is Missing from Inflation Models?

There are a number of reasons why inflationary pressures may be muted in advanced economies around the world and inflation generally lower than predicted by standard models. Earlier today, Stock and Watson (2018) suggested that part of the disconnect results from the measurement of inflation, with measures isolating the cyclical component of inflation showing a stronger link to economic activity. Other papers have suggested that part of the disconnect comes from insufficiently capturing the degree of slack in the economy, such as Albuquerque and Baumann (2017) and Hong *et al*. (2018). Yet other papers have highlighted the role of inflation expectations (such as Coibion and Gorodnichenko, 2015) and the credibility of central banks (Miles *et al.*, 2017) in keeping inflation close to target despite sharp swings in output gaps. Borio and Filardo (2007) suggest that it is important to adjust for global slack, not just domestic slack, an explanation which could be even more important since their analysis was done given the weakness in the global economy since the 2008 financial crisis.

Each of these arguments seems to have merit and at least some empirical support – and there are undoubtedly other explanations. Recent work (Forbes, 2018) suggests, however, that at least part of the disconnect results from an insufficient treatment of changes in the global economy in our standard inflation models. The global economy has changed in many fundamental ways since the original Phillips curve framework was developed, such as through increased trade flows, the greater heft of emerging markets and their impact on commodity prices, and the greater ease of using supply chains to shift parts of production to cheaper locations. In the past, standard inflation models may not have needed comprehensive controls for these aspects of globalization as spillovers from the global economy to domestic prices may have been smaller. The standard approach of simply controlling for domestic slack, and often one "supply shock" (such as oil prices or import prices), could have been "sufficient statistics" to capture any effects of changes in the global economy.

As the global economy has evolved and integration has increased, however, it has become more important to explicitly control for these types of changes related to globalization. For example, greater integration in the world economy may have caused global slack, global price competition, exchange rates, and commodity prices (not just for oil) to have different effects on inflation dynamics than in the past. Moreover, if these types of global factors are becoming more important in the inflation process, this could correspond to a smaller role for domestic factors – such as domestic slack and the bargaining power of local workers.

As a test for the role of global factors in the inflation process, I begin by estimating a standard Phillips curve regression that controls for domestic slack, inflation expectations, and lagged inflation, but then I also add a set of five global variables: exchange rates[4], the world output gap, oil prices, commodity prices, and a measure of global producer price dispersion (to capture the role of supply chains, as in Auer,

4 Exchange rates incorporate a global and domestic component, but as they are usually not explicitly included in Phillips curve regressions, I include them as part of the non-traditional set of "global" variables.

Levchenko and Sauré, 2016).[5] I estimate the model for quarterly CPI and core inflation from 1990 to 2017 for a cross-section of up to 43 countries (largely advanced economies, plus several emerging markets for which data is available).

Table 1 shows the results, replicated from Forbes (2018). The positive and significant coefficients on inflation expectations, domestic slack, and lagged inflation all suggest that the standard domestic variables included in most inflation models still play a significant role in explaining inflation dynamics. The significant coefficients on almost all of the global variables, however, suggest that they are also important. More specifically, exchange rate depreciations, larger world output gaps, higher oil and commodity price inflation, and a greater dispersion in PPI prices (less competitive producer pricing) are all correlated with higher CPI and core inflation.

Table 1

Pooled Phillips Curve Regressions: 1990q1-2017q4

(regression results)

	CPI Inflation	Core Inflation
Inflation Expectations	0.670*** (0.073)	0.462*** (0.052)
Lagged Inflation	0.646*** (0.034)	0.704*** (0.024)
Domestic Output Gap	0.094*** (0.017)	0.084*** (0.012)
Real Exchange Rate	-0.020*** (0.006)	-0.013*** (0.004)
World Output Gap	0.072*** (0.023)	0.043*** (0.012)
World Oil Prices	0.002*** (0.001)	0.001** (0.000)
World Commodity Prices	0.010*** (0.002)	0.003** (0.001)
World PPI Dispersion	0.114*** (0.034)	0.019 (0.028)
Adj. R2	**0.55**	**0.63**
# observations	**3002**	**3038**

Sources: Replicated from Forbes (2018).
Notes: Regressions of quarterly, annualized, seasonally-adjusted inflation for a sample of 43 countries with fixed coefficients over full period. *** is significant at the 1% level and ** at the 5% level.

