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Low Inflation Bends the Phillips Curve around the World

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Abstract

This paper finds strong support for a Phillips curve that becomes nonlinear when inflation is "low"—which our baseline model defines as less than 3 percent. The nonlinear curve is steep when output is above potential (slack is negative) but flat when output is below potential (slack is positive) so that further increases in economic slack have little effect on inflation. This finding is consistent with evidence of downward nominal wage and price rigidity. When inflation is high, the Phillips curve is linear and relatively steep. These results are robust to placing the threshold between the high and low inflation regimes at 2, 3, or 4 percent inflation or for a threshold based on country-specific medians of inflation. In this nonlinear model, international factors play a large role in explaining headline inflation (albeit less so for core inflation), a role that has been increasing since the global financial crisis. These results provide evidence of channels which could boost inflation in the future, even if they were dormant before the Covid pandemic.

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1. Introduction

Many economists have noted that the effect of unemployment or economic slack on price and wage inflation was weaker before the Covid pandemic, even going so far as to question if the relationship is "dead".[1] In other words, the Phillips curve relationship between slack and inflation had flattened so much that large changes in slack appeared 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 indices that is not cyclically sensitive (Stock and Watson, 2018), the decline in worker bargaining power (Lombardi et al., 2020) and the stabilizing role of inflation expectations and central bank credibility (Coibion and Gorodnichenko, 2015; Bernanke, 2007).

Another explanation for the apparent flattening of the Phillips curve is nonlinearities in the relationship between slack and inflation. Gagnon and Collins (2019) show that a nonlinear model—in which the Phillips curve is normally steep but becomes flat only when inflation is very low and slack is high—can explain US inflation data as well as a linear model in which the Phillips curve has flattened over time. We call this 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]

Another factor that could explain a flattening of the Phillips curve over time is the increased role of globalization. Forbes (2020) shows that in a multi-country panel, international influences can affect the slope of the Phillips curve (as well as having other significant effects on inflation). The Phillips curve still has a highly statistically significant downward slope in all periods after controlling for these global influences, however, and is thus not completely flat.

This paper tests the low inflation bend model within a cross-country data set that also includes controls for the role of globalization. It finds strong evidence for the low inflation bend model in this multi-country setting (both with and without controls for global factors). 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. Moreover, incorporating these features of a low inflation bend model has little effect on the remaining coefficients in our different frameworks, thus supporting a role for international influences on different price measures and an increased role of globalization on headline inflation over the last decade.

This analysis builds on an extensive literature on the Phillips curve, recently well summarized in Ha et al. (2019) and Miles et al. (2017). The theoretical motivation and specific control

[1]For example, see the title of Albuquerque and Baumann (2017) and the cover story of *Bloomberg Businessweek* magazine on April 22, 2019, which shows a deflated and dying dinosaur with the heading "Is Inflation Dead?".

[2]Other work has found some support for nonlinearities and shifts in the Phillips curve using different specifications, such as Hooper et al. (2019) and Albuquerque and Baumann (2017), 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 the latter paper does 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, however, are averages over millions of transactions. When average inflation is not far above zero, say two percent, a substantial fraction of transactions becomes affected by resistance to outright declines (Akerlof et al., 1996; Fallick et al., 2016).

variables used in these models predicting inflation have varied somewhat over time, such as the addition of inflation expectations in the "New Keynesian" framework[4] and more focus on supply shocks in the "triangle" model developed in Gordon (2007). At the core of each of these models, however, has been a focus on the relationship of inflation with domestic slack—the Phillips curve—which has appeared to "flatten" in recent decades. Two recent additions to this literature merit additional mention: the endogenous behavior of central banks and role of globalization.[5]

One recent focus of this literature that could explain the breakdown of the Phillips curve is that inflation-targeting central banks which adjust monetary policy to prevent extended periods of high or low slack will reduce the variation in inflation derived from movements in slack (Jorgensen and Lansing, 2019; McLeay and Tenreyro, 2019).[6] McLeay and Tenreyro suggest adjusting for this with US state-level data, in which case they find evidence of a steeper and robust Phillips curve. Hazell et al. (2020) also use state-level data and still find some flattening of the Phillips curve since the 1980s, which they argue is driven by long-run inflation expectations becoming more firmly anchored. This paper is not able to fully control for this endogenous behavior of central banks in its cross-country framework, an approach which would be expected to weaken estimates of the Phillips curve relationship.[7] It is noteworthy, however, that the results in this paper still find evidence of a robust Phillips curve when nonlinearity is incorporated, indicating that any such downward bias from endogeneity is not strong enough to completely flatten or eliminate the Phillips curve, even at the national level.

Another recent addition to this literature is a focus on the role of globalization. Global interactions have traditionally played an ancillary role in Phillips curve models, especially for large advanced economies. In some papers, global variables are completely ignored. This has been justified by the assumption that any changes in the global economy should be captured in measures of domestic slack or import prices, so these measures are sufficient statistics for changes in the global economy. In the mid-2000s, however, the role of global factors gained attention as policymakers discussed how increased imports from low-wage economies appeared to be moderating inflation (Yellen, 2006), a focus which gained even more prominence when Borio and Filardo (2007) showed that global slack was becoming more important than domestic slack in inflation models. This prompted a heated debate on the role of global factors—with some papers finding less support for an effect of globalization (e.g., Ball, 2006 and Ihrig et al., 2010). The debate shifted after the 2008 crisis as research focused on explaining the "Missing Deflation"

[4]See Hornstein (2008) for a summary of key models and research leading to the New Keynesian Phillips curve.

