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20-6 Low Inflation Bends the Phillips Curve around the World

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ABSTRACT

This paper models inflation by combining the multicountry framework of one of its authors (Forbes) with the nonlinear specification proposed by the other two (Gagnon and Collins). The results find strong support for a Phillips curve that becomes nonlinear when inflation is low, in which case excess economic slack has little effect on inflation. This finding is consistent with evidence of downward nominal wage and price rigidity. The estimates also show a significant and economically meaningful Phillips curve relationship between slack and inflation when slack is negative (i.e., when output is above long-run potential). In this nonlinear model, international factors play a large role in explaining headline inflation, a role that has increased over time, supporting the results of Forbes' linear model.

JEL codes: E31, E37, E52, E58, F62

Keywords: Economic slack, globalization, output gap, price dynamics

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INTRODUCTION

Many economists have noted that the effect of unemployment or economic slack on price and wage inflation has diminished in recent years, even going so far as to question whether the relationship is dead.[1] The Phillips curve relationship between slack and inflation has flattened so much that large changes in slack appear to have little effect on inflation. Numerous studies have attempted to explain this apparent change, proposing explanations such as challenges in measuring slack (Albuquerque and Baumann 2017; Hong et al. 2018); the large component of inflation indexes that is not cyclically sensitive (Stock and Watson 2018); and the stabilizing role of inflation expectations and central bank credibility (Bernanke 2007; Coibion and Gorodnichenko 2015).

Two of the authors of this paper (Gagnon and Collins 2019) propose a different explanation: nonlinearities in the Phillips curve. They show that a nonlinear model—in which the Phillips curve is normally steep but becomes flat when inflation is very low and slack high—can explain US inflation data as well as a linear model in which the Phillips curve has flattened over time. Gagnon and Collins called their model the *low inflation bend model*.[2] This specification was motivated by the fact that firms and workers strongly resist cuts in nominal wages and prices, a phenomenon known as downward nominal wage and price rigidity.[3]

Independently, one of the authors of this paper (Forbes 2019) proposes another explanation: the increased role of globalization. She finds some support for a flattening of the Phillips curve over time in a multicountry panel, with international influences contributing to this weaker relationship (as well as having other significant effects on inflation). The Phillips curve still has a highly statistically significant downward slope in all periods, however, and is thus not completely flat.

This paper tests the Gagnon-Collins low inflation bend model within the specification and larger cross-country data set of Forbes. It finds strong evidence for the low inflation bend model in this multicountry setting. Allowing for this nonlinearity in the Phillips curve leads to a steeper slope in most circumstances and a flatter slope when the effects of downward rigidity become important. Incorporating these features of a low inflation bend model has little effect on the remaining coefficients in our different frameworks and thus supports the key

1 A 2017 paper by Albuquerque and Baumann is entitled "Will US Inflation Awake from the Dead? The Role of Slack and Non-Linearities in the Phillips Curve"; the April 22, 2019 cover story of *Bloomberg Businessweek* magazine shows a deflated and dying dinosaur with the heading "Is Inflation Dead?"

2 Other work (such as Hooper, Mishkin, and Sufi 2019 and Albuquerque and Baumann 2017) finds some support for nonlinearities and shifts in the Phillips curve using different specifications, but these papers estimate their models only for the United States, do not control for international influences, and do not link nonlinearity to the level of inflation (though Albuquerque and Baumann do allow the slope of a linear Phillips curve to shift with inflation).

3 It might seem that downward rigidity should not matter as long as inflation is positive (prices are rising). Aggregate measures of inflation are averages over millions of transactions, however. When average inflation is not far above zero—say, 2 percent—a substantial fraction of transactions is affected by resistance to outright declines (Akerlof, Dickens, and Perry 1996; Fallick, Lettau, and Wascher 2016).

conclusions in Forbes (2019) on the role for international influences on different price measures and an increased role of globalization on headline inflation over the last decade.

Several recent papers review the extensive literature on the Phillips curve.[4] Two recent papers highlight why a relationship between slack and inflation may be obscured in simple time-series analysis. McLeay and Tenreyro (2019) and Geerolf (2020) propose mechanisms to explain a flat or nonexistent Phillips curve in countries with independent monetary policies and flexible exchange rates. McLeay and Tenreyro (2019) argue that inflation-targeting central banks adjust monetary policy to prevent extended periods of high or low slack, such that little of the variation in inflation derives from movements in slack. Geerolf (2020) argues that periods of low slack do put upward pressure on nontradables prices but that central bank reactions to low slack tend to appreciate the exchange rate, putting downward pressure on the prices of tradables and thus generating little net effect on overall inflation. One implication of these studies is that Phillips curves should be steeper and more apparent in states or regions within a currency or monetary union, because they lack independent central banks.