It is important to note, however, that although the variables in Table 1 are significant in the pooled cross-section results, when the same model is estimated for individual countries, the coefficients are less often significant, once again reflecting the diversity of country experiences. For example, consider the estimates for CPI inflation for two different European nations: Germany and Iceland. For Germany,

[5] Inflation expectations is the 5-year ahead forecast from the IMF's World Economic Outlook. The domestic output gap is measured as a principal component of seven measures of domestic slack. The exchange rate is the percent change in the real exchange rate index relative to two years earlier. The world output gap is reported by the OECD. Oil and commodity prices are measured relative to the CPI or core inflation. The dispersion in producer prices is the change in the quarterly variance in PPI prices relative to four quarters earlier for all countries in the sample. See Forbes (2018) for more details on variable definitions, sources, and summary statistics.

inflation expectations, lagged inflation and the world output gap are positively and significantly correlated with CPI inflation, but the coefficients on domestic slack and the other variables are not significant (all at the 10% level). In contrast, for Iceland domestic slack, world oil prices, and the exchange rate are all significantly correlated with CPI inflation (with the expected signs), with no significant role for the other variables. The results for the pooled regressions mask these significant differences in the inflation process for different countries. This could also explain why different studies have found different results on the roles for key variables (such as for global slack); the composition of countries in the sample can significantly affect results.

4 Changes in the Roles of Different Factors over Time

Not only do the factors which drive inflation vary across countries, but also over time. A number of studies have highlighted the instability in the coefficients in Phillips curve models. The coefficients on the global factors affecting inflation could also change over time, particularly given changes in globalization and the many ways in which this could affect firm price-setting decisions. To test for any instability in the role of the global factors affecting inflation, I reestimate the same Phillips curve model shown in Table 1, except now estimate rolling regressions over eight-year windows instead of holding coefficients fixed over the full sample.[6] These rolling estimates confirm that in many cases the coefficients on variables in the Phillips curve relationship change over time.

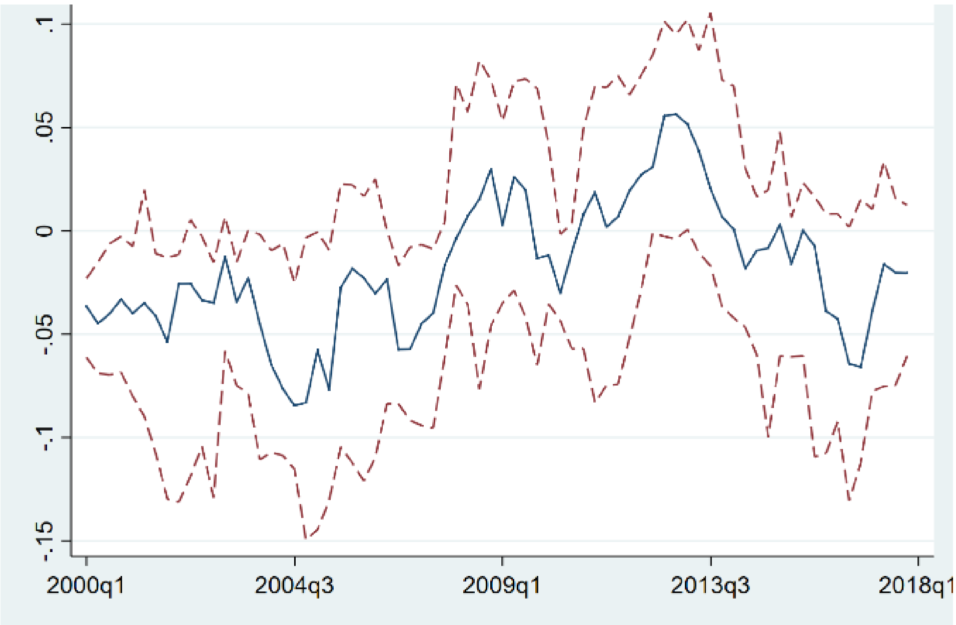
More specifically, Charts 9 through 11 show a sample of these rolling coefficients, focusing on the coefficients on the global variables and domestic slack. Each graph shows the median coefficient estimate when the model is estimated separately for each country for which data is available, with the dashed lines showing the coefficient estimates for the 33% and 66% of the distribution. Chart 9 shows the corresponding coefficients on the real exchange rate; they are negative in the first part of the sample (as expected if depreciations are correlated with higher inflation), with the average coefficient of about -0.05 implying that a 10% depreciation corresponds to roughly a 0.5 percentage point increase in CPI inflation over the following two years. This coefficient, however, becomes smaller and then positive in the period after the financial crisis (albeit becoming negative again more recently). This reduction in pass-through from exchange rate movements to inflation (including the shift to a positive coefficient) could occur if demand shocks were a primary factor causing exchange rate movements over this period, as shown in Forbes, Hjortsoe and Nenova (2015, 2017).