[5]Another focus of the recent literature on inflation is the fall in the natural rate of interest around the world, as in Holston et al. (2017), Wynne and Zhang (2018a,b) and Grossman et al. (2019). Incorporating this in empirical models is extremely challenging, however, given the very wide range in estimates of the natural rate. For example, Forbes (2019) shows the huge discrepancy in estimates of the natural rate in the US, UK and Euro area using very similar methodologies—a discrepancy that is likely to be even larger in other economies used in this paper.

[6]In contrast, Geerolf (2020) models this endogeneity concern by incorporating an international component. He 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 tradables prices and thus generating little net effect on overall inflation.

[7]In principle, controlling for inflation expectations should remove this bias, but expectations cannot be measured with a high degree of precision.

in the post-crisis period with domestic variables (such as financial frictions in Gilchrist et al., 2017). The debate on the role of global factors has recently reemerged, however, as a possible explanation for why inflation remained muted in the 2010s. Forbes (2020) provides an extensive summary of this work and simultaneously evaluates the role of five different global factors (instead of just considering individual factors in isolation, as done in past work). This more inclusive set of five global factors is the basis of the analysis below.

The estimates in this paper build on this body of research to suggest that the Phillips curve is alive and the slope is strongly statistically significant, whether one accounts for global factors or not. 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.

The remainder of this paper is divided into four sections. Section 2 outlines the empirical framework and measurement of different variables. Section 3 presents the main results for several different nonlinear models, with and without global variables. Section 4 reports an extensive series of robustness tests and extensions. Section 5 concludes.

2. Empirical Framework and Variables

The baseline regression specifications follow Forbes (2020), with the addition of a term in Gagnon and Collins (2019) that captures various nonlinearities by interacting slack with a dummy variable:

$$\begin{aligned} n_{it} = \beta_1 SLACK^D_{it} + \beta_2 SLACK^D_{it}\, x\, DUMMY_{it} + \beta_3 \pi^e_{it} + \beta_4 \pi^4_{it-1} + \gamma_1 SLACK^W_t \\ + \gamma_2 REER_{it} + \gamma_3 POIL^W_{it} + \gamma_4 PCOMM^W_{it} + \gamma_5 GVC^W_t + a_i. \end{aligned} \tag{1}$$

The sample includes a large cross-section of 31 advanced economies and emerging markets. For a list of countries in the sample, see Appendix A. The regression sample runs from 1996Q1 through 2017Q4, using 1995 data for initial lagged inflation. Variables are defined below, with more detail on definitions and data sources in Appendix B.

- π_{it} is quarterly consumer price index (CPI) inflation or core inflation (based on the CPI excluding food and energy) at a seasonally adjusted annual rate;[8]
- π^e is medium-run inflation expectations, measured by the five-year-ahead forecast for CPI inflation from the International Monetary Fund's (IMF) World Economic Outlook;
- 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 more detail below);[9]
- $DUMMY_{it}$ is a dummy variable defined in one of three ways described below;

[8] Adjustments are also made for several large VAT increases: Australia in 2000Q3, Japan in 1997Q2 and 2014Q2, New Zealand in 2010Q4, and United Kingdom in 2010Q1 and 2011Q1.

[9] This measure of slack captures not only any difference between the unemployment rate and estimated NAIRU, but also other forms of slack—such as in participation, hours worked, and the share of workers that are part-time, self-employed or temporary. See discussion in text below.

- $SLACK_t^W$ is world economic slack, measured as a weighted average of the estimated output gap in advanced economies and China (described in Appendix B);
- $REER_{it}$ is the percent change over eight quarters in a country's real effective exchange rate as reported by the IMF;
- $POIL_{it}^W$ is the quarterly change in world oil prices relative to country i's CPI inflation;
- $PCOMM_{it}^W$ is the quarterly change in world nonfuel commodity prices relative to country i's CPI inflation;
- GVC_t^W is the principal component of four variables related to global value chains (described in Appendix B);
- α_i refers to the coefficients on a full set of country fixed effects.

Many of these variables are standard in the literature, but the key measure of domestic slack merits additional discussion. Papers such as Albuquerque and Baumann (2017) and Hong et al. (2018) have convincingly demonstrated the importance of measuring slack more broadly than simply the deviation of unemployment from a hard-to-estimate NAIRU. An unemployment gap may not capture important aspects of slack, such as the "discouraged workers" who are no longer recorded as looking for work, or people who are working part-time, fewer hours, or self-employed, but would prefer to be working full-time and/or more hours at a company. Data on these other aspects of slack, however, are not widely available on a comparable basis across countries, so we follow Forbes (2020) and Albuquerque and Baumann (2017) and estimate a principal component of labor market slack for each country, building on the set of cross-country variables in Hong et al. (2018). More specifically, the principal component is calculated using three "gaps" based on OECD data (the output gap, unemployment gap, and participation gap) and four "gaps" calculated as percent deviations from the "normal" level (for hours worked per person employed, the share of involuntary part-time workers, the share of temporary workers, and the share of self-employed workers).[10] Many of these variables are not available for all countries in the sample, in which case the principal component is calculated using as many as are available for each country, ensuring that a consistent set of variables is included throughout the sample period.