Although these mechanisms may be important and weaken estimates of the Phillips curve in most models that do not have appropriate instruments, the results in this paper (as well as in Gagnon and Collins 2019 and Forbes 2019) indicate that they are not strong enough to completely flatten or eliminate the Phillips curve, even at the national level. The estimates in this paper suggest that the Phillips curve is alive and its slope strongly statistically significant. Incorporating a flat region of the curve in order to allow for downward wage and price rigidity suggests an even steeper Phillips curves when slack is low or inflation is high.

EMPIRICAL FRAMEWORK

This section estimates regressions of the two principal specifications in Forbes (2019, table 2) along with alternatives that add breaks and/or nonlinearities in the Phillips curve as proposed by Gagnon and Collins (2019). The specifications take the following generic form:

$$\pi_{it} = \beta_1 SLACK_{it}^{D} + \beta_2 SLACK_{it}^{D} \times DUMMY_{it} + \beta_3 \pi_{it}^{e} + \beta_4 \pi_{it-1}^{4}$$
$$+ \gamma_1 SLACK_{t}^{W} + \gamma_2 REER_{it} + \gamma_3 POIL_{it}^{W} + \gamma_4 PCOMM_{it}^{W} + \gamma_5 GVC_{t}^{W} + \alpha_i,$$

where variables are defined for each country *i* in quarter *t* as in Forbes (2019):

- π_{it} is quarterly consumer price index (CPI) inflation or core inflation (based on CPI excluding food and energy) at a seasonally adjusted annual rate,[5]

4 See, for example, Gagnon and Collins (2019); Forbes (2019); Ha, Kose, and Ohnsorge (2019); and Miles et al. (2017).

5 Adjustments are also made for large increases in value-added tax in Australia in 2000Q3, Japan in 1997Q2 and 2014Q2, New Zealand in 2010Q4, and the United Kingdom in 2010Q1 and 2011Q1.

- π^{e}_{it} is medium-run inflation expectations, measured by the five-year-ahead forecast for CPI inflation from the *World Economic Outlook* of the International Monetary Fund (IMF),
- π^{4}_{it-1} is a four-quarter average of CPI or core inflation, lagged one quarter,
- $SLACK^{D}_{it}$ is domestic economic slack (the negative of the output gap), measured as the principal component of seven variables (described in appendix table A.1),[6]
- $DUMMY_{it}$ is a dummy variable defined in one of the three ways described below,
- $SLACK^{W}_{t}$ is world economic slack, measured as a weighted average of the estimated output gap in advanced economies and China (described in appendix table A.1),
- $REER_{it}$ is the percent change over eight quarters in a country's real effective exchange rate as reported by the IMF,
- $POIL^{W}_{it}$ is the quarterly annualized change in world oil prices relative to country *i*'s CPI inflation,
- $PCOMM^{W}_{it}$ is the quarterly annualized change in world nonfuel commodity prices relative to country *i*'s CPI inflation,
- GVC^{W}_{it} is the principal component of four variables related to global value chains as described in appendix table A.1, and
- α_{i} refers to the coefficients on a full set of country fixed effects.

FULL SAMPLE RESULTS

The sample includes a cross-section of 31 advanced economies and emerging markets (for a list of countries in the sample, see the appendix table A.2). The regression sample runs from 1996Q1 through 2017Q4, using 1995 data for initial lagged inflation.

Table 1 shows the main results. The regressions in the first four columns include only domestic variables; the regressions in the four columns on the right repeat the same specifications with the full set of international variables used in Forbes (2019).[7] Column 1 is a constant linear Phillips curve. It indicates a significant positive effect of inflation expectations and lagged inflation (as expected).[8] The estimated slope of the Phillips curve slope is rather flat: A 1 percentage point increase in slack reduces inflation by only 0.17 percentage points. This effect is highly statistically significant, however, and a sustained increase in slack would have an effect that builds up over time, as it works its way into lagged inflation and inflation expectations.

6 This measure of slack captures not only any difference between the unemployment rate and the estimated non-accelerating inflation rate of unemployment (NAIRU) but also other forms of slack, such as participation; hours worked; and the share of workers that are part-time, self-employed, or temporary.

7 In order to compare these results with those that include the international variables, we restricted the sample to observations in which all data are available for both specifications.

8 None of the slack coefficients in table 1 is sensitive to either dropping inflation expectations or constraining the coefficients on inflation expectations and lagged inflation to sum to 1.