[6] The regression windows are rolled forward one quarter at a time so that the number of observations remains constant across specifications. I focus on time-varying coefficients in rolling regressions, rather than using Kalman-filter based models with time-varying coefficients, due to the evidence in Albuquerque and Baumann (2017) that this yields the lowest RMSE.

Chart 9

Rolling Coefficients on the Real Exchange Rates

(rolling regression coefficient)

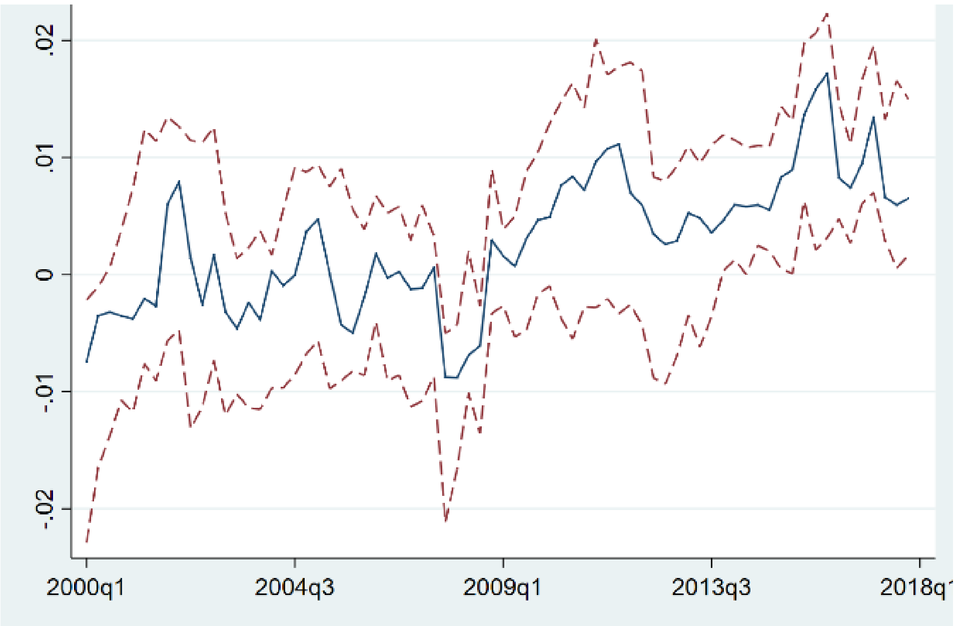


Sources: Based on data in Forbes (2018).
Notes: Median coefficient from rolling regressions from Table 1 using 8-year windows for quarterly, annualized CPI inflation from 1990-2017, estimated separately for each country. Dashed red lines are the 33% and 66% of the distribution.

Chart 10

Rolling Coefficients on Commodity Prices

(rolling regression coefficient)



Sources: Based on data in Forbes (2018).
Notes: Median coefficient from rolling regressions from Table 1 using 8-year windows for quarterly, annualized CPI inflation from 1990-2017, estimated separately for each country. Dashed red lines are the 33% and 66% of the distribution. Commodity prices measured relative to corresponding quarterly CPI inflation.