3. Full Sample Results

Table 1 reports the central set of results based on the specification in equation (1) and variables discussed above. The regressions in the first four columns include only domestic variables, while the regressions in the four columns on the right repeat the same specifications with the full set of international variables.[11] (The coefficients in the first four columns are not noticeably

[10]"Normal" is defined as the relevant mean for each country over the sample period. The last three measures are as a share of total employed. The hours data is from the OECD and involuntary workers, temporary workers, and self-employed were all shared by Hong et al. (2018). Many are only available annually and are interpolated to quarterly to calculate the principal component.

[11]In order to compare the results with just the domestic variables with those which include the international variables, the sample is restricted to observations in which all data are available for both specifications.

affected by the inclusion of a common time effect.) Column (1) is a constant linear Phillips curve and indicates a significant positive effect of inflation expectations and lagged inflation (as expected).[12] The estimated slope of the Phillips curve is negative but rather shallow; a one 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.

The regression reported 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 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 in recession or just at full employment. The interaction term is significant at the 5 percent level. Its inclusion steepens the curve when slack is negative to 0.35 (more than double that of the linear specification in column (1)), and flattens the curve when slack is positive, to roughly 0.

The regression in column (4) adds an interaction of slack with a dummy variable that equals 1 when slack is positive and inflation is low (and 0 otherwise). This corresponds to the "low inflation bend" model. It is motivated by downward nominal wage and price rigidity that flattens the Phillips curve only when slack is high and inflation is low. The interaction coefficient is significant at the 1 percent level and 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 is low. To put this in context, a one 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.

The regressions shown 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 the additional variables (either for the shifting linear model, constant nonlinear model, or low inflation bend model) all continue to be positive and statistically significant. Most of the changes are fairly minor. Once again, the best fitting model is the low inflation bend model (column (8)) and in each case including variables to capture nonlinearities leads to a meaningful steepening of the Phillips curve—continuing to be about double that in the linear model. In fact, most of the coefficients are remarkably stable when the large set of international variables is added to the simple Phillips curve specification.

[12] 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 one.

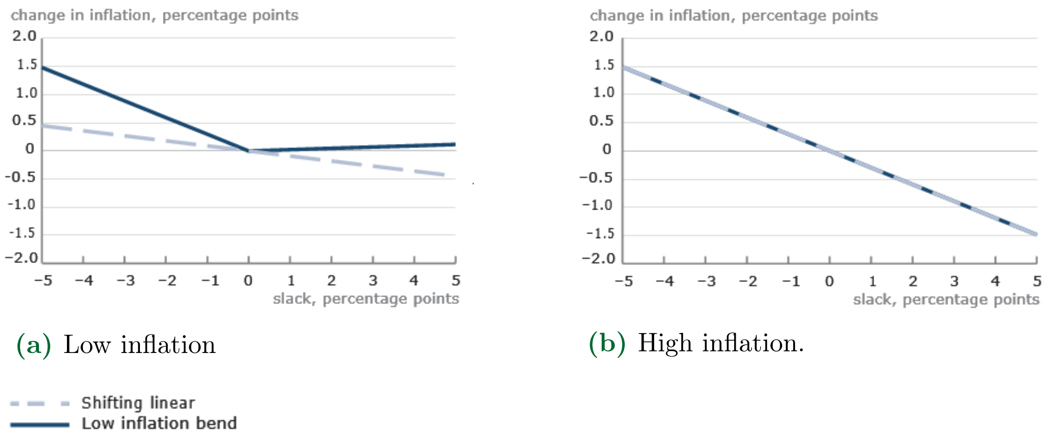
Table 1
Headline CPI inflation, 1996Q1–2017Q4.

	(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***	-0.30***	-0.35***	-0.30***	-0.15***	-0.32***	-0.35***	-0.31***
	(0.03)	(0.07)	(0.08)	(0.05)	(0.03)	(0.06)	(0.08)	(0.05)
Inflation < 3		0.21**				0.27***		
		(0.09)				(0.08)		
Domestic slack > 0			0.35**				0.38**	
			(0.14)				(0.14)	
Domestic slack > 0 and inflation < 3				0.32***				0.38***
				(0.10)				(0.10)
Inflation expectations	0.79***	0.80***	0.87***	0.85***	0.73***	0.74***	0.80***	0.79***
	(0.09)	(0.09)	(0.10)	(0.10)	(0.08)	(0.09)	(0.10)	(0.09)
Lagged inflation	0.56***	0.57***	0.55***	0.58***	0.59***	0.59***	0.58***	0.60***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)
World slack					-0.09**	-0.11**	-0.08*	-0.08*
					(0.04)	(0.05)	(0.04)	(0.04)
Real exchange rate					-0.03***	-0.03***	-0.03***	-0.03***
					(0.01)	(0.01)	(0.01)	(0.01)
World oil prices					0.04***	0.04***	0.04***	0.04***
					(0.00)	(0.00)	(0.00)	(0.00)
Nonfuel commodity prices					0.05***	0.05***	0.04***	0.04***
					(0.01)	(0.01)	(0.01)	(0.01)
Global value chains					-0.11***	-0.12***	-0.13***	-0.13***
					(0.03)	(0.03)	(0.04)	(0.03)
Intercept	-0.67***	-0.75***	-1.12***	-1.06***	-0.63***	-0.70***	-1.07***	-1.06***
	(0.17)	(0.17)	(0.22)	(0.22)	(0.16)	(0.17)	(0.21)	(0.22)
R-squared	0.472	0.478	0.478	0.480	0.532	0.540	0.538	0.543
Observations	2,633	2,633	2,633	2,633	2,633	2,633	2,633	2,633
F-test *p*-value: Global					0.000	0.000	0.000	0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

It is also worth noting that the coefficients on the additional international variables always 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.