Table 1
Headline CPI inflation, full sample, 1996Q1–2017Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	*Constant linear*	*Shifting linear*	*Constant nonlinear*	*Low inflation bend*	*Constant linear*	*Shifting linear*	*Constant nonlinear*	*Low inflation bend*
Domestic slack	−0.17*** (0.03)	−0.30*** (0.07)	−0.34*** (0.08)	−0.30*** (0.05)	−0.15*** (0.03)	−0.31*** (0.06)	−0.35*** (0.08)	−0.31*** (0.05)
Domestic slack [inflation < 3]		0.21** (0.09)				0.27*** (0.08)		
Domestic slack > 0			0.34** (0.14)				0.37** (0.14)	
Domestic slack > 0 [inflation < 3]				0.32*** (0.10)				0.38*** (0.09)
Inflation expectations	0.76*** (0.09)	0.78*** (0.10)	0.84*** (0.11)	0.82*** (0.10)	0.70*** (0.10)	0.71*** (0.10)	0.77*** (0.11)	0.75*** (0.11)
Lagged inflation	0.57*** (0.04)	0.58*** (0.05)	0.56*** (0.05)	0.58*** (0.04)	0.60*** (0.04)	0.60*** (0.04)	0.59*** (0.04)	0.61*** (0.03)
World slack					−0.09** (0.04)	−0.11** (0.05)	−0.07* (0.04)	−0.08* (0.04)
Real exchange rate					−0.03*** (0.01)	−0.03*** (0.01)	−0.03*** (0.01)	−0.03*** (0.01)
World oil prices					0.04*** (0.00)	0.04*** (0.00)	0.04*** (0.00)	0.04*** (0.00)
Nonfuel commodity prices					0.05*** (0.01)	0.05*** (0.01)	0.04*** (0.01)	0.04*** (0.01)
Global value chains					−0.11*** (0.03)	−0.13*** (0.03)	−0.14*** (0.04)	−0.14*** (0.03)
Intercept	−0.63*** (0.17)	−0.71*** (0.16)	−1.07*** (0.23)	−1.02*** (0.22)	−0.58*** (0.17)	−0.65*** (0.18)	−1.02*** (0.23)	−1.01*** (0.23)
R-squared	0.478	0.483	0.484	0.486	0.537	0.545	0.543	0.547
Observations	2,635	2,635	2,635	2,635	2,635	2,635	2,635	2,635
F-test *p*-value: Global					0.000	0.000	0.000	0.000

CPI = consumer price index

Note: Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The regression in column 2 adds an interaction of slack with a dummy variable that equals 1 when lagged four-quarter core inflation is less than 3 percent and 0 otherwise. This "shifting linear" model reflects the hypothesis that the Phillips curve becomes flatter when inflation is very low. The interaction term is significant at the 5 percent level. Its inclusion steepens the curve when inflation is high to –0.30 (almost double that of the linear specification in column 1) and flattens the curve when inflation is low to –0.09 (the sum of the two coefficients). The remaining coefficients are not meaningfully affected.

The regression in column 3 adds an interaction of slack with a dummy variable that equals 1 when slack is positive and 0 otherwise. This "constant nonlinear" model reflects a Phillips curve that is steep when the economy is running above potential and flat when the economy is below potential (e.g., in a recession). The interaction term is significant at the 5 percent level. Its inclusion steepens the curve when slack is negative to –0.34 (double that of the linear specification in column 1) and flattens the curve when slack is positive to 0.

The regression in column 4 adds an interaction of slack with a dummy variable that equals 1 when slack is positive and inflation low and 0 otherwise. It corresponds to the "low inflation bend" model of Gagnon and Collins (2019). It is motivated by downward nominal wage and price rigidity that flattens the Phillips curve only when slack is high and inflation low. The interaction coefficient is significant at the 1 percent level; the R^2 of this model is the highest of the first four columns. The estimated slope of the Phillips curve is moderately steep, at –0.30 under most circumstances, but very flat (0.02) when slack is positive and inflation low. To put this result in context, a 1 percentage point increase in slack reduces inflation by 0.30 percentage points in most contexts but has essentially no effect when slack is positive and inflation low. Although the overall fit of the models in columns 2–4 is close in terms of R^2, the better fit of the low inflation bend model is statistically significant at the 5 percent level compared with the shifting linear and constant nonlinear models.[9]

The regressions in the last four columns of table 1 show that adding a broad set of international variables to these four specifications continues to support these nonlinear versions of the Phillips curve. In each case, the coefficient on domestic slack remains negative and significant, and all additional variables (for the shifting linear model, the constant nonlinear model, or the low inflation bend model) continue to be positive and statistically significant. Most of the changes are minor. The best fitting model is the low inflation bend model (column 8). The improvement in fit is significant at the 10 percent level compared with the shifting linear model and the 1 percent level compared with the constant nonlinear model. In columns 6–8, including variables to capture nonlinearities leads to a meaningful steepening of the Phillips curve, which is about twice as steep as in the linear model. Most of the coefficients are remarkably stable when the large set of international variables is added to the simple Philips curve specification.