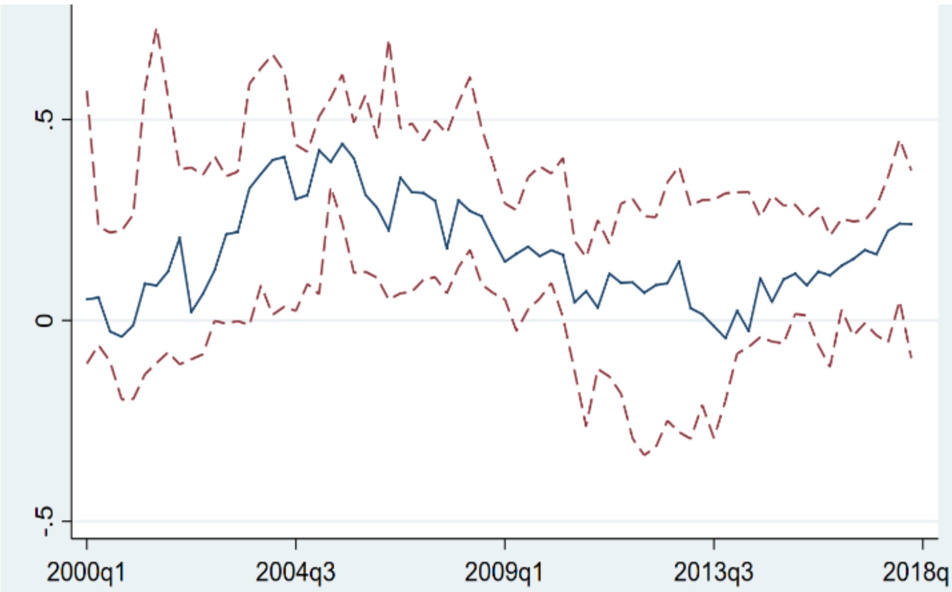
Chart 10 shows the same median rolling coefficients on the variable for relative commodity price inflation excluding energy (with a separate control for oil price inflation). This coefficient on commodity prices also fluctuates over time, but increases after the global financial crisis as well as in the later part of the sample. This suggests that the impact of a given change in commodity prices on CPI inflation has increased over the last decade. Some of the shifts in the coefficients correspond to sharp movements in commodity prices, which would be consistent with nonlinear effects (Hamilton, 2010) and sticky-price models in which firms are more likely to adjust prices after larger price shocks (Ball and Mankiw, 1995). Some of the estimated effects of commodity price movements may also capture changes in growth prospects in emerging markets, a link that has increased over time (see World Bank, 2018).

Also noteworthy are the estimated changes in the median coefficients on the domestic output gap, shown in Chart 11. The coefficient on the domestic output gap was positive during most of the pre-crisis window, but then fell steadily, even becoming negative for part of 2013. This is consistent with the weaker performance of standard Phillips curve models in predicting inflation over much of the crisis and post-crisis period. Over the last few years, however, the coefficient on slack appears to be picking up again, possibly indicating that the traditional relationship between domestic slack and inflation may be beginning to reassert itself.

Chart 11

Rolling Coefficients on Domestic Slack

(rolling regression coefficient)

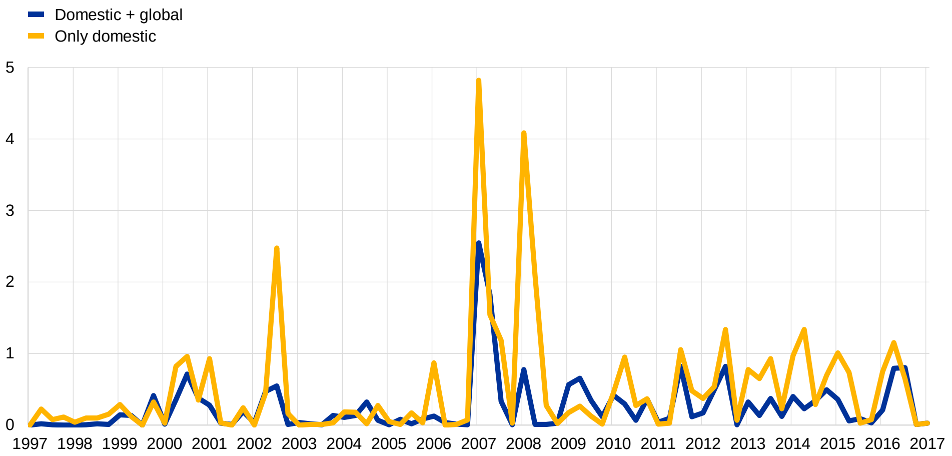


Source: Based on data in Forbes (2018).
Notes: Median coefficient from rolling regressions from Table 1 using 8-year windows for quarterly, annualized CPI inflation from 1990-2017, estimated separately for each country. Dashed red lines are the 33% and 66% of the distribution. Domestic output gap measured as principal component of seven measures of slack.