Figure 1 displays the Phillips curves implied by columns (2) and (4) of Table 1. In each panel, the horizontal axis displays economic slack and the vertical axis displays the marginal effect of slack on inflation after conditioning on the other variables in the equation. (In other words, the panels display the relevant slack coefficients times the value of slack.) The panel on the left refers to periods of low inflation (below 3 percent); the panel on the right refers to periods of high inflation (above 3 percent). In the left panel, the Phillips curves from the two models are notably different. The shifting linear model has a relatively flat slope of −0.09, whereas the low inflation bend model has a slope of −0.30 when slack is negative and 0.02 when slack is positive. In the right panel, the two models are essentially identical, with linear slopes of −0.30 when lagged inflation is high.



(a) Low inflation

(b) High inflation.

Source: Authors' calculations based on columns (2) and (4) of Table 1.

Figure 1. Two estimated Phillips curves.

Table 2

Core CPI inflation, 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***	-0.26***	-0.24***	-0.24***	-0.15***	-0.26***	-0.24***	-0.24***
	(0.02)	(0.05)	(0.06)	(0.04)	(0.03)	(0.04)	(0.06)	(0.03)
Inflation < 3		0.19***				0.20***		
		(0.06)				(0.05)		
Domestic slack > 0			0.18*				0.18*	
			(0.09)				(0.09)	
Domestic slack > 0				0.24***				0.25***
and inflation < 3				(0.05)				(0.05)
Inflation expectations	0.76***	0.77***	0.80***	0.79***	0.76***	0.76***	0.79***	0.78***
	(0.12)	(0.12)	(0.13)	(0.13)	(0.12)	(0.11)	(0.12)	(0.12)
Lagged inflation	0.61***	0.62***	0.61***	0.62***	0.62***	0.62***	0.61***	0.63***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
World slack					-0.03	-0.05	-0.03	-0.03
					(0.03)	(0.03)	(0.03)	(0.03)
Real exchange rate					-0.02***	-0.02***	-0.02***	-0.02***
					(0.01)	(0.00)	(0.01)	(0.00)
World commodity prices					0.01**	0.01**	0.01*	0.01**
(including fuel)					(0.01)	(0.01)	(0.01)	(0.01)
Global value chains					-0.02	-0.03	-0.03	-0.04
					(0.03)	(0.03)	(0.03)	(0.03)
Intercept	-0.83***	-0.89***	-1.05***	-1.09***	-0.82***	-0.86***	-1.03***	-1.06***
	(0.23)	(0.23)	(0.26)	(0.25)	(0.20)	(0.20)	(0.24)	(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

Notes: CPI = consumer price index. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 repeats the same series of regressions as in Table 1, except for core inflation, which is 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.

The slope of the Phillips curve is somewhat less steep for core inflation in Table 2 compared to that of headline inflation in Table 1. The key results discussed above, however, are fairly consistent. 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 the Phillips curve can flatten sharply when the specific threshold for inflation (< 3 percent) and/or slack (> 0) is 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.

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. More specifically, 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 always at the 1 percent level, suggesting 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.

4. Robustness and Extensions

In order to explore the robustness of our key results supporting a nonlinear specification for the Phillips curve, we examine if results change when: (1) high and low inflation observations are excluded; (2) different inflation thresholds are used to locate the change in the Phillips curve slope; (3) domestic slack is measured using the unemployment gap or output gap, rather than our more comprehensive measure; (4) members of a monetary union are excluded or the regression focuses only members of a monetary union; (5) emerging-market economies are excluded; (6) the dependent variable is wage (instead of CPI or core) inflation; (7) time-fixed effects are included instead of the global variables; and (8) the sample is divided into pre-crisis and post-crisis (post-2007) periods.

First, we assess the impact of excluding outliers and high/low values for inflation based on different criteria. This could be important as several countries in the sample experienced periods of unusually high or low inflation, often associated with periods of crisis or severe economic stress. The inflation range in the sample used for the regressions in Tables 1 and 2 is from -10 percent to 35 percent for headline CPI, and -10 percent to 30 percent for core CPI.[13] Although these 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 outliers. The first four columns in Table 3 use a more restricted sample by winsorizing the inflation and domestic control variables at the 10 percent level. It reports the constant linear model with and without international variables, and then adds the low-inflation bend variable

[13] It is worth noting that these are annualized quarterly inflation rates, which vary more than commonly reported inflation rates calculated on four quarters (or 12 months) of data.