9 When the shifting linear and low inflation bend models are estimated together (not shown), Wald tests reject dropping the low inflation bend model at the 5 percent level but do not reject dropping the shifting linear model at any level. Similar results obtain for the constant nonlinear model relative to the low inflation bend model.

All of the additional international coefficients have the expected signs and are strongly significant, both individually and jointly (as denoted by the *F*-statistic *p*-values at the bottom of the table). The individual coefficient estimates on these global variables are also fairly constant across the various nonlinear specifications of the Phillips curve. Greater world slack and a stronger real exchange rate depress inflation. Higher oil and commodity prices increase inflation. Growth in global value chains restrains inflation.

Table 2 repeats the same series of regressions as in table 1 for core inflation, defined as the change in the CPI excluding food and energy prices. Given the reduced importance of commodity prices in core inflation, the world oil and nonfuel commodity price variables are replaced by a single commodity price index that includes fuel, as in Forbes (2019, table 6).

The slope of the Phillips curve is somewhat flatter for core inflation in table 2 than that of headline inflation in table 1. The main results are fairly consistent with the results discussed above, however. The slope of the Phillips curve roughly doubles in each of the nonlinear specifications in "normal" times, but the additional nonlinear term is significant in each case and suggests that the Phillips curve can flatten sharply when the thresholds for inflation (< 3 percent) and slack (> 0) are met. The shifting linear and low inflation bend models fit roughly equally well, and both fit better than the constant linear and constant nonlinear models.[10]

The more noteworthy changes in these estimates for core inflation are on the coefficients for the global variables, which are often smaller than for CPI inflation and sometimes insignificant (as in Forbes 2019). The coefficients on the real exchange rate and commodity prices are still statistically significant but smaller than in table 1. The coefficients on world slack and global value chains retain the expected signs but are no longer significant. The *F*-statistics for the joint significance of the international variables are significant at the 5 percent level but not the 1 percent level in columns 5 and 7 and only barely at the 1 percent level in columns 6 and 8. These results suggest that global variables are still important for core inflation but less so than for CPI inflation, even when adjusting for different possible nonlinearities in the Phillips curve.

ROBUSTNESS AND EXTENSIONS

In order to further explore the robustness of our key results supporting a nonlinear specification for the Phillips curve, we examine whether results change when (a) high and low inflation observations are excluded, (b) members of a monetary union are excluded, (c) the dependent variable is wage (instead of CPI or core) inflation, and (d) the sample is divided into precrisis and postcrisis (post-2007) periods.

In a first extension, we assess the impact of excluding outliers and high/low values for inflation based on different criteria. Several countries in the sample experienced periods of unusually high or low inflation, often associated with

10 Based on nested tests as described above for table 1, the improved fit of the low inflation bend model relative to the constant nonlinear model is significant at the 1 percent level. Relative to the shifting linear model, there is a tiny improvement in fit that is significant at the 5 percent level.

Table 2
Core CPI inflation, full sample, 1996Q1–2017Q4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	*Constant linear*	*Shifting linear*	*Constant nonlinear*	*Low inflation bend*	*Constant linear*	*Shifting linear*	*Constant nonlinear*	*Low inflation bend*
Domestic slack	−0.15*** (0.02)	−0.26*** (0.05)	−0.24*** (0.06)	−0.24*** (0.04)	−0.15*** (0.03)	−0.26*** (0.04)	−0.24*** (0.06)	−0.24*** (0.03)
Domestic slack [inflation < 3]		0.19*** (0.06)				0.20*** (0.05)		
Domestic slack > 0			0.18* (0.09)				0.18* (0.09)	
Domestic slack > 0 [inflation < 3]				0.24*** (0.05)				0.25*** (0.05)
Inflation expectations	0.76*** (0.12)	0.77*** (0.12)	0.80*** (0.13)	0.79*** (0.13)	0.76*** (0.12)	0.76*** (0.11)	0.79*** (0.12)	0.78*** (0.12)
Lagged inflation	0.61*** (0.03)	0.62*** (0.03)	0.61*** (0.03)	0.62*** (0.03)	0.62*** (0.03)	0.62*** (0.03)	0.61*** (0.03)	0.63*** (0.03)
World slack					−0.03 (0.03)	−0.05 (0.03)	−0.03 (0.03)	−0.03 (0.03)
Real exchange rate					−0.02*** (0.01)	−0.02*** (0.00)	−0.02*** (0.01)	−0.02*** (0.00)
World commodity prices (including fuel)					0.01** (0.01)	0.01** (0.01)	0.01* (0.01)	0.01** (0.01)
Global value chains					−0.02 (0.03)	−0.03 (0.03)	−0.03 (0.03)	−0.04 (0.03)
Intercept	−0.83*** (0.23)	−0.89*** (0.23)	−1.05*** (0.26)	−1.09*** (0.25)	−0.82*** (0.20)	−0.86*** (0.20)	−1.03*** (0.24)	−1.06*** (0.22)
R-squared	0.600	0.605	0.602	0.605	0.604	0.609	0.605	0.609
Observations	2,636	2,636	2,636	2,636	2,636	2,636	2,636	2,636
F-test *p*-value: Global					0.019	0.008	0.024	0.008