Chart 12

Fit of Model with and Without Global Variables

(squared deviation of actual from predicted inflation)



Source: Based on data in Forbes (2018).
Notes: Median of squared difference between actual and predicted inflation in model estimated for each country with and without global variables. Regressions for CPI inflation using Phillips curve model in Table 1 with 8-year rolling windows.

5 Pulling it all Together: Adding Time-Varying Global Factors to Dynamic Inflation Models

This set of charts suggests that global factors, which have traditionally not been included in simple inflation models, can significantly affect inflation, and that the role of these global factors (as well as domestic factors) can change over time. But can including dynamic global factors meaningfully improve our ability to understand inflation?

To test this, Chart 12 shows the fit of two simple models predicting inflation: one that only includes the traditional domestic variables (inflation expectations, lagged inflation, and the domestic output gap), and the other which also adds the five global variables (exchange rates, world output gap, oil prices, commodity prices, and the dispersion in global PPI pricing). More specifically, I re-estimate the Phillips curve model from Table 1 for each country individually, using the same sample and variable definitions, but instead of fixing the coefficients over the full period, estimate rolling regressions over eight-year windows (as in Charts 9-11). Then I calculate the difference between actual quarterly CPI inflation and predicted inflation using each model, and graph the squared deviation of this “error” for the median country in the sample. The lighter yellow line shows the “error” for the model using only the domestic variables, and the darker blue line shows the “error” for the model using both the global and domestic variables. Including the global variables meaningfully reduces the “errors” (the deviations between actual and predicted inflation), especially in the later part of the period. This shows that adding global variables to inflation models, and allowing their impact to vary over time and across countries, can meaningfully improve our ability to understand inflation dynamics relative to models which only include domestic factors.

While Chart 12 suggests that including a set of dynamic global factors can improve the performance of our inflation models, it does not show which of the global factors are most important. A closer look at the estimates for individual countries, however, suggests a diversity of experiences – as found for the simple Phillips curve estimates with fixed coefficients.[7] Different global (and domestic) factors play different roles in different countries.

Empirical analysis in Forbes (2018), however, finds several results that are consistently robust for the cross-section of countries. In regressions for CPI inflation, the world output gap and commodity prices appear to be important over the last decade, but not the pre-crisis window. In contrast, in regressions for core inflation, there is less change in the role of the global variables over the last decade, although the exchange rate is important over the full sample period.

6 Conclusions

To conclude, adding global factors – such as exchange rate movements, commodity prices, oil prices, the world output gap, and the competition in producer pricing – to our basic models can meaningfully improve our ability to understand inflation dynamics. This does not mean "throwing away" our standard domestic variables, such as inflation expectations and slack, which both still play a role. Instead, simply adding these more comprehensive controls for global factors to standard inflation models can go some way towards better understanding why inflationary pressures have been so muted in many advanced economies over the last few years, despite solid growth and sharp falls in unemployment. Although the role of different global factors varies over time and across countries, commodity prices and global slack seem to have become more important to understanding CPI inflation over the last decade. Exchange rate movements have continued to be important in explaining movements in CPI as well as core inflation over the last decade – as well as before.

Finally, back to Prince Henry the Navigator's faulty astrolabe. Supposedly the Portuguese sailors were responsible for an "innovation" that made the use of the astrolabe more reliable: read the instrument on solid land (or at least a rock or very calm day). This simple innovation of reading astrolabes in a more stable environment made them more accurate. Similarly, a fairly modest innovation to our simple inflation models – incorporating a more comprehensive set of controls for dynamic global factors – could also make our inflation models more accurate.

[7] See Forbes (2018) for country-specific regression results.

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