Table 3
Headline CPI inflation, 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	-0.15***	-0.09***	-0.24***	-0.23***	-0.16***	-0.12***	-0.24***	-0.23***
	(0.03)	(0.03)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)	(0.02)
Domestic slack > 0 and inflation < 3			0.19**	0.27***			0.21***	0.27***
			(0.07)	(0.06)			(0.05)	(0.05)
Inflation expectations	0.75***	0.71***	0.77***	0.73***	0.60***	0.55***	0.65***	0.60***
	(0.11)	(0.11)	(0.12)	(0.13)	(0.06)	(0.07)	(0.06)	(0.07)
Lagged inflation	0.58***	0.62***	0.59***	0.64***	0.48***	0.51***	0.49***	0.52***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)
World slack		-0.15***		-0.14***		-0.12***		-0.11***
		(0.03)		(0.04)		(0.03)		(0.03)
Real exchange rate		-0.03***		-0.03***		-0.02***		-0.02***
		(0.01)		(0.01)		(0.00)		(0.00)
World oil prices		0.03***		0.03***		0.03***		0.04***
		(0.00)		(0.00)		(0.00)		(0.00)
Nonfuel commodity prices		0.03***		0.03***		0.04***		0.04***
		(0.01)		(0.01)		(0.01)		(0.01)
Global value chains		-0.06**		-0.07***		-0.08***		-0.10***
		(0.03)		(0.03)		(0.02)		(0.03)
Intercept	-0.61**	-0.62**	-0.81**	-0.88**	-0.08	-0.07	-0.36*	-0.40*
	(0.27)	(0.25)	(0.31)	(0.32)	(0.18)	(0.19)	(0.20)	(0.21)
R-squared	0.417	0.487	0.420	0.492	0.396	0.483	0.402	0.491
Observations	2,633	2,633	2,633	2,633	2,581	2,581	2,581	2,581
F-test p-value: Global		0.000		0.000		0.000		0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

to this specification (in columns (3) and (4)). These restrictions generate a regression sample for which inflation ranges from 0 percent 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 (CPI inflation) in Table 1. This restricts the regression sample to inflation ranging from -2.5 percent to roughly 17 percent.[14]

When the highest and lowest inflation observations are dropped from the sample using either of these criteria in Table 3, the Phillips curve slopes are uniformly smaller than their counterparts in Table 1, but not by a large margin and they remain highly significant.[15] Adding the interaction term of the low inflation bend model continues to increase the Phillips curve slope in general, but flattens it when inflation is low and slack is 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

[14] The shifting linear and constant nonlinear models, not shown, had uniformly lower R^2s than the low inflation bend model.

[15] A further restriction of the regression to quarterly annualized inflation rates between -2 percent and 10 percent leads to a further reduction in the Phillips curve slopes and a dramatic drop in regression R^2s, but the low inflation bend model remains highly significant and continues to have a higher explanatory power than the other models.

Table 4
Headline CPI inflation, different inflation thresholds for the low inflation bend model, 1996Q1–2017Q4.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	k=2 percent		k=3 percent (baseline)		k=4 percent		k=country median	
Domestic slack	-0.27***	-0.27***	-0.30***	-0.31***	-0.32***	-0.34***	-0.26***	-0.26***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Domestic slack > 0 and inflation < k	0.32***	0.36***	0.32***	0.38***	0.36***	0.42***	0.26**	0.29***
	(0.09)	(0.08)	(0.10)	(0.10)	(0.09)	(0.09)	(0.10)	(0.10)
Inflation expectations	0.85***	0.79***	0.85***	0.79***	0.85***	0.78***	0.84***	0.78***
	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Lagged inflation	0.58***	0.60***	0.58***	0.60***	0.58***	0.61***	0.58***	0.60***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
World slack		-0.07*		-0.08*		-0.08*		-0.08*
		(0.04)		(0.04)		(0.05)		(0.04)
Real exchange rate		-0.02***		-0.03***		-0.03***		-0.02***
		(0.01)		(0.01)		(0.01)		(0.01)
World oil prices		0.04***		0.04***		0.04***		0.04***
		(0.00)		(0.00)		(0.00)		(0.00)
Nonfuel commodity prices		0.04***		0.04***		0.04***		0.04***
		(0.01)		(0.01)		(0.01)		(0.01)
Global value chains		-0.12***		-0.13***		-0.14***		-0.12***
		(0.04)		(0.03)		(0.03)		(0.04)
Intercept	-1.03***	-1.00***	-1.06***	-1.06***	-1.12***	-1.10***	-0.97***	-0.94***
	(0.21)	(0.21)	(0.22)	(0.22)	(0.20)	(0.20)	(0.19)	(0.19)
R-squared	0.481	0.542	0.480	0.543	0.482	0.544	0.478	0.539
Observations	2,633	2,633	2,633	2,633	2,633	2,633	2,633	2,633
F-test p-value: Global		0.000		0.000		0.000		0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

value chains than estimated in Table 1 with the less restricted sample.

When these different sample restrictions are applied to comparable estimates for core inflation (instead of CPI inflation), the results are similar (not shown). In particular, the low inflation bend model fits as well 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 is high.

As a second extension, we explore the sensitivity of our Phillips curve slope coefficients to different inflation thresholds (for the change in the slope). Table 4 displays estimates of the low inflation bend model of Table 1 for thresholds of 2 percent, 3 percent (used in all other tables), 4 percent, and a different threshold for each country set at that country's median inflation rate. The slope coefficients are very close across thresholds and never significantly different from each other. The equation fit (measured by the R^2) is similar across thresholds. Similar results hold for core inflation. These results suggest that the information in the data that identifies different Phillips curve slopes is concentrated in observations with inflation less than 2 percent and greater than 4 percent.

Next, for our third extension we consider two simpler measures of economic slack: the out-

Table 5
Headline CPI inflation, different slack measures, 1996Q1–2017Q4.