CPI = consumer price index
Note: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

periods of crisis or severe economic stress. The inflation range in the sample used for the regressions in tables 1 and 2 is –10 percent to 35 percent for headline CPI and –10 percent to 30 percent for core CPI.[11] Although these large ranges do not reflect errors in the data, it is possible that inflation has different dynamic properties when far away from the values typical in most advanced economies over the last few years.

To address these concerns, we use two different approaches to assess the role of these inflation observations. The first four columns in table 3 use a more restricted sample, following the approach adopted in Forbes (2019).[12] Table 3 reports the baseline results from columns 1 and 4 of table 2 in Forbes (2019) and then adds the low-inflation bend variable to this specification (in columns 3 and 4). These restrictions generate a regression sample for which inflation ranges from 0 to 12.5 percent. The right half of the table repeats the same regressions but drops the top 99th percentile and bottom 1st percentile of the dependent variable in table 1. This step restricts the regression sample to inflation ranging from –2.5 percent to roughly 17 percent.[13]

When the highest and lowest inflation observations are dropped from the sample using either of these criteria, the Phillips curve slopes in table 3 are uniformly flatter than their counterparts in table 1; the margin is not large, however, and the results remain highly significant.[14] Adding the interaction term of the low inflation bend model continues to increase the Phillips curve slope in general, but it flattens it when inflation is low and slack high (as seen by the sum of the two slack coefficients). Adding the international variables tends to reduce the Phillips curve slope in the constant linear model but has little effect in the low inflation bend model. International variables remain important, with a slightly larger effect of world slack and a slightly smaller effect of global value chains than estimated in table 1 with the less restricted sample.

The results are similar when these different sample restrictions are applied to comparable estimates for core inflation instead of CPI inflation (not shown). In particular, the low inflation bend model fits as well as or better than the other models. The coefficients on slack and on the break in the Phillips curve are always significant at the 1 percent level, with the additional nonlinear control variables leading to a steeper slope under most conditions but a very flat slope when inflation is low and slack high.

11 These ranges are for annualized quarterly inflation rates, which vary more than commonly reported inflation rates calculated on four quarters (or 12 months) of data.

12 Forbes (2019) winsorizes the sample at the 10 percent level for each of the domestic variables in the raw dataset. Many of the affected observations are for emerging markets during periods of stress or early in the sample and reflect observations that were not included in the regressions in this paper because data for some of the independent variables are not available. Other minor changes in the data (the end date for the constructed slack variables and interpolation of IMF forecasts) have no meaningful impact on the results.

13 The shifting linear and constant nonlinear models (not shown) have uniformly lower R^2s than the low inflation bend model.

14 A further restriction of the regression to quarterly annualized inflation rates between –2 percent and 10 percent leads to a further flattening of the Phillips curve slopes and a dramatic drop in R^2, but the low inflation bend model remains highly significant and fits better than the other models.