	Output gap				Unemployment gap			
	(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	-0.13***	-0.11***	-0.27***	-0.30***	-0.07*	-0.04	-0.10	-0.12
	(0.03)	(0.03)	(0.06)	(0.06)	(0.03)	(0.04)	(0.10)	(0.09)
Domestic slack > 0			0.27***	0.34***			0.06	0.14
and inflation < 3			(0.10)	(0.09)			(0.13)	(0.11)
Inflation expectations	0.67***	0.62***	0.79***	0.73***	0.72***	0.68***	0.73***	0.69***
	(0.11)	(0.11)	(0.13)	(0.13)	(0.09)	(0.10)	(0.08)	(0.09)
Lagged inflation	0.56***	0.59***	0.57***	0.59***	0.60***	0.62***	0.61***	0.62***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
World slack		-0.08*		-0.04		-0.17***		-0.16***
		(0.04)		(0.04)		(0.04)		(0.04)
Real exchange rate		-0.03***		-0.03***		-0.02***		-0.02***
		(0.01)		(0.01)		(0.01)		(0.01)
World oil prices		0.04***		0.04***		0.04***		0.04***
		(0.00)		(0.00)		(0.00)		(0.00)
Nonfuel commodity		0.05***		0.04***		0.04***		0.04***
prices		(0.01)		(0.01)		(0.01)		(0.01)
Global value chains		-0.11***		-0.16***		-0.11***		-0.12***
		(0.03)		(0.03)		(0.03)		(0.03)
Intercept	-0.36	-0.36	-0.89***	-0.91**	-0.63***	-0.57***	-0.68***	-0.67***
	(0.23)	(0.24)	(0.31)	(0.33)	(0.18)	(0.18)	(0.15)	(0.16)
R-squared	0.440	0.503	0.451	0.518	0.464	0.527	0.464	0.528
Observations	2,619	2,619	2,619	2,619	2,549	2,549	2,549	2,549
F-test p-value: Global		0.000		0.000		0.000		0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. $^{***}\,p < 0.01$, $^{**}\,p < 0.05$, $^{*}\,p < 0.1$.

put gap and the unemployment gap. These are narrower measures of slack than the principal component based on seven variables used to construct our baseline measure, but are closer to most work estimating Phillips curves. The first four columns of Table 5 display results for the constant linear and low inflation bend models using the output gap. The slope coefficients are close to, and never significantly different from, those in Table 1. The last four columns of Table 5 display results using the unemployment gap. Here the slope coefficients are significantly smaller than those in Table 1, but the signs are unchanged. This weaker estimated relationship between inflation and slack when slack is measured using a narrower definition agrees with prior work and supports arguments that the unemployment rate is not a sufficient statistic for slack.[16] On balance, this result supports our choice of a more broadly based slack measure. Similar results hold for core inflation.

The fourth extension is to evaluate if 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 higher when the sample is restricted to countries that were in the euro area for most of the sample (compared with the remaining

[16] Changes in labor market institutions or labor force demographics that are not fully controlled for by the unemployment gap measure may contribute to this result. Gagnon and Collins (2019) find that the unemployment gap yields robustly significant Phillips curve slopes in US data.

Table 6
Headline CPI inflation, euro area vs. non-euro area, 1996Q1–2017Q4.

	Euro area				Non-euro area			
	(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	-0.16***	-0.05*	-0.19**	-0.19***	-0.20***	-0.21***	-0.32***	-0.33***
	(0.01)	(0.03)	(0.09)	(0.06)	(0.03)	(0.03)	(0.05)	(0.05)
Domestic slack > 0 and inflation < 3			0.06	0.25*			0.38***	0.38***
			(0.15)	(0.12)			(0.12)	(0.12)
Inflation expectations	0.76***	0.65***	0.77***	0.69***	0.79***	0.74***	0.86***	0.80***
	(0.10)	(0.08)	(0.12)	(0.08)	(0.10)	(0.10)	(0.11)	(0.12)
Lagged inflation	0.42***	0.55***	0.42***	0.55***	0.58***	0.59***	0.59***	0.60***
	(0.06)	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)	(0.04)	(0.03)
World slack		-0.15**		-0.13**		-0.08		-0.07
		(0.06)		(0.05)		(0.06)		(0.06)
Real exchange rate		-0.05***		-0.05***		-0.02***		-0.02***
		(0.01)		(0.01)		(0.01)		(0.01)
World oil prices		0.04***		0.04***		0.03***		0.04***
		(0.00)		(0.00)		(0.01)		(0.01)
Nonfuel commodity prices		0.05***		0.05***		0.05***		0.04***
		(0.01)		(0.01)		(0.01)		(0.01)
Global value chains		-0.11***		-0.13***		-0.13**		-0.14**
		(0.03)		(0.04)		(0.06)		(0.06)
Intercept	-0.33*	-0.41**	-0.40	-0.71**	-0.72***	-0.61**	-1.19***	-1.07***
	(0.17)	(0.15)	(0.31)	(0.23)	(0.20)	(0.22)	(0.27)	(0.32)
R-squared	0.274	0.459	0.274	0.465	0.510	0.550	0.520	0.559
Observations	1,131	1,131	1,131	1,131	1,502	1,502	1,502	1,502
F-test p-value: Global		0.000		0.000		0.000		0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

countries).[17] A test of this hypothesis, however, finds the opposite result, as shown in Table 6. Estimates of the slope of the Phillips curve in a sample of only euro-area countries (the first four columns) were smaller in every case than the slopes estimated for non-euro-area countries (the last four columns). The results are similar for estimates of the Phillips curve using core (instead of CPI) inflation.[18] These results, however, are far from a conclusive test of differences in Phillips curve slopes within versus across monetary unions. Our sample starts shortly before the launch of European Monetary Union, and convergence across countries continued to be an important story for many years after union. Also, fiscal policy differences within the euro area may have played a role comparable to monetary differences outside the euro area.

The fifth extension is to drop the emerging-market countries from the sample. As there are only four emerging markets in our sample (listed in Appendix A), it is perhaps not surprising that dropping these observations has only a minor effect on the regression results. The Phillips curve slopes are slightly, but not significantly, larger in this reduced sample.

[17]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 pegged to the euro continuously.

[18]One other noteworthy change is that world slack is typically significant with euro-area countries, but never with non-euro-area countries.

As a sixth extension, we repeat the main parts of the analysis for wage inflation. This necessitates a 35 percent drop in the sample size, due to more limited data on wages that is comparable across countries. The regressions have a markedly worse fit, with an R^2 of around 0.15. The Phillips curve slope almost always has the correct sign, but is not always significant, and the interaction terms in the shifting linear, constant nonlinear, and low inflation bend models have the wrong signs, though not significantly so for the low inflation bend model. This is somewhat surprising, given the relatively good fit of these models in US data.[19] The lack of a strong relationship in the cross-country data may result from higher real 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 seventh extension, we include time-fixed effects in our standard specification with the domestic variables (i.e., the left side of Table 1) as an alternative control for common global factors. There are no noticeable changes in the Phillips curve coefficients and no significant changes in the other coefficients.

As a final extension, Table 7 examines if the key results on the nonlinearity of the Phillips curve for headline CPI inflation change over the last decade relative to the pre-crisis period.[20] To test this, we estimate the main regression from Table 1 for two samples: 1996–2007 (the pre-crisis window) and 2008–2017 (the post-crisis window). The slope of the constant linear Phillips curve declines somewhat in the more recent period (as found in other research), whereas the slope of the low inflation bend Phillips curve actually steepens. The degree of nonlinearity (as reflected in the slack interaction coefficient) is much greater over the last decade and is highly significant, whereas it is not quite significant at the 10 percent level in the pre-crisis window. This 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 different periods are also worth noting. The coefficients on inflation expectations are sometimes insignificant and the coefficients on lagged inflation are slightly smaller in the post-crisis window. This could reflect the more modest variation in these inflation variables over the last decade, particularly in inflation expectations, which makes it hard to estimate these coefficients with any precision. The coefficients on the international variables also become larger and more statistically significant in the

[19] Gagnon and Collins (2019) find a robust Phillips curve using the employment cost index, which controls for changes in the composition of employment. They find a less robust relationship using compensation per hour, which does not control for composition effects and is similar to the international wage data in that respect.

[20] Another approach could be to estimate the Phillips curve with rolling regression windows. This approach is limited, however, by the need to include a full business cycle in any such regression combined with the relatively short time series in our data (of only 20 years). For more discussion of the advantages and disadvantages of rolling regressions, as well as for estimates of how different coefficient estimates change over shorter periods of time (including global factors), see Forbes (2020).

Table 7
Headline CPI inflation, different periods, 1996Q1–2017Q4.

	Pre-crisis (1996–2007)				Post-crisis (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***	-0.25***	-0.28***	-0.29***	-0.18***	-0.18***	-0.38***	-0.41***
	(0.05)	(0.06)	(0.07)	(0.08)	(0.06)	(0.06)	(0.07)	(0.06)
Domestic slack > 0			0.14	0.14			0.51***	0.55***
and inflation < 3			(0.10)	(0.11)			(0.14)	(0.11)
Inflation expectations	0.63***	0.70***	0.63***	0.70***	0.95*	0.55	1.15**	0.81**
	(0.16)	(0.16)	(0.16)	(0.16)	(0.50)	(0.44)	(0.46)	(0.37)
Lagged inflation	0.57***	0.57***	0.58***	0.58***	0.40***	0.46***	0.41***	0.47***
	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.06)	(0.04)
World slack		-0.35**		-0.36**		-0.41***		-0.33***
		(0.13)		(0.13)		(0.10)		(0.08)
Real exchange rate		-0.02***		-0.02***		-0.04***		-0.04***
		(0.01)		(0.01)		(0.01)		(0.01)
World oil prices		0.03***		0.03***		0.04***		0.04***
		(0.01)		(0.01)		(0.00)		(0.00)
Nonfuel commodity		0.01		0.01		0.05***		0.04***
prices		(0.02)		(0.02)		(0.01)		(0.01)
Global value chains		-0.30***		-0.30***		-0.41***		-0.43***
		(0.10)		(0.10)		(0.12)		(0.12)
Intercept	-0.27	-0.85**	-0.38	-0.97***	-0.78	0.79	-1.66*	-0.30
	(0.33)	(0.34)	(0.34)	(0.35)	(1.00)	(0.86)	(0.92)	(0.75)
R-squared	0.465	0.494	0.466	0.495	0.230	0.421	0.264	0.458
Observations	1,402	1,402	1,402	1,402	1,231	1,231	1,231	1,231
F-test p-value: Global		0.000		0.000		0.000		0.000

Notes: CPI = consumer price index. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

post-crisis period, suggesting that global factors play a greater role in CPI inflation dynamics over the last decade.[21] Other results for core inflation across the two sub-samples (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.[22]

To summarize, the baseline results reported in Table 1 are robust to this wide range of sensitivity tests and extensions. The Phillips curve is alive and the slope is strongly statistically significant, whether one accounts for global factors or not. 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.