Table 3
Headline CPI regressions, excluding extreme observations, 1996Q1–2017Q4

	Inflation and domestic control variables winsorized at 10 percent level				Excluding observations with inflation below 1st or above 99th percentile			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	*Constant linear*	*Constant linear*	*Low inflation bend*	*Low inflation bend*	*Constant linear*	*Constant linear*	*Low inflation bend*	*Low inflation bend*
Domestic slack	−0.14*** (0.03)	−0.09*** (0.03)	−0.24*** (0.05)	−0.23*** (0.05)	−0.16*** (0.02)	−0.12*** (0.02)	−0.24*** (0.02)	−0.23*** (0.02)
Domestic slack > 0 [inflation < 3]			0.20** (0.07)	0.28*** (0.06)			0.21*** (0.05)	0.27*** (0.05)
Inflation expectations	0.68*** (0.10)	0.65*** (0.10)	0.72*** (0.09)	0.69*** (0.09)	0.61*** (0.05)	0.56*** (0.06)	0.66*** (0.06)	0.60*** (0.07)
Lagged inflation	0.60*** (0.04)	0.64*** (0.04)	0.61*** (0.04)	0.66*** (0.04)	0.48*** (0.04)	0.52*** (0.04)	0.49*** (0.04)	0.53*** (0.04)
World slack		−0.15*** (0.04)		−0.14*** (0.04)		−0.12*** (0.03)		−0.11*** (0.03)
Real exchange rate		−0.03*** (0.01)		−0.03*** (0.01)		−0.02*** (0.00)		−0.02*** (0.00)
World oil prices		0.03*** (0.00)		0.03*** (0.00)		0.03*** (0.00)		0.04*** (0.00)
Nonfuel commodity prices		0.03*** (0.01)		0.03*** (0.01)		0.04*** (0.01)		0.04*** (0.01)
Global value chains		−0.06** (0.03)		−0.07** (0.03)		−0.08*** (0.02)		−0.10*** (0.03)
Intercept	−0.51* (0.26)	−0.54** (0.23)	−0.74*** (0.24)	−0.84*** (0.23)	−0.11 (0.17)	−0.10 (0.18)	−0.39* (0.19)	−0.42** (0.20)
R-squared	0.418	0.487	0.421	0.493	0.404	0.489	0.410	0.497
Observations	2,635	2,635	2,635	2,635	2,583	2,583	2,583	2,583
F-test *p*-value: Global		0.000		0.000		0.000		0.000

CPI = consumer price index

Note: Regressions in columns 1 and 2 are taken from columns 1 and 4 in Forbes (2019). Columns 3 and 4 add the low inflation bend term to columns 1 and 2. Columns 5–8 correspond to columns 1, 5, 4, 8, respectively, from table 1 after dropping observations with inflation below the 1st or above the 99th percentile. Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As a second extension, we evaluate whether the Phillips curve is more pronounced in regions within a monetary union, as proposed by McLeay and Tenreyro (2019) and Geerolf (2020). The analysis in these two papers suggests that the estimated slopes should be greater when the sample is restricted to countries that were in the euro area for most of the sample.[15]

A test of this hypothesis finds the opposite result. Estimates of the slope of the Phillips curve in a sample of only euro-area countries are smaller in every case than the eight models shown in table 1, and the slopes estimated on non-euro-area countries are uniformly larger. The results are similar for estimates of the Phillips curve using core (instead of CPI) inflation.[16] These results do not provide support for the argument that little variation in inflation is derived from changes in slack (McLeay and Tenreyro 2019) or that changes in movements in traded and nontraded prices balance out in periods of slack (Geerolf 2020).

As a third extension, we follow Forbes (2019, table 7) and repeat the main parts of the analysis for wage inflation. Doing so requires reducing the sample size by 35 percent, because comparable cross-country data on wages are more limited. The regressions have a markedly worse fit, with an R^2 of about 0.15. The Phillips curve slope usually has the correct sign, but it is not always significant, and interaction terms in the shifting linear, constant nonlinear, and low inflation bend models enter with the wrong sign.

These results are somewhat surprising, given the relatively good fit of these models in US data (Gagnon and Collins 2019). The lack of a strong relationship in the cross-country data may reflect higher wage growth outside the United States, so that there are fewer episodes of downward nominal wage rigidities that would be required to estimate the nonlinear terms with any precision. This weak relationship could also result from changes in labor market structures and institutions in different countries that are not captured in this simple model, such that any relationship between wages and the slack variable is overwhelmed by these omitted variables. We hope to explore this puzzle in future work.

As a final extension, in table 4 we examine whether the key results on the nonlinearity in the Philips curve for headline CPI inflation changed over the last decade relative to the precrisis period, a comparison central to the analysis in Forbes (2019). The slope of the constant linear Phillips curve flattens somewhat in the more recent period, whereas the slope of the low inflation bend Phillips curve actually becomes steeper. The degree of nonlinearity (as reflected in the slack interaction coefficient) is much greater over the last decade and is highly significant; in the precrisis window, it is not quite significant at the 10 percent level. These results may reflect the preponderance of negative slack observations in the earlier window and positive slack (corresponding to low inflation) more recently.

Several changes in the other coefficient estimates across the two periods are also worth noting. There is some evidence for reduced inflation persistence in the postcrisis period, with smaller coefficients on lagged inflation. The coefficients on inflation expectations are larger but less significant, perhaps reflecting

15 Countries included in the euro-area sample are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. Denmark is included because its currency has been continuously pegged to the euro.

16 One other noteworthy change is that world slack is typically significant for euro-area countries but never with non-euro-area countries.

Table 4
Headline CPI inflation, different periods, 1996Q1–2017Q4

	Precrisis (1996–2007)				Postcrisis (2008–2017)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	*Constant linear*	*Constant linear*	*Low inflation bend*	*Low inflation bend*	*Constant linear*	*Constant linear*	*Low inflation bend*	*Low inflation bend*
Domestic slack	−0.24*** (0.05)	−0.25*** (0.06)	−0.28*** (0.07)	−0.29*** (0.08)	−0.18*** (0.06)	−0.18*** (0.06)	−0.38*** (0.07)	−0.41*** (0.06)
Domestic slack > 0 [inflation < 3]			0.14 (0.10)	0.14 (0.11)			0.51*** (0.14)	0.55*** (0.11)
Inflation expectations	0.60*** (0.17)	0.65*** (0.17)	0.59*** (0.17)	0.65*** (0.17)	0.95* (0.50)	0.55 (0.44)	1.15** (0.46)	0.81** (0.37)
Lagged inflation	0.58*** (0.05)	0.58*** (0.04)	0.59*** (0.05)	0.60*** (0.04)	0.40*** (0.05)	0.46*** (0.04)	0.41*** (0.06)	0.47*** (0.04)
World slack		−0.35** (0.13)		−0.35** (0.13)		−0.41*** (0.10)		−0.33*** (0.08)
Real exchange rate		−0.02*** (0.01)		−0.02*** (0.01)		−0.04*** (0.01)		−0.04*** (0.01)
World oil prices		0.03*** (0.01)		0.03*** (0.01)		0.04*** (0.00)		0.04*** (0.00)
Nonfuel commodity prices		0.01 (0.02)		0.01 (0.02)		0.05*** (0.01)		0.04*** (0.01)
Global value chains		−0.30*** (0.10)		−0.31*** (0.10)		−0.41*** (0.12)		−0.43*** (0.12)
Intercept	−0.22 (0.33)	−0.78** (0.35)	−0.33 (0.34)	−0.90** (0.35)	−0.78 (1.00)	0.79 (0.86)	−1.66* (0.92)	−0.30 (0.75)
R-squared	0.473	0.502	0.474	0.503	0.230	0.421	0.264	0.458
Observations	1,404	1,404	1,404	1,404	1,231	1,231	1,231	1,231
F-test *p*-value: Global		0.000		0.000		0.000		0.000

CPI = consumer price index
Note: Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

less variation in expectations over the last decade. The coefficients on the international variables also become larger and more statistically significant in the second period, supporting the results in Forbes (2019) that global factors played a greater role in CPI inflation dynamics over the last decade.[17] Other results for core inflation across the two subsamples (not reported) are broadly similar to those for headline inflation and continue to suggest a more modest impact of the international variables on core than headline inflation.

CONCLUSION

The analysis in this paper finds strong evidence that the Phillips curve is nonlinear as a result of downward nominal wage and price rigidities. A "low-inflation bend model," which controls for periods when countries have both economic slack and low inflation, explains CPI and core inflation better than simple linear and nonlinear Phillips curve models. The results also suggest that the slope of the Phillips curve is steeper than generally estimated in linear models; it becomes roughly twice as steep when inflation is at least 3 percent or there is no slack in the economy.

The estimates of this Phillips curve relationship are not only significant but also economically meaningful. In the baseline estimates, a 1 percentage point reduction in slack increases inflation about 0.3 percentage point immediately, with additional increases over time as lagged inflation and inflation expectations begin to rise. If inflation is running below 3 percent and there is spare capacity in the economy, the relationship between slack and inflation falls to almost zero. These results for a cross-section of countries are consistent with the results in Gagnon and Collins (2019) for the United States and are robust to controlling for international influences (as in Forbes 2019). The results are also robust across different samples and time periods.

These results have important implications for the current debate on monetary policy and the potential risks to inflation from a "high-pressure" economy (where unemployment falls below the level believed to be the natural rate). It suggests that although recent reductions in unemployment and slack appear to have had negligible effects on inflation, this weak relationship may not persist. If slack is indeed now negative (i.e., output is above potential) in a country such as the United States, then any further reductions in slack could have increasingly large effects on inflation.

The results also suggest that when inflation is starting from the low level found in most advanced economies today, it is unlikely to pick up very quickly, even if slack remains somewhat negative. If economies were to fall into recession soon, perhaps as a result of a global pandemic, inflation likely would not immediately fall much farther, because the economy would be returning to the flat section of the Phillips curve. One important question for future work will be where the "bend" (i.e., the threshold that separates economies from being in the flat and steep sections of the Phillips curve) is in different countries.

17 The coefficients on world slack and global value chains are much larger in both subsamples than they are in the full sample (as also found in Forbes 2019). This result does not occur with core inflation, but may reflect the fact that the variation in these variables is greater across the full time period than across the shorter subsamples.