[21] The coefficients on world slack and global value chains are much larger in both subsamples than they are in the full sample. 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.

[22] We also tested if the coefficient estimates changed over time with a different version of Table 7: restricting the intercept and country fixed effects to be constant across the entire sample but allowing the coefficients on the other variables to vary across periods. This had no noticeable effect on any coefficient except that the inflation expectations coefficient declined in the post-crisis sample, though not by a statistically significant amount.

5. Conclusion

The analysis in this paper finds strong evidence that the Phillips curve is nonlinear due to 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; for example, the slope of the Phillips curve roughly doubles when inflation is high (using different thresholds) and/or when economic slack is negative (that is, output is above potential). Moreover, 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 corresponds to about a 0.3 to 0.4 percentage point increase in inflation under most circumstances. On the other hand, 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. The results are 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 reductions in unemployment and slack prior to the COVID-19 pandemic appear to have had negligible effects on inflation, this weak relationship may not persist. If slack becomes negative again (i.e., output rises above potential), then any further reductions in slack could have increasingly large effects on inflation. Moreover, in countries where inflation has picked up to above 3 percent, it is possible that reductions in slack may begin to have more impact on inflation than in the past, even before output gaps close. One important question for future work, however, will be where the "bend" is in different countries, i.e., the thresholds that separate them from being in the flat and steep sections of the Phillips curve.

Appendix A

The sample used in this analysis includes a cross-section of 31 countries. See Table A.1 below for a list of countries in the sample.

Table A.1
Country sample.

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

Note: Division between advanced and emerging-market economies is based on definitions in IMF, World Economic Outlook, 2017Q4.

Appendix B

This appendix provides more detail on the definitions of the variables and data sources used in this analysis.

Table B.1
Data definitions and statistics.

Variable	Definition	Details	Source
Inflation and Price Data			
Commodity prices	World commodity price index, including fuel	Calculated as quarterly percent changes, in regressions measured as difference relative to quarterly CPI inflation	Index data from IMF
Commodity prices, exc. fuel	World commodity price index, excluding fuel	Calculated as quarterly percent 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 percent changes, annualized, seasonally adjusted[1]	Index data from OECD
CPI inflation	Consumer prices, all items	Calculated as quarterly percent changes, annualized, seasonally adjusted[1]	Index data from IMF
Inflation expectations	5-year ahead forecast for CPI inflation	Forecasts released in spring WEO are treated as Q1, and in fall WEO as Q3; Q2 and Q4 are interpolated between the nearest spring and fall forecasts	IMF, from historical WEO forecasts, at: https://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 percent 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 percent changes, annualized, seasonally adjusted	Index data from OECD
Labor Market and Slack Data			
Domestic slack	Principal component of 7 measures of domestic slack, with a positive value indicating more slack	Negative of principal component of as many of 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
Hours gap	Difference between hours worked and "normal" hours	Calculated as % of "normal" hours worked (the sample average for each country)	Calculated based on OECD data
Involuntary part-time workers gap	Difference between "normal" involuntary workers and current involuntary workers	Calculated as % of "normal" involuntary workers (the sample average for each country); available annually and interpolated to quarterly	Calculated based on Hong et al. (2018) data
OECD domestic output gap	Output gap as % of GDP	Available annually and interpolated to quarterly	OECD
Participation gap	Gap between actual participation rate and "normal" participation rate	Calculated as % of "normal" participation rate (the sample average for each country); available annually and interpolated to quarterly	Calculated based on OECD data

(Continued on next page)

Table B.1 (continued)

Variable	Definition	Details	Source
Self-employment gap	Difference between "normal" self- employment and current rate of self- employment	Calculated as % of "normal" self- employment (sample average for each country)	Calculated based on OECD data
Temporary workers gap	Difference between "normal" temporary workers and current temporary workers	Calculated as % of "normal" temporary workers (sample average for each country); available annually and interpolated to quarterly	Calculated based on Hong et al. (2018) data
Unemployment gap	Difference of NAIRU and unemployment rate	Available annually and interpolated to quarterly	OECD
World slack	Weighted average of slack in advanced economies and China	Slack in advanced economies reported by the IMF; slack in China calculated as the deviation in growth over the previous two years relevant to the 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: (1) relative growth of merchandise trade volumes relative to global GDP; (2) traded intermediate goods as a share of global GDP; (3) share of these traded intermediate goods that are "complex" in the sense that they cross country borders at least twice; and (4) PPI dispersion (defined below). Available annually and interpolated to quarterly.	First three components from Li et al. (2019).
Real exchange rate index	Real effective exchange rate based on consumer prices	% change in real exchange rate, relative to 8 quarters earlier	IMF, IFS

[1]CPI and core inflation are adjusted for VAT increases: Australia in 2000Q3, Japan in 1997Q2 and 2014Q2, New Zealand in 2010Q4, and United Kingdom in 2010Q1 and 2011Q1.

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