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APPENDIX A
DATA DEFINITIONS AND LIST OF COUNTRIES IN THE SAMPLE

Table A.1
Data definitions

Variable	*Definition*	*Details*	*Source*
Inflation and price data			
Commodity prices	World commodity price index, including fuel	Calculated as quarterly percentage changes in regressions measured as difference relative to quarterly consumer price index (CPI) inflation	Index data from the International Monetary Fund (IMF)
Commodity prices, except fuel	World commodity price index, excluding fuel	Calculated as quarterly percentage changes in regressions measured as difference relative to quarterly CPI inflation	Index from Datastream (code: WDXWPCN.F)
Core CPI inflation	Consumer prices (all items except food and energy)	Calculated as quarterly percentage changes, annualized and seasonally adjusted	Index data from the Organization for Economic Cooperation and Development (OECD)
CPI inflation	Consumer prices (all items)	Calculated as quarterly percentage changes, annualized and seasonally adjusted	Index data from IMF
Inflation expectations	Five-year ahead forecast for CPI inflation	Forecasts released in spring *World Economic Outlook* (WEO) are treated as Q1. Forecasts, in fall WEO are treated as Q3. Forecasts in Q2 and Q4 are interpolated between the nearest spring and fall forecasts	IMF, from historical WEO forecasts (www.imf.org/external/pubs/ft/weo/faq.htm)
Oil prices	World oil price index	Index of crude oil, Brent, spot prices in US$, calculated as quarterly percentage changes in regressions measured as difference relative to quarterly CPI inflation	Index from Datastream (code: WDXWPOI.F)
Wage inflation	Hourly earnings in the private sector	Calculated as quarterly percentage changes, annualized and seasonally adjusted	Index data from OECD

table continues

Table A.1
Data definitions (continued)

Variable	*Definition*	*Details*	*Source*
Labor market and slack data			
Domestic slack	Principal component of seven measures of domestic slack (positive value indicates more slack)	Negative of principal component of as many of the following variables as available: OECD domestic output gap, unemployment gap, participation gap, hours gap, involuntary workers gap, self-employment gap and temporary workers gap, all defined below	Calculated based on other labor market and slack data listed below
Hours gap	Difference between hours worked and "normal" hours	Calculated as percentage of "normal" hours worked (sample average for each country)	Calculated based on OECD data
Involuntary part-time worker gap	Difference between "normal" involuntary workers and current involuntary workers	Calculated as percentage of "normal" involuntary workers (sample average for each country), available annually and interpolated to quarterly	Calculated based on data from Hong et al. (2018)
OECD domestic output gap	Output gap as percent of GDP	Available annually and interpolated to quarterly	OECD
Participation gap	Gap between actual participation rate and "normal" participation rate	Calculated as percentage of "normal" participation rate (sample average for each country), available annually and interpolated to quarterly	Calculated based on OECD data
Self-employment gap	Difference between "normal" self-employment and current rate of self-employment	Calculated as percentage of "normal" self-employment (sample average for each country)	Calculated based on OECD data
Temporary worker gap	Difference between "normal" temporary and current temporary workers	Calculated as percentage of "normal" temporary workers (sample average for each country), available annually and interpolated to quarterly	Calculated based on data from Hong et al. (2018)
Unemployment gap	Difference between non-accelerating inflation rate of unemployment (NAIRU) and unemployment rate	Available annually and interpolated to quarterly	OECD

table continues

Table A.1
Data definitions (continued)

Variable	*Definition*	*Details*	*Source*
World slack	Weighted average of slack in advanced economies and China	Slack in advanced economies reported by the IMF; slack in China calculated as deviation in growth over previous two years relevant to current quarter. Weights vary over time based on IMF calculation of advanced economy share of global GDP.	Calculated based on IMF data
Other control variables			
Global value chains	Principal component of four measures	Components are (a) relative growth of merchandise trade volumes relative to global GDP; (b) traded intermediate goods as share of global GDP; (c) share of traded intermediate goods that are "complex," in the sense that they cross country borders at least twice; and (d) producer price index dispersion (defined below). Data are available annually and interpolated to quarterly.	First three components from Li, Meng, and Wang (2019)
Real exchange rate index	Real effective exchange rate based on consumer prices	Percentage change in real exchange rate, relative to eight quarters earlier	IMF *International Financial Statistics*

Note: CPI and core inflation are adjusted for increases in value-added tax in Australia in 2000Q3, Japan in 1997Q2 and 2014Q2, New Zealand in 2010Q4, and the United Kingdom in 2010Q1 and 2011Q1.

Table A.2
Advanced and emerging-market economies in the sample

Type of economy	**Countries**
Advanced	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, France, Finland, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Latvia, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, the United Kingdom, and the United States
Emerging-market	Chile, Hungary, Mexico, and Poland

Note: Division between advanced and emerging-market economies is based on definitions in *World Economic Outlook*, October 2017.